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Foreword

The organizers of the International Conference on Systematic Innovation (ICSI) and Global Competition on Systematic Innovation (GCSI) are pleased to present the proceedings of the conference and the Program of Innovative Project Exhibition which includes 76 papers and 11 finalist innovation projects. Author and non-author participants from more than 15 countries will interact in the conference.

This conference is co-organized by The Society of Systematic Innovation (SSI), Universidade Nova de Lisboa, Institute of Portugese Industrial Engineers, and the Journal of Systematic Innovation (IJoSI) which is an affiliation of the SSI. Whether the papers included in the proceedings are work-in-progress or finished products, the conference and proceedings offer the authors an opportunity to disseminate the results of their research and receive early feedback from colleagues, without the long waiting associated with publication in peer-reviewed journals. On the other hand, the presentations and the proceedings do not preclude the option of submitting the work in an extended and finished form for publication in any peer-reviewed journal.

The organizers are indebted to a number of people who gave their time to make the conference a reality. In particular, Prof. Helena Navas, Prof. Virgílio Cruz Machado, and their wonder team from the local host greatly contributed to the conference. Special credit should also go to the SSI team. The list of organizations and working team who have contributed tremendous amount of time and efforts to create this conference are acknowledged at the end of this program brochure. There are more contributors who are beyond the list.

The conference is one of the leading SI/TRIZ international conferences in the world and typically publish the most papers in the field. The next ICSI conference will be in Tsinghua University, Beijing. As you may already knew, Tsinghua is the most prestigious university in China in the area of Science and Engineering. It is also regarded as one of the most beautiful universities in Asia. There are many sites of scenic or historic interests on campus. You are invited to continue joining the 2017 ICSI/GCSI events.

We welcome proposals for locations of future conferences in various countries. Please submit your proposal to myself. In addition, you are cordially invited to submit scholarly papers to the IJoSI at www.IJoSI.org. The conference and the journal are synergetic and closely related. The journal is intended to be with academic rigor while addressing realworld problems and opportunities.

We are confident that you will find the participation in this conference rewarding. If there is anything needing assistance, please feel free to let the attendant(s) at the service desk know. We are here to serve you.

With best regards,
D. Daniel Sheu, Ph.D., MBA, CMfgE
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Paper List

Full Papers in English

Paper ID: 13

Parameter Manipulations: Unified strategies for Solving Physical Contradictions

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Abstract

Physical contradiction is at the heart of TRIZ contradiction problem solving. The essence of a physical contradiction is that for two objectives, we have two contradictory demands on the same parameter of the same system. As part one of the two-part Parameter Manipulation approach to solve physical contradiction, this paper proposes a systematic new method to solve physical contradictions using the parameter deployment and separation.

By defining the Local System to include the components directly at the immediate relevant components of the physical contradiction, the proposed parameter deployment systematically deploys the two objectives and the contradictory parameter into their respective constituent parameters. The essence of parameter separation is to assign the two contradictory requirements, either at the objective level or at the contradictory parameter level, to be satisfied separately by separate constituent parameters or distinct value ranges of a constituent parameter. In this way, the contradiction can be avoided. An accompanying paper will describe the method of using Parameter Transfer to solve a physical contradiction by delegating the issue of satisfying one or both of the contradictory requirements to some parameters of a component seemingly irrelevant to the problem core.

The contributions of this research include: 1) Establishing the concept of Parameter deployment and strategy of using it to solve physical contradictions systematically, 2) Addressing the problem at both objective level and the contradictory parameter level producing 6 strategies for solving physical contradictions, 3) Using parameter deployment to identify all possible combinations of separation methods to solve a physical contradiction, 4) Providing standard operational templates for problem-solving process, tool descriptions, and examples for ease of learning and applications, 5) Together with the Parameter Transfer to form a comprehensive 17 problem solving strategies in which all the disconnected existing methods are only parts of this unified theory of parameter manipulation.

Keywords: Physical contradiction, Parameter deployment, parameter Separation, Parameter transfer, TRIZ, Systematic Innovation.

1 Introduction

1.1 Research Background and Objectives

Physical contradiction is at the heart of all problematic contradictions. At present, all methods to solve physical contradictions are based on either separation principles, by-passing contradictions, or satisfying contradictions. All of them at the end converted to inventive principles to solve the problems. The deficiencies of the existing methods to solve physical contradictions include:

1) All existing methods appear to be independent and are lack of synergy among them.
2) All existing methods at the end converted to the inventive principles. That means that the problem solver need only to examine the selected inventive principles. Many times, the 40 inventive principles may not be enough to inspire good specific solutions. There is no detail thinking process which can lead the problem solver to look at problems systematically.
3) All the existing separating principles focus on the solving problem at the contradictory parameter level. Solving problem at the objective level has not been considered for separation principles.

This research established a comprehensive thinking process which generate 17 strategies to solving physical contradictions of which All the existing methods constitute only 4 of 17 strategies identified by this research. Furthermore, all the 17 problem solving strategies are under the same set of theory based on parameter manipulation.

2 Theoretical Background for Physical Contradiction and Parameter Manipulation

2.1 Formulation of Physical Contradiction

Physical contradiction occurs when one parameter cannot satisfy two demands in order to achieve two objectives at the same time. Model of physical contradiction can be expressed as:

- To O_1, P should be +P. But,
- To O_2, P should be -P.

Among them, “O_1” and “O_2” are two disparate objectives, “P” is the contradictory parameter which causes the problem. “+P” and “-P” represent the two demands which needed to be satisfied in order to achieve O_1 and O_2. Taking desk area for example, in order to accommodate more stuffs on the desk, the area of the desk should be big. But, in order to occupy less space in a room, the area of the desk should be small. This can be shown in the following formulation:

- To accommodate more stuffs on the desk, the area of the desk should be big. But,
- To occupy less space in a room, the area of the desk should be small.

2.2 Parameter Deployment

To solve physical contradiction, how those related parameters influence the two objectives O_1 and O_2 or the contradictory parameter P needs to be investigated. This paper proposes the method of parameter deployment to assist users in identifying the relationship among all related parameters and the two objectives or the contradictory parameter in a systematic fashion. By constructing the problem with parameter generic forms (at objective level and at contradictory parameter level), the physical contradiction can be located easily and clearly.

2.2.1 The Generic Form of Two Objectives

The two objectives can be shown in the following generic forms:

- $O_1=fn(P^1_1, \ldots ; E^1_1, \ldots ; Z^1_1, \ldots)$
- $O_2=fn(P^2_1, \ldots ; E^2_1, \ldots ; Z^2_1, \ldots)$

Contradictory parameters can be shown in the following generic form:

- $\pm P=fn(X_1, X_2, X_3, \ldots, X_n)$

In the generic forms above, "P" represents "contradictory parameter" of two objectives, "E" represents "exclusive parameter" of each objective, and "Z" represents "compatible parameters of the same direction" of the two objectives. The relationships between each parameter category and the definition of each category are shown in Table 1. In the contradictory parameter generic form above, "X" refers to the constituent parameter(s) of the contradictory parameter.

Some related symbols are defined in Table 1.

Table 1. Definitions and Descriptions of Each Parameter Categories

Symbol	Definition	Description
X_b^a	Constituent Parameter(s)	● All related parameters influencing the objective ● X_b^a represents the "b" constituent parameter of objective "a"
C_i	Common Parameter(s)	● The constituent parameters that influence both objectives ● C_i represents the "i" common parameter of the two objectives
Z_k	Compatible parameter(s)of the same direction	● The common parameter of the two objectives which requires the same demands ● Z_k represents the "k" compatible parameter of the two objectives
P_j	Contradictory Parameter(s)	● A common parameter which cannot satisfy different demands of each of the two objectives simultaneously ● P_j represents the "j" contradictory parameter of the two objectives
E_c^a	Exclusive Parameter(s)	● Constituent parameters that are not common parameters of the two objectives ● E_c^a represents the "c" exclusive parameter of objective "a"

The existing separating principles, including separation in space, separation in time, separation in relations, separation in system levels, and separation in directions, all fall into one category of separation principle only with different parameters as the target of separation, such as space, time, relations, system levels, and directions to satisfy the two contradictory demands separately. For example, in the case of separation in time, "time" is used as the separating parameter and so forth.

2.3 The Essence of Problem Solving Strategies in Parameter Manipulation

The method of parameter manipulation proposed in this paper is a systematically comprehensive theory. The essence of the method, as a starting point, is to "separate the demand of contradictory parameter" or to "satisfy the two objectives separately". By manipulating parameters such as "parameter separation" or "parameter transitions", the two contradictory demands generated by the two objectives or the two contradictory parameters can be satisfied. There are various problem solving modes as follows:

- Satisfying the two contradictory demands with two different constituent parameters separately (as shown in Figure 3: COPE/COEP/COEE)
- Satisfying the two contradictory demands with distinct value ranges of a constituent parameter separately (as shown in Figure 3: IPV/IOV)
- Splitting the contradictory parameter into two parameters from the perspective of component and have these two parameters satisfy the two contradictory demands separately (as shown in Figure 3: CPS)

- Satisfying one of the contradictory demands with an additional parameter to eliminate the contradiction (as shown in Figure 3: TPPA/TPAP/TOPA/TOAP)
- Satisfying two contradictory demands separately with two other additional parameters to eliminate the contradiction (as shown in Figure 3: TPAA/TOAA)
- Satisfying two contradictory demands simultaneously with an additional parameter (as shown in Figure 3: TOA)
- Satisfying two contradictory demands with distinct value ranges of an additional parameter separately (as shown in Figure 3: TPAV/TOAV)

Parameter Separation can be divided into two modes: Separation within Parameters and Separation across Parameters. Separation within parameters satisfies two contradictory demands (either at objective level or at contradictory parameter level) separately with distinct value ranges of a constituent parameter. The existing separation principles all fall into this mode of parameter separation within different ranges of one parameter. Separation across parameters is to satisfy two contradictory demands (either at objective level or at contradictory parameter level) simultaneously with two different constituent parameters. Furthermore, separation across parameters can be divided into "Separation" and "Splitting". The former aims to satisfy two contradictory demands separately with two existing constituent parameters, while the latter aims to satisfy two contradictory demands by two different parameters which are split from the contradictory parameter from component perspectives.

Parameter Transfer satisfies one or two of the two contradictory demands (either at objective level or at contradictory parameter level) with additional parameters that are "seemingly" not relevant to the local system as defined in Table 3. These additional parameters (Destination of the Parameter Transfer) can be parameters outside the local system or those within the local system but were not part of constituent parameters for O_1, O_2, or P.

2.4 Definition of Systems

This paper suggests that a contradiction must be influenced by parameters of "center component" or "interactive component". Center component is either a component of contradictory parameters or a component of two objectives. The interactive components are other components which have interactive functions with the center components. Local System (LS) is the combination of center components and interactive components with respective to a contradiction. A local system is the scope of parameter deployment which provides all related parameters influencing the two objectives or contradictory parameter for parameter separation that follows. However, in order to facilitate parameter transfer, a few more systems are defined in Table 3. The systems involved in parameter manipulation are divided into two general aspects: physical hierarchy aspect and functional aspect. The categorizations and definitions of these systems are explained in Figure 1 and Table 2 below.

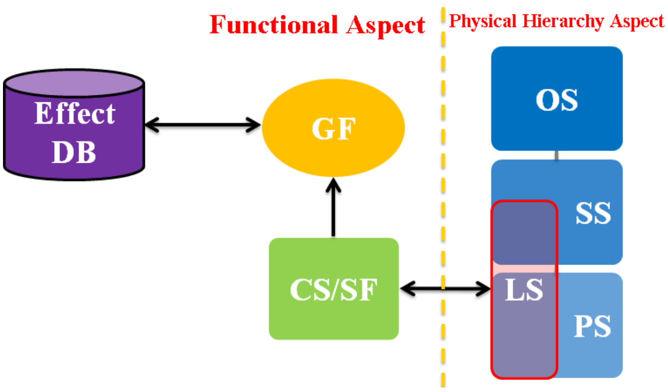


Figure 1. Relationship Diagram among Systems

Table 2. Definition of Systems

	System	Definition
Physical Hierarchy Aspect	Center Component	Contradictory parameters or the exact point where two objectives contradict
	Interactive Component	Around, in contact with, and in functional relationships with center component.
	LS（Local System）	Local system (LS) consists of center component and its interactive components. In addition to the exact point where physical contradiction occurs within the physical system, super system which interacts with the physical system during its performance of specific function is also included. Local System is considered to be two levels : ● Contradictory Parameter Level: the contradictory component within the physical system ● Objective Level: the component where the contradictory demands of two objectives lies in. Problem can be solved with useful functions or by changing attributes within the local system. When it comes to contradiction, it is important to locate, within the local system, the manipulation zone where solutions can be found.
	PS（Physical System）	The actual system where center component of the contradiction belongs to
	SS（Super System）	Systems or components beyond physical system (PS) yet interact with PS
	OS（Outer-super System）	Systems or components beyond PS but within the same time and space which have no interactions with the PS.
Functional Aspect	CS（Competing System）	Specific Function (SF) is the useful function LS desires to achieve and it has specific solutions and an object. Competing System (CS) does not necessarily interacts with LS, but both of them perform the same specific function to the same object. CS can replace LS completely.
	GS（System via Generic Function）	Generic Function (GF) refers to specific functions in a general term.

		System via Generic Function (GS) does not necessarily interacts with LS, but both of them perform the same generic function. GS can be used to search for useful resources in Effect Database.

2.5 Strategies of Parameter Manipulation

Two aspects for parameter manipulation are discerned: manipulation targets and manipulation modes. In terms of manipulation target, it is observed that previous solutions by parameter separations to solve physical contradictions were mainly about separating demands of contradictory parameters. Separating parameters to satisfy the two contradictory objectives was not taken into consideration. Therefore, this paper proposes two hierarchies of parameter manipulation targets to achieve: separation of parameter for two contradictory demands and separation of parameters to satisfy two contradictory objectives.

With combinations of different Manipulation Modes and different Target Levels of Satisfaction, seventeen strategies of solving physical contradiction can be conceived as shown in Figure 2. The first letter of the strategies means the mode of manipulation (I: separation within parameter, C: separation across parameters, T: parameter transfer); the second letter means the target of manipulation (P: contradictory parameter as target, O: two objectives as target); the third (and the fourth) letter means manipulation methods (V: using parameter value ranges, S: splitting parameters, P: using contradictory parameters, E: using exclusive parameters, A: using non-constituent additional parameters). Problem solving strategies of parameter manipulation will be explained respectively in the following sections.

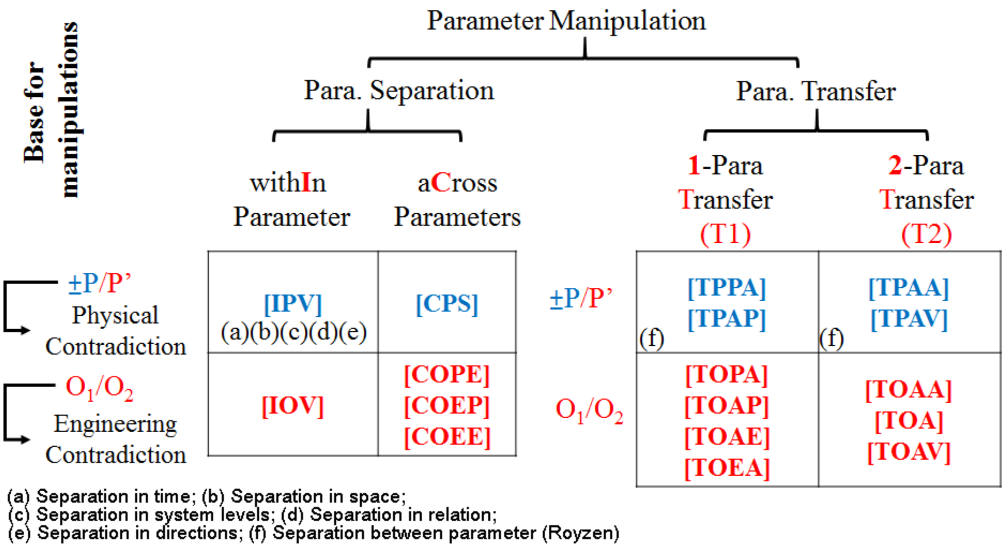


Figure 2. Overview of strategies of parameter manipulation

2.5.1 Parameter Separation

2.5.1.1 Contradictory Parameter Orientation

2.5.1.1.1 Separation within Parameter

The manipulation target in this section is set to be “contradictory parameters” and the mode of manipulation is “separation within parameter”. In this case, the problem solving strategy is “IPV”.

- [IPV]: I — separation within parameter; P — Separation of contradictory demands; V — separation of distinct value ranges of specific parameter +P/-P

It makes the contradictory parameter to satisfy different demands from two objectives separately in distinct value ranges of a specific parameter. That is, the specific parameter can satisfy +P in certain value range and satisfy -P in another value range. Specific parameters can be space, time, relation, system levels, and so on.

Take a pencil for example. To make it comfortable to hold (O_1), the pencil shaft should have no angles (+P). To keep the pencil from rolling (O_2), the pencil shaft should have angles (-P). With [IPV], separation in space is applicable to solve the problem so that a pencil shaft can have no angles (+P) on the part where people hold it and have angles (-P) at the end of the pencil shaft.

2.5.1.1.2 Separation between Parameters

Here, the manipulation target is set to be “contradictory parameters” and the mode of manipulation is “separation across parameters”. In this case, the problem solving strategy is “CPS”.

- [CPS]: C — separation across parameters; P — separation of contradictory parameters; S — splitting contradictory parameters.

It splits the contradictory parameter of the two objectives or its center component. That is, the contradictory parameter is split into parameters exclusive to the two objectives and the contradictory demands of each objective can be undertaken respectively by the parameters split from the contradictory parameter.

To take indoor temperature as an example, to prevent the machine from over-heating (O_1), the indoor temperature should be low (+P). To prevent people from catching a cold (O_2), the indoor temperature should be high (-P). With [CPS], the contradictory parameter, indoor temperature, can be split into two new parameters: “indoor temperature around machine” and “indoor temperature around people”. The former can satisfy the demand of keeping indoor temperature low (+P) while the latter can satisfy the demand of keeping indoor temperature high (-P).

2.5.2 Objective-Orientated

2.5.2.1 Separation within parameter

The manipulation target in this section is set to be “two objectives” and the mode of manipulation is “separation within parameter”. In this case, the problem solving strategy would be “IOV”.

- [IOV]：I－Separation within parameters; O－satisfy objectives separately; V－ satisfy O_1 and O_2 separately with distinct value ranges of a specific parameter.

It makes the specific parameter satisfy the two objectives in distinct value ranges. That is, the specific 使 parameter can satisfy O_1 in certain value range and satisfy O_2 in another. Specific parameters include space, time, relation, system levels and so on.

Take a pencil for example. To make it comfortable to hold (O_1), the pencil shaft should have no angles (+P). To keep the pencil from rolling (O_2), the pencil shaft should have angles (-P). With [IOV], separation in space is applicable to solve the problem so that a pencil shaft should have no angles (+P) on the part where people can hold it comfortably (O_1) and have angles (-P) at the end of the pencil shaft to create a rough and frictional part so the pencil will not roll that easily (O_2).

2.5.2.2 Separation across Parameters

The manipulation target in this section is set to be “two objectives” and the mode of manipulation is “separation across parameters”. In this case, the problem solving strategy is “COPE”, “COEP”, and “COEE”.

- [COPE]：C－Separation across parameters; O－satisfy objectives separately; PE-P satisfies O_1、E^2 satisfies O_2

It makes contradictory parameter P to satisfy the demand of O_1. The influence imposed on O_2 by the contradictory parameter is offset by O_2’s exclusive parameter E^2.

Take outdoor display panel for example. To prevent the panel from damage due to rain leakage (O_1), the holes of front plate and rear plate should not exist (+P). To allow good heat dissipation for the panel (O_2), the holes of front place and rear plate should exist (-P). With [COPE], there will be no holes on the plates which prevents the panel from damage due to rain leakage (O_1). Moreover, by replacing the original material of the plates with metal that dissipates heat better, the panel will also dissipate heat better (O_2).

- [COEP]: C－separation across parameters; O－satisfy objectives separately; EP－E^1 satisfies O_1, P satisfies O_2

It makes contradictory parameter P to satisfy the demand of O_2. The influence imposed on O_1 by the contradictory parameter is offset by O_1’s exclusive parameter E^1.

Take outdoor display panel for example. To prevent the panel from damage due to rain leakage (O_1), the holes of front plate and rear plate should not exist (+P). To allow good heat dissipation for the panel (O_2), the holes of front place and rear plate should exist (-P). With [COEP], the holes will still be on the plates which allows good heat dissipation (O_2). Plus, by enhancing waterproof capability of the plates (ex: covering the plates with a waterproof cloth), rain leakage which damages the panel can be avoided (O_1).

- [COEE]: C－Separation across parameters; O－satisfy objectives separately; ignore P, E^1 satisfies O_1, E^2 satisfies O_2

It makes the contradictory parameter P to be an arbitrary value acceptable to the two objectives. Satisfy the demand of O_1 with O_1's exclusive parameter E^1 and satisfy the demand of O_2 with O_2's exclusive parameter E^2.

Take outdoor display panel for example. To prevent the panel from damage due to rain leakage (O1), the holes of front plate and rear plate should not exist (+P). To allow good heat dissipation for the panel (O2), the holes of front place and rear plate should exist (-P). With [COEE], the material of the plates is changed to metal that dissipate heat better which helps heat dissipation for the panel (O2). Plus, by enhancing waterproof capability of the plates (ex: covering the plates with a waterproof cloth), rain leakage which damages the panel can be avoided (O1).

2.6 Parameter Transfer

2.6.1 Thinking Model of Parameter Transfer

When a problem occurs within the system, we can try to transfer the core of the problem to another system (subsystem, super system, negative system, and alternative system) or component, so the problem can be solved in another system or component. This is called "System Transfer".

"Parameter Transfer" follows the concept of system transfer by satisfying one or two of the two contradictory demands (at objective level or at contradictory parameter level) with additional parameters "seemingly" not relevant to local system. Additional parameters can be those originated from physical system, super system, and outer-super system of the physical hierarchy aspect as well as competing system and system via generic function of the functional aspect. Parameters which were not taken into account within the local system in the first place can also be introduced as additional parameters.

There are two methods to solve physical contradiction by parameter transfer: Transfer Out and Transfer In. "Transfer Out" means to satisfy one or two of the contradictory demands with parameters outside the local system (parameters from physical system, super system, outer-super system, and competing system). In this way, the dilemma where local system need to satisfy two contradictory demands at the same time can be solved. On the other hand, "Transfer In" means to introduce attributes from other systems (physical system, super system, outer-super system, competing system, and systems via generic functions) into local system, which is called "attribute transfer". By changing the original design of local system, contradiction can be solved. Take sewing needle for example, to make threading easier, the hole at the end of the needle should be big. To avoid damaging the clothes, the hole at the end of the needle should be small. This contradiction can be solved by using a needle threader which helps threading and does not belong to local system. Or, the contradiction can also be solved by changing the material of the needle, making the needle softer and foldable like a needle threader so the holes can be contractible.

When it comes to contradictory-parameter-oriented parameter transfer, additional parameters are used to satisfy the contradictory demands of contradictory parameters (+P/-P). That is, one of the contradictory parameters is satisfied by additional parameters (TPPA/TPAP). Or, two contradictory demands are satisfied by two additional parameters separately (TPAA) or distinct value ranges of an additional parameter (TPAV). Objective-oriented parameter transfer, on the other hand, satisfies contradictory demands of two objectives (O_1/O_2) with additional parameters. In this way, one of the contradictory demands can be satisfied by additional parameters (TOPA/TOAP). Or, two contradictory demands can be satisfied by additional parameters and exclusive parameters respectively (TOEA/TOAE) or two additional parameters respectively (TOAA). Moreover, an additional parameter may satisfy two contradictory demands simultaneously (TOA); distinct value ranges of an additional parameter may also satisfy two contradictory demands respectively (TOAV).

2.6.2 Contradictory Parameter - Oriented

The manipulation target in this section is set to be “contradictory parameters” and the mode of manipulation is “parameter transfer”. In this case, problem solving strategies would be “TPPA”, “TPAP”, “TPAA”, and “TPAV”.

- [TPPA]: T-Parameter transfer; P — contradictory parameter-oriented; PA — P satisfies +P, A^2 satisfies -P

It renders contradictory parameter P to satisfy +P; -P is undertaken by additional parameter A^2 which means -P is satisfied by A^2.

Take a pencil for example. To make it comfortable to hold (O_1), the pencil shaft should have no angles (+P). To keep the pencil from rolling (O_2), the pencil shaft should have angles (-P). With [TPPA], the pencil shaft have no angles which satisfies +P and decorations (A^2) added to the end of the shaft creates some angles which satisfy -P.

- [TPAP]: T-Parameter transfer; P — contradictory parameter-oriented; AP — A^1 satisfies +P, P satisfies-P

It renders contradictory parameter P to satisfy -P; +P is undertaken by additional parameter A^1 which means -P is satisfied by A^1.

Take a pencil for example. To make it comfortable to hold (O_1), the pencil shaft should have no angles (+P). To keep the pencil from rolling (O_2), the pencil shaft should have angles (-P). With [TPAP], the pencil shaft have angles which satisfies -P, but the addition of a soft pencil grip (A^1) makes the user feel no angles on the pencil shaft (+P).

- [TPAA]: T — Parameter transfer; P — contradictory parameter-oriented; AA — A^1 satisfies +P, A^2 satisfies -P

Instead of satisfying two contradictory demands (+P, -P) with P, it satisfies them with additional parameters. That is, +P is satisfied by A^1 and -P is satisfied by A^2.

Take a pencil for example. To make it comfortable to hold (O_1), the pencil shaft should have no angles (+P). To keep the pencil from rolling (O_2), the pencil shaft should have angles (-P). With [TPAA], a soft pencil grip (A^1) is added so the user feel no angles on the pencil shaft (+P). Moreover, decorations (A^2) added to the end of the shaft create angles (-P).

- [TPAV]: T — Parameter transfer; P — contradictory parameter-oriented; AV — distinct value ranges of A satisfy +P and -P separately

Instead of satisfying two contradictory demands (+P, -P) with P, it satisfies them with different vale ranges of additional parameter A.

Take a pencil for example. To make it comfortable to hold (O_1), the pencil shaft should have no angles (+P). To keep the pencil from rolling (O_2), the pencil shaft should have angles (-P). With [TPAV], the pencil shaft have no angles (+P) when it is held and used properly (v1); however, when the pencil is dropped and fell on the floor (v2), the angles will bounced up from the shaft itself (-P).

2.6.3 Objective-Oriented

The manipulation target in this section is set to be "objectives" and the mode of manipulation is "parameter transfer". In this case, problem solving strategies would be "TOPA", "TOAP", "TOEA", "TOAE", "TOAA", "TOA", and "TPAV", the descriptions of which are as follows:

- [TOPA]: T—Parameter transfer; O—objective-oriented; PA—P satisfies O_1, A^2 satisfies O_2

It allows contradictory parameter P to satisfy +P, and further satisfy O_1. The influence imposed on O_2 by +P is offset by O_2's additional parameter A^2.

Take outdoor display panel for example. To prevent the panel from damage due to rain leakage (O_1), the holes of front plate and rear plate should not exist (+P). To allow good heat dissipation for the panel (O_2), the holes of front place and rear plate should exist (-P). With [TOPA], there will be no holes on the plates (+P) which prevents the panel from damage due to rain leakage (O_1). Moreover, a fan (A^2) is installed on the plates to help dissipate heat (O_2).

- [TOAP]: T—Parameter transfer; O—objective-oriented; AP—P satisfies O_2, A^1 satisfies O_1

It allows contradictory parameter P to satisfy -P, and further satisfy O_2. The influence imposed on O_1 by -P is offset by O_1's additional parameter A^1.

Take outdoor display panel for example. To prevent the panel from damage due to rain leakage (O_1), the holes of front plate and rear plate should not exist (+P). To allow good heat dissipation for the panel (O_2), the holes of front place and rear plate should exist (-P). With [TOAP], the plates have holes (-P) to facilitate heat dissipation (O_2). In addition, with the installation of the rain shield (A^1) on the plates, raindrops will be blocked from getting into the panel (O_1).

- [TOEA]: T—Parameter transfer; O—objective-oriented; EA—E^1 satisfies O_1, A^2 satisfies O_2

It renders contradictory parameter P to be arbitrary values acceptable to both objectives, satisfying the two objectives with parameters other than P. The demand of O_1 will be satisfied by its exclusive parameter E^1, and the demand of O_2 by its additional parameter A^2.

Take outdoor display panel for example. To prevent the panel from damage due to rain leakage (O_1), the holes of front plate and rear plate should not exist (+P). To allow good heat dissipation for the panel (O_2), the holes of front place and rear plate should exist (-P). With [TOEA], whether holes on the plates exist or not is ignored, and the focus will be to enhance waterproof capability (E^1) to avoid rain leakage (O_1). Plus, a fan (A^2) will be installed on the plates to help heat dissipation (O_2).

- [TOAE]: T—Parameter transfer; O—objective-oriented; AE—A^1 satisfies O_1, E^2 satisfies O_2

It renders contradictory parameter P to be arbitrary values acceptable to both objectives, satisfying the two objectives with parameters other than P. The demand of O_1 will be satisfied by its additional parameter A^1, and the demand of O_2 by its exclusive parameter E^2.

Take outdoor display panel for example. To prevent the panel from damage due to rain leakage (O_1), the holes of front plate and rear plate should not exist (+P). To allow good heat dissipation for the panel (O_2), the holes of front place and rear plate should exist (-P). With [TOAE], whether holes on the plates exist or not is ignored. Instead, the focus will be to replace the material of plates with one that allow better heat dissipation, so the heat dissipation capacity of the plates is enhanced (E^2)

which helps dispel heat better (O_2). Moreover, the rain shield (A^1) will be installed on the plates to prevent raindrops from getting into the panel (O_1).

- [TOAA]: T—Parameter transfer; O—objective-oriented; AA—A^1 satisfies O_1, A^2 satisfies O_2

It renders contradictory parameter P to be arbitrary values acceptable to both objectives, satisfying the two objectives with parameters other than P. The demand of O_1 will be satisfied by its additional parameter A^1, and the demand of O_2 by its additional parameter A^2.

Take outdoor display panel for example. To prevent the panel from damage due to rain leakage (O_1), the holes of front plate and rear plate should not exist (+P). To allow good heat dissipation for the panel (O_2), the holes of front place and rear plate should exist (-P). With [TOAA], whether holes on the plates exist or not is ignored. A rain shield (A^1) will be installed on the plates to prevent raindrops inside the panel (O_1). In the meantime, a fan (A^2) is also installed on the plates to help dispel heat (O_2).

- [TOA]: T—Parameter transfer；O—objective-oriented; A—A satisfies O_1 and O_2 simultaneously

It renders contradictory parameter P to be arbitrary values acceptable to both objectives, satisfying the two objectives with parameters other than P. The demands of both O_1 and O_2 will be satisfied by an additional parameter A.

Take cycling gloves for example. To avoid frozen fingers (O_1), the length of fabric covering the fingers should be long (+P); to grip the handlebar tight (O_2), the length of fabric covering the fingers should be short (-P). With [TOA], the fabric length covering fingers is ignored and the cycling gloves are equipped with temperature control function (A) which helps keep hands in constant temperature climate and prevents frozen fingers (O_1) in cold weather. Moreover, cyclers can also grip handlebars tight (O_2) in hot weather because temperature controlling helps avoid hand sweat.

- [TOAV]: T—Parameter transfer；O—objective-oriented; AV— satisfy O_1 and O_2 separately with different value ranges of A

It renders contradictory parameter P to be arbitrary values acceptable to both objectives, satisfying the two objectives with parameters other than P. The demand of O_1 will be satisfied by additional parameter A in one certain value range while the demand of O_2 will be satisfied by additional parameter A in another value range.

Take cycling gloves for example. To avoid frozen fingers (O_1), the length of fabric covering the fingers should be long (+P); to grip the handlebar tight (O_2), the length of fabric covering the fingers should be short (-P). With [TOAV], the fabric length covering fingers is ignored. Cycling gloves will be equipped with function of temperature control (A), so hands will not be frozen (O_1) in cold weather with warm (regulated) temperature (v1) and cyclers can grip handlebars tight (O_2) since hand sweat will be prevented in hot weather with cool (regulated) temperature (v2).

2.6.4 Thought-Provoking Questions of Parameter Transfer

To help users search for additional parameters, this paper proposes a number of questions (Thought-Provoking Questions, TPQ) to provoke thoughts. Users can find out additional parameters for parameter transfer by answering a series of thought-provoking questions in Table 3.

Table 3. Thought-Provoking Questions (TPQ)

<table>
<tr><td>O_1</td><td colspan="2">(Description of O_1)</td><td>SF_1</td><td colspan="2">(Specific function required by O_1)</td><td>GF_1</td><td>(Generalized specific function of O1)</td></tr>
<tr><td>O_2</td><td colspan="2">(Description of O_2)</td><td>SF_2</td><td colspan="2">(Specific function required by O_2)</td><td>GF_2</td><td>(Generalized specific function of O_2)</td></tr>
<tr><td>Center component of P</td><td colspan="2"></td><td>MF</td><td colspan="2">(Main function of center component of P)</td><td>GF_M</td><td>(Generalized MF)</td></tr>
<tr><td>Physical System</td><td>(Description of PS and its components)
PS (Component 1, Component 2, ...)</td><td>P</td><td>(Contradictory Parameters)</td><td>+P</td><td>(O_1's demand from P)</td><td>-P</td><td>(O_2's demand from P)</td></tr>
<tr><td>Super System</td><td colspan="7">(Description of super system and its components)
SS_1 (Component 1-1, Component 1-2, ...); SS_2 (Component 2-1, Component 2-2, ...); ...</td></tr>
<tr><td>Outer-super System</td><td colspan="7">(Description of outer-super system)
OS_1 (Component 1-1, Component 1-2...); OS_2 (Component 2-1, Component 2-2...);...</td></tr>
<tr><td>Local system</td><td colspan="7">(Description of local system and its components)
LS_1 (Component 1-1, Component 1-2...); LS_2 (Component 2-1, Component 2-2...);...</td></tr>
<tr><td>Competing System</td><td colspan="7">(Description of local system's competing system)
CS_1; CS_2; ...</td></tr>
<tr><td>System via generic function</td><td colspan="7">(Description of local system's system via generic function)
GS_1; GS_2; ...</td></tr>
<tr><td colspan="2">Questions</td><td colspan="5">Thoughts</td><td>Corresponding Parameters</td></tr>
<tr><td colspan="2">How does [Component X] satisfy [O_1/F_1] under [-P]?</td><td colspan="5">(Answer the Q with [X-element] and provide ideas)</td><td>(Parameters correspond to the idea)</td></tr>
<tr><td colspan="2">How does [Comp. X] satisfy [O_2/F_2] under [+P]?</td><td colspan="5">(Answer the Q with [X-element] and provide ideas)</td><td>(Parameters correspond to the idea)</td></tr>
<tr><td colspan="2">How does [Comp. X] satisfy [O_1/F_1] with other parameters instead of P? (Satisfy O_2/F_2 with other parameters)</td><td colspan="5">(Answer the Q with [X-element] and provide ideas)</td><td>(Parameters correspond to the idea)</td></tr>
<tr><td colspan="2">How does [Comp. X] satisfy [O_2/F_2] with other parameters instead of P? (Satisfy O_1/F_1 with other parameters)</td><td colspan="5">(Answer the Q with [X-element] and provide ideas)</td><td>(Parameters correspond to the idea)</td></tr>
<tr><td colspan="2">How does [Comp. X] satisfy [O1/F1] and [O2/F2]?</td><td colspan="5">(Answer the Q with [X-element] and provide ideas)</td><td>(Parameters correspond to the idea)</td></tr>
<tr><td colspan="2">Which attribute of [Comp. X] satisfies [MF] and is acceptable to [O_1/ O_2/+P/-P]?</td><td colspan="5">(Answer the Q with [X-element] and provide ideas)</td><td>(Parameters correspond to the idea)</td></tr>
</table>

3 Problem Solving Process

3.1 Overall Process Overview

The parameter deployment and manipulation methods proposed in this paper can be divided into two major parts. As demonstrated in figure 3, "Component Identification and Parameter Deployment" on the left includes Step 1: Physical Contradiction Identification, Step 2: Related Component Identification, and Step 3: Parameter Deployment, and "Parameter Manipulation and Contradiction Solution" on the right includes Step 4: Parameter Manipulation and Step 5: Solution Integration.

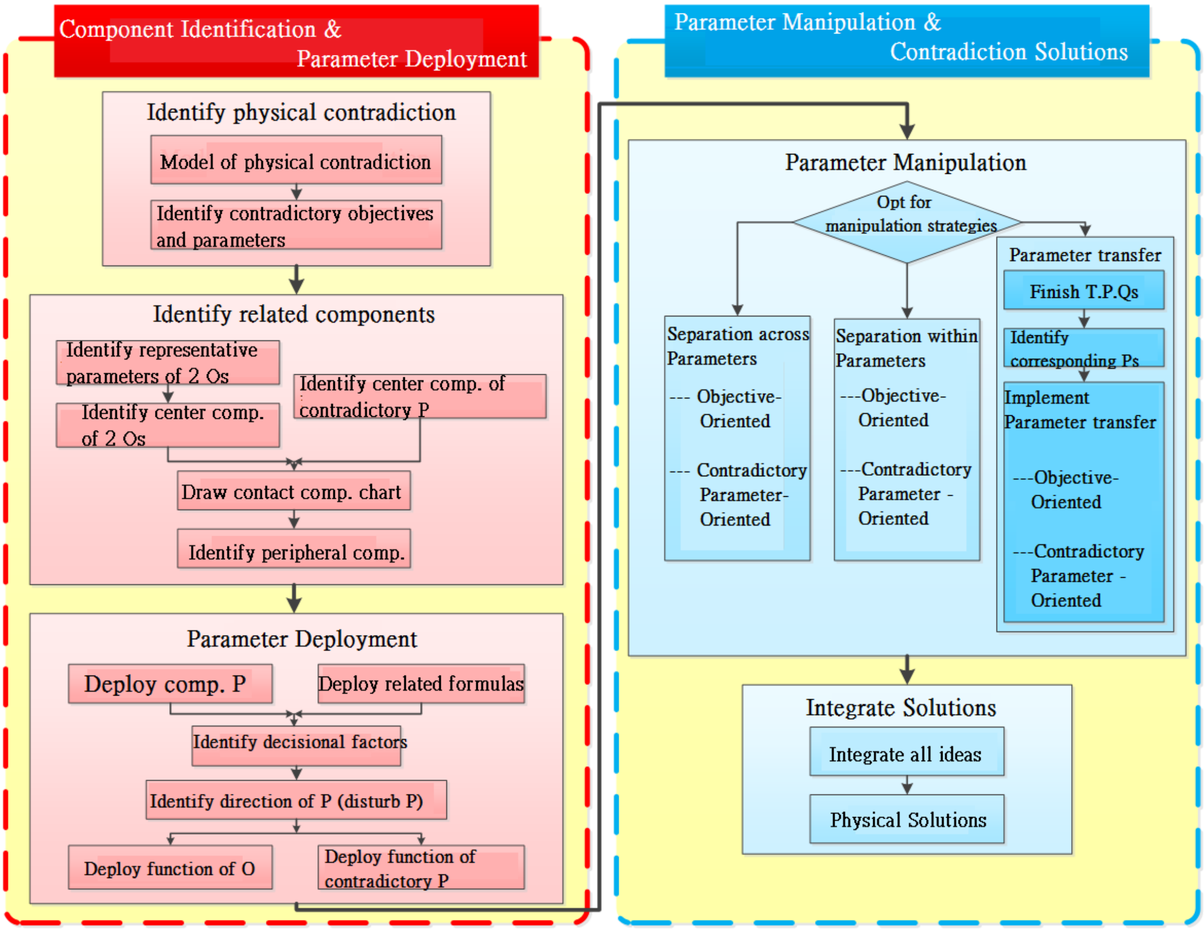


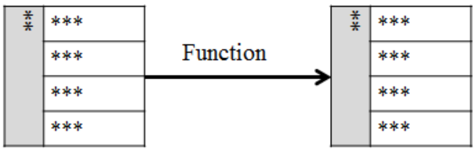
Figure 3. Flow chart of parameter deployment and manipulation

3.2 Component Identification and Parameter Deployment

In order to assist users in Physical Contradiction Identification (Step 1), Related Component Identification (Step 2), and Parameter Deployment (Step 3), the paper designed a parameter identification table (Table 4), a parameter deployment table (Table 5), and a parameter integration table (Table 6). With these three systematically designed tables, users can gather relative information needed for the following steps.

First of all, model of physical contradiction should be filled in a Parameter Identification Table (Table 4) to identify contradictory objectives and parameters. Through the representative parameters and contradictory parameter of two objectives, the center component and interactive components of the contradiction can be identified. A chart of contacting component can be completed accordingly.

Table 4. Parameter Identification Table

System：				
To [O_1]__________, [P] Contradictory Parameter____ should be [＋P]__________. But, To [O_2]__________, [P]Contradictory Parameter should be [－P]__________.				
O_1	Representative Parameters：	Center Comp.:	P	(Center Comp. of [P])
O_2	Representative Parameters:	Center Comp.:		
Contact Component Chart				
Take center components of O_1 / O_2 / P as centers and find out functional components contacting each center component when O_1 and O_2 are satisfied.  The arrow indicates the relationships between components, showing the function one component gives to another. ** ：Center Component *** ：Parameters related to component and O_1 / O_2 / P				

After that, put all related components and parameters of the contradiction into a Parameter Deployment Table (Table 5) and impose some disturbances on these parameters (EX: adding or decreasing the value of the parameter or changing the status of parameters) to examine possible influences each parameter may have on the two objectives and the contradictory parameter. Then, fill the empty box at the bottom of the table with objective functions of the two objectives and contradictory parameter function of the contradictory parameter.

Table 5. Parameter Deployment Table

System：														
O_1					O_2									
Center Component / Peripheral Component														
Comp. 1			Comp. 2			Comp. 3			Comp. 4			Comp. 5		
Parameter	O_1	O_2	Param.	O_1	O_2	Param.	O_1	O_2	Param.	O_1	O_2	Param.	O_1	O_2
(Descrip. of Para.)	(Demand)	(Demand)												
Parameter Deployment	[O_1] {Description of O_1} = fn(P, …; E,…; Z,…) {constructing the objective function of O_1} [O_2] {Description of O_2} = fn(P, …; E,…; Z,…) {constructing the objective function of O_2} [P] {Description of P} = fn(X_1, X_2, …) {constructing the contradictory parameter function of P}													

Lastly, fill a Parameter Integration Table (Table 6) with center components of two objectives and contradictory parameter respectively. Examine the formula of each center component to acquire more relative parameters from the formulas and impose some disturbances on these relative parameters to identify the influences they have on the two objectives and contradictory parameter. Readjust the objective functions of the two objectives and the contradictory parameter function of the contradictory parameter at the bottom of the table.

Table 6. Parameter Integration Table

O_1				O_2				P			
Center comp.	(Center comp. of O_1)			Center comp.	(Center comp. of O_2)			Center comp.	(Center comp. of P)		
Formula	(Formulas related to center comp. of O_1)			Formula	(Formulas related to center comp. of O_2)			Formula	(Formulas related to center comp. of P).		
Parameter		O_1	O_2	Parameter		O_1	O_2	Parameter		O_1	O_2
(Parameters not shown in the original function)		Demand	Demand								
Parameter Deployment	[O_1] { Description of O_1 } = fn(P, …; E,…; Z,…) { integrating the objective function of O_1 } [O_2] { Description of O_2 } = fn(P, …; E,…; Z,…) { integrating the objective function of O_2 } [P] { Description of P } = fn(X_1, X_2, …) { integrating the contradictory parameter function of P }										

3.3 Parameter Manipulation Table

To assist users in solving physical contradiction with problem solving strategies, a series of parameter manipulation tables (Table 7, Table 8, Table 9, Table 10, and Table 11) are designed in this paper to help users gain all possible answers to physical contradiction with systematically designed tables.

Table 7. Parameter Manipulation Table (IP)

System：			
Separation within Parameters — [IPV]			
[±P]_____ = fn(X_1, X_2,…) { constructing contradictory parameter function of contradictory parameter (P) }			
Contradictory P		Decisional Factor	(Decisional factors for P)
Questions	**Answers**	**Ideas**	
Where do we need +P? Where do we need –P?		{ If the answers are different, use separation in space to think of possible solutions }	
When do we need +P? When do we need –P?		{ If the answers are different, use separation in time to think of possible solutions }	
Which object needs +P? Which object needs -P?		{ If the answers are different, use separation in relation to think of possible solutions }	
+P/-P can be satisfied in super system; +P/-P can be satisfied in sub-system		{ If +P/-P can be satisfied in different super/sub system, use separation in system levels to think of possible solutions }	
Other independent parameters	**Value ranges**	**Ideas**	
{ Implicit Parameters that satisfy two demands by separating value ranges }	{ separated value ranges and their corresponding +/-P	{ Possible solutions by value range separation of other independent parameters }	

Table 8. Parameter Manipulation Table (IO)

<table>
<tr><td colspan="4">System：</td></tr>
<tr><td colspan="4">Separation within parameter — [IOV]</td></tr>
<tr><td colspan="4">[O_1] {Description of O_1} = fn(P, …; E,…; Z,…) {integrating objective function of O_1}
[O_2] {Description of O_2} = fn(P, …; E,…; Z,…) {integrating objective function of O_2}
[±P] {Description of P} = fn(X_1, X_2, …) {integrating contradictory parameter function of P}</td></tr>
<tr><td>Contradictory parameter (P)</td><td></td><td>Parameter of same direction (Z)</td><td></td></tr>
<tr><td>Exclusive parameter of O_1 (E_i^1)</td><td></td><td>Exclusive parameter of O_2 (E_j^2)</td><td></td></tr>
<tr><td>Questions</td><td>Answers</td><td colspan="2">Ideas</td></tr>
<tr><td>Where do we need O_1?
Where do we need O_2?</td><td></td><td colspan="2">{If answers are different, use separation in space to think of possible solutions.}</td></tr>
<tr><td>When do we need O_1?
When do we need O_2?</td><td></td><td colspan="2">{If answers are different, use separation in time to think of possible solutions.}</td></tr>
<tr><td>Which object needs O_1?
Which object needs O_2?</td><td></td><td colspan="2">{If answers are different, use separation in relation to think of possible solutions.}</td></tr>
<tr><td>O_1/ O_2 can be satisfied in super system; O_1/ O_2 can be satisfied in sub-system</td><td></td><td colspan="2">{If O_1/ O_2 can be satisfied in super/sub system, use separation in system levels to think of possible solutions.}</td></tr>
<tr><td>Other independent Parameters</td><td>Value Ranges</td><td colspan="2">Ideas</td></tr>
<tr><td>{Implicit Para. that satisfy two demands by separating value ranges}</td><td>{separated value ranges and their corresponding O_1/ O_2}</td><td colspan="2">{Possible solutions by value range separation of other independent parameters}</td></tr>
</table>

Table 9. Parameter Separation Table (CP/CO)

<table>
<tr><td colspan="4">System：</td></tr>
<tr><td colspan="4">Seperation across parameters — [CPS/COPE/COEP/COEE]</td></tr>
<tr><td colspan="4">[O_1] {Description of O_1} = fn(P, …; E,…; Z,…) {integrating objective function of O_1}
[O_2] {Description of O_2} = fn(P, …; E,…; Z,…) {integrating objective function of O_2}
[±P] {Description of P} = fn(X_1, X_2, …) {integrating contradictory parameter function of P}</td></tr>
<tr><td>Contradictory parameter (P)</td><td></td><td>Decisional factors</td><td>{Decisional factors for P}</td></tr>
<tr><td>Exclusive parameter of O_1 (E_i^1)</td><td></td><td>Exclusive parameter of O_2 (E_j^2)</td><td></td></tr>
<tr><td>Strategies</td><td>Target</td><td colspan="2">Ideas</td></tr>
<tr><td>[CPS]
$P \Rightarrow E^1, E^2$</td><td>Contradictory Parameters</td><td colspan="2">{If P can be split into exclusive parameters of both of the objectives, what ideas can we think of?}</td></tr>
<tr><td>[COPE]
$P \sim> O_1$
$E_j^2 \sim> O_2$</td><td>Objective</td><td colspan="2">{If P can satisfy O_1 and exclusive parameters can satisfy O_2, what ideas can we think of?}</td></tr>
<tr><td>[COEP]
$P \sim> O_2$
$E_i^1 \sim> O_1$</td><td>Objective</td><td colspan="2">{If P can satisfy O_2 and exclusive parameters can satisfy O_1, what ideas can we think of?}</td></tr>
<tr><td>[COEE]
$E_i^1 \sim> O_1$
$E_j^2 \sim> O_2$</td><td>Objective</td><td colspan="2">{If P is ignored and exclusive parameters can satisfy O_1 and O_2 respectively, what ideas can we think of?}</td></tr>
</table>

Before filling out the Parameter Transfer Table (TP) and Parameter Transfer Table (TO), users can complete the TPQ questionnaire (as shown in Table 3) to identify all additional parameters and add these additional parameters to the objective functions of the two objectives and to the contradictory parameter function of the contradictory parameter for more solutions.

Table 10. Parameter Transfer (TP)

System：	
Parameter Transfer – [TPPA/TPAP/TPAA]	
[O_1] {Description of O_1} = fn(P, …; E,…; Z,…; A) {constructing the objective function of O_1} [O_2] {Description of O_2} = fn(P, …; E,…; Z,…; A) {constructing the objective function of O_2} [±P] {Description of P} = fn(X_1, X_2, …) {constructing contradictory function of contradictory parameter (P)}	
Contradictory parameter (P)	Additional Parameter (A)
Strategies	**Ideas**
[TPPA] P~>+P A^2~>−P	{If +P is adopted to satisfy O_1 and the role of -P is undertaken by additional parameter A, what ideas can we think of?}
[TPAP] A^1~>+P P~>−P	{If -P is adopted to satisfy O_2 and the role of +P is undertaken by additional parameter A, what ideas can we think of?}
[TPAA] A^1~>+P A^2~>−P	{If the roles of +P and –P are undertaken by two additional parameters respectively, what ideas can we think of?}
[TPAV] A (V=v1) ~>+P A (V=v2) ~>−P	{If different value ranges of additional parameter A can satisfy +P and –P respectively, what ideas can we think of?}

Table 11. Parameter Transfer (TO)

System：	
Parameter Transfer – [TOPA/TOAP/TOEA/TOAE/TOAA/TOA/TOAV]	
[O_1] {Description of O_1} = fn(P, …; E,…; Z,…; A) {constructing the objective function of O_1} [O_2] {Description of O_2} = fn(P, …; E,…; Z,…; A) {constructing the objective function of O_2} [±P] {Description of P} = fn(X_1, X_2, …) {constructing contradictory function of contradictory parameter (P)}	
Contradic. para. (P)	Additional Para. (A)
Exc. para. of O_1 (E_i^1)	Exc. para. of O_2 (E_j^2)
[TOPA] P~>O_1 A^2 ~>O_2	{If +P is adopted to satisfy O_1 and additional parameter A is used to satisfy O_2, what ideas can we think of?}
[TOAP] A^1 ~>O_1 P~>O_2	{If -P is adopted to satisfy O_2 and additional parameter A is used to satisfy O_1, what ideas can we think of?}
[TOEA] E_i^1~>O_1 A^2 ~>O_2	{If exclusive parameter E is adopted to satisfy O_1 and additional parameter A is used to satisfy O_2, what ideas can we think of?}
[TOAE] A^1 ~>O_1 E_j^2~>O_2	{If exclusive parameter E is adopted to satisfy O_2 and additional parameter A is used to satisfy O_1, what ideas can we think of?}
[TOAA] A^1 ~>O_1 A^2 ~>O_2	{If two additional parameters are used to satisfy O_1 and O_2 respectively, what ideas can we think of?}
[TOA] A ~> O_1/ O_2	{If an additional parameter is used to satisfy O_1 and O_2 simultaneously, what ideas can we think of?}
[TOAV] A (V=v1) ~> O_1 A (V=v2) ~> O_2	{If different value ranges of an additional parameter A are used to satisfy O_1 and O_2 respectively, what ideas can we think of?}

3.4 Solution Compilation

To assist users in integrating and utilizing solutions derived from problem solving strategies, this paper designed solution compilation table as demonstrated in Table 12.

Table 12. Solution Compilation Table

System：		
Solutions		
{ ID of Strategies }	{ Model of Solution }	{ Ideas Triggered }

4 Case Study

The physical contradiction of a sewing needle is taken as an example in this section.

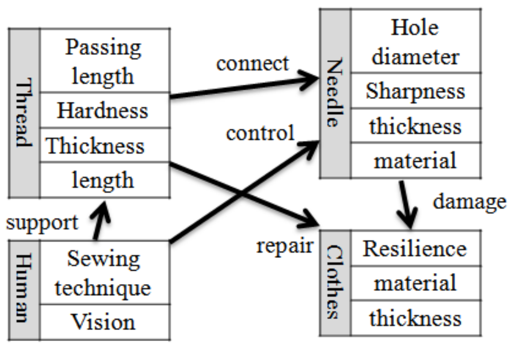
A needle is the earliest sewing tool in human history. It can be used to sew or repair clothes. To make the thread go through the hole on the needle eye easily, the diameter of the hole should be big. But, if the diameter of hole is big, the needle may damage the fabrics of the clothes when sewing.

4.1 Component Identification and Parameter Deployment

The objectives are "to facilitate threading" and "to avoid damage the clothes" respectively while the contradictory demand is that the same physical parameter (the diameter of the hole) should be big and small at the same time. By using Parameter Identification Table, the representative parameters of the two objectives and their center components as well as the center component of the contradictory parameter are filled in the table respectively. A contact component chart (as shown in Table 13) is drawn according to these center components and peripheral components.

Table 13. Parameter Identification Table of Sewing Needle Case

System：Needle				
To [O_1] facilitate threading , [P] hole diameter should be [+P] big. But, To [O_2] advoid damaing clothes, [P] hole diameter should be [-P] small.				
O_1	Representative parameter: length of the thread passing through the hole	Center Component: thread	P	Center Component: needle
O_2	Representative parameter: intactness of clothes	Center Component: clothes		
Contact Component Chart				



With the parameters identified via Parameter Identification Table, a Parameter Deployment Table can be used to examine whether or not the disturbances on these parameters impose influences on the two objectives or the contradictory parameter. By doing so, the objective function of the two objectives and the contradictory parameter function of the contradictory parameter can be generated as shown in Table 14.

Table 14. Parameter Deployment Table of Sewing Needle Case

System：Needle														
O_1	To facilitate threading							O_2	To avoid damaging clothes					
Center components/ Peripheral components														
Needle			Thread			Clothes			Human					
Parameter	O_1	O_2	Parameter	O_1	O_2	Parameter	O_1	O_2	Parameter	O_1	O_2	Para.	O_1	O_2
Hole diameter	↑	↓	Passing length	↑	×	Intactness	×	↑	Sewing technique	↑	↑			
Needle sharpness	×	↑	Hardness	↑	×	Resilience	×	↑	Vision	↑	×			
Thread thickness	×	↓	Thickness	↓	↓									
			Length	↑	×									
Parameter deployment	[O_1] To facilitate threading=fn(hole diameter ↑; passing length ↑, thread hardness ↑, thread length ↑, human vision ↑; thread thickness ↓, human sewing technique ↑) [O_2] To avoid damaging clothes=fn(hole diameter ↓; needle sharpness↑, clothes intactness ↑, clothes resilience ↑; →, thread thickness ↓, human sewing technique ↑) [±P] Hole diameter=fn(thread thickness)													

Lastly, use the formulas of two objectives and the contradictory parameter listed in the Parameter Integration Table to examine if any other parameters are left out and disturb them, so the functions of two objectives and the contradictory parameter can be completed more thoroughly. Table 15 demonstrates the Parameter Integration Table of the needle case.

Table 15. Parameter Integration Table of Sewing Needle Case

System：Needle								
O_1	To facilitate threading		O_2	To avoid damaging clothes		P	Hole diameter	
Center Comp.	Needle		Center Comp.	Clothes		Center Comp.	Needle	
Formula			Formula			Formula	hole diameter < thread thickness	
Parameter	O_1	O_2	Parameter	O_1	O_2	Parameter	O_1	O_2
Parameter Deployment	[O_1] To facilitate threading =fn(hole diameter ↑; thread thickness↑, thread material →, human vision↑; thread thickness↓, human sewing technique↑, human carefulness↑) [O_2] To avoid damaging clothes=fn(fn(hole diameter ↓; needle sharpness↑, needle thickness↓, clothes resilience ↑; thread thickness↓, human sewing technique↑, human carefulness↑) [±P] Hole diameter=fn(thread thickness)							

Through Parameter Identification Table, Parameter Deployment Table, and Parameter Integration Table, the functions of the two objectives and the contradictory parameter in the needle case are described below:

[O_1] To facilitate threading=fn (hole diameter ↑; thread hardness ↑, thread material →, human vision ↑; thread thickness ↓, human sewing technique ↑, human carefulness ↑)

[O_2] To avoid damage on the clothes=fn (hole diameter ↓; needle sharpness ↑, needle thickness ↓, clothes resilience ↑; thread thickness ↓, human sewing technique ↑, human carefulness ↑)

[±P] hole diameter = fn (thread thickness)

Among them, hole diameter is the contradictory parameter of the two objectives while thread hardness, thread material, and human vision are exclusive parameters for the objective not to damage the clothes.

4.2 Parameter Manipulation and Contradiction Solution

The required time and the required objects of the contradictory demand can be figured out by using Parameter Manipulation Table (IP). And the ideas generated accordingly can be put into the corresponding boxes as shown in Table 16.

Table 16. Parameter Manipulation Table of Sewing Needle Case (IP)

System：Needle			
Separation within parameter -[IPV]			
[±P] Hole parameter=fn(thread thickness)			
Contradictory Parameter (P)	hole diameter	Decisional Factors	thread thickness
Questions	Answers	Ideas	
Where do we need +P? Where do we need –P?	Needle Needle		
When do we need +P? When do we need –P?	When threading When sewing	Choose soft and bendable metal to make needles and intensify the sharpness of the needle so as to satisfy both demands for a big hole when passing threads and a small hole when sewing	
Which object needs +P? Which object needs -P?	thread clothes	Choose soft and bendable metal to make needles and intensify the sharpness of the needle so as to satisfy both demands for a big hole when passing threads and a small hole when sewing	
+P/ -P can be satisfied in super system? +P/ -P can be satisfied in sub-system?	No No		
Other independent parameters	Value ranges	Ideas	

Through Parameter Manipulation Table (IO), it is found that the required time and required object from contradictory demand are different. Since there is no other contradictory parameter in this case, it is impossible to do separation within parameter. However, separation of system levels can be adopted to solve the problem. Parameter Manipulation Table (IO) is shown in Table 17.

Table 17. Parameter Manipulation Table of Sewing Needle Case (IO)

System：Needle			
Separation within parameter -[IOV]			
[O_1] To facilitate threading=fn(hole diameter ↑; passing length ↑, thread hardness ↑, thread length ↑, human vision ↑; thread thickness ↓, human sewing technique ↑) [O_2] To avoid damaging clothes=fn(hole diameter ↓; needle sharpness↑, clothes intactness ↑, clothes resilience ↑; thread thickness ↓, human sewing technique ↑) [±P] Hole diameter=fn(thread thickness)			
Contradictory Parameter (P)	hole diameter	Parameter in same direction (Z)	thread thickness, human sewing techniques
Exclusive parameter of O_1 (E_i^1)	Passing length, thread hardness, length, human vision	Exclusive parameter of O_2 (E_j^2)	Needle sharpness, needle thickness, clothes intactness, clothes resilience
Questions	Answers	Ideas	
Where do we need O_1? Where do we need O_2?	Needle Needle	N/A	
When do we need O_1? When do we need O_2?	When threading When sewing	N/A	
Which object needs O_1? Which object needs O_2?	thread clothes	N/A	
O_1/ O_2 can be satisfied in super system? O_1/ O_2 can be satisfied in sub-system?	Super system ~> O_1	Ask someone with good eyesight for help when threading (u)	
Other independent parameters	Value ranges	Ideas	

With Parameter Manipulation Table (CPS/COPE/COEP/COEE), ideas resulted from manipulating contradictory parameter and each exclusive parameter are put in the corresponding boxes as shown in Table 18.

Table 18. Parameter Manipulation Table of Sewing Needle Case (CPS/COPE/COEP/COEE)

System：Needle			
Separation across parameters -[CPS/COPE/COEP/COEE]			
[O_1] To facilitate threading=fn(hole diameter ↑; passing length ↑, thread hardness ↑, thread length ↑, human vision ↑; thread thickness ↓, human sewing technique ↑) [O_2] To avoid damaging clothes=fn(hole diameter ↓; needle sharpness↑, clothes intactness ↑, clothes resilience ↑; →, thread thickness ↓, human sewing technique ↑) [±P] Hole diameter=fn(thread thickness)			
Contradictory parameter (P)	hole diameter	Decisional factor	thread thickness, human sewing techniques
Exclusive parameter of O_1 (E_i^1)	Passing length, thread hardness, length, human vision	Exclusive parameter of O_2 (E_j^2)	Needle sharpness, needle thickness, clothes resilience, clothes intactness
Strategies	Target	Ideas	
[CPS] P => E^1, E^2	Contradictory parameter	Choose soft and foldable metal to make needles and intensify needle sharpness. Split hole diameter into "diameter for threading" and "diameter for sewing", satisfying the demands for big holes when threading as well as small holes when sewing.	
[COPE] P~>O_1 E^2~>O_2	Objective	Satisfy the demand for big hole diameter (needle thickness is increased at the same time). Opt for fabrics of better resilience to make clothes (x).	
[COEP] E^1~>O_1 P~>O_2	Objective	Satisfy the demand for small hole diameter. Opt for threads of greater hardness (x); ask someone with better eyesight for help when threading (u).	
[COEE] E^1~>O_1 E^2~>O_2	Objective	Opt for fabrics of better resilience to make clothes (x). Opt for threads of greater hardness (x); ask someone with better eyesight for help when threading (u).	

Before solving the contradiction by using parameter transfer, thought-provoking questions must be used to search for additional parameters. The specific function of "threading facilitation" is to "thread a needle" and its generic function would be to "pass through a solid object". On the other hand, the specific function of "clothes damage avoidance" is to "protect clothes" and its generic function would be to "remain intact".

In this case study, the needle is the physical system and the contradiction is the result of different demands for the hole diameter (big and small). Super system would be those in contact with the needle: clothes, threads, and human beings, while outer-super system would be those around it: lights, desks, and chairs. Local system includes the needle, threads, clothes, and human beings involving in the contradiction. Competing system includes threaders, sneakers, laundry bags, and dustproof bags. Systems via generic functions would be tableware and packing boxes.

With the systems described above and the five questions at the bottom of the table, ideas should be listed and corresponding parameters should be put in the boxes for later use of parameter transfer. The thought-provoking questions for this case is shown in Table 19.

Table 19. Thought-provoking Questions (TPQ) for Sewing Needle Case

O_1	To facilitate threading	SF_1	Threading	GF_1	Pass through a solid object		
O_2	To avoid damaging clothes	SF_2	Protecing clothes	GF_2	Remain intactness		
Center Comp. of P	needle	MF	sew clothes	GF_M	Repair solid object		
Physical System	needle	P	hole diameter	+P	big	-P	small
Super System	Clothes, threads, human being (eyes, nose, mouth, ears, hands, feet, hair, body, ...)						
Outer-super System	lights, desks, chairs ,...						
Local System	needle, threads, clothes, human being (eyes, nose, mouth, ears, hands, feet, hair, body,...						
Competing System	threader (plastic sheet, iron wires), sneakers (tongue, insole, shoe laces), laundry bag, dustproof bag, sewing machine						
Systems via GF	tableware, packing boxes, tapes, double-sided tapes						

Qestions	Ideas	Corresponging Para.
How [comp. X] satisfies [O_1 /F_1] with [-P]?	[threader] helps threading	threader
How [comp. X] satisfies [O_2 /F_2] with [+P]?	[clothes] equip clothes with self-cure capacity to cure itself	self-cure capacity on clothes itself
How [comp. X] satisfies [O_1/F_1] without P? ([O_2 /F_2] are satisfied by other parameters)	[threader] helps threading	threader
How [comp. X] satisfies [O_2 /F_2] without P? ([O_1 /F_1] are satisfied by other parameters)	[clothes] equip clothes with self-cure capacity to cure itself	self-cure capacity on clothes itself
How [comp. X] satisfies [O_1 /F_1] &[O_2 /F_2]?	[needle, threader] change needle ends to soft wires so as to change the eye diameter on demands	thread material
What attribute of [comp. X] satisfies [MF] and is acceptable to [O_1/O_2 /+P/-P]?	[sewing machine] facilitates threading, keeps needle from piercing through the clothes	sewing machine

Put additional parameters in the functions listed in a Parameter Manipulation Table (TP) respectively and list the ideas generated from the problem solving strategies (as shown in Table 20).

Table 20. Parameter Manipulation Table (TP)

System：needle			
Parameter Transfer -[TPPA/TPAP/TPAA]			
[O_1] To facilitate threading=fn(hole diameter ↑; passing length ↑, thread hardness ↑, thread length ↑, human vision ↑; thread thickness ↓, human sewing technique ↑; threader 3, thread material →, sewing machine 3) [O_2] To avoid damaging clothes=fn(hole diameter ↓; needle sharpness ↑, clothes intactness ↑, clothes resilience ↑; thread thickness ↓, human sewing technique ↑; self-cure capacity on clothes 3, needle material →, sewing machine 3) [±P] Hole diameter=fn(thread thickness)			
contra. P		Add. Para. (A)	threader, self-cure capacity, needle material, sewing machine
Strategies	Ideas		
[TPPA] P~>+P A^2~>−P			
[TPAP] A^1~>+P P~>−P			
[TPAA] A^1~>+P A^2~>−P			
[TPAV] A(V=v1)~>+P A(V=v2)~>−P	change the end of a needle to soft wires so as to change the eye diameter on demands		

By the same token, as shown in Table 21, list ideas generated from the problem solving strategies in the corresponding boxes of Parameter Manipulation Table (TO).

Table 21. Parameter Manipulation Table (TO)

System：Needle			
Parameter Transfer -[TOPA/TOAP/TOEA/TOAE/TOAA/TOA/TOAV]			
[O_1] To facilitate threading=fn(hole diameter ↑; passing length ↑, thread hardness ↑, thread length ↑, human vision ↑; thread thickness ↓, human sewing technique ↑; threader 3, thread material →, sewing machine 3) [O_2] To avoid damaging clothes=fn(hole diameter ↓; needle sharpness ↑, clothes intactness ↑, clothes resilience ↑; thread thickness ↓, human sewing technique ↑; self-cure capacity on clothes 3, needle material →, sewing machine 3) [±P] Hole diameter=fn(thread thickness)			
Contra. Para. (P)	hole diameter	Addtional Para. (A)	threader, self-cure capacity (clothes), needle material, sewing machine
Excl. para. of O_1 (E_i^1)	thread passing length, thread hardness, length, human vision	Excl. para. of O_2 (E_j^2)	sharpness, needle thickness, clothes intactness, clothes resilience
Strategies	Ideas		
[TOPA] P~>O_1 A^2 ~>O_2	Satisfy the demand for big hole diameter. Equip clothes with self-cure capacity which helps cure clothes itself for small holes (x).		
[TOAP] A^1 ~>O_1 P~>O_2	Satisfy the demand for small hole diameter. Use a threader to facilitate threading.		
[TOEA] E_i^1~>O_1 A^2 ~>O_2	Opt for harder threads (u); ask someone with better eyesight for help when threading (u). Equip clothes with self-cure capacity which helps cure clothes itself for small holes (x).		
[TOAE] A^1 ~>O_1 E_j^2~>O_2	Use a threader to facilitate threading. Opt for sharper needles; opt for thinner needles; opt for fabrics of better reliance to make clothes (u).		
[TOAA] A^1 ~>O_1 A^2 ~>O_2	Use a threader to facilitate threading. Equip clothes with self-cure capacity which helps cure clothes itself for small holes (x).		
[TOA] A ~>O_1/ O_2	Use a sewing machine as a replacement to repair clothes.		
[TOAV] A(V=v1)~>O_1 A(V=v2)~>O_2			

A Solution Compilation Table (shown in Table 22) can help sort out ideas generated from problem solving strategies which facilitates the examination of each solution.

Table 22. Solution Compilation Table for Sewing Needle Case

System：Needle		
Solutions		
Strategies	Modes	Ideas triggered
[IPV] [CPS] [TPAV]	Sol=(hole diameter: time-when threading/sewing→big/small; thread passing length~, thread hardness~, thread length~, human vision~; needle sharpness~, needle thickness~, clothes intactness~, clothes resilience~, clothes thickness~, human sewing techniques~; threader~, clothes self-cure capacity~, needle material →, sewing machine~)	Use soft and foldable metal to make needles and intensify the needle sharpness to pierce through the clothes. Satisfy the demands for big holes when threading and small holes when sewing.
[IOV] [COEP]	Sol=(hole diameter ↓ ; thread passing length~, thread hardness~, thread length~, human vision ↑ ; needle sharpness~, needle thickness~, clothes intactness~, clothes resilience~, thread thickness~, human sewing techniques~; threader~, clothes self-cure capacity~, needle material →, sewing machine~)	Satisfy the demand for small hole. Ask for someone with better eyesight for help when threading(u).
[COPE]	Sol=(hole diameter ↑ ; thread passing length~, thread hardness~, thread length~, human vision~; needle sharpness~, needle thickness~, clothes intactness~, clothes resilience ↑ ; thread thickness~, human sewing techniques~, clothes self-cure capacity~, needle material ~, sewing machine~)	Satisfy the demand for big hole (thicken the needle at the same time). Opt for fabrics of better resilience to prevent clothes from damage when sewing(u).
[COEP]	Sol=(hole diameter ↓ ; thread passing length~, thread hardness ↓ , thread length~, human vision~; needle sharpness~, needle thickness~, clothes intactness~, clothes resilience~; thread thickness~, human sewing techniques~; threader~, clothes self-cure capacity~, needle material ~, sewing machine~)	Satisfy the demand for small hole. Opt for harder threads to facilitate threading (u).
[COEE]	Sol=(hole diameter~; thread passing length~, thread hardness ↑ , thread length~, human vision~; needle sharpness~, needle thickness~, clothes intactness~, clothes resilience~; thread thickness~, human sewing techniques~; threader~, clothes self-cure capacity~, needle material ~, sewing machine~)	Opt for fabrics of better resilience to prevent clothes from damage when sewing (u). Opt for harder threads to facilitate threading (u).
[COEE]	Sol=(hole diameter~; thread passing length~, thread hardness~, thread length~, human vision ↑ ; needle sharpness~, needle thickness~, clothes intactness~, clothes resilience ↑ ; thread thickness~, human sewing techniques~; threader~, clothes self-cure capacity~, needle material ~, sewing machine~)	Opt for fabrics of better resilience to prevent clothes from damage when sewing. Ask for someone with better eyesight for help when threading (u).
[TOAP]	Sol=(hole diameter ↓ ; thread passing length~, thread hardness~, thread length~, human vision~; needle sharpness~, needle thickness~, clothes intactness~, clothes resilience~; thread thickness~, human sewing techniques~; threader 3, clothes self-cure capacity~, needle material ~, sewing machine~)	Satisfy the demand for small hole. Use a threader to facilitate threading.
[TOAE]	Sol=(hole diameter~; thread passing length~, thread hardness~, thread length~, human vision~; needle sharpness~, needle thickness~, clothes intactness~, clothes resilience~; thread thickness~, human sewing techniques~; threader 3, clothes self-cure capacity~, needle material ~, sewing machine~)	Use a threader to facilitate threading. Opt for sharper and thinner needles.
[TOAE]	Sol=(hole diameter~; thread passing length~, thread hardness~, thread length~, human vision~; needle sharpness~, needle thickness~, clothes intactness~, clothes resilience ↑ ; thread thickness~, human sewing techniques~; threader 3, clothes self-cure capacity~, needle material ~, sewing machine~)	Use a threader to facilitate threading. Opt for fabrics of better resilience to prevent clothes from damage when sewing (u).
[TOA]	Sol=(hole diameter~; thread passing length~, thread hardness~, thread length~, human vision~; needle sharpness~, needle thickness~, clothes intactness~, clothes resilience~; thread thickness~, human sewing techniques~; threader ~, clothes self-cure capacity~, needle material ~, sewing machine 3)	Use a sewing machines as a replacement to repair clothes.

5 Conclusion and Contribution

This paper establishes an integrated theory for parameter deployment and parameter manipulation in an attempt to encompass all principles of separation and system transfer and to provide methods of parameter identification to help users complete a thorough list of parameters. By using different separation methods and separated targets, seventeen problem solving strategies are generated, assisting users in gathering more solution ideas and opportunities. Figure 4 shows a testing of the proposed methods on twenty five cases. It is found that the methods proposed can help locate more solutions (21.76 on average) than "traditional separation principles (1.28 on average)" and "traditional separation principles plus Royen's parameter separation (4.56 on average)" do. The performance on solution search by methods proposed in this paper is about five times of that from using all existing methods.

The main contributions of this paper include:

1. Providing a systematical parameter identification and deployment method in which all problem related constituent parameters are exposed for possible resources of problem solving in each system. Problem solving can be achieved by manipulating all the parameters for systematic separation for problem solving at contradictory parameter level or objective level.
2. Providing systematic methods of parameter transfer to solve problems by external parameters

which are seemingly not relevant to the problem itself.

3. Modeling the expressions for problems and solutions to facilitate a systematical problem solving and the expressions thereof.
4. Proposing seventeen problem solving strategies within a unified theory of parameter manipulations to achieve many more solutions beyond current approaches. All current solution methods fall only within four out of the seventeen strategies.
5. Providing a thorough list of systematical parameter separation strategies, along with all the processes, tables, explanations, and cases, making it convenient to learn and use.

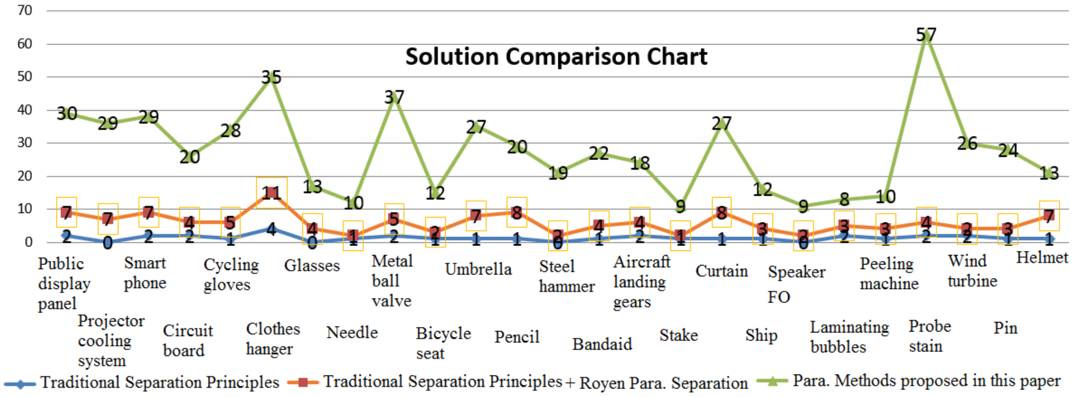


Figure 4. Comparison of Number of Solution Generated

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Paper ID: 22

Mobius Ring for a Spin Top

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Abstract

A Mobius ring is devised for a spin top to enhance the amount of exercise, and it might be used as a rehabilitation equipment. The function analysis is used to evolve the new design of the spin top from its previous version which is a modern spin top running on two rings attached to a handle held by hand. The function analysis indicates that the handle can be eliminated by transferring its function to the rings. Furthermore, to enhance its maneuver challenge, the two rings are changed to a Mobius ring in which the ordinary Mobius ring is bent twice to make a two circle shape. That way, the Mobius ring is twisted to cause the top moves along the two circles so that it twists along the track. A prototype is developed and tested with certain possible revision on further design.

Keywords: Mobius ring, spin top, function analysis, rehabilitation, twist along the track.

1. Introduction

Playing the spin top is a favorite pastime of children in the old days of Taiwan in the 1960s. The way to play it is to use a whip wrapped around the spin top and spin it on the ground. After that, the spinning top dies out gradually as it loses its momentum. Then, as it comes to a full stop, the player does the same steps to restart a new game. Other way to play with a bigger one is to keep whipping on the surface of the spinning top to keep it going. This way, the top only needs to be started once, then the top will keep on spinning. The function of this game is to train the player with one hand movement to control the whip. In 2000, a Japanese company named TAKARA TOMY launched a new spinning top game called Beyblade (Wikipedia, 2016). It is a spin top played on a plate (a plastic arena known as a Beystadium) with a plastic strip pulling along the side of the spin top. Beyblade is a specific game of power and angle for the player to use his/her two hands to start the spin top. The game emphasizes using one hand to pull the strip to get started. Once it gets started, the hands remain idle until the next game. The Beyblade was very popular in Taiwan from 2002 until 2006. Over time, a modern spin top came to the market with it moving around two rings, not on the ground. The rings are attached to a handle which is held by one hand. The player swings the handle, then the spin top moves around the rings. Color lights come out of the spin top as the spinning top move faster to a certain speed. The function of the modern spin top is to train the player with wrist movement with one hand. For these three spin top games, only one hand is trained and exercised. Will it be possible to train two hands at the same time when playing the spin top? What will be the spin top look like? Since two is better than one in terms of the amount of exercise and rehabilitation, it is interesting to explore the new design of spin top. Thus it becomes the research topic of this paper.

2. Literature Review

Spinning top appeared in literature as an ancient Chinese game dated back in Song dynasty around A.D. 1100. By then it was called, chien-chien, which means thousands of thousands. But the archeological proof of the spinning top can only be traced back to Ming dynasty around A.D. 1600 (Wang, 2004). Big spin top has even become a local culture in Taiwan (Seto, Lin and Matsuda, 2012). In western history, spinning top can be traced even earlier to 3500 B.C. where clay tops were found in the ancient city of Ur. An interesting historical review of spin top can be retrieved from the website of Spintastics Skill Toys, Inc. (Oliver, 2015).

The evolution of spin top can be classified into following stages: First, to spin the top on the ground with hands (Oliver, 2015). The weakness of this approach is that the momentum exerted on the spin top is limited. Second, to spin the top on the ground with a whip. This improves the momentum because the whip has a larger contacting area with the spin top. Besides, if the spin top is big enough, it can keep spinning with repeated beating of the whip on the side of the spin top. Third, the top is activated by pulling a thread along a gear track and is placed on an arena. There are two things special: one is it is easier to pull the thread, second it provides an arena so that two or more spin tops can be played in the same arena to compete with each other (Wikipedia, 2016). The arena is placed on the ground. Note that the spin top was previously played on the ground. Hence, to some extent, the arena confines the movement of the spin top with limited space. Fourth, the top orbits along two rings which are extended to a handle (Figures 1 and 2). The spin top is now off the ground and the activation comes from the swinging of the hand. In some design, the color lights can be emitted from the spin top if the spinning speed of the spin top is faster than a threshold. There is a common feature in all these four designs: only one hand is really exercised.

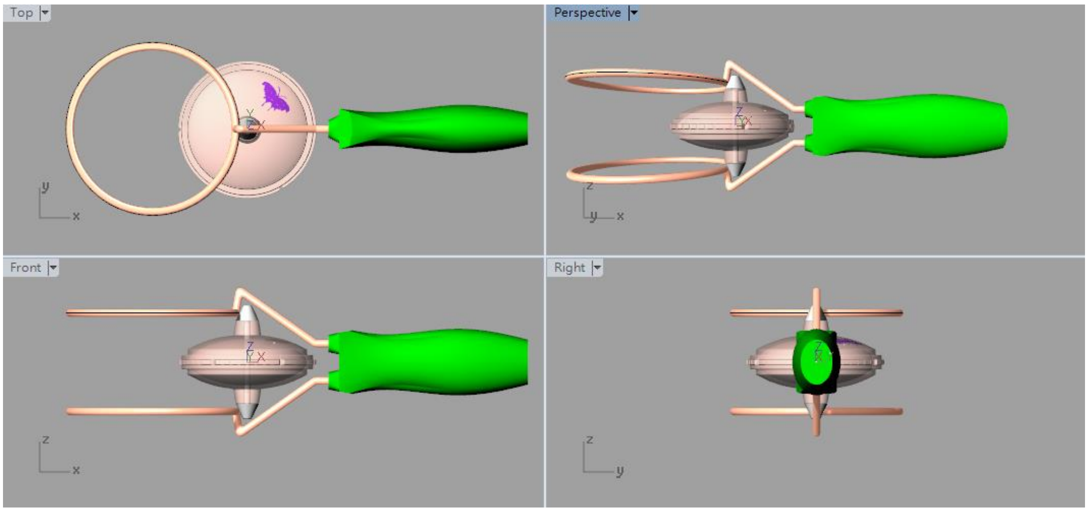

Figure 1. Implementation mode 1 of modern spin top

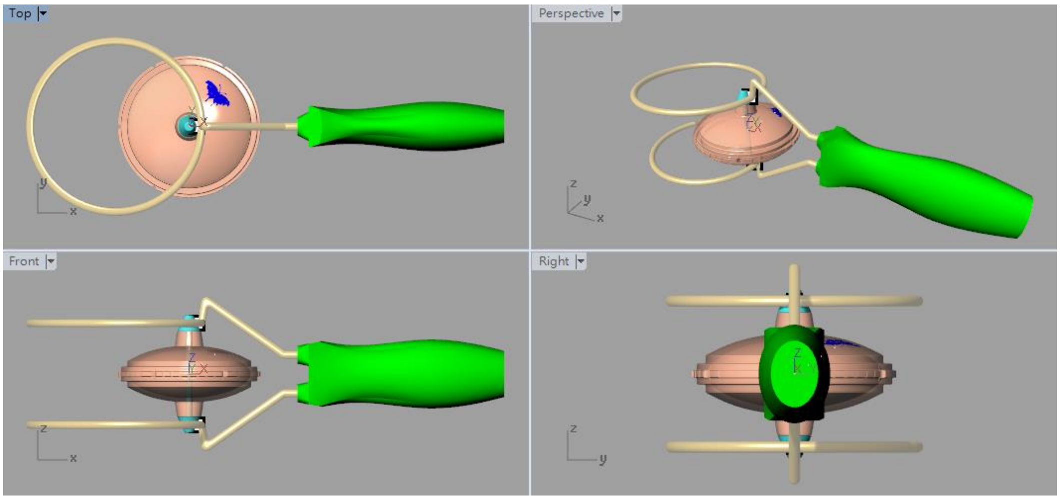

Figure 2. Implementation mode 2 of modern spin top

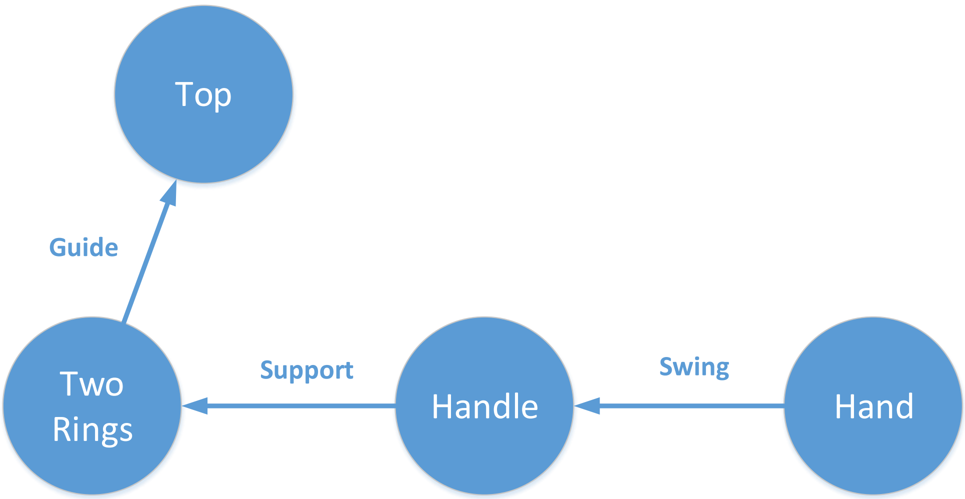

Figure 3. Functional analysis of modern spin top

Figure 4. Prototype for bending rings with spin top

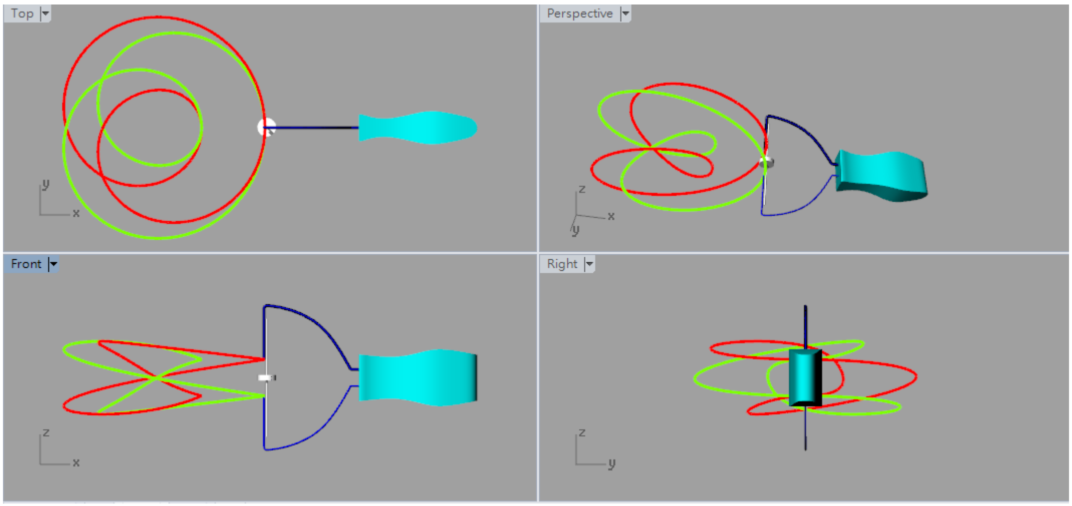

Figure 5. Tentative proposal for two Mobius rings

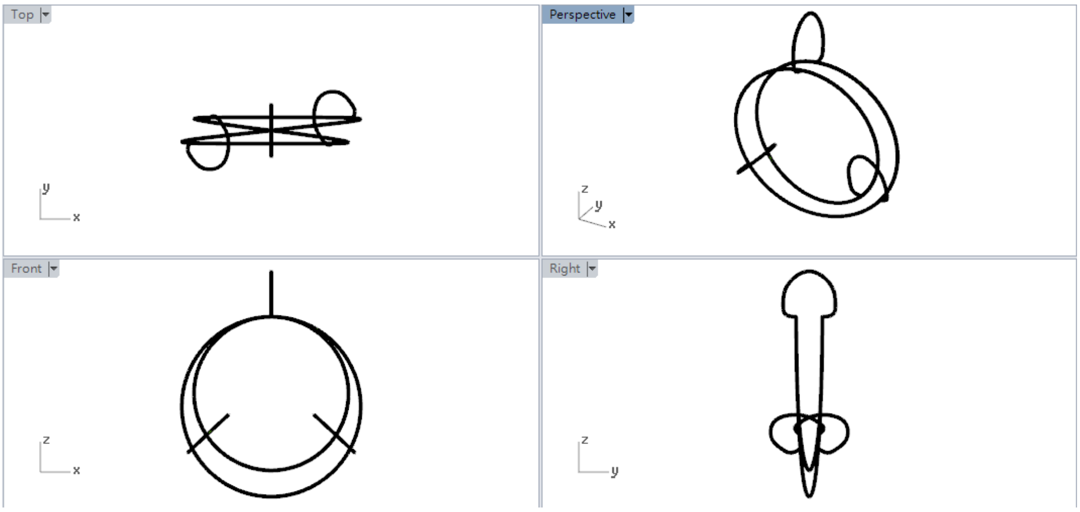

Figure 6. Mobius ring for spin top

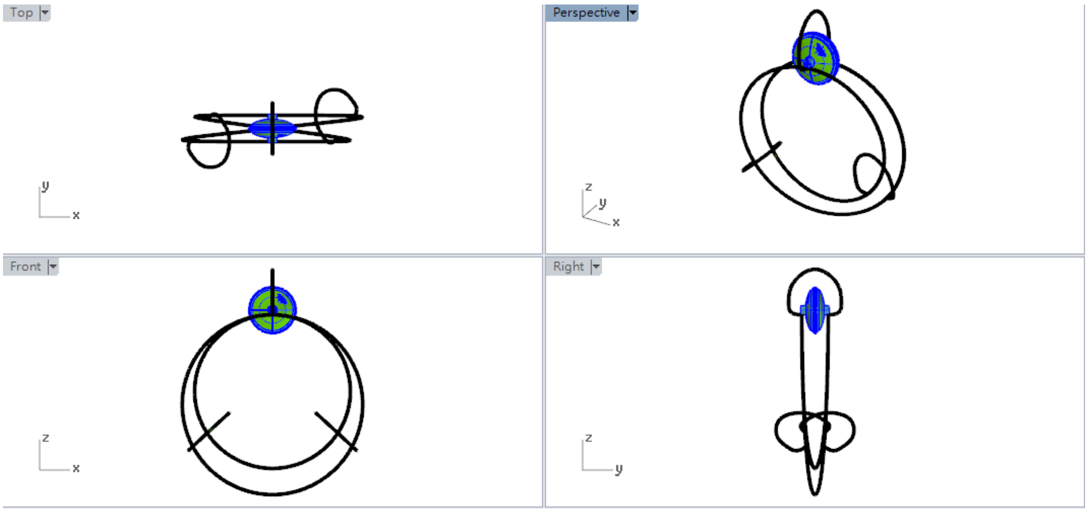

Figure 7. Mobius ring with spin top

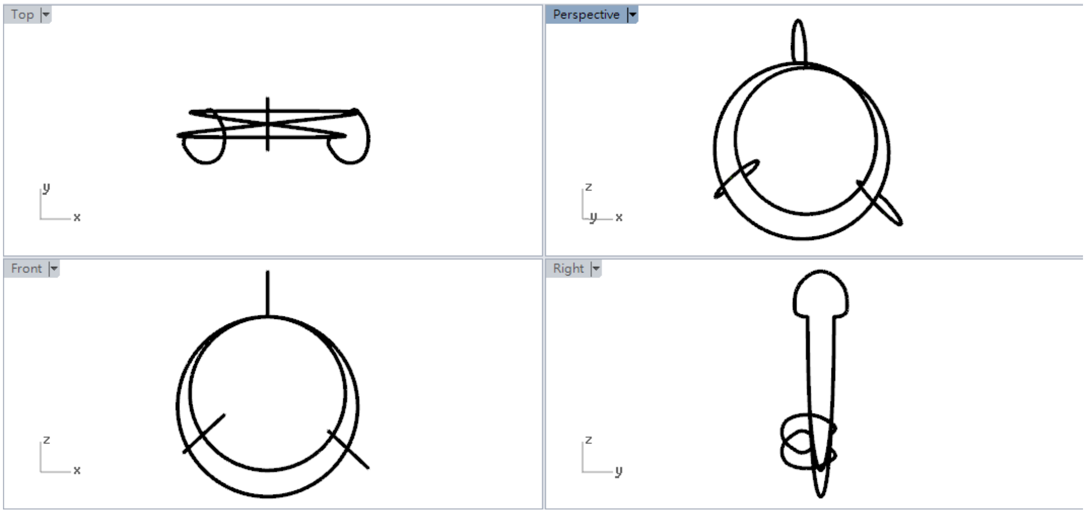

Figure 8. Alternative A for Mobius ring for spin top

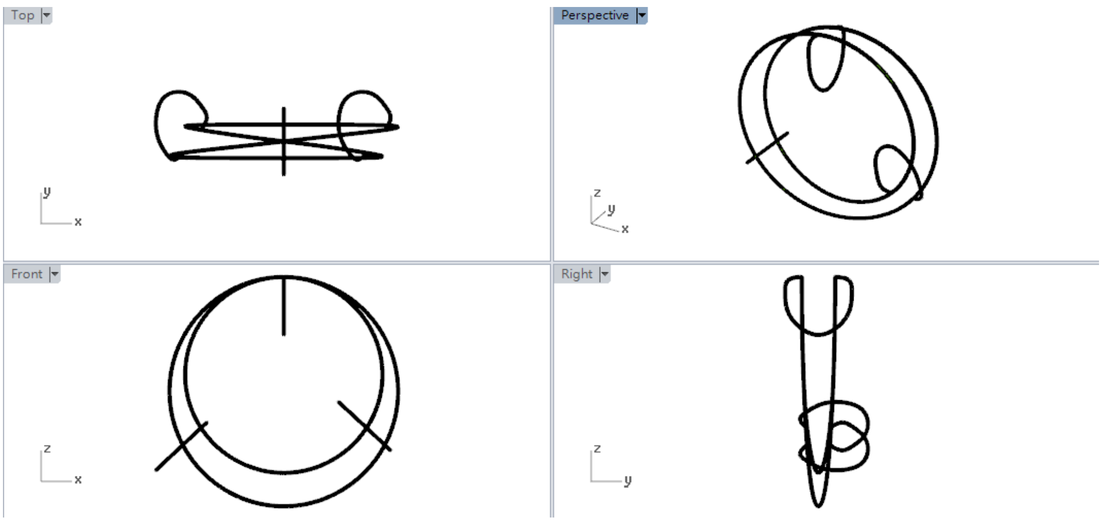

Figure 9. Alternative B for Mobius ring for spin top

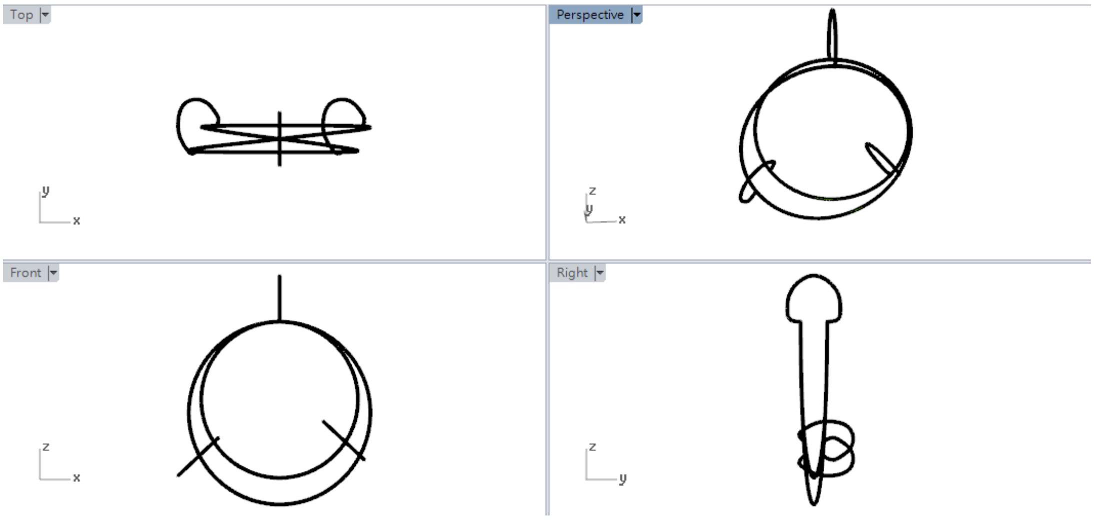

Figure 10. Alternative C for Mobius ring for spin top

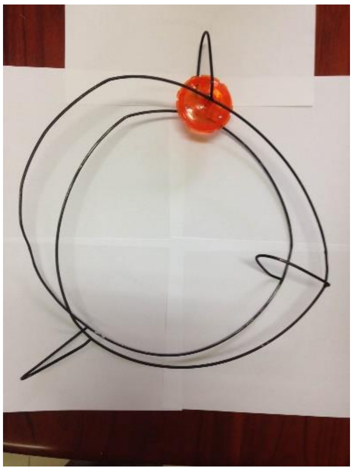

Figure 11. Prototype for Mobius ring with spin top

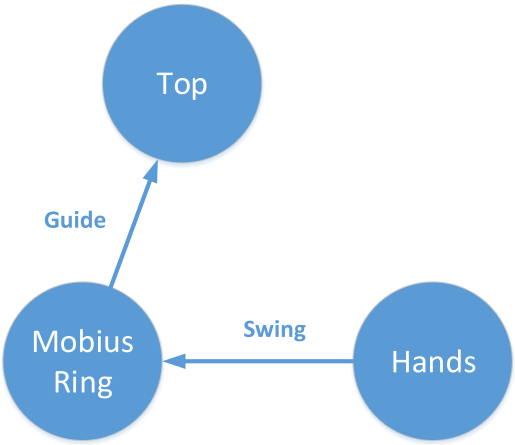

Figure 12. Functional analysis of new spin top

3. Methodology

Functional analysis is used to develop the new design of the spin top. The concept of function originated from value engineering (Mann, 2002). In value engineering, a functional diagram organizes the functions of a product in terms of their purpose functions and their means functions in a hierarchical manner. Here, each function is expressed by a noun (object) and a verb. For example, the functions of the cutter in a grass cutting unit are boost pressure and maintain angle. Here boost and maintain are verbs, whereas pressure and angle are nouns. Creating a functional diagram clarifies the purpose of the design and provides the inspiration for numerous ideas (Makinoa, Sawaguchib and Miyataa, 2015). The functional analysis in TRIZ was derived from the functional diagram in a simpler form where the interactions between any pairs of the components are described. The interaction between two components, namely, function carrier and function object is to cause the former to perform a result to the latter (Mann, 2002).

The design requirement is to exercise two hands at the same time. It is particularly helpful to people who need rehabilitation. The functional analysis on the modern spin top in Figures 1 and 2 is shown in Figure 3. There the hand swings the handle; the handle supports the rings; and the rings guide the top. The intuitive way of the new design is to use two large rings with two hands to hold them. The spin top is placed on the two rings and is orbited around them with two hands rotating the rings. The function of the handle is transferred to the rings. Now the rings provide functions as a track and a handle. This design can be alternated with certain bending of the rings. One possible design is shown in a prototype in Figure 4. That way, it does impose some challenge of the game. But, how can we increase the challenge of the game? Well, twisting the band from inside out is probably one of the ways. This is where Mobius ring comes into play. The Mobius ring is created by twisting a band itself around its imaginary axis 180 degrees and then bending itself to cause two ends to meet. There are two circle in the edges of an ordinary Mobius ring. To make the spin top run smoothly on the ring, it must form two circles in one ring. Several alternatives of the Mobius ring for spin top are shown in Figures 5-10. Figure 5 shows the tentative design with two Mobius rings are attached to a handle. The two Mobius rings are shown in green and red respectively. Figures 6 and 7 shows a symmetric design of three rib Mobius ring without and with spin top on it. Figures 8-10 shows three alternatives of asymmetrical design of three rib Mobius ring. For the sake of saving space, the Mobius rings with more than three ribs are not shown here. However, the readers can easily create the design with the inspiration from Figures 6-10.

4. Result and Discussion

A prototype has been developed and shown in Figure 11 after several experiments. There are three ribs on the ring as bridges connecting two opposite points to enhance its stability. The spin top can be run smoothly on the ring with two hands holding the opposite side of the ring and rotating it around. The Mobius ring was made by a local forge shop with an iron wire. The design is simple and elegant, and its functional analysis is shown in Figure 12. There the hands swing the Mobius ring; the Mobius ring guides the top. The player guides the spin top through the seeming two tracks in the Mobius ring and moves it in a twisting way. It takes great skill in maneuvering the spin top and two hands must be used at all times during the game.

The prototype is handmade with a thin wire. Thus three ribs are needed to enhance its stability. In mass production, an iron bar is used to ensure the stability of operation. This way, the three ribs with the prototype to enhance its stability is not necessary.

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A Study on the Economic Tool of Innovation

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Abstract

Price elasticity is the most basic concept to be used in assessing the sensitivity of the variation of product's price to cause the corresponding change of quantity (demand quantity or supply quantity). No matter the supplier's price strategy or government's public policy making, its strategic effectiveness is usually highly related to price elasticity. Although price elasticity affects supplier's pricing strategy and the effectiveness of government's public policy, yet the requirement of supplier to analyze, under different supply (demand) price elasticity, the effect of price or other commercial strategies it has adopted, to general public who has not received professional economic analysis course, is very difficult. In order to solve enterprise's dilemma in decision making, a solution is proposed. First, through literature collection, supply and demand price elasticity is summarized, database is built, Next, through the use of EXCEL software tool, acomplete set of "economic decision making system" is set up so that the supplier can put the known supply and demand price elasticity into economic model to make correct commercial strategy.

Keywords: Demand price elasticity; supply price elasticity; economy decision making tool; 9 screen diagram; TRIZ.

1. Introduction

Price elasticity is a fundamental concept of elasticity used in measuring the responsiveness of supply and demand to changes in product prices. The effectiveness of firm price strategies and government policy decisions are closely related to price elasticity. Thus, this research selects price elasticity as the theoretical basis for economic decision-making tools. It establishes a set of tools including a searchable database system of the outcomes of government policies and industry strategies involving price elasticity. It discusses how price elasticity of demand affects policy (strategy) outcomes, and how to it may be used to develop optimal policies (strategies).

Price elasticity of demand, or elasticity of demand, is a measure of the effect of a change in the price of a good on demand for that good. When price changes 1%, there is a corresponding percentage change in demand. Thus, price elasticity of demand is equal to the change in the quantity demanded divided by the percentage change in price. Price elasticity of supply, or elasticity of supply, measures the effect of a change in the price of a good on the supply of that good. When price changes 1%, there is a corresponding percentage change in supply. Thus, supply elasticity is equal to the percentage change in quantity supplied over the percentage change in price. If elasticity of demand is greater than 1, the demand for the good is defined as elastic. If it is less than one, demand is inelastic. For example, since diabetes sufferers must have insulin to live and there is no substitute, demand is inelastic. Thus, any manufacturer which can increase the price of insulin will increase its revenues. The existence of consumer price elasticity of demand for a good implies that if firms raise price, demand will fall, reducing firm revenues. Thus, when setting price strategies, manufacturers must understand the nature of elasticity of demand in order to set accurate prices. Similarly, supply elasticity of demand is a key factor in government subsidy and tax policies. The concept of elasticity may be extended to many different domains, permitting individuals and the government to analyze the strength of the response of selected variables to related variables, assisting in the analysis and estimation of outcomes, enabling prediction of future changes and acting as a key information resource for strategy and policy decision-making.

Though price elasticity helps determine the effectiveness of firm price strategies and government policy, analysis of different supply (demand) elasticies and their effects on firm pricing and other business strategies is difficult for individuals without a background in professional economic analysis. First, they do not know what models to use. Second, economic data (price elasticity of supply and demand) are difficult to collect. Eventually most firms give up the use of economic analysis to determine business strategies.

This research offers a method for solving the difficulties firms have in formulating strategies. First, we survey the literature on the elasticity of supply and demand and establish a database. Next, we use Excel to construct a comprehensive economic strategy system under which firms input existing knowledge about supply and demand elasticity into a model to support creation of accurate firm strategies.

2. Literature Review

This research uses price elasticity as the theoretical basis of the strategy tool proposed and constructed in this study. Price elasticity shows how quantity supplied or quantity demand are affected by changes in a specific good’s price, thus showing the sensitivity of the decision making of firm and government policy makers.

▪2.1 Price elasticity of Demand

Price elasticity of demand, also known as demand elasticity, is represented by (E^d). It measures the effect on change in demand for a good when its price changes. When price changes 1%, the quantity demanded will change by a corresponding percentage, as given below:

$$E^d = \frac{\text{Percentage change in demand}}{\text{Percentage change in price}}$$

There are five types of price elasticity of demand:

(1) Elastic demand: $E^d > 1$, the percentage change in quantity demanded is greater than the percentage change in price.
(2) Inelastic demand: $E^d < 1$, the percentage change in quantity demanded is less than the percentage change in price.
(3) Unit elastic: $E^d = 1$, the percentage change in quantity demanded is equal to the percentage change in price.
(4) Perfectly elastic: $E^d =$ ¥ , even the tiniest percentage change in price produces massive percentage changes in demand
(5) Perfectly inelastic: $E^d = 0$, no matter how great the percentage change in price, there is no change in the quantity demanded.

Factors affecting price elasticity of demand for a given good include: the number of substitutes for a good, the proportion of consumer spending among all spending on a good, whether it is a luxury or a necessity, and time elapsed since the change in price.

▪2.2 Price elasticity of Supply

Price elasticity of supply, also known as supply elasticity, is represented by (E^s). It measures the effect on change in supply of a good when its price changes. When price changes 1%, the quantity supplied will change by a corresponding percentage, as given below:

$$E^d = \frac{\text{Percentage change in quantity supplied}}{\text{Percentage change in price}}$$

There are five types of price elasticity of supply:

(1) Elastic supply: $E^s > 1$, the percentage change in supply is greater than the percentage change in price, showing that quantity supplied is sensitive to changes in price.
(2) Inelastic supply: $E^s < 1$, the percentage change in supply is less than the percentage change in price, showing that quantity supplied is not very sensitive to changes in price.
(3) Unit elasticity: $E^s = 1$, the percentage change in quantity supplied is equal to the percentage change in price.
(4) Perfectly elastic: $E^s =$ ¥ , even the tiniest percentage change in price produces massive percentage changes in supply.
(5) Perfectly inelastic: $E^s = 0$ no matter how great the percentage change in price, there is no change in the quantity demanded.

Factors affecting price elasticity of supply for a given good include: whether substitutes in production for the good exist, the sensitivity of changes in production costs, time elapsed since the change in price.

▪2.3 Applications of price elasticity

The concept of elasticity has wide application, offering analysts a set of selected variables that determine the movements of related variables, in process aiding analysis and evaluation of outcomes, making it an important resource for policy and strategy prediction.

Loderer, Cooney, and Drunen (1991) studied price elasticity of demand for the common stock of a firm. Their findings are consistent with the idea of finite price elasticities. Ermisch, Findlay, and Gibb (1996) estimate the price and income elasticities of housing demand for a half dozen British urban areas. Schoengold, Sunding, and Moreno (2006) calculate the price elasticity of demand for irrigation water, finding it to be -0.79. Pagoulatos and Sorensen (1986) discussed factors affecting elasticity of demand in U.S. food and tobacco industries and tests a model of interindustry elasticity, finding that high advertising expenditures result in lower elasticities of demand. Demand elasticity is also affected by industry concentration, the stage of production, the existence of industry protection from domestic and foreign entry, and the volume of new product introduction in a particular market. Bolton (1989) analyzed factors shaping brand price elasticities for specific products, an under-researched area, showing that market traits such as brand market share, coupon activity, display activity, and feature activity explain much of the variation in promotional price elasticities, making these factors useful in evaluating and predicting price elasticity.

Differences in price elasticity lead to differing firm and government strategy outcomes, affecting strategic choices. Agthe and Billings (1987) explored the effect of block rate pricing structure on individual demand for water. They observed that demand models show that under increasing block rate pricing schedules, higher income households use more water and have lower elasticities of demand. This implies that a uniform proportional rate increase reduces water use among low income households proportionally more than among high income households. Behrman (1966) estimated the price elasticity of the marketed surplus of a subsistence crop, a key topic as it is hotly debated in discussions of the effects of agricultural and tax policies. Hodrick (1999) showed that expected stock price elasticity may be an important factor in firm financial decisions that affect the supply and demand of stock. Lewit and Coate (1982) estimated the price elasticity of demand and explored the possibility of of reducing cigarette smoking by increasing cigarette taxes.

Looking at supply elasticity, Stover (1986) estimated the price elasticity of the housing supply, finding it to be infinite. Quigley and Raphael (2005) calculated the price elasticity of the housing supply in more and less regulated urban areas, finding that regulations strongly affect housing outcomes.

3. System Programming Design

Because this tool requires large quantities of supply and demand price elasticity information, the first step is gathering the existing knowledge of supply and demand elasticity from the literature. The next step is to use Excel to design and construct a tool for economic strategy analysis.

▪3.1 Supply and Demand Price Elasticity

1. Price elasticity of demand

The results of our literature survey on price elasticity of demand are:

Table 1. price elasticity of demand.

Paper	Commidity	Elasiticity
Tsai (2003)	USA	0.4226
	Japen	3.634053
	Hong kong	10.17036
	Thailand	12.97343
Tsai(2009)	the price and quantity of small size LCD panel applied on mobile phone	1.17
Schoengold, Sunding and Moreno (2006)	agricultural water demand is	0.79

2. Price elasticity of supply

The results of our literature survey on price elasticity of supply are:

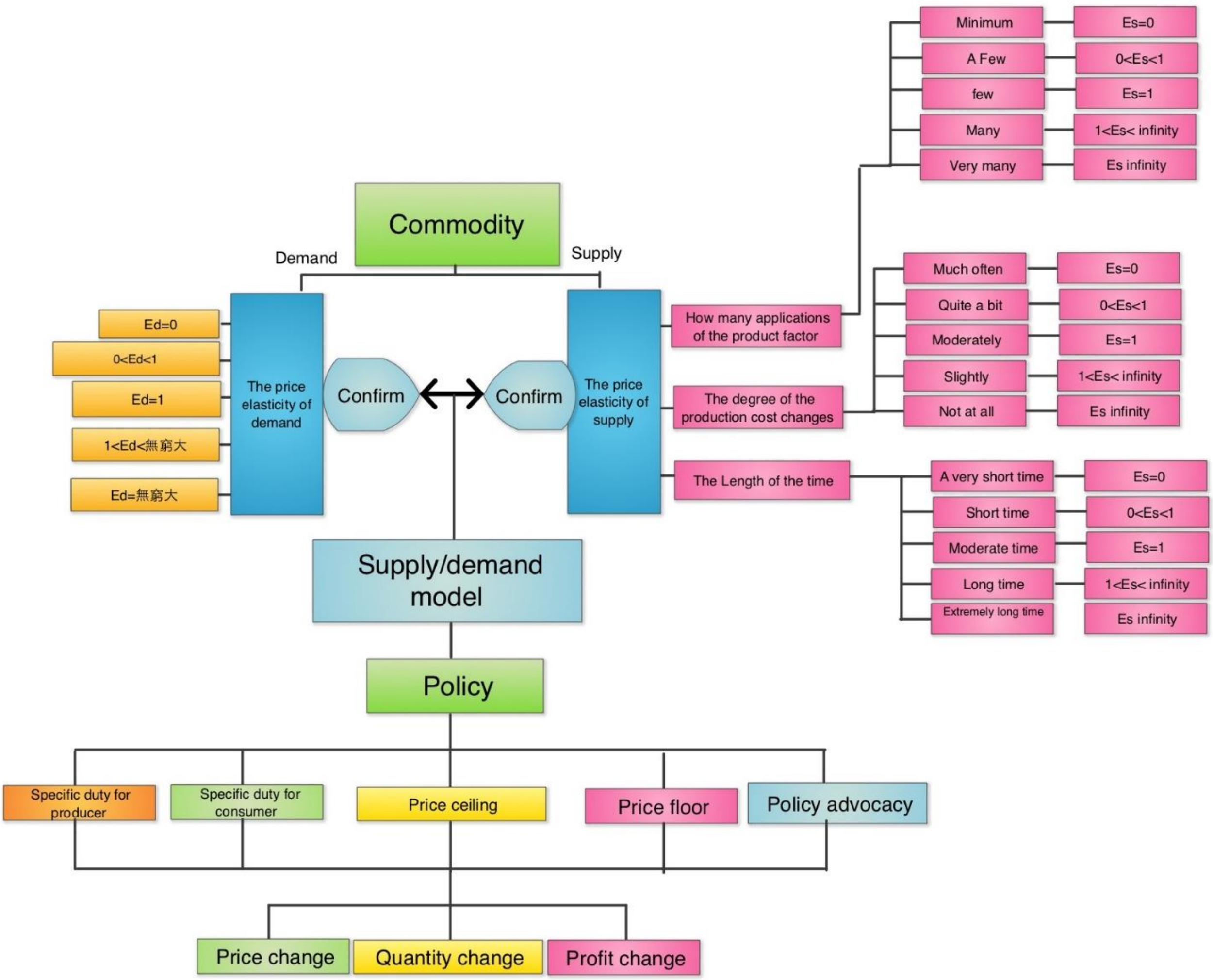
Table 1. price elasticity of supply.

Paper	Commidity	Elasiticity
Zeng (2011)	Glutinous Rice	0.686229
Stover (1986)	house	infinite

▪3.2 Search system for known price elasticities of demand and unknown price elasticities of supply

This paper proposes and constructs a search tool for known price elasticities of demand and unknown supply elasticities of demand. The system is shown in the figure below:

Figure 1. Interface of the search system for known price elasticities of demand and unknown price elasticities of supply



▪3.3 System Operating Interface

The operating steps are shown below:

Step 1: User inputs the desired good into the search system

Step 2: Using the data on the price elasticity of demand for the good already in the database, the system displays the value for the price elasticity of demand

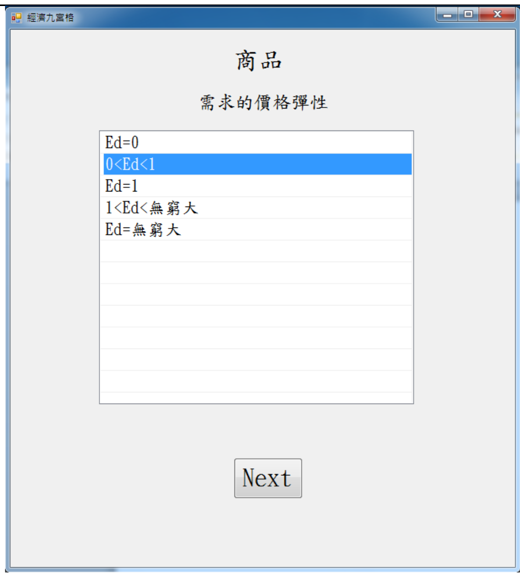
Step 3: the user enters the supply elasticity search system. Based on the factors affecting price elasticity of price, such as number of substitutes, production cost changes, and time elapsed since the price change, it predicts the expected price elasticity of supply.

Step 4: When supply and demand price elasticity are ascertained, the system completes the establishment of an economic model.

Step 5: the user selects strategies, such as taxes on production value or consumption, or price floors and ceilings.

Step 6: the system then calculates the probable outcome for the strategy, including changes in prices, quantities, and profits.

The following example illustrates the steps and results.

<table>
<tr><td colspan="2">Step 1：user inputs the desired good into the search system__north Taiwan international sightseeing traveling lodgings price。</td></tr>
<tr><td>Step 2：using the data on the price elasticity of demand for the good already in the database, the system displays the value for the price elasticity of demand.</td><td>
</td></tr>
<tr><td>Step 3:the user enters the supply elasticity search system. Based on the factors affecting price elasticity of price, such as number of substitutes, production cost changes, and time elapsed since the price change, it predicts the expected price elasticity of supply.</td><td>
</td></tr>
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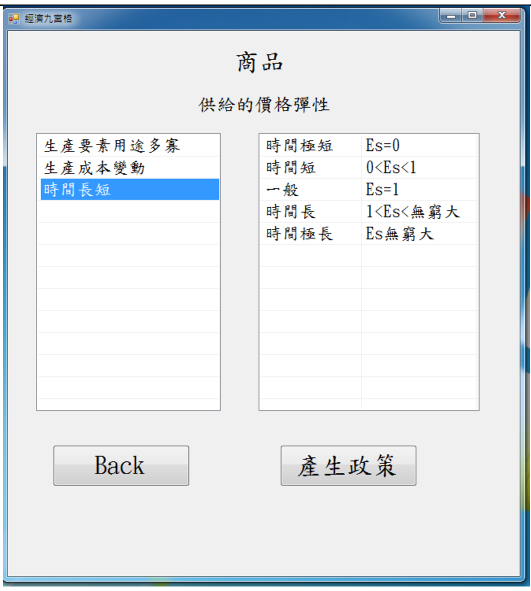
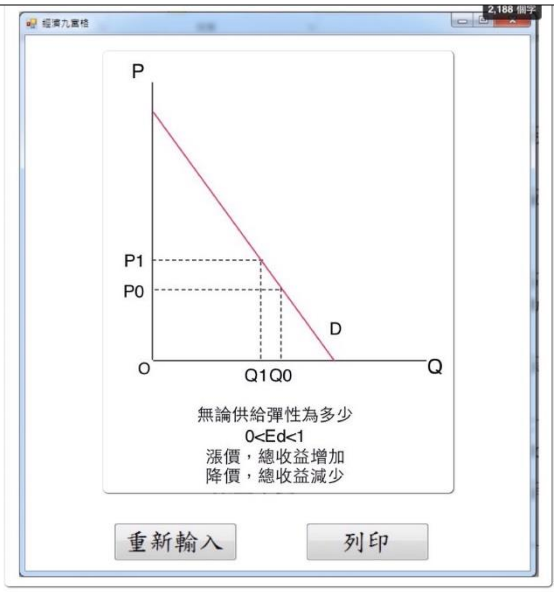
<table>
<tr><td>Step 4: when supply and demand price elasticity are ascertained, the system completes the establishment of an economic model. 。</td><td>
</td></tr>
<tr><td colspan="2">Step 5: the user selects strategies, such as taxes on production value or consumption, or price floors and ceilings. 。</td></tr>
<tr><td>Step 6: the system then calculates the probable outcome for the strategy, including changes in prices, quantities, and profits.</td><td>
</td></tr>
<tr><td colspan="2">As the result，If the firms of the Northern Taiwan international tourism accommodation raise the price of accommodation，the revenue will increase.</td></tr>
</table>

4. Conclusion

Price elasticity is a fundamental concept of elasticity used in measuring the responsiveness of supply and demand to changes in product prices. The effectiveness of firm price strategies and government policy decisions are closely related to price elasticity. This research offers a method for solving the difficulties firms have in formulating strategies. First, we conduct a literature survey to understand the application of TRIZ and the 9 screen diagram. Next, we survey the literature on the elasticity of supply and demand and establish a database. Finally we use Excel to construct a comprehensive economic strategy system under which firms input existing knowledge about supply and demand elasticity into a model to support creation of accurate firm strategies.

Though this system can help users craft accurate business strategies, many areas of the model require further refinement. First, because of limits on labor, time, and information, we were unable to acquire sufficient data on elasticities, limiting the usefulness of the system. Furthermore, the evaluation of the elasticity information was limited since we fell behind schedule on the data collection, producing erroneous and missing data. If large amounts of data can be collected from the literature, and a system for returning robust and timely evaluations of price elasticity can be established, this strategy search system will have a much greater effect.

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The novel risk analysis requirements in ISO 9001:2015

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Abstract

The recent 2015 edition of ISO 9001 brings an innovative risk-thinking approach in its new section 6.1. Comparing with previous editions of the standard, the main innovation is the introduction of risk analysis and identification of opportunities within quality management processes. The aim of this work was to show how the new requirements can be fulfilled. This was achieved through a case-study in an industrial company, by applying a structured analysis to a specific management process. This paper describes a practical example, demonstrating how this type of analysis can be applied to any management process within a companies' quality system. Two methods were used; the first was Failure Mode and Effect Analysis (FMEA/FMECA), and the second was a Hazard and Operability Study (HAZOP). In the latter case, the authors used the designation QF-HAZOP to highlight the fact that this is a HAZOP study applied to the analysis of Quality Functions. The work covered three vital management functions, including "Maintenance", "Human Resources" and "Sales". In this paper, only the last one is thoroughly analysed and discussed. The methods applied allowed identifying and scrutinizing 23 specific activities (functions) associated with around 54 risk factors (failure modes). After being categorised by risk level (or hierarchy of priorities), these risk factors provided a way of finding improvement opportunities. This work shows that either FMEA/FMECA or the adapted QF-HAZOP constitute useful approaches to fulfil the new requirements of ISO 9001:2015 Quality Standard.

Keywords: Quality risk assessment, Risk thinking approach, Quality management, ISO 9001:2015, FMEA / FMECA, HAZOP.

1. Introduction

Until the early 1990s, there were several competitive standards associated with quality systems.

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The need to standardize procedures emerged at that time, in order to contribute to reducing barriers to international trade and increase efficiency, involving the various stakeholders and especially consumers. This standardization was materialized with the creation of ISO 9000.

Based on a previous British Standard (BS-5750), created during the 2nd World War for managing the production of ammunition, the ISO 9000 series appeared in 1987, addressing Quality Management and Quality Assurance. Of this series the most relevant was ISO 9001, which consisted of a quality management model for organisations wishing to certify their management systems. These ISO standards are reviewed every five years by a responsible technical committee, in order to remain current and effective. The new ISO 9001:2015, recently published, replaces the 2008 version. The changes associated with this new edition require companies to adopt a novel *risk thinking approach* towards quality management. The evolution of ISO 9001 underlying philosophy is summarized in Table 1.

Table 1. Evolution of the ISO 9001 standard

Version	Description
ISO 9001:1987	Based on specifications for Quality Management Systems, focusing on specific objectives of each organization, oriented for the Manufacturing Process in order to create a rigorous process and stable production. Focused on the product.
ISO 9001:1994	To modernize the previous version, the emphasis was reinforced on Quality Assurance through prevention and evidence of compliance with documented procedures. Unfortunately, and following the image of the first edition, companies tended to implement its measures through the creation of documentation, which led to excessive bureaucracy.
ISO 9001:2000	The standard sought to make a radical change in thinking by introducing the concept of Process Management as a centrepiece of the standard in the attempt of turning a “document system” into an “documented system". The objective would be to increase the efficiency of the system by implementing performance measures. In this review, the continuous improvement of expectations and customer satisfaction also had great prominence.
ISO 9001:2008	This review contains only minor changes. The aim was to clarify existing requirements and improve the consistency of the approach, in parallel with other management standards (ISO 14001).
ISO 9001:2015	It was launched to reflect the good practices recently associated with quality management. Although there are more strict requirements, the standard in general is much more flexible and has a greater integration with other ISO management criteria, through greater involvement of top management and the introduction of risk analysis.

The requirements included in the ISO 9000 series are generic and applicable to any economic sector, regardless of the type of product supplied. However, the diversity of products manufactured, services rendered, their specific aspects and the characteristics of the organization, should be properly considered during the design and implementation of a quality management system (Pereira and Requeijo 2012).

The ISO 9001:2015 encourages organizations to follow a sustainable development path, promoting improvement that will reflect on the overall performance. Specifically, this standard is intended to introduce changes in the practice of quality management on technological and increasingly complex dynamic environments. Nevertheless, it is necessary that the standard keeps being generic and helps simplifying the implementation. The main changes in this new standard are the explicit requirements for risk analysis and opportunities identification, meaning to assess actions that could potentially affect in a positive or negative way any product or service and/or jeopardize or enhance the whole performance of the organization.

In this sense, other assessment techniques will then be applied to identify and solve any situations that may be harmful to the company and should also give guidance on future improvement actions. The notion of risk is now an additional concept, not replacing the principles already present in the previous editions. Risk is embedded in the foundations of the standard, since it will be part of the planning phase. The “process approach” and the PDCA (Plan-Do-Check-Act) philosophy remain two key pillars. Therefore, risk management works towards continuous improvement and preventive action.

From what was mentioned before it becomes clear that the new 2015 edition produced a (new) gap that organisations need to fulfil, namely with regard to risk analysis of management functions.

The objective of this study is to show how the new requirements can be accomplished by applying a preliminary analysis to a specific management process. The case-study presented was carried out in a flat steel manufacturer (coils), in a Portuguese plant of a multinational company.

2. Methods

FMEA – Failure Modes and Effects Analysis

Failure Modes and Effects Analysis (FMEA) is a well-established method, which has been used since the beginning of the 1950s. The method is extensively described in the literature (e.g.: ISO 31010:2009, Harms-Ringdahl, 2013). As its name suggests, the technique focus on identifying component’s failure modes, their causes and their effects on a system (or process). It provides inputs for corrective actions and/or monitoring programmes.

There are variants of the method; consequently, just saying FMEA does not define exactly what an analysis will look like. One popular alternative is FMECA – Failure Modes, Effects and Criticality Analysis, in which "Criticality" is a function that allows estimating a "risk index" (RPN – Risk Priority Number). This index is established using scales (usually between 1 and 10) for rating severity of failure (S), likelihood of failure (O) and ability to detect the problem (D).

There are several applications of FMEA: **Design** (or product) which is used for components and products, **System** which is used for systems, **Process** which is used for manufacturing and assembly processes. More recently, FMEA/FMECA has also entered the application field of Service processes and procedures (Stamatis, 2003). This is why this method appeared to be a good candidate for conducting this case study. The method also has its limitations, which include: 1) it can only be used to identify single failure modes, not combinations of failures, and 2) the studies can be time consuming and costly.

HAZOP – Hazard and Operability study

HAZOP is the acronym for Hazard and Operability study, and the method consists of a structured and systematic examination of a planned or existing product, process, procedure or system. It is a technique to identify risks to people, equipment, environment and/or organizational objectives.

The HAZOP process is a qualitative technique originated in the 1960's (Kletz, 1999). It is based on the use of guide words, which allow the identification of specific "deviations" in the intention of a system's function (ISO 31010:2009). These guide words are simple words or phrases that are applied to the intention of either a part of an installation or a process step (Ringdahl 2013). HAZOP is similar to FMEA in the way that it identifies failure modes of a process, system or procedure, as well as their causes and consequences. It differs because it starts with the deviation to the intention and works back to possible causes and failure modes, whereas FMEA starts by identifying failure modes (ISO 31010:2009).

The technique was initially developed to analyse chemical processes, but it has been extended to other types of systems and complex operations. Examples of application within other fields are, for instance, the development of SCHAZOP (Safety Culture HAZOP) by Kennedy and Kirwan (1998), to analyse safety management vulnerabilities, and to assist in the improvement of safety management. Another example is the HSE (2005) human-HAZOP technique for the analysis of "human factors", or "human functions" in the management of major accidents hazards.

In alignment with the variants above mentioned, the authors decided to explore the use of HAZOP within quality management functions, the reason why it was designated QF-HAZOP, to highlight this new application field.

3. Risk analysis of the quality function "Sales". Main results.

3.1 Results of FMEA / FMECA analysis

The case-study carried out covered three management processes of the company's quality system. This paper, however, only describes the "Sales" process, largely due to the fact that this is a key process. Not only it involves several functional areas, but it also requires interaction with a large number of people in leadership positions, rendering this process into the most complete of the three. Roughly, the main process "Sales" is divided into 10 sub-processes, namely:

1. Sales plan development 6. Expedition of orders
2. Soliciting orders and negotiation 7. Preparation and submission of documentation
3. Identification of customer requirements 8. Sales analysis
4. Capacity analysis and acceptance of customer 9. Complaints, treatment and analysis orders / contract changes 10. Evaluation of customer satisfaction
5. Follow-up and customer information

Based on internal documents and brainstorming sessions, the research team produced checklists with foreseen failure modes, which were later on validated by the process owners. These checklists helped identifying the relevant failure modes and opportunities registered in the FMEA tables. Not all the failure modes and opportunities were identified through this process; the remaining were recognised as a result of proactive discussions with those responsible for the process. Table 2 shows an example of some failure modes and opportunities identified within the two sub-processes "Capacity analysis and acceptance of customer orders/contract changes" and "sales analysis".

Table 2. Example of failure modes and opportunities (FMEA/FMECA)

Sub-process	Failure Mode
Capacity analysis and acceptance of customer orders / contract changes	
Orders	Acceptance of orders outside product range (OPPORTUNITY)
	Errors on planning small orders
	Infeasibility of the deadline established
HRC'S Stock	Incorrect mapping of HRC'S (Hot Rolled Coils) stock
Sales Anaylsis	
Sales statistics	Deviation Analysis from pre-defined objectives (OPPORTUNITY)
	Incorrect quantification of sales volumes
	Failure to pay the invoice (by the customer)

It can be expected that both opportunities (*c.f.* Table 2) have the potential to generate a considerable positive impact, since "Acceptance of orders outside product range" allows to streamline the production process and to diversify the supply, consequently increasing revenue. As for the "Deviation analysis from defined objectives", not only it allows complying with the sales objectives, but also stimulates to go beyond expectations, which relates to the continuous improvement perspective.

The next step consisted on the identification of the effects. To facilitate the process, the expected (negative) effects were previously classified into seven main categories, listed below.

1. Non-compliant Product / Service
2. Increase in cost
3. Business loss
4. Failure on delivery time
5. Loss of economic and financial flexibility
6. Disruption of production capacity
7. Others – to include special cases that occur less frequently

In order to identify potential causes associated with failure modes, two approaches were used. One of them was the so-called SHELL model (or acronym), which enabled the categorisation of the components that could potentially generate risk. This model allowed to create 5 categories of causes divided into:

- **Software** – intangible components, such as includes rules, regulations, etc., which represent the normal operational procedures;
- **Hardware** – technical systems, equipment or tools (e.g.: displays, controls, manuals, etc.);
- **Liveware** – refers to the human element of the system (e.g.: operators, managers), who interact with the other categories;
- **Environmen**t – includes the external influences and other factors beyond the above three categories (L-S-H). These influences include organisational factors, such as social or safety climate, economic or commercial pressure, etc., as well as the natural environment in which operations take place.

The second technique used to identify potential causes was the Ishikawa Diagram. In this case the diagram allowed relating effects-to-causes, which facilitates filling in the FMEA table.

The analysis proceeded with the FMEA's evaluation phase. This comprised two different stages: the Qualitative Analysis, which described the functional analysis and identified failure modes, effects and related causes. The second stage consisted on the Valuation of Risk, where the severity indexes (S) are established, as well as the detection (D) and occurrence indexes (O). Table 3 shows the criteria for evaluating severity.

Table 3. Criteria for severity index (S) (FMEA/FMECA)

Level	Severity description	Definition
1	Insignificant	The failure does not cause any noticeable impact on service
2	Very low	Failure can occur unnoticed, although with minor effects on service
3-4	Low	Failure is noticeable and slightly affects the service beneficiaries
5-6	Medium	Failure has undesirable consequences and let the beneficiaries unhappy
7-8	High	The mistake affects the service performance significantly
9	Very High	The failure has serious consequences on service performance
10	Catastrophic	Failure is unacceptable and / or irredeemable

The application of FMEA / FMECA methodology to this case-study is illustrated next, using the sub-process "Sales plan development" as an example. The effects of a failure are, commonly, the negative consequences on products and business, and it represents a poorly managed process or organization, which in turn, may be scored to measure the severity of the failure. An extract of Qualitative Analysis and Valuation of Risk is shown in Table 4.

Table 4. Application example for potential effect of failure (FMEA/FMECA)

Failure Mode	Potential effect of failure	S
Stagnation in exploring new markets and customers	Loss of economic and financial flexibility	4
Lack of monitoring the market price levels		
Lack of gathering customer information	Business loss	4
Sales history not available for a particular client		
Not using forecasts for customer needs		
Lack of information on availability of manufacturing capacity	Disruption of production capacity	8
Insufficient manufacturing capacity for galvanized steel		
Inadequate distribution of sales volumes in the sales plan (by product, market, customer)	Increase in cost	4
Not developing partnerships with suppliers		
Inefficiency in completing the company's orders		

The next step consists in analysing the causes. To carry out this assessment, the potential causes of each failure mode are associated with an occurrence index (O). This index helps identifying the most problematic causes (i.e., leading to a higher RPN), which require priority improvement from a preventive perspective.

In this study a large number of potential causes were identified, some of which being associated with more than one failure mode. The idea of categorising "causes" under the acronym SHELL, proved to be useful, because it simplified the assignment of scores to occurrence index. Higher scores were assigned to the cause(s) more likely to occur, thus, identifying which might give a higher contribution to its related failure mode(s). Table 5 shows the results of "causes" and "occurrence" for the failure modes under scrutiny in this case-study.

Table 5. Application example for potential cause of failure (FMEA/FMECA)

Failure Mode	Potential cause of failure	O
Stagnation in exploring new markets and customers	Absence of strategy to reach new customers Outdated network for professional contacts Insuficient information about competition	1
Lack of monitoring the market price levels	Technology and Equipment (Insuficient technological requirements) Insufficient data collection and processing of information	
Lack of gathering customer information	Failure to communicate with the customer Insufficient data collection and processing of information	3
Sales history not available for a particular client	Insuficient information about competition Poor assessment regarding the relevance of business	
Not using forecasts for customer needs	Technology and Equipment (Insuficient technological requirements)	
Lack of information on availability of manufacturing capacity	Ineficcient information flow within the company Unpredictability of orders (quantities / specifications)	7
Insufficient manufacturing capacity for galvanized steel	Poor production planning	
Inadequate distribution of sales volumes in the sales plan (by product, market, customer)	Bad data analysis and results calculation Breach on procedures	2
Not developing partnerships with suppliers Inefficiency in completing the company's orders	Insufficient data collection and information processing Unfavorable economic situation	

Finally, the detection index (D) rates how likely the means of control implemented by the company would preventively detect the failures and causes, as illustrated in Table 6. The scores given assess the quality of the control measures applied, and unveil which sub-processes have better control actions.

Table 6. Application example of control measures (FMEA/FMECA)

Failure Mode	Control measures*	D
Stagnation in exploring new markets and customers	Monitoring the DC reporting	2
Lack of monitoring the market price levels	Monitoring CRU index ORG_17	
Lack of gathering customer information Sales history not available for a particular client Not using forecasts for customer needs	ERP X3	2
Lack of information on availability of manufacturing capacity	ERP X3	6
Insufficient manufacturing capacity for galvanized steel	Portfolio balance	
Inadequate distribution of sales volumes in the sales plan (by product, market, customer)	Sales plan	2
Not developing partnerships with suppliers Inefficiency in completing the company's orders	ERP X3	

*The control measures listed in this table use an internal coding representation; Most are admnistrative softwares and procedures

Once all three indexes (S, O, D) had been rated for each item in the table, the next step is the calculation of the respective Risk Priority Number (**RPN = S x O x D**), which gives an estimation of the global "risk index": the higher the RPN, the higher is the risk of failure. This is an important attribute of FMECA, since it allows not only prioritising the risk level(s) within an ordinal scale, but also making post-analysis comparisons between two consecutive evaluations and estimating the level of "risk reduction" after implementing corrective actions.

In this case-study, each of the ten sub-processes that constitute the "Sales" process was coded taking into account the relevant department (c.f. Table 7). For that matter, a column has been added to the FMEA table, where each coded item was associated with the corresponding set of failure modes. Once again, the sub-process “Sales plan development” was chosen for demonstration purposes. Table 7 shows the corresponding RPN indexes. The item encoded VAT3 has a different colour to highlight that it was identified as critical, due to its very high RPN.

In this case-study, each of the ten sub-processes that constitute the “Sales” process was coded taking into account the relevant department (*c.f.* Table 7). For that matter, a column has been added to the FMEA table, where each coded item ***(set of potential causes)*** was associated with the corresponding set of failure modes. Once again, the sub-process “Sales plan development” was chosen for demonstration purposes. Table 7 shows the corresponding RPN indexes. The item encoded VAT3 has a different colour to highlight that it was identified as critical, due to its very high RPN.

Table 7. Application example showing RPN values for sets of potential causes (FMEA/FMECA)

Item	Sub-process	Failure Mode	RPN
	Company		
VAT1	Market	Stagnation in exploring new markets and customers Lack of monitoring the market price levels	8
VAT2	Clients	Lack of gathering customer information Sales history not available for a particular client Not using forecasts for customer needs	24
VAT3	Production	Lack of information on availability of manufacturing capacity Insufficient manufacturing capacity for galvanized steel	336
	Budget		
VAT4	Business	Inadequate distribution of sales volumes in the sales plan (by produc Not developing partnerships with suppliers Inefficiency in completing the company's orders	16

Within the main process “Sales” and its 10 sub-processes, a total of 23 specific activities (management functions) were scrutinised, revealing around 54 risk factors (failure modes), that may arise from 38 different sets of causes, given that certain causes are common to more than one failure mode. The many different causes, classified by their respective RPN, were subjected to a traditional Pareto analysis (Figure 1), which helped to isolate the most critical ones.

By the analysis of Figure 1, and in accordance with the well-known 80:20 principle underlying the Pareto law, the authors considered that the five leading sets of causes should be examined more carefully. These critical causes correspond to about 60 % of importance and represent around 13 % of the total number of causes identified. After further analysis of these 5 cases, corrective measures were established, as shown in Table 8. These measures will define the future path for improving the Sales process.

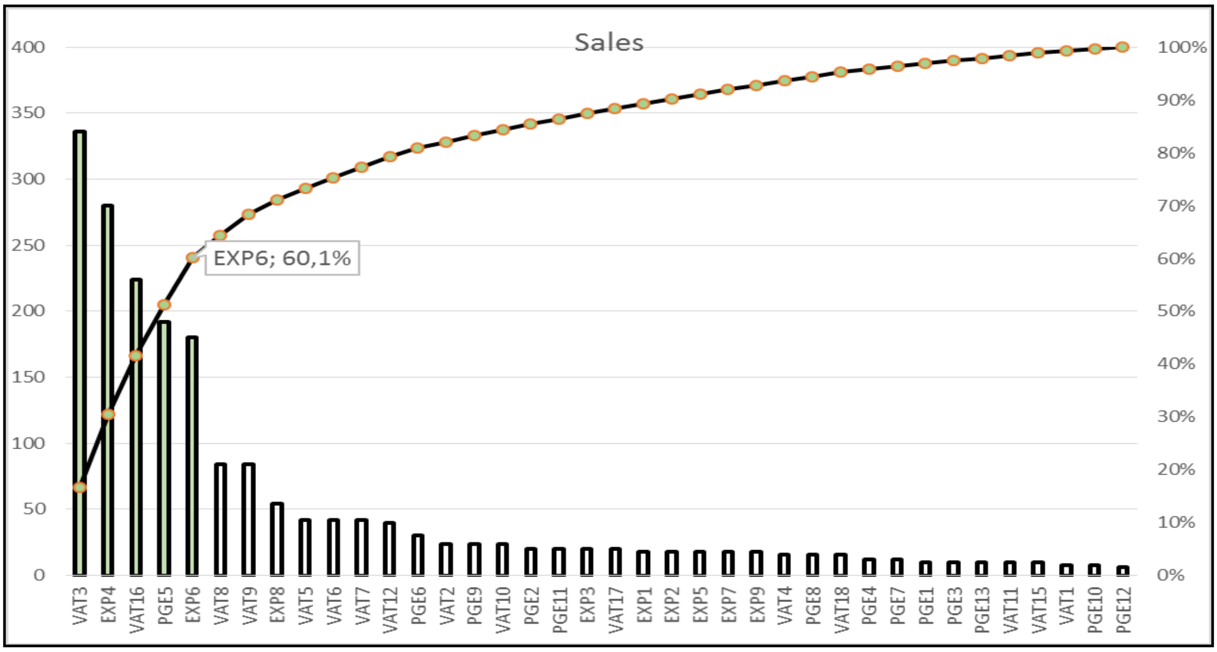

Figure 1. Pareto Chart (coded sets of potential causes *versus* RPN)

Table 8. Improvement actions (priority actions)

Item	Improvement actions
VAT3	Monitoring and updating portfolios on a daily basis
EXP4	Preventive maintenance and purchasing of spare parts for equipment
VAT16	Setting goals and monitoring the process of handling complaints, monthly
PGE5	Strategic Stock (for standard specifications)
EXP6	Increase awareness of those in charge of daily checking the status of repacking activities

Noteworthy, the corrective actions identified in Table 8 comprise two key components: “procedures” and “people”.

The management of the Production and Quality systems should be well adjusted to the company’s reality. Information and Equipment should always be available, minimising bureaucracy and anticipating problems. Therefore, through **preventive maintenance and purchasing of spare parts** and by **improving the process of handling customer complaints**, the overall performance is expected to improve.

The company’s strategy must be tailored to market characteristics, in order to reflect the business’ risks and therefore set an appropriate and well prepared response. For this to happen, measures should be taken such as **monitoring and updating portfolios on a daily basis**, as well as defining and keeping a **strategic stock (for standard specifications)**.

The workers skills should also be taken into account, to ensure that they are specialized and motivated for the work. In this sense, the measures to be taken involve increasing the **awareness of those in charge of the daily check of the status of repacking activities**. All these opportunities are related to the continuous improvement ideology.

3.2 Results of QF-HAZOP analysis

With regard to the QF-HAZOP analysis, the risks identified were basically the same of those found with FMEA/FMECA. This is possibly explained by the fact that FMEA/FMECA was used first and the analysis was comprehensive enough. Nevertheless, the HAZOP application carried the authors to find the **specific intentions** behind each failure mode, as exemplified in Table 9. This peculiarity, not used by FMEA, pushes the analysts to extend their understanding of the failure modes.

Table 9. Application example of QF-HAZOP showing specific intention (*in brackets*)

Sub-process *(Specific intention)*	**Key-Words**	**Failure Mode**
1 Sales plan development		
1.1 Company strategy		
Market	Less	Stagnation in exploring new markets and customers
(Market research)	Less	Lack of monitoring on market price levels
Customers	No	Lack of gathered customer information
	No	Sales history not available for a particular client
(Collecting and organizing customer information)	No	Do not use forecasts for customer needs
Operational	Less	Lack of information about the current situation of the manufacturing capacity available
(Monitoring manufacturing capacity)	Less	Insufficient manufacturing capacity for galvanized steel
1.2 Budget		
Business	Different	Inadequate distribution of volumes in the sales plan (by product, market, customer)
	No	Not developing partnerships with suppliers
(Negotiation and Strategic Planning)	Less	Inefficiency in completing the company's order book

There was no need to modify or change the traditional HAZOP key-words, as they seemed to be sufficient and good enough for detecting “deviations” leading to failure modes. However, this might not be so obvious if the HAZOP analysis was carried out first. Table 9 also shows an application example of the key-words.

Apparently there is no advantage in using QF-HAZOP over FMEA/FMECA, with the exception of clarifying the functions’ “intention”. By contrast, it was felt that application of FMEA/FMECA was more intuitive and that its ability to estimate a RPN number is useful to establish priorities. Nevertheless, one should be cautious when dealing with RPN indexes, since the ratings are (or can be) rather subjective. In any case, in the authors’ opinion, the HAZOP approach is also seemingly accurate for the purpose of this type of study.

4. Concluding remarks

This paper described a case-study that shows how to comply with the new edition of Standard ISO 9001:2015, which now requires risk analysis to quality management functions. The illustration case presented here covered the management process (function) “Sales”. Ten sub-processes were analysed, subdivided into various specific activities. The analysis allowed the identification of 54 failure modes that were thoroughly examined with two different methodologies. After applying QF-HAZOP it was felt that FMEA/FMECA has an additional strength related to its ability to rate failure modes and their specific causes. This allows establishing priorities for corrective actions and pinpointing opportunities for intervention. However, care must be taken, since its evaluation step based on ratings, can be quite subjective. All in all, both approaches were considered adequate within this new field of application, i.e., to assess potential risks in quality management functions.

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Developing a Kano-QFDE-TRIZ Model for Transforming Customer Requirements into Innovative Green Product

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Abstract

In this globalization era, it's essential for companies to grasp customer and environmental requirements accurately as well as embodying them in product specifications. However, in reality, just fulfilling these requirements mostly is not enough to compete in the fierce business competition. Companies must have the capability to transform these requirements into an innovative product. Several popular methodologies can solve some portion of these problems. For example, Kano model can identify important customer requirements which brings satisfaction to customers, Quality Function Deployment for Environment (QFDE) can transform customer and environmental requirements into product specifications, TRIZ can support innovative idea creation and solve technical problems; however, until now no method has been proposed to integrate these three tools. Therefore, this paper focuses on the development of a new methodology using a multidisciplinary approach by integrating these three tools to answer the previously mentioned problems. This methodology consists of four phases. Phase one starts with classifying customer and environmental requirements that have direct effects on the customer satisfaction. In phase two, results from phase one serve as an important factor to determine product specifications. In phase three, product design targets are being generated. Phase four selects the most relevant inventive principles to solve contradiction problems from product design targets. These selected inventive principles are used to generate solution concepts that can fulfill customer and environmental requirements. In this study, a technical innovation in desk lamp is used as an example to illustrate this methodology. The contributions of this study are as follows. It proposes a new way to integrate Kano model, QFDE and TRIZ to precisely capture customer and environmental requirements, transform them into product specifications, as well as generating an innovative results. This methodology also increases the efficiency of TRIZ technical idea generation process.

Keywords: Environmentally Conscious Design, Kano Model, Quality Function Deployment for Environment, TRIZ.

1. Introduction and Literature Review

For years, customer satisfaction has been used as one of the most important performance evaluation indicators by many companies. With the current trend of business globalization, the need to maintain or even increase customer satisfaction becomes more and more important, because customer satisfaction leads to customer loyalty. Loyal customers mean a steady stream of cash flow and lower cost for companies, as the cost to attract new customers is higher than to maintain customer loyalty. Therefore, the higher the level of customer satisfaction, the higher the probability companies can survive in the fierce business competition. To be able to maintain customer satisfaction, companies must have an adequate capability to recognize customer requirements and infuse them into product specifications. Quality and cost are usually the main aspects of customer's concern; however, in recent years, environmental requirements have also become a fundamental product design focus for companies. Furthermore, to give companies an edge in the competition, merely fulfilling customer requirements is not enough. Companies need to leverage that information into more attractive and innovative product specifications. As a result of the previously mentioned challenges, there is a need for companies to have a reliable procedure to recognize customer and environmental expectations and accurately transform them into innovative product concepts.

Eventually, the previously mentioned problems can be solved partially by employing existing tools. Kano model can help companies to distinguish which customer requirements bring more satisfaction or dissatisfaction (Kano et al. 1984). Masui et al. (2003) developed Quality Function Deployment for Environment (QFDE) by adding environmental aspects into a popular and widely used tool, Quality Function Deployment (QFD) (Chan and Wu, 2002), to integrate environmental and product quality requirements together in the product design and development process. TRIZ is a method of solving innovation problems proposed by Genrich Altshuller (Altshuller and Shulyak, 1996), a Soviet engineer and scientist, to support idea creation in the conceptual design process. TRIZ main idea is that the creativity process for innovation is a structured and systematic method, not just a try-and-error method. Besides having the potential for supporting product planning and development process, these three tools also have a deficiency when being applied independently. Kano model basically is used only for customer requirements' identification. QFDE is unable to find concrete solutions of improvement. TRIZ is inadequate to find which product's functions to be targeted.

Certainly, these three tools have the potential to solve the previously mentioned problems if being used together harmoniously. There are numerous studies associated with the combination of Kano model, QFDE/QFD, and TRIZ over the past several years. The authors have done a literature analysis about these combination studies, but are unable to find a single literature proposing full combination of these three particular tools. Previous researches have done partial combinations involving these two tools or with other tools. Matzler and Hinterhuber (1998) showed a way to use Kano results as QFD input, Hashim and Dawal (2012) proposed Kano and QFD integration based on ergonomic approach, Hong and Chung (2013) used this combination to construct a framework for shared research equipment service system. Chen et al. (2009) and Chiang et al. (2013) combined Kano with TRIZ to solve problems in home life industry and E-commerce service quality area respectively. QFD and TRIZ combination studies have been done to increase the effectiveness of each tool (Domb, 1998; Yamashina et al., 2002; Chaoqun, 2010). Other studies proposed three tools combination consisting of at least two of the previously mentioned tools and with another tool (Chen et al., 2010; Butdee and Trakunsaranakom, 2013; Melemez et al., 2013; Vinodh et al., 2014). No previous researches have combined these three particular tools, thus potential benefits from the combination are still unexplored. To summarize, this study will address two interdependent problems:

1. Nowadays, to stay competitive in the market, companies need to have a reliable product development process which is able to distinguish and incorporate customer and environmental requirements into product specifications and produce an innovative and attractive product.
2. Kano model, QFDE, and TRIZ, each of this methodology presents a partial solution to the previously mentioned problems. Therefore, the integration of these three tools in product development process can answer these problems; however, previous literatures lack a technique that incorporates these three particular tools together.

The objective of this study is to propose a different approach for product development process by combining these three popular tools: Kano model, QFDE, and TRIZ to help companies produce an innovative design based on customer and environmental requirements in their product development stage. To further illustrate our methodology, we analyzed a desk lamp product and proposed a conceptual design as an example.

2. The Proposed Methodology

This study proposes a new methodology which integrates Kano model, QFDE, and TRIZ for innovative and sustainable product development. This methodology consists of four phases as shown in Figure 1.

2.1. Phase one: Identifying customer and environmental requirements

The first step in this methodology is to distinguish customer and environmental requirements. Kano questionnaire was used to collect data from the customers. When formulating Kano questionnaire, usually voice of customers (VOC) are the only main criteria, but in this methodology we also added voice of environmental (VOE) attributes to the questionnaire. The purpose for this addition is to perceive not only standard customer requirements, but also green customer requirements. We used a standardized VOE set from Masui et al. work (2003).

Kano’s questionnaire is formulated to direct customers to answer a pair of questions, which take functional and dysfunctional form, related to each product feature. The results from Kano evaluation table are classified by six customer and environmental profiles: Must-be (M), One-dimensional (O), and Attractive (A), which determine product requirements that strongly influence customer satisfaction; and Indifferent (I), Reverse (R), and Questionable (Q) (these last three results still have some ambiguity in them). Contrary to the first three profiles, the latter three have either very small or questionable effects to customer satisfaction. Because of this, product features that belong to the first set would be carried on to the next step, while the latter one would be omitted.

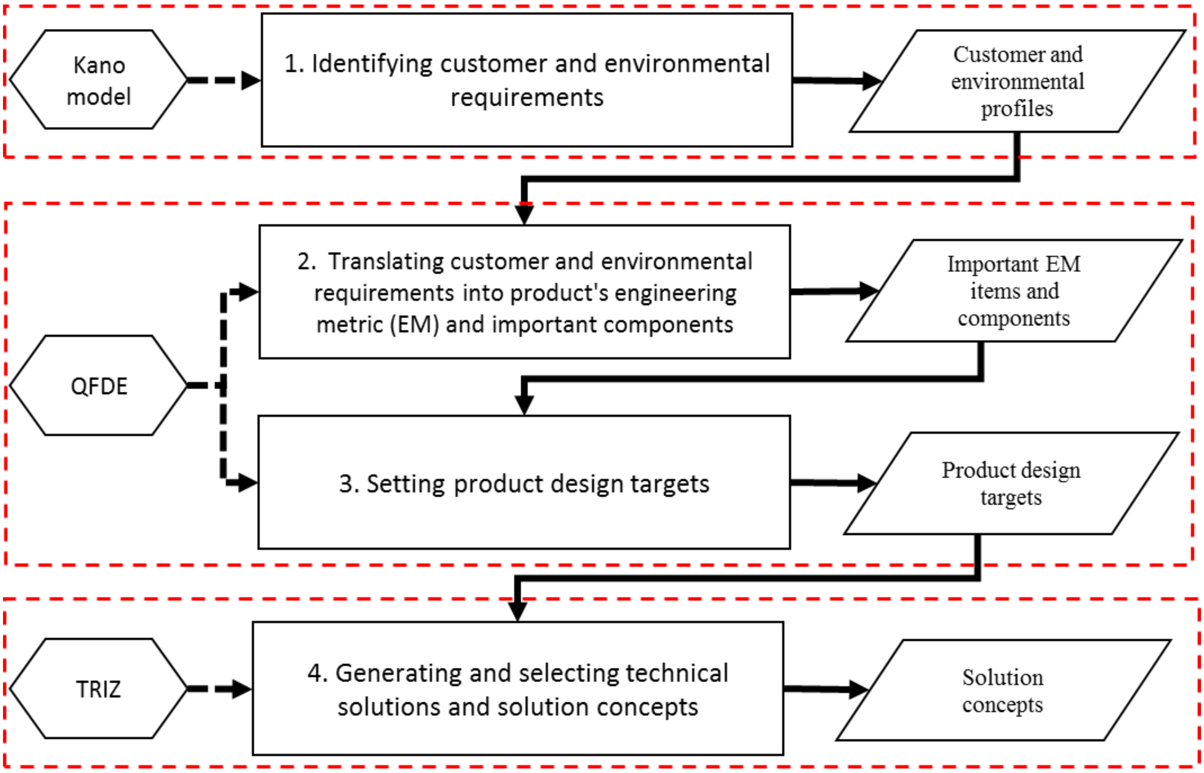

Figure 1. Flowchart of the proposed methodology.

In phase one, the relative importance value of individual product criteria was being collected. Customers were asked to rank individual product requirement (self-stated importance) using a rating scale 1 -5 where 1 is “completely unimportant”, 2 is “unimportant”, 3 is “neutral”, 4 is “important” and 5 is “very important” as can be seen in Figure 2. Results from this ranking would be served as the input for the next phase.

2.2. Phase two: Translating customer and environmental requirements into product's engineering metric (EM) and important components

The second step is to deploy VOC and VOE obtained from the previous phase into product’s engineering metrics (EM) and components. Here, aside from the green customer requirements, we also used a standardized set of environmental EM from the work of Masui et al. (2003). We used an improved QFDE methodology in term of how to obtain the customer weight value. In this improved method, customer weight values were calculated more precisely using Kano model result. Therefore, it can eliminate the ambiguity resulted from usual direct question’s answers. We also used different approaches to propose the design improvement target. The remaining methods and equations are identical to the original one (Masui et al. 2003).

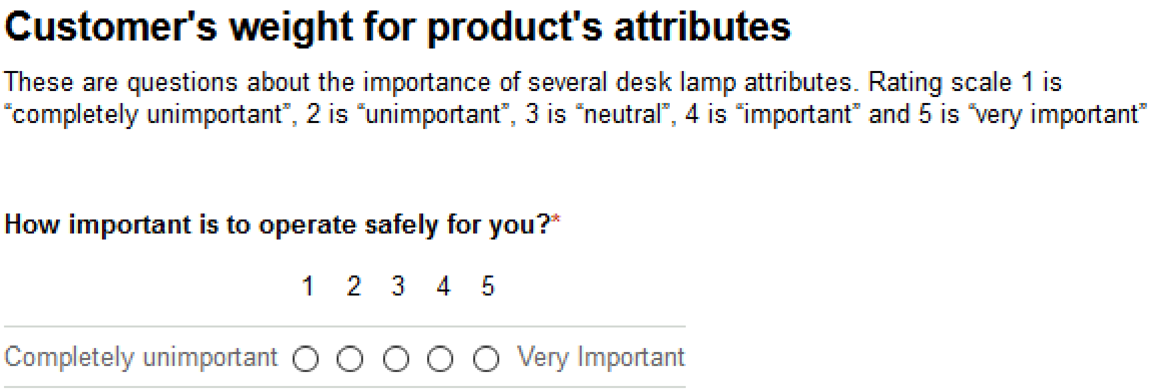

Figure 2. Example of self-stated importance question.

The same VOC and VOE items that were used for Kano questionnaire in phase one, except any items belong to indifferent, reverse, and questionable profiles, were deployed into one table with EM items. Indifferent, reverse, and questionable profiles were omitted due to their small or questionable effects to customer satisfaction. Customer weight for each VOC and VOE item was obtained from the relative importance value of individual product criteria. In the first matrix, formed by the VOC/VOE item and the EM item, there is a value indicating the relational strength between the respective items. The relational strength scales are as follows: "9" indicating strong relational strength, "3" moderate relational strength, "1" weak relational strength, and "0" no relation. These relational strength values were determined subjectively by the designers'. The raw score can be obtained by multiplying each customer weight with the relational strength for each EM item, and adding each result together. Furthermore, the relative weight for each EM item can be obtained by dividing each raw score with the sum of all raw scores. By using the relative weight value, the ranking of important EM items can be obtained. Then, EM items were deployed into one table with product's components to form the second matrix. With steps similar to those in the first matrix, the importance level of each component can be obtained. The result from the second matrix was the relative weight for each component.

2.3. Phase three: Setting product design targets

The purpose of phase three from this methodology is to evaluate and select the best design improvement target by estimating the potential outcome from set of product design changes on EM items. Designers must consider two options. The first option was based on the result from the first matrix. Designers first picked a set of EM items which have the highest relative weight values and then paired them with component items based on the relational strength values. Components with "weak" or "no relation" relational value were omitted from the design option. The second option was based on important components identified from the second matrix. Designers picked set of component items with the highest relative weight values. Then, paired them with EM items by using the same rule as the first option. The next step was to calculate the improvement rate ir_j for each EM item by using Equation (1).

$$ir_j = \frac{\sum_{k=1}^{K} s_{j,k} p_{j,k}}{\sum_{k=1}^{K} s_{j,k}} \quad (j = 1, ? \quad J) \tag{1}$$

K is the number of components, J is the number of EM items, $S_{j,k}$ is the relational strength of EM item j for component k, and $p_{j,k}$ is the possibility to improve EM item j for component k. Originally, the value for $p_{j,k}$ can take the real number from 0.0 to 1.0. The closer the value is to 0, the more infeasible this design target is and vice versa. However, to simplify the process, the authors assumed that all design targets are possible, thus the value used for $p_{j,k}$ is always 1.0.

The purpose for all design improvements made in the system must be solely to satisfy customer requirements. Therefore, all effect from the design changes must be evaluated by VOC and VOE items. The same items from the first matrix combined with the improvement rate ir_j obtained from Equation (1) were deployed into a single table. Here, improvement rate for each VOC and VOE items vr_i was obtained from Equation (2).

$$vr_i = \frac{\sum_{j=1}^{J} ir_j v_{i,j}}{\sum_{j=1}^{J} v_{i,j}} (i = 1, ? \quad I) \tag{2}$$

J is the number of EM items, I is the number of VOC/VOE items, vr_i the relational strength of VOC item i for EM item j. The improvement effects for VOC/VOE items were calculated by considering customer weight for each item. These improvement effects were obtained by multiplying vr_i with customer weight of VOC/VOE item i. From this calculation, designers chose the option with the highest score as their product design targets.

2.4. Phase four: Generating and selecting technical solutions and solution concepts

In phase four, product design targets obtained from previous phase were further analyzed. All of the possible technical problems that might emerge and ways to solve them were identified in this phase. To support these processes, phase four comprised of TRIZ's contradiction analysis and inventive principles selection. Firstly, designers identified all possible contradiction problems and matched them with the appropriate TRIZ 39 engineering parameters. Secondly, by using TRIZ contradiction matrix, all possible inventive principles from the selected components can be identified. A point was given to the inventive principle for each time it was being recommended by the contradiction matrix. The relational strength value between each EM item with their respective component became the weight value. By multiplying the weight value with each inventive principle's given points and then summing the result, one can obtain the total weight for each inventive principle. The higher the weight value, the more relevant that inventive principle to generate the suitable solution concept. In this study, the top three ranked inventive principles were used as the guidance to produce the solution concept for the product.

3. Case Study

In order to validate the applicability of the proposed methodology, this paper carried out a case study for a desk lamp product. A desk lamp consists of a base, a post, a goose neck, a cord, a head/shade, a lamp socket, and a bulb. The base acts as a support for the whole desk lamp's structure. The post supports the goose neck and connects it to the base. The goose neck gives the user the flexibility to adjust the position of the lamp. The head/shade holds the lamp socket and connects it to the goose neck, while lamp socket holds the lamp. The bulb is the light source. The cord allows electricity to power the product.

3.1. Phase one

First, we constructed Kano questionnaire with series of functional and dysfunctional questions. VOC and VOE are the main criteria in this questionnaire. In addition to the Kano questionnaire, we also asked respondents to rank the relative importance of each VOC and VOE item. We conducted an online survey to gather information. In this questionnaire, we tried to collect respondents' data such as gender, group age, and educational backgrounds. We also asked whether respondents ever used desk lamp or not. This question served as the scope limitation for the data collection. Respondents that had never use a desk lamp before, had their responses omitted from the analysis because we assumed they did not have a proper knowledge about desk lamp product. A total sample of 40 people was taken. From this total sample, 35 people said that they had ever used a desk lamp. The response analysis identified ten VOC and VOE items with their respective requirement profiles and relative importance value as can be seen in Table 1.

3.2. Phase two

The purpose of phase two is to merge customer and environmental requirements into product's EM items and important components. EM items used for this case study were brightness (EM1), heat produced (EM2), volume (EM3), degree of adjustability (EM4), weight (EM5), physical lifetime (EM6), amount of energy consumption (EM7), and rate of recycled material (EM8). Results from phase one served as the input for the first matrix. The relative importance value became the customer weight value for each VOC and VOE item. VOC and VOE items that belong to the indifferent profile were omitted from further analysis. Tables 2 and 3 show the first and second matrix respectively. Results from the first matrix show the important EM items are: heat produced, degree of adjustability, and brightness. Results from the second matrix show that the important components are: bulb, lamp socket, and head/shade.

Table 1. Kano analysis results.

VOC and VOE Items	Profile	Relative Importance Value
Operates safely	One-directional	4.80
No glare issues	One-directional	3.40
Dimmer function	Indifferent	2.91
Flexible head and arm	Attractive	4.06
Less material usage	Indifferent	3.37
Less energy consumption	One-directional	4.40
High durability	One-directional	4.43
Easy to disassemble	Indifferent	3.09
Harmless to the environment	Must-be	4.17
Possible to dispose of at the ease	Must-be	3.34

3.3. Phase three

In phase three, we proposed two option design changes. The first option consisted of design changes based on important EM items, while the second option consisted of design changes based on important components. Table 4 shows the improvement rate for each option obtained by using Equation (1). Then, in order to obtain product design targets, the result was further evaluated by customer and environmental requirements using Equation (2). In this case study, the evaluation process' final scores are 13.92 and 18.49 for option 1 and 2 respectively as can be seen in Table 5. Therefore, option two is being concluded as the best option. Option two consisted of these design changes:

1. Bulb and lamp socket: Heat produced, volume, weight, and amount of energy consumption should be reduced as much as possible. Brightness, degree of adjustability, physical lifetime, and rate of recycled material should be increased as much as possible.
2. Head/shade: Heat produced, volume, and weight should be reduced as much as possible. Degree of adjustability, physical lifetime, and rate of recycled material should be increased as much as possible.

Table 2. VOC and VOE deployment to EM.

No.	VOC and VOE Items	Customer Weight	Engineering Metric							
			EM1	EM2	EM3	EM4	EM5	EM6	EM7	EM8
1	Operates safely	4.80	3	9	1	3	3	9	3	1
2	No glare issues	3.40	9	1	0	9	0	1	0	0

3	Flexible head and arm	4.06	3	0	3	9	3	3	0	1
4	Less energy consumption	4.40	9	9	0	0	0	1	9	1
5	High durability	4.43	3	3	1	9	1	9	0	9
6	Harmless to the environment	4.17	3	9	0	0	0	0	3	9
7	Possible to dispose of at the ease	3.34	0	0	9	1	9	3	0	9
Raw score			122.57	137.03	51.49	124.71	61.09	113.06	66.51	120.74
Relative weight			0.15	0.17	0.06	0.16	0.08	0.14	0.08	0.15
Rank			3	1	8	2	7	5	6	4

3.4. Phase four

In this phase, product design targets from previous phase were further analyzed. The application of TRIZ allowed designers to explore all possible contradiction problems for each selected component. For example, increase lamp's brightness can cause an undesirable effect, because increased brightness produce more heat. This contradicting effect was translated into TRIZ's 39 engineering parameters: "18 Illumination intensity" and "17 Temperature". Then, by using TRIZ contradiction matrix we obtained the recommended inventive principles: "19 periodic action", "32 changing color", and "35 change of physical and chemical parameters." A point was given for each inventive principle recommended by TRIZ contradiction matrix. The same method was used for all remaining product design targets. Then, these results were deployed into a table with a weight value for each component's EM item. By multiplying the weight with each given point and summing the result, designers obtained the total weight and the rank order for each inventive principle. This analysis can be seen in Table 6. The top three highest ranked inventive principles are: "35 change of physical and chemical parameter", "19 periodic action", and "2 extraction". Examples of solution concepts using the suggested inventive principles include:

1. Substituting rigid head/shade body with flexible one (e.g. rubber) to reduce the total weight and volume. It is also increases the rate of recycled material (inventive principle 35 "change of physical and chemical parameters").
2. Using several groups of lamps that work in periodic action based on the fix parameter such as temperature to reduce the heat and prolong lamp's physical life time (inventive principle 19 "periodic action").

3. Changing lamp's position by applying light pipes technique to isolate the heat and also reduce the total weight and volume because we can eliminate head/shade component from the system (inventive principle 2 "extraction").

Table 3. EM deployment to PC.

No.	Engineering Metric	Relative Weight	Component						
			Base	Post	Goose Neck	Cord	Head/shade	Lamp Socket	Bulb
1	Brightness	0.15	0	0	3	0	1	9	9
2	Heat produced	0.17	0	0	0	1	3	9	9
3	Volume	0.06	9	9	3	1	9	9	9
4	Degree of adjustability	0.16	3	9	9	1	3	3	3
5	Weight	0.08	9	1	1	1	9	3	3
6	Physical lifetime	0.14	3	1	3	3	3	9	9
7	Amount of energy consumption	0.08	0	0	0	3	0	3	9
8	Rate of recycled material	0.15	9	3	3	1	9	3	3
Raw score			3.53	2.66	3.02	1.30	4.20	6.19	6.69
Relative weight			0.13	0.10	0.11	0.05	0.15	0.22	0.24
Rank			4	6	5	7	3	2	1

Table 4. Improvement rate for each design options.

No.	Engineering Metric	Option 1	Option 2
1	Brightness	0.95	0.82
2	Heat produced	0.95	0.95
3	Volume	0.00	0.55
4	Degree of adjustability	0.97	0.29
5	Weight	0.00	0.56
6	Physical lifetime	0.00	0.68
7	Amount of energy consumption	0.00	0.80

8	Rate of recycled material	0.00	0.48

Table 5. Improvement effect on customer requirements for each design options.

No.	VOC and VOE Items	Option 1	Option 2
1	Operates safely	2.15	3.47
2	No glare issues	3.10	1.97
3	Flexible head and arm	2.13	2.01
4	Less energy consumption	2.61	3.69
5	High durability	1.83	2.47
6	Harmless to the environment	1.99	3.09
7	Possible to dispose of at the ease	0.10	1.79
Total score		**13.92**	**18.49**

Several respondents were interviewed about their opinions of these solution concepts. We asked them to analyze these solution concepts from several viewpoints such as technical possibility, cost, and market opportunity. Majority express their positive opinions as can be seen in Table 7. They believe that these solution concepts can reduce the heat significantly and prolong lamp's life without sacrificing its performance. These solution concepts also can alter the standard design to make it smaller and lighter. Based on their opinions, we can conclude that these solution concepts can meet customer and environmental requirements. It has been demonstrated that this methodology can accurately incorporate VOC and VOE to the product design and help product designers create an innovative design concept. This methodology can also improve the efficiency of TRIZ methodology. This case study has proved its capability to reduce the number of possible inventive principles from more than ten into only best three principles. Therefore, it can greatly save time and effort to produce the best solution concept.

Table 6. Technical solution analysis.

CP	EM	RW	IP	DP	TRIZ Inventive Principles												
					2	3	6	10	16	17	19	27	31	32	34	35	38
Bulb	EM1	9	18	17							1			1		1	
	EM2	9	17	18					1					1			
	EM4	3	2	18							1			1		1	
	EM5	3	2	18							1			1		1	
	EM7	9	20	18	1						1			1		1	
Lamp socket	EM2	9	17	36	1				1	1							
	EM3	9	8	16											1	1	1

	EM4	3	2	16	1		1				1	1					
	EM5	3	2	16	1		1				1	1					
	EM6	9	16	32				1								1	
	EM8	3	26	16		1							1			1	
Head/ shade	EM2	3	17	36	1				1	1							
	EM3	9	8	16											1	1	1
	EM4	3	2	16	1		1				1	1					
	EM5	9	2	16	1		1				1	1					
	EM6	3	16	32				1								1	
	EM8	9	26	16		1							1			1	
Total Weight					39	12	18	12	21	12	42	18	12	33	18	66	18
Rank					3	10	6	10	5	10	2	6	10	4	6	1	6

Notes: CP = Component; EM = Engineering metric; RW = Relational strength value; IP = Increasing parameter ; DP = Decreasing parameter

4. Conclusion

This study has developed a new methodology that combined Kano model, QFDE, and TRIZ. This methodology has utilized Kano model to capture customer and environmental requirements. Then, by combining them with QFDE, these requirements are infused into product's requirements to generate product design targets. TRIZ methodology has been utilized to solve contradiction problems to acquire an innovative design. This proposed methodology has combined these three different tools in a good synergy and maximized the benefit from each tool.

Table 7. Case study result.

TRIZ Inventive Principles	Possible Solution Concepts	Improvement Benefits	The Percentage of Positive Opinions
35. Change of Physical and Chemical Parameters	Using a flexible material (e.g. rubber) for head/shade component.	1. Increase rate of recycled material 2. Increase degree of adjustability 3. Reduce weight 4. Reduce volume	80%

19. Periodic Action	Several groups of lamps that work in periodic action based on the fixed parameter (temperature).	1. Increase physical lifetime 2. Increase amount of energy consumption 3. Reduce heat produced	80%
2. Extraction	Applying light pipes technique to change lamp's position.	1. Reduce heat produced, 2. Reduce weight 3. Reduce volume	70%

Results from case study have demonstrated that this methodology is applicable to help product designers integrate VOC and VOE to the product design and create an innovative design concept. This methodology has managed to identify three important components with set of EM items and has used the information to produce three innovative solution concepts: using a flexible material, groups of lamps that work in periodic action, and applying light pipes technique. Positive opinions from customer have proved these solution concepts suited their requirements. The effectiveness of this methodology in capturing VOC/VOE accurately and transforming them into innovative concepts is one of the major contributions of this research. Another contribution of this research comes from the capability to decrease the number of possible inventive principle used for generating solution concepts, thus it has increased the efficiency of TRIZ application.

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Using A TRIZ Approach To Analyse Consumer Lighting To Predict The Future Of Service Innovation For A Circular Economy

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Abstract

The TRIZ 8 Trends of Evolution is a tried a tested method for assessing the development path of a product or invention, but how can these evolutionary steps be best applied to service innovation? The lighting industry is currently under-going a systems shift; a light bulb, once a consumable, is now a long-life product. This is just one example of developments taking place across many other sectors; new technologies, such as the Internet of Things, are creating exciting opportunities for service innovation, challenging designers and researchers not only to be more mindful of lifecycle thinking and durability, but also prompting us to consider how this may influence the way we use and consume products in the future. Traditional thinking regarding ownership has evolved in recent years, enabling new modes of consumption to become common place; with some services replacing products entirely; Product Service Systems (PSS) have been proposed as one of these alternatives. These frameworks have been extensively explored, however little research has been conducted on their development in relation to TRIZ. This paper demonstrates work in progress of how the TRIZ Trends of Evolution can, firstly be used to assess the state of art of a Lighting system and secondly how PSS models correlate in order to potentially predict the future of service innovation. This was achieved by determining two key factors: structural and relational classification which provides a simple method for translating services to trends.

Keywords: TRIZ, Lighting, Trends, Product Service Systems, Circular Economy

Introduction

With the world's population expecting to increase to 9 billion by 2050, the economy is predicted to quadruple, creating a greater demand for energy and natural resources. If consumption patterns remain the same and new methods are not introduced there will be a significant impact on the environment. Circular Economy is one solution to this problem, simply defined as rethinking, a re-design how we make stuff; suggesting the radical re-thinking of how we deliver products and services to our consumers, moving us from a linear process to one that is regenerative by design. By shifting the mindset from traditional thinking around ownership and viewing products as providers of performance aims to encourage mutual investment between consumers and manufacturers in products' functions and efficiency over the whole lifecycle. Product Service Systems (PSS) provide a necessary framework to achieve this, and are a key component in a functioning Circular Economy. A theory born of academic research, PSS can be defined as convergence or combination of product and services within a system that fulfill a particular customer need or function (Baines et al., 2007). These types of business models provide attractive incentives to both companies and consumers recommended not only as a practice for mitigating idle capacity and wasteful patterns of use but also as a vehicle for value creation through continued engagement.

Philips Lighting are pioneers in adopting and adapting Circular practice, initially with the implementation of 'light as a service' their Pay-Per-Lux model, developed collaboratively with RAU Architects in Netherlands in 2011 (Ellen Macarthur Foundation, 2013) but have yet to fully explore this type of innovation from a business to consumer perspective. This study is an on-going AHRC funded research collaboration between Philips Lighting and University of Brighton to explore the development of innovative design systems, tools and methods to assist in the transition towards a more Circular Economy

1. Literature review

A systematic search was conducted utilizing the key words 'TRIZ', 'Trends', 'Evolution', 'Lighting' ', 'Innovation' Services' and 'Product Service Systems'

1.1. Managing Innovation in NPD and TRIZ

The initial phases of new product development are usually described as idea generation, idea screening / or classification, concept development and concept testing. Beyond these stages costs tend to increase exponentially (Trott, 2008) Managing innovation within new product development is a complex system with a variety of different methods available developed to handle any problems that arise. Davalia et al., (2006) argues that the first role of an innovation system is to improve efficiency of the innovation process; to bring great concepts to market with speed and minimal resources. But what tools are available for these early stages and can point us towards opportunities for invention?

TRIZ (The Theory of Inventive Problem Solving), is a knowledge-based systematic toolkit that provides a logical approach to inventive problem solving (Ilevbare et al., 2013; Savranksy, 2000) and is often described as the most comprehensive systematic inventive and creative thinking methodology known to man (Livotov, 2008). With the main steps to problem solving often described as: problem definition, problem resolution and solution evaluation. (Chai, Zhang & Tan 2005; Kim & Yoon, 2012) with the three central concepts to TRIZ toolkit described as the Contradictions, Ideality and patterns (Trends) of evolution. (Ilevbare et al., 2013) with a large selection of tools and techniques that work in conjunction with within these main concepts. But where does this fit within the NPD development process? Developed initially as a method for technical problem solving, Gadd, (2011) claims that TRIZ can be utilized at any point of your innovation journey, while other practitioners believe it can be used for more - ‘Human orientated’ ill-defined problems (Savransky, 2000. P23) arguing that the theory and framework itself was based on ‘human invention and creativity’. So is this how TRIZ can possibly be used in a more user-centric service design context?

1.2. TRIZ and Product Service System Innovation

Originally defined by Tukker, (2004) three categories of product service innovation were proposed:

Product - Orientated: Product-related service, advice and consultancy

Use - Orientated: Product lease, rent, share, pooling

Results - Orientated: Activity management / outsourcing, pay per service

Bakker et al., (2014) further developed these concepts, outlining 5 archetypal business models: ***Classic long life***, ***Hybrid***, ***Gap Exploiter***, ***Access*** and ***Performance***. These types of services can provide attractive incentives to both companies and consumers; although more interaction is required, a prolonged relationship is facilitated which can provide steady revenue and opportunities for value creation though resource recovery (Accenture, 2014; Bhamra & Lofthouse, 2007).

With relation to service innovation and TRIZ most research is focused on uncovering and identifying contradictions within various applications as demonstrated by Gazem & Rahman (2014); Low et al., (2000) initially through the interpretation and adaptation of the 40 principles with some analysis of the 4 Separation principles and 39 parameters. Others combine them with toolkits such as Quality Function Deployment (Kim & Yoon, 2012) and House of Quality (Yang and Xing, 2013 & 2014). With, Chai, Zhang and Tan (2005) fully embracing not only the tools but also the philosophy of problem solving without compromise and the breaking of psychological inertia within the mind-set. However, in all of this research the Trends of Technical Evolution are not mentioned.

1.3. Trends or Patterns of Technical Evolution and Product Service System Innovation

Altschuller (1984) observed, that the development of all technical systems follows eight laws, which could also be described as trends or patterns. The recognised method of using these laws is to conduct a TRIZ trend analysis, which Verhaegen et al., (2009) states is a process based on observations of a metric, patents being one example. Some have attempted to automate the analysis, which has proven to be more efficient when dealing with large patent databases (Kim & Yoon, 2011), however for this small study such an undertaking is not necessary.

Uncovering the ‘evolutionary potential’ as described by Mann (2003) within a system, can be a powerful guide for innovation development. The process is described as the specific categorisation of the current state of the part or system along the trends in order to discover if there are any further developments that can be made and the next generation of a product found. (Gadd, 2011; Haines-Gadd, 2016) Romero & Molina, (2015) recognised the potential for analysing existing trends (not TRIZ trends however) within product development as a tool early stage innovation opportunity, using it a method for 'divergence: imagination' as part of their three step framework for customer focused NPD - defining it as 'retro and prospective analyses: consumption trends, social mega trends, technological megatrends, and lifecycle's. However, like most of the researchers Trends are only mentioned as a late stage development tool, imploring the Ideality to help maximise ideal function as part of the (Jobs To Be Done). In relation to service Innovation Zhao, (2005) combined it with step four of Six Sigma: implement and improve; and Zhang, (2004) in their New Service Design Model (NSD) as a method for idea screening, and concept testing but again only introduced late in the process.

1.4. TRIZ and Sustainability

Many studies have explored the combination of using TRIZ and an eco-design approach to innovation (Chou, Chen & Conley 2014; Hosseinpour & Peng, 2012; Liu et al., 2014; Low et al., 2000), most focusing on the notion of reductionism (Russo et al., 2014). Furthermore, Jones and Harrison (2000) state, that the ethos of sustainable design (and in theory Circular Economy thinking) aligns with many of the TRIZ principles; so this combination approach was determined to warrant further inquiry.

2. Methodology

A TRIZ approach was used to firstly, map out the existing lighting systems to uncover the opportunities for innovation development within lighting products and secondly see how the Trends of Technical Evolution could be applied to product service systems. A 9-Box approach was adopted to ensure that multiple systems were considered: the sub-system - bulb; system - Luminaire; and Super System - Connected lighting systems which were then mapped against all the Trends to demonstrate the current development. This study was conducted initially by the primary researcher and then evaluated by experts in the field of TRIZ and innovation processes.

The aim of this study was to examine the state of art of the current lighting systems and also explore whether or not there is a correlation between the development of current products into services and if the Trends of Evolution adequately describe these.

3.1. Reflection on the Trends and hypothesis

***Increased Ideality* -** is probably one of the more effective tools that can be applied to more abstract systems when thinking about trends. It teaches us that a system will always improve over time, it will increase in benefits and reduce in costs and harms. But as Gadd, (2011) argues it is more effective than most value analysis tools as it separates out costs from harms which allows for more clarity when determining what needs improving; furthermore, when combined with Function Analysis and the TRIZ Trimming Rules can result in an elegant more resource efficient system.

***S-Curves* -** A simple and effective way of describing the current state of development of the system.

***Uneven Development Of Parts* -** Often it can be the undeveloped part of the system that either is causing the issues in the system or provide us with the clearest opportunity for innovation.

***Increasing System Automation* -** Describes the level of automation of the system and suggests the next steps towards more automation

***Simplicity - Complexity - Simplicity* -** Lighting historically has been very simple but is now moving to a state of complexity (Philips expert, 18) and is also true of product service systems moving from a linear transactional interaction to something more reflexive.

***Matching and Mismatching* -** As systems evolve needs do as well and they become better aligned, this is potentially a way of describing what happens when a product is servitized.

***Increased Segmentation and Use of Fields* -** Segmentation and increased flexibility is essentially a process of dematerialization of an offering or function.

Increased Dynamism and Controllability - As we increase the complexity of our product service offering is it increasing in flexibility and therefore needing more control.

Conclusion of literature review

Research into the product service innovation and TRIZ is small but focused; with most of the studies investigating the 40 principles as the main line of enquiry and the Trends of Evolution have not been explored in this context. Therefore, it was determined that this warrants further study but also a prediction there is a natural correlation between the development of service models within product development and Trends of Evolution which will be further demonstrated in the study.

3. The Study

The primary researcher created several iterations of a worksheet that explored the Trends within their various system boundaries as described in the methodology above; this proved to be a useful exercise as it showed how the initial analysis had been unclear, the system boundaries were then redefined into these categories, with the sub-system dropped from the study as it would deemed that the scope of the project was not in fact to design the next new technology light bulb, but then next technology system. See figure 1 & 2 for a completed version on the worksheet.

The System Boundary: Domestic Setting

System - Connected Luminaire light system: bulbs, Luminaires and LED strips, bridge, app.

Super-system - How light could be delivered from producers to consumers.

This further classification integrated the analysis of services innovation into the process with much more clarity which are shown in figures below.

3.1. Study 1 - System - Connected Luminaire

Results and Process

Within the new framework the connected light system was analysed from a functional perspective and a classification made on each Trend in order to demonstrate the state of art of the system which is shown in the figures 1 & 2 below.

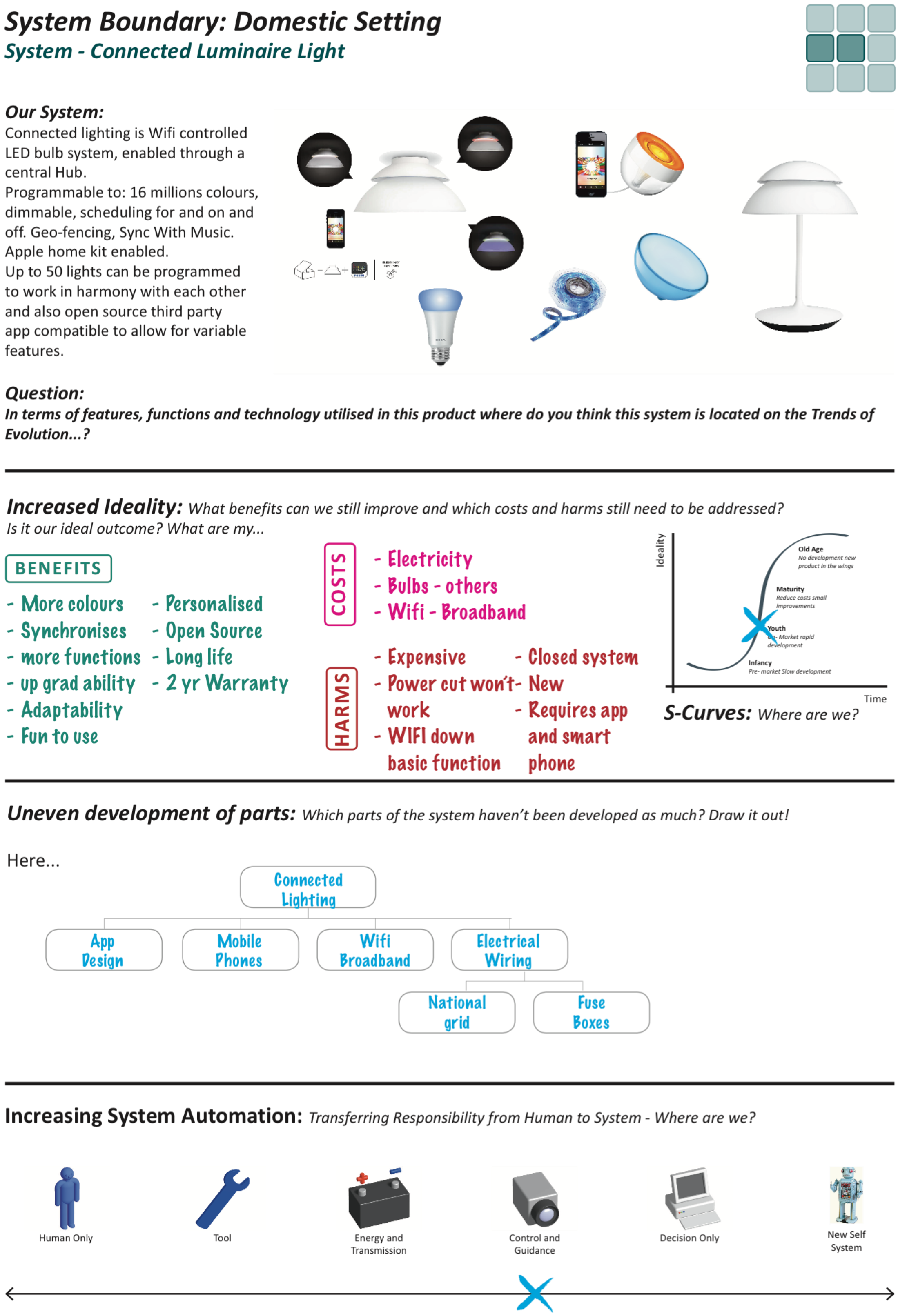


Figure 1. System Worksheet 1 - Completed

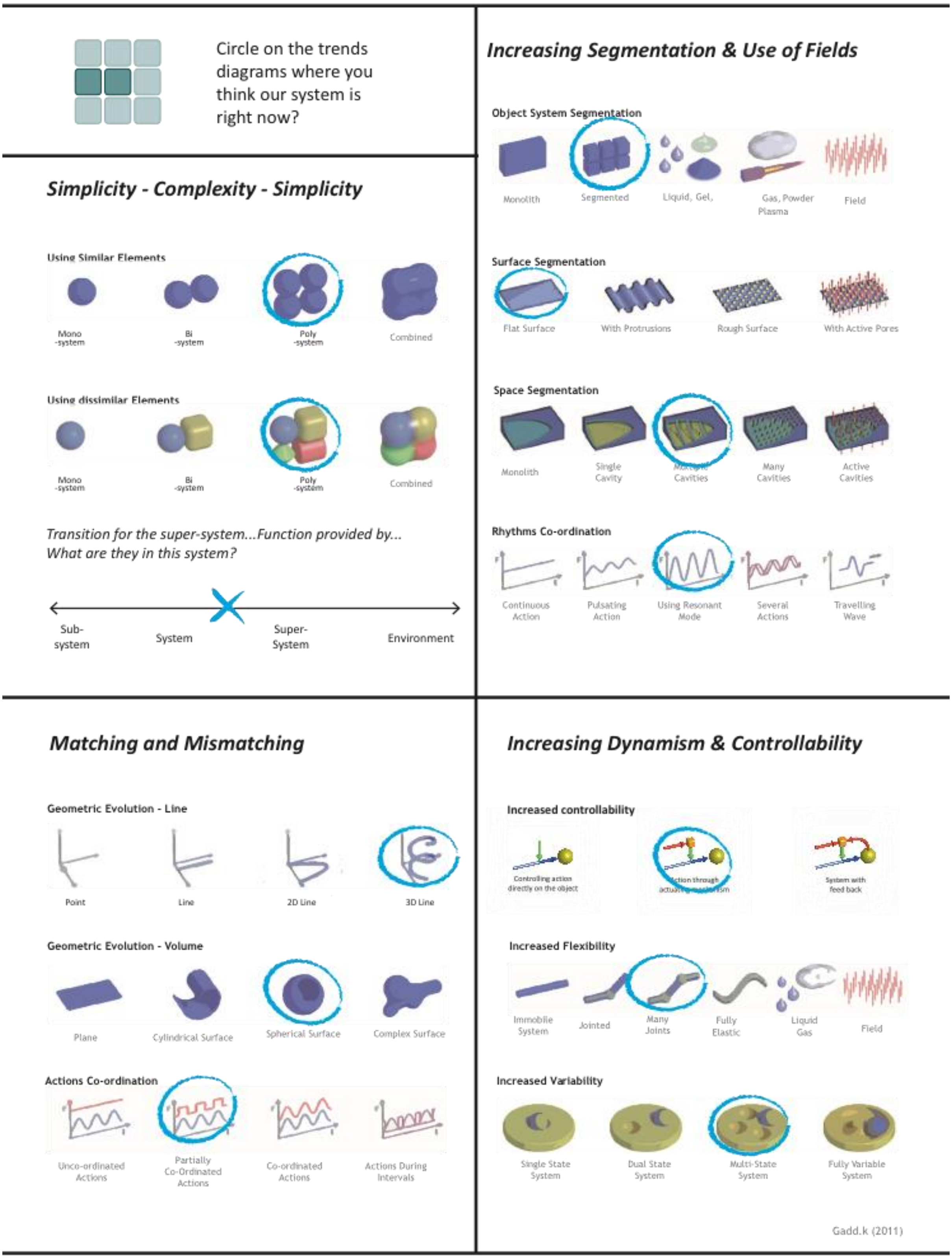


Figure 2. System Worksheet 2 - Completed

3.2. Super-System: How Is Light Delivered To Consumers From Producers?

3.2.1. Process and Results

Initial trials of the worksheet revealed that each type of service should be treated separately and have been separated into these classifications and service example: ***A - Dr Martens***, ***B - Splosh, C - Enterprise Car Club, D - Utilities.*** Information of these services were gathered through informal ethnographic observations by the primary researcher and provide insight for the analysis. The table below not only demonstrates the framework for analysis but also combines the previous thinking in regards to PSS and TRIZ (40 principles).

Pure Product ⟷ Pure Service

<table>
<tr><td>A</td><td>B</td><td colspan="2">C</td><td>D</td></tr>
<tr><td>Dr Martens</td><td>Splosh</td><td colspan="2">Enterprise Car Club</td><td>Utilities</td></tr>
<tr><td>Classic long life</td><td>Hybrid</td><td colspan="2">Access</td><td>Performance</td></tr>
<tr><td>Single transaction</td><td>Consumable part</td><td colspan="2">Sell Access</td><td>Sell functions</td></tr>
<tr><td colspan="2">Product-Orientated
Product-related service
Advice and consultancy</td><td>Use-Orientated
Product lease, rent,
share, pooling</td><td colspan="2">Results-Orientated
Activity management /
outsourcing, pay per service</td></tr>
<tr><td colspan="2">9 - Prior counteraction
11 - Cushion in Advance</td><td>5 - Merging (Consolidation)
34 - Discarding and recovering</td><td colspan="2">24 - Intermediary
40 - Composites</td></tr>
</table>

Table 1. Product Service System Classifications and TRIZ

Kim & Yoon, (2012); Bakker et al., (2014); Tukker, (2004); Wong, (2004*)*

Each type of service was evaluated according to the Trends through the method of abstraction of the core concept while also considering the perspective of the two main stakeholders (Producers and Users) as well. The initial investigation led to a further classification of analysis to be determined:

Structural: how the various components of the service system operate

Relational: the interaction occurring between the User and Producer

Increased Ideality	Structural and Relational
S-Curves	Structural
Uneven Development Of Parts	Structural
Increasing System Automation	Relational
Simplicity - Complexity - Simplicity	Structural
Matching and Mismatching	Structural and Relational
Increased Segmentation and Use of Fields	N/A
Increased Dynamism and Controllability	Structural and Relational

Table 2. Classification Structural and Relational per Trend

3.2.2. Analysis of the Trends

Increased Ideality

The Ideality of each stakeholder is shown in the Table 3 below:

		Benefits	*Costs*	*Harms*
A - Dr Martens	*Producer*	*- Clear, measured profit*	*- Wholesaler marketing - User marketing*	*- No contact with end users - No after sales revenue - No end user feedback on product*
	User	*- It's mine, I own it and could do what I like*	*- I have to buy it up front - Maintenance costs*	*- Risk that don't like it and can't return - If break have to buy another*
B- Splosh	*Producer*	*- Continued engagement - Aware of and can mostly control what goes into product*	*- Reselling of part /consumable to suppliers - Potential partnership deal with manufactures of machines - Have a supply chain*	*- Building in a consumable can increase risk of system failure*
	User	*- Can Re-assess of product while using - can switch flavour / smells - Spreads costs over time - I still own it! - I like that I keep the bottle*	*- Have to keep buying consumable - Water from tap*	*- If machine breaks I have to replace - Hassle often forget to order*
C- Enterprise Car Club	*Producer*	*- Retain ownership and control of object quality and maintenance - Liquid asset*	*- Infrastructure for service needs to exist - Telephone, sales, website - Logistics*	*- Hard to predict use - Proof of sales - Up front Financing - Risky*
	User	*- Only use when needed - No burden of hidden costs - Large choice of vehicles - Flexibility*	*- Subscription - Smart Phone most likely*	*- Young system - Prices can seem high - Could feel trapped*

D - Utilities	***Producer***	*- Little waste* *- Very measured use*	*- High tech monitoring and back end architecture* *- More networks to manage*	*- High level of responsibility for how is delivered most likely higher expectations from User*
	User	*- Get what you want when you want it* *- Knowledge that company invested in high quality product that won't fail*	*- Pay for time, space access* *- Training*	*- What control do I have to fix it if it's not working?* *- Hard to quantify and perceive use & needs*

Table 3. Ideality of each main stakeholder

System Boundary: Domestic Setting

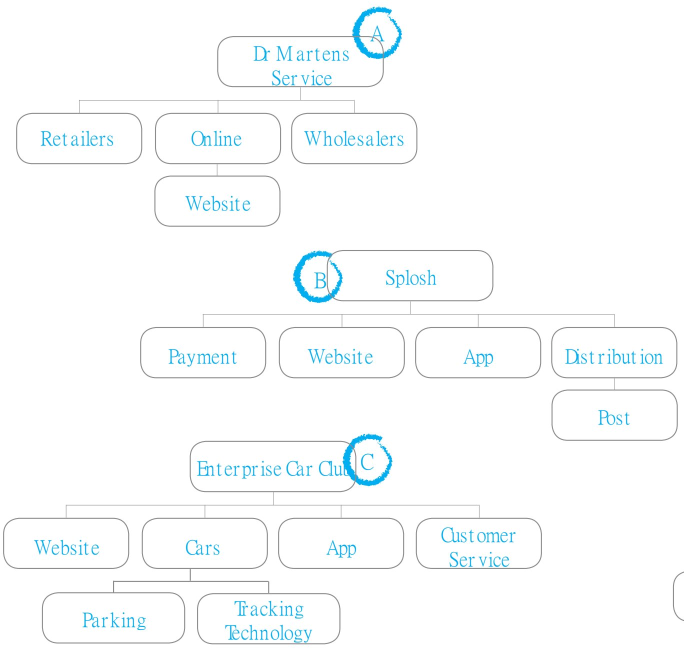
Super-System : How is light delivered to consumers from producers?

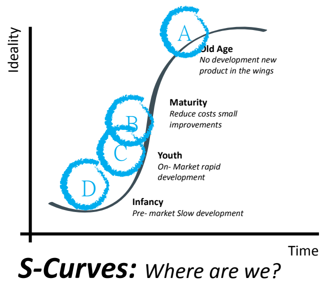
Pure Product ⟷ Pure Service

A	B	C		D
Dr Martens	***Splosh***	***Enterprise Car Club***		***Utilities***
Classic long life	***Hybrid***	***Access***		***Performance***
Single transaction	Consumable part	Sell Access		Sell functions
Product-Orientated Product-related service Advice and consultancy		**Use-Orientated** Product lease, rent, share, pooling	**Results-Orientated** Activity management / outsourcing, pay per service	
9 - Prior counteraction 11 - Cushion in Advance		5 - Merging (Consolidation) 34 - Discarding and recovering	24 - Intermediary 40 - Composites	

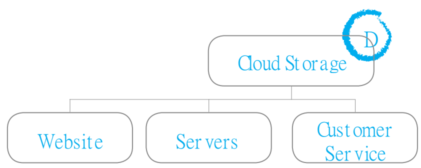
Described above are the various types of product service system and examples on the market... do we think these types of services apply to the trends and if so could they work with lighting systems? It was determined while completing the form that these should be treated as separate models and split into A, B,C, D.

Uneven development of parts: *Which parts of the system haven't been developed as much? Draw it out!*





S-Curves: *Where are we?*



Increasing System Automation: *Transferring Responsibility from Human to System - Where are we?*

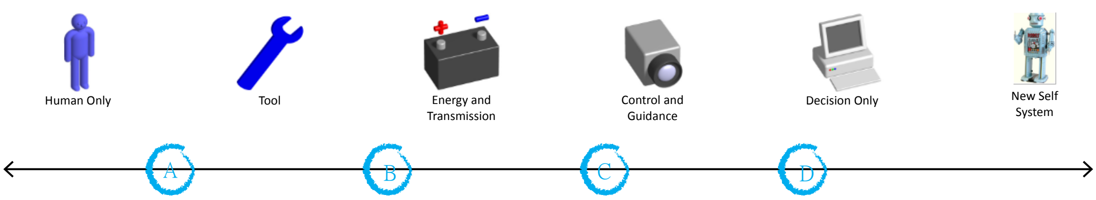


Figure 3. Super-System Worksheet 1 - Completed

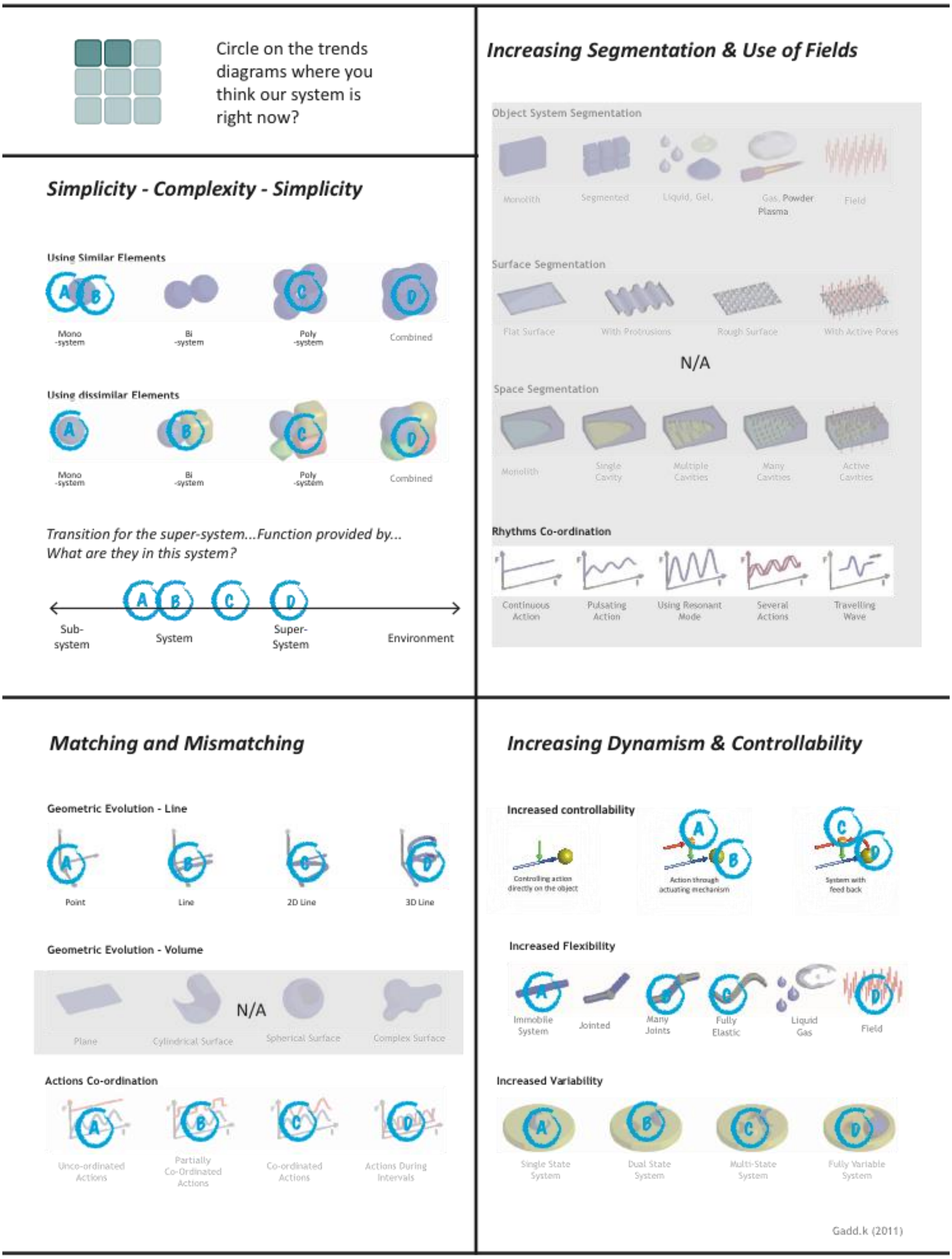


Figure 4. Super-System Worksheet 1 - Completed

3.2.3. Trends not Included in the study

It is important to state that when analyzing a system, it is common that not every Trends may apply and some were classified and not applicable to the study. In general, as the choice was made to put the service at the Super-system level, the Trends which focus more on more physical systems or description of the system were less relevant, as these would apply more to light source itself and the technology used to deliver it. Analysis of the light source or bulb may make these Trends more useful and is another field and study of research all together.

3.2.4. Limitations

This is an on-going study with this section of the research conducted over several months of independent study. Although the findings were validated by experts in the field of TRIZ it has not yet been by those Lighting and TRIZ. A longer, more in depth analysis could be conducted and further reflection on the direction of light as a service proposed, however it was decided to show only the state of art of the system at this time.

4. Discussion and Conclusions

Reflection on theory

It was previously proposed that there exists a natural correlation between trends and services and Ideality would be most salient. As TRIZ suggests, when systems develop they increase in ideality, by improving benefits and reducing costs and harms creating more elegant systems. The inherent nature of ideality is about how to deliver benefits through functions that meet needs. This does not always mean through a product solution. This approach is similar to that of a 'Function Economy', whereby focus is placed on the economic potential of the performance of goods (Stahel, 2010. P,93). This type of thinking breaks psychological inertia and challenges traditional modes of consumption, finding new ways to provide value, which underpins PSS principles and is a core component of Circular Economy theory.

Reflection on practice

The method undertook throughout the study was the abstraction of core concepts and translating them to new scenarios, which in itself is a fundamental practice of TRIZ the philosophy. TRIZ Trends were developed through studying the patterns of human creativity and invention, therefore as we continue to invent new service systems is not likely that this concept will still apply?

The Trends reflect how technology changes to meet evolving consumer needs and market requirements (Haines-Gadd, 2016) therefore future needs can be found from analyzing technology, but is it possible that needs predict technology? This author would argue that by defining where we are within this framework, we can look to the future, along the trends to uncover new solutions, new ways of providing benefits for our consumer and design more ideal methods for providing light in the domestic space. However, it could be argued that once you go past any of the first steps on any of the trends that is when you are moving to more of a service as a product transaction is by nature static and anything that is one step more complex, is more ideal.

Structural and Relational

This distinction between structural and relational analysis was the key component to understanding how these service business models apply to TRIZ thinking but also elegantly describes the two main dimensions of how a service can be understood (Agarwal et al., 2015):

- Front end (Visible, experience, interaction on both sides) = Relational

- Back end (Invisible, infrastructure, operations) = Structural

It was found that some Trends followed one or both of these categories, but ultimately provides clarity for thought and a synergy between these two theories which could be expanded upon in future research.

Circular Economy and TRIZ

Moving to a field effect is about dematerializing a function or offering, which in relation to Circular economy thinking is a better solution, creating less waste and common type of performance and access based service. This insight could prove to be a linking force between these theories and something exploring further when developing ideas in this space.

Consumable and Durable

The majority of product services system currently operating are hybrid systems, which the results concluded could be described as a (bi-system of dis-similar elements), a consumable and a durable. On reflection, these types of configurations are quite common amongst mechanical systems, with components fluctuating between conditions of being consumable and durable but how is this reflected in the trends? It could be argued that this is merely another state of increasing or decreasing ideality over time, or is there something missing? The lighting market is shifting, lighting products are becoming durable objects, increasing in complexity but also opportunity. The system is young, but there are new needs yet to be found or fully understood that provide exciting opportunities for innovation.

Reflection on Literature

It was determined that there was a gap in the literature in regards to Trends of evolution and services, which this paper hopefully will help to spark new debate and inquiry. Recommendation for further work would be to use the framework to analyse in more detail examples of services to further validate the conclusions drawn.

Conclusions

The results clearly show a synergy between the evolution and development of Product Service Systems and the Trends of Evolution as predicted, with the access and performance based models sitting further at the end of each trend. The structural and relational classification creates a coherent method for understanding how to translate services to trends which is something to be explored further.

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Paper ID: 33

Kando Story Understanding toward an Attractive Product in the Conceptual Design

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Abstract

Making new ideas is the centerpiece of conceptual design activity. In this activity, to explore one big hit product, over 3,000 ideas are required (Stevens and Burley, 1997). Moreover, successful companies provide the highest quality service, by which customers receive satisfaction through a Kando experience. Thus, customer satisfaction through their experience is necessary for greater success in business. In this paper, we propose the Kando story understanding for new Idea Creation Support System (ICSS) of not expecting the implicit Kando story but drawing the explicit Kando story which can solve needs.

1. Introduction

Making new ideas is the centerpiece of conceptual design activity. In this activity, to explore one big hit product, over 3,000 ideas are required (Stevens and Burley, 1997). Moreover, successful companies provide the highest quality service, by which customers receive satisfaction through a Kando experience. Thus, customer satisfaction through their experience is necessary for greater success in business. Sato and Hasegawa (2011) have drawn focus to Kando requirement through Kando experience, and have proposed the Idea Creation Support System (ICSS) including the Kando Understanding Support Process through Word Of Mouth (WOM) communication effectiveness (Sato and Hasegawa, 2011). Kando has been explained as "A mind moves through deep feelings about things" in the Kojien (the most famous Japanese dictionary, published by Iwanami). Sato and Hasegawa (2011) have defined Kando in detail using emotional design theory (Norman, 2005) and the Attention Interest Desire Experience Enthusiasm Share (AIDEES) model (Katahira, 2006) for consumer behaviour understanding. Therefore, their proposal is that "Kando is generated by the interaction of the behavioural level and the reflective level, when a favourable experience, including a surprise, is greater than a past experience during the re-evaluation process". To gather Kando requirements in Kando understanding process, authors have generated pseudo WOM communication based on World Café methodology (Brown and Isaacs, 2005) on ICSS (Figure 1), and the Kando requirements have been drawn through the Kando element, i.e., a reason of surprise, an element concerning surprise, and an element of past experience as the comparative target of surprised experience on World Café. Moreover, ICSS assessment system has been developed including quality assurance in order to create attractive product ideas—"Are we drawing the Kando requirement for attractive product idea right? " as the verification & "Are we creating the right attractive product idea which inspired Kando in you? " as the validation—based on a V-model with Verification & Validation (V&V) (Utsumi et al. and Takezawa et al, 2014). Because ICSS's Kando understanding support process depends heavily on the human mind and emotion. Especially, when its product idea is experienced, it is necessary to predict the implicit Kando story, made by a Kando element and a solution, whether to inspire Kando in advance. However, an accuracy and an easy quality assurance through the implicit Kando story is difficult, even the hybrid estimation method using SD analysis and fNIRS as a bioinstrumentation.

In this paper, we propose a Kando story understanding for new ICSS (Figure 2) of not expecting the implicit Kando story but drawing the explicit Kando story which can solve needs.

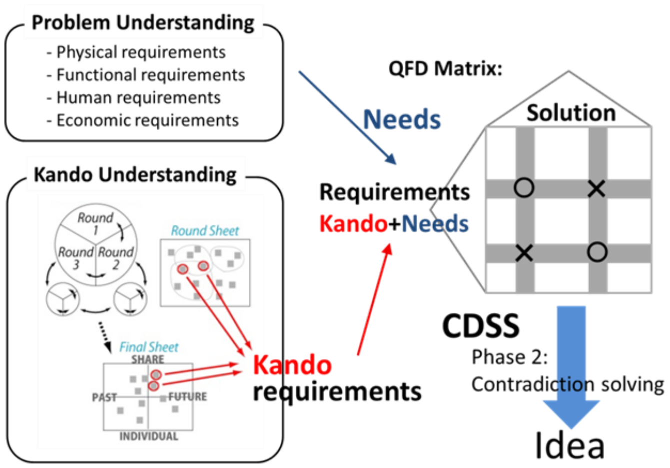

Figure 1. Outline of ICSS (Sato and Hasegawa, 2011)

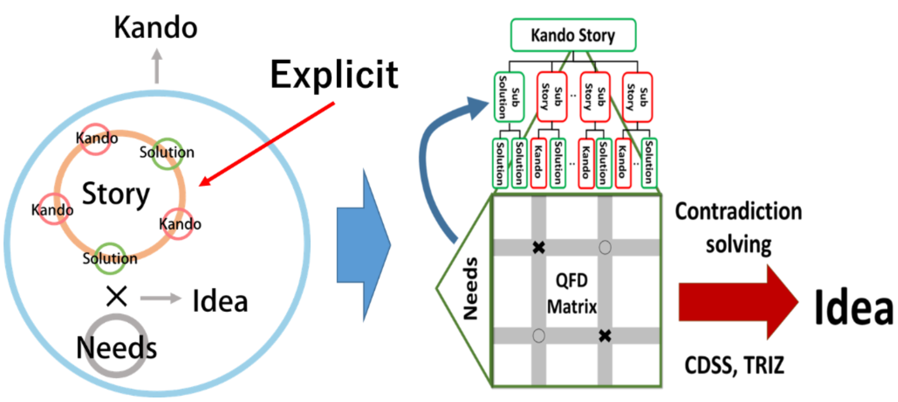

Figure 2. New outline of ICSS with Explicit Kando story

2. Kando story understanding process

In Figure 3, the Kando story understanding process is shown. World Café in the Kando story understanding process was organized within the following round steps. First, the theme of the discussion was "What is most story which inspired Kando until now?" In Round 1, participants explain their own Kando story using the Show Me Your Values and record an image, episode, and a keyword related to the explained Kando story using sticky notes. In Round 2 to 3, after moving a table, each table host introduces images, episodes, and keywords of the Kando stories obtained in the round, and these items are shared between all the members. Then, the characteristics of the element which construct a Kando story is summarized through gathering round steps. In final session, Empathy Map is created through referring the elements summarized in the round 3, i.e., Kando elements and solutions. The theme of the mapping is "Considering the highest Kando story for inspiring this person." Finally, Kando story is written out by analyzing obtained Empathy Map.

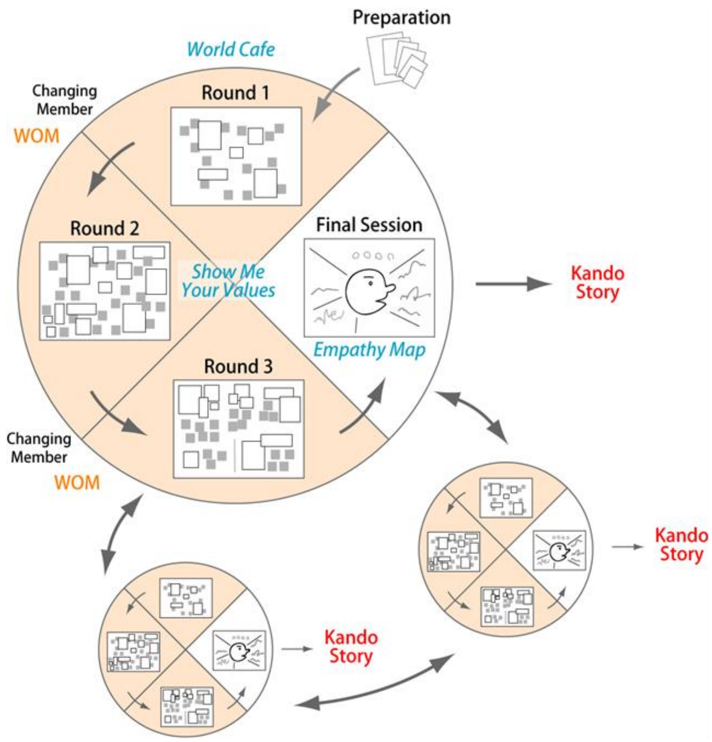

Figure 3. Kando story understanding process for new ICSS with Explicit Kando story

3. Trial on Kando story understanding process for drawing an explicit Kando story

In this paper, we carried out the Kando story understanding for a bathtub cleaning problem. In order to carry out this problem, the 30 items' needs were extracted from the part-timer of the university co-op, mostly housewife, 42 persons. As a result of performing the Kando story understanding process to these needs, the example of Show Me Your Values in Round 1 and the example of Empathy Map created by Final Session were shown in Figure. 4 and 5. For example, the idea "A thin film peels off when a bathtub wall, which consisted of thin film structures, became dirty" was obtained as the final outcomes by the idea creation through the Kando story understanding process. The Kando story of this idea became "One sheet’s skin peeled off! Baby face! Be surprised at the bathtub was born again."

Figure 4. Example of the Show Me Your Values in Round 1

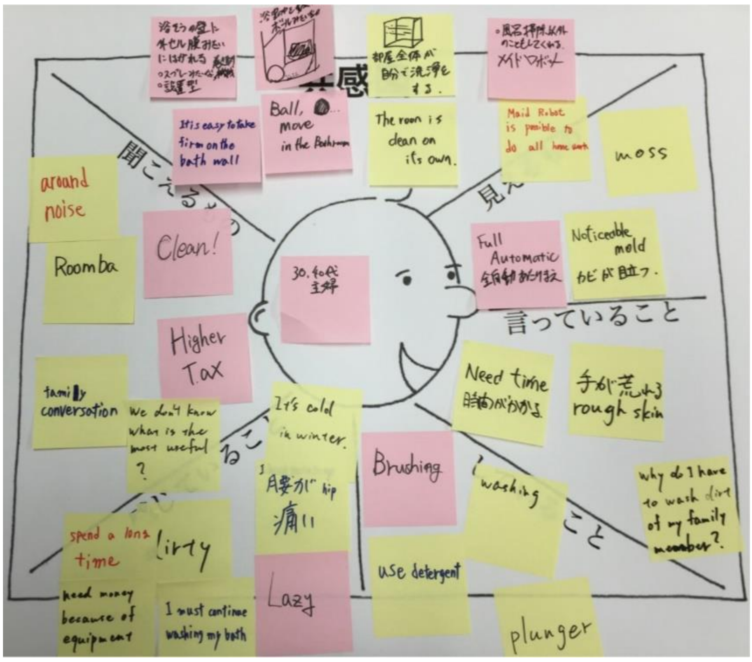

Figure 5. Example of the Empathy Map in Final session

4. Conclusion

We proposed the Kando story understanding for new Idea Creation Support System of not expecting the implicit Kando story but drawing the explicit Kando story which can solve needs. As the result of trials, we confirmed the following:

- A Kando story for housewife as a target person using a bathroom cleaner was drawn.
- This Kando story aims at reducing a housewifely workload.
- The desirable understanding process for drawing Kando story was confirmed by visualizing the scene of using an idea as a product for the bathtub cleaning problem.
- However, we cannot guarantee whether an idea developed from this story turns into a creative idea.

Therefore, for a verification of Kando story, we are planning to compare ideas which obtained from the conventional ICSS, new ICSS using a Kando story, and non-support.

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Paper ID: 37

Integration of ECQFD and TRIZ for sustainable product model design

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Abstract

Nowadays, the green-design concept has been implemented in new product development due to the growing consideration of environmental issue. However, it has always been a contradiction between environment-oriented or profit-oriented products. Therefore, this study aims to adopt the model of environmentally conscious quality function deployment (ECQFD) and the theory of inventive problem solving (TRIZ) for creating sustainable and innovative green-design product development process. The voice of the customer (VoC) divided into three dimension are cost, quality and environmental. ECQFD is utilized for transforming customer demand into engineering characteristics, so contradictions may be revealed during the modeling; meanwhile, TRIZ is taken as a tool for generating creativity to solve the contradictions. A case of household baking utensils has been used to examine the approach in this study.

Keywords: Environmentally conscious quality function deployment, Household baking utensils, TRIZ.

1. Introduction

The environmental issue has become prominent nowadays because more and more people are aware of its importance. In the past, product design was lack of considerations of environmental design. Furthermore, product innovation has always been more technology driven but less market demand concern. Thus, this study extends QFD by adding environmental awareness which is called ECQFD. However, there are usually contradictions while designing new products especially while considering the environment effect. The brainstorming which ideas are randomly generated may increase the uncertainty and cost of innovation. TRIZ has been recognized as a systematic creative thinking method for helping generate novel ideas at the beginning of new product development. This study adopts TRIZ to solve contradictions while using ECQFD at the stage of new product design. In recent years, the demand of household baking products increase gradually. According to Maslow's "hierarchy of needs", food is one of the fundamental requirements for human survival. Furthermore, food scandal occurs frequently in Asia area. People began to pay more attention to the impact of food on human health which result that more and more people tend to cook by themselves instead of dining outsides. Therefore, this study apply a pastry decorating set for demonstrating the integrated model of ECQFD and TRIZ.

2. Literature review

We reviewed the literature on applying ECQFD and TRIZ for green-design product.

▪2.1 green-design product using QFD

ECQFD, also called Quality Function Deployment for Environment (QFDE), is originally developed from Quality Function Deployment (QFD). QFD is a powerful systematic tool, arising from Yoji Akao (2004) and Shigeru Mizuno in the late 1960th. Firstly, VoC focuses on the quality, such as operation safety, easy to maintain, easy to use and so on. In recent years, many researchers have combined QFD with other model, such as that Gary (1993) incorporates a decision model for the prioritization of requirements with QFD, and Bode and Fung (2013) integrate the concept of design cost into QFD in order to achieve low product development and high customer satisfaction.

Lately, the environment has become a crucial issue, many scholars has extend QFD model toward more sustainable concern, it has been applied to many products, such as green mobile phone (Yung-Hung Wu, 2015), cast resin dry-type distribution transformer (Mojdeh Younesi, 2015), air conditioning products (Suiran Yu, 2014), hand blender (Ilke Bereketli, 2013), rotary switches (S. Vinodh, 2010), fishing fleet (Ingrid Bouwer Utne, 2008), hair drier (Tomohiko Sakao, 2007) and so on.

However, ECQFD only consider environmental factors, there is a conflict between environmental concern and product design concern. For instance, the most common conflict is trade-offs among manufacturing cost and product design. Consequently, this study solves the conflicts by using a creativity tool.

▪2.2 TRIZ (theory of inventive problem solving)

TRIZ, introduced by G. Altshuller and Altov (1946), is the acronym for Teoriya Reshniya Izobretatelskikh Zadatch in Russian, by analyzing and organizing over four hundred thousand principle of successfully innovative patents. Over the past decades, TRIZ has gradually come to maturity, it has become a powerful innovative methodological with a highly growing popularity, user can follow through the process of TRIZ to achieve the purpose of accelerated creative problem solving. Moreover, companies can generate more high-quality solutions in a shorter period of time. Currently, many top companies of the world incorporated TRIZ into their organizational cultures, such as Samsung, Siemens, Intel, and so on.

The core of TRIZ incorporate the 40 inventive principles, 39 engineering parameters and the contradiction matrix.

In addition, the innovative problem mechanism is to filter the original engineering problem and identify the key issues of the improvement project then correspond to the problem-solving process, for example, the most commonly used method like Contradiction Matrix, Substance-Field, Ideal Result and ARIZ and so on. After using the method described above, start to analogy your specific problem, and then to find out the solution of the problem, as shown in Figure 1.

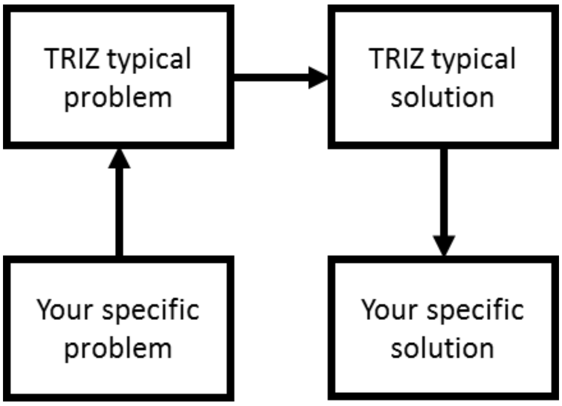


Figure 1. TRIZ problem-solving process

Typically, solving problems occur with some contradictions. Contradiction is divided into two types, the first one is technical contradiction (TC), is defined as a contradiction between two different parameters, also known as engineering contradiction. For example, we want phone screen bigger, because it is easier to use, but if it becomes bigger, it is not convenient to carry on, so big and small is a TC. The other contradiction is physical contradiction (PC), is defined as a contradiction within the same parameter. Continuing the previous example, the phone screen has a physical conflict.

In the application, Ruchti, B., & Livotov, P. (2001) combined commercial with TRIZ, realized that most of the line managers decide purely based on their business experience and intuition without following a problem solving process while facing the problems, so they proposed a TRIZ-based approach for solving non-technical problems. Hauser, J., Tellis, G. J., & Griffin, A. (2006) raised a review and agenda for marketing science by identifying 16 marketing-related topics as examples and dividing into five research areas. Kevin N. Otto, Kristin L. Wood. (2003) describe that systematic thinking can quickly produce new products in the product development stage. In addition, TRIZ not only applied to the above areas, but also applied in environmental product design, such as hair dryer (Tomohiko Sakao, 2007), electric vehicle (Vinodh, S., & Rathod, G., 2011), high temperature machine (Butdee, S., & Trakunsaranakom, C.,2013), etc. but there are still no scholar research an environmental friendly product areas in household baking utensils as their verification. However, all of these applications only solve TC, without researching on PC while solving problems with conflicts. Therefore, TC and PC will both be discuss in this study.

3. Methodology

The aim of this study is to propose an integrated ECQFD-TRIZ design approach for accomplishing sustainable and innovative product development. For most designers, there is always some contradictions between customer requirements and the environmental conscious while designing product. Due to the fact that we apply ECQFD to our product deployment process by having innovative and environmental characteristics. In Phase I, identified and correlated voice of customers (VoC), voice of the environment (VoE), traditional and environmental quality characteristics (QC). In Phase II, QC and components are also correlated, while components can be derived from function units or components. TRIZ, generates improvement design options, is applied to solve the contradictions while using ECQFD.

▪3.1 Identifying requirements of customers and environment

Sorting out the more representative of VoC/VoE (Voices), collecting the literature from *International Journal of Production Research*, *Journal of Cleaner Production* (Bereketli and Genevois, 2013) based on their impact factors and some others important researches (Masui et al., 2003) (Vinodh et al., 2014) correlated to our study. We selected and reviewed those literature according to the title with ECQFD and TRIZ for sustainable product design. However, gathering through market survey integrate with previous literature review to have definition on each VoC. Table 1 below are just designed for general use, it should be adjust to suit for the target product.

Table 1. Requirements of customers and environment.

VoC (cost or quality)	VoE (environmental)
Durable	Energy saving
Easy to use	Easy to recycle
Easy to storage and maintain	Easy to clean
Easy to repair/reuse	Easy to smash
Good appearance	Easy to transport and retain
High automation	Easy to dissemble and assemble
High production	Harmless to the living environment
Light weight	Less hazardous substances
Operation safety	Less energy consumption
Price	Less material usage
Quiet	Safe emission
Reliability	Safe to incinerate
	Safe to landfill

▪3.2 Identifying product specifications

Product specifications are correlated to the Table 1 that we identified. VoCs are used to meet customers need and VoEs were listed to solve environmental problems. Quality characteristics (QC) should relate directly to the Voices that figure out each solution in engineering technology approach, product information and even the process of transportation to sale. It is crucial to change our thinking into the view of object to make definitions for fear of confusing with Voices and QC.

▪3.3 Identifying the target for design improvement

3.3.1 ECQFD Phase I

The house of quality at phase I have three parts to illustrate the process of implementation. First, the weighting on a category of Voices is determined by collecting data samples through the expert interview and marketing survey. Using the 1–3–5 (less important–important–very important–important–very important) scale to obtain the weighting of Voices.

Second, the correlation among Voices and QC should make a distinction between positive correlation and negative correlation depending on the direction of improvement for QC correspond to Voices. For instance, the direction of improvement for “strength” is “↑” that means we want to improve the degree of product or components which can bear an external force without being damaged. There is a positive correlation between “strength” and “durable” while a negative relationship exists between “strength” and “easy to smash”. Furthermore, at crossing-points between Voices and QCs are shown numbers indicating the magnitude of both factors called “relational strength” determined by seniors R&D engineers and managers over a 0–1–3–9 (no relation–weak–moderate–strong) scale. The total sum multiplied by the customer weight and the relational strength is the raw score for each QC. The relative weight for each QC is given as the raw score divided by the sum of the raw scores.

Third, ECQFD phase I shows the deployment of Voices to QC. However, there are contradictions among the QC and those among Voices.

To represent these, this study follows an extension on the existing QFDE (Sakao, 2007) in the correlation table for both QCs and Voices. The former ‘correlation table for QC’ will first be introduce. Adding positive or negative number is useful for designers to distinguish the effect that cause not only relationship in different QC (with synergetic effect, with contradicting effect, or otherwise), but also a relationship of same QC (always with synergetic effect). The equation (1) is formulated for QC of which elements is denoted as $mc_{j1,j2}$ $(1 \leq j_1 \leq j_2 \leq J)$, while QC being given as $\{m_j | 1 \leq j \leq J\}$. The value of $mc_{j1,j2}$ is given by seniors R&D engineers and managers. Note that J stands for the number of given QC in phase II. Furthermore, j, j_1 and j_2 are referred as an ordinal number of a QC element:

$$mc_{j1,j2} = \begin{cases} +1, & where\ a\ synergetic\ effect\ exists \\ -1 & where\ a\ contradicting\ effect\ exists \\ \ \ 0 & else \end{cases} \tag{1}$$

The latter 'correlation table for Voices' will obtain automatically from the matrix of Voices and QC: a correlation table is introduced for Voices whose elements are $vc_{k1,k2}(1 \le k_1 \le k_2 \le K)$ determined by the equation (2), when Voices are given as $\{v_k | 1 \le k \le K\}$. Note that K stands for the number of given Voices in phase I. Furthermore, k, k_1 and k_2 are referred as an ordinal number of a Voices:

$$vc_{k1,k2} = \begin{cases} -1 \ \textit{where either}\ (3)\ \textit{or}\ (4) \textit{is satisfied} \\ \ \ 0\ \ \textit{else} \end{cases} \tag{2}$$

$$a_{j1,k1} \cdot a_{j2,k2} \cdot mc_{j1,j2} \le -z^2 \tag{3}$$

$$a_{j2,k1} \cdot a_{j1,k2} \cdot mc_{j1,j2} \le -z^2 \tag{4}$$

In the case of $vc_{k1,k2} = -1$, there a contradicting effect exists between Voices. It should be notice that $a_{j,k}$ denotes the correlation strength between QC, m_j and voice v_k, and take any value from $+z$, $+y$, $+x$, 0, $-x$, $-y$, $-z (0 < x < y < z)$. Therefore, $vc_{k1,k2}$ is automatically calculated using the matrix and the correlation of QC.

The calculation of relational strength in the matrix are correlation between VoC and QC. Taking Figure 3 as the example for this case study, set up the numerical value : $x = 1$, $y = 3$, $z = 9$, the formula on the right-hand side of (3)、(4)'s minimum value = -81. In order to search out the importance of contradicting effect in the matrix for further study. For instance, the value of $a_{1,1} = +9$, $a_{3,2} = -9$, and $mc_{1,2} = +1$ is satisfied the inequality (3). Thus, $vc_{1,3}$ is equivalent to -1. It means that there is a contradiction effect between v_1 and v_3. Another example is multiply $a_{1,1} = +9$ by $a_{2,3} = +9$ to get 81 indicates that there is no contradiction effect among Voices. However, multiply 81 by $mc_{1,3}$ to get -81 indicates that there is a contradiction effect between m_1 and m_3 where $mc_{1,3} = -1$ is given.

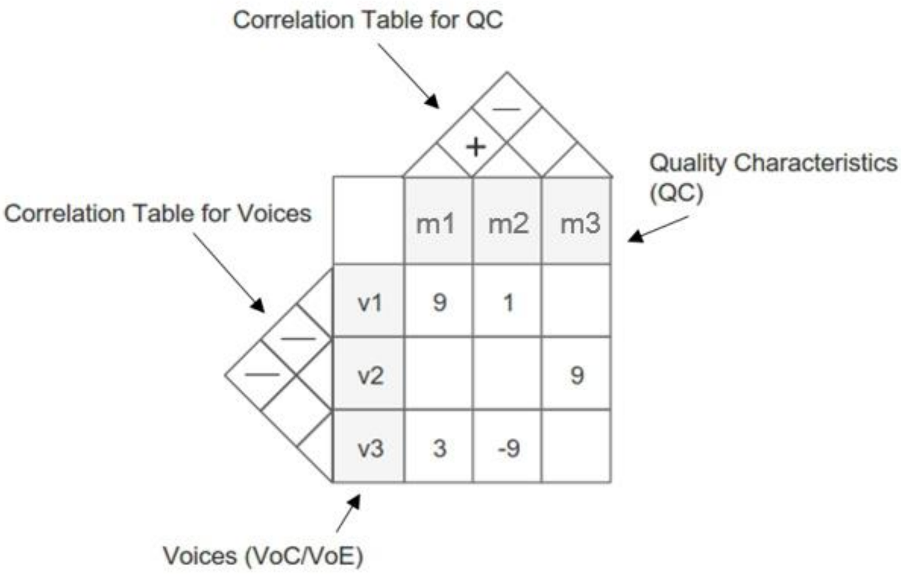


Figure 2. Quality function development

3.3.2 ECQFD Phase II

The deployment of QC to components need to utilize the relative weight of QC that came from the result of phase I. Furthermore, at crossing-points between QCs and components are shown numbers indicating the magnitude of both factors called "relational strength" determined by seniors R&D engineers and managers over a 0–1–3–9 (no relation–weak–moderate–strong) scale. The total sum multiplied by the relative weight from phase I and the relational strength is the raw score for each component. The relative weight for each component is given as the raw score divided by the sum of the raw scores. Eventually, designers can focus on more influential components by selecting out the higher weight of component to improve a QC for target product.

3.3.3 TRIZ

Obtaining results from phase I, some physical contradictions were determined and figuring out the higher weight of QC, which is the crucial Voices, solving by technical solutions. Moreover, the more influential candidates were chosen from phase II. To do so, matching the 39 engineering parameters appropriately defined in the matrix. The correlation between finding improve parameter and worsen parameter can receive the inventive principles. It is efficient to obtain trigger solutions by considering those inventive principles.

4. Case study

▪4.1 Example

In this study, the application of the proposed methodology is illustrated using a pastry decorating set. The case study conducted in a bakery equipment company, which located in central Taiwan. The reason we select the product is that it's specific function and more complicated while compared to other baking utensils.

▪4.2 Results

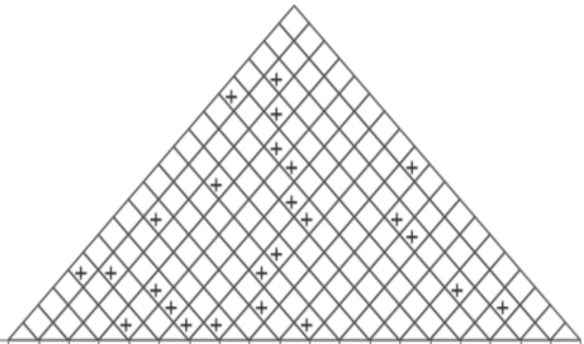
4.2.1 ECQFD Phase I

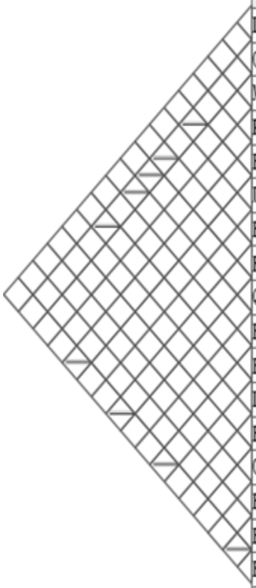
Before constructing the house of quality, there are two operations should be done first. One is identified requirements of customers and environment, and the other is identified product specifications. Figure 3 shows the adjustments of these operations for pastry decorating set. For example, QC such as strength (0.107), disassembly (0.106) and physical lifetime (0.102) are relatively vital for satisfying customer requirements of operation safety, easy to disassemble and assemble.

The top root in Figure 3 represents the correlation table for QC. For instance, there is a positive correlation between 'disassembly' and "easy to disassemble and assemble' while a negative relationship exists between 'disassembly' and 'operation safety'. On the other hand, the left root represents the correlation table for Voices addresses only the contradicting relations denoted as '–'. At crossing-points between 'operation safety' and 'easy to smash' shows the strong correlation with 'strength' positive (+9) and negative (-9), respectively. The important QC for improvement are jointly agreed on and detailed in the house.

4.2.2 ECQFD Phase II

Figure 4 shows the pastry decorating set is divided into 9 parts, such as, front of tenon, transparent cylinder, rear of tenon, plastic sheet, serrated strip, spring, pressing the handle, holding the handle, pastry tube. As a result, components such as front of tenon (0.14), rear of tenon (0.134), serrated strip (0.134) are relatively crucial for finding out the more influential components in ECQFD Phase II.





QFDE Phase I	Weight	The amount of ingredient containing	Stability	Visual measurement	Weight	Volume	Number of parts	Disassembly	Strength	Rate of recycled materials	Physical life time	Repairability	Functionality	Energy consumption	Sound	Materials used	Number of types of materials	Production technology	Packaging	Biodegradability
Unit		ml			g	cm^3								kwh	dB					
Direction of improvement		↑	↑		↓	↓	↓	↑	↑	↑	↑	↑	↑	↓	↓		↓			↑
Less hazardous substances	9					3	1			9				3		1	3	3		9
Operation safety	9	1		3		3		<u>9</u>	9								3			
More environmentally friendly material usage	3	3	1			<u>3</u>			3	9						3			3	9
Price	3	<u>3</u>	<u>3</u>		<u>1</u>			<u>1</u>	<u>3</u>		<u>3</u>		<u>3</u>		<u>3</u>		1	3	<u>1</u>	<u>1</u>
Energy saving	3	<u>1</u>	1						<u>3</u>		9	3		9				3		
Durable	9		3		<u>1</u>		3	<u>3</u>	9		9	9		<u>3</u>		1				
Easy to use	9			9	3	<u>3</u>	3						<u>1</u>							
Reliability	9		9	3		<u>1</u>	<u>1</u>	<u>1</u>	3		9						<u>3</u>	9		
Quiet	3			3					<u>1</u>						9			3		
Easy to storage and maintain	1	<u>1</u>			3	9	3	3										3		
Easy to repair/reuse	3		3						3		9	9								
Light weight	3	<u>3</u>			9	3	1											3		
Easy to recycle	1									9							3			
Good appearance	3	3		3	1	1												3	9	9
Easy to clean	3			1		<u>1</u>	3	9												
Easy to disassemble and assemble	9	<u>1</u>		3		1	3	9												
Easy to smash	1							3	<u>9</u>	3										9
Weight score		46	126	183	90	132	113	234	237	120	225	117	18	81	36	27	87	156	39	147
Relative weight		0.021	0.057	0.083	0.041	0.060	0.051	0.106	0.107	0.054	0.102	0.053	0.008	0.037	0.016	0.012	0.039	0.070	0.018	0.066

.

Figure 3. Phase I of ECQFD

Note: 1. The correlation strength; number underline mean negative correlation, while others are positive. 2. The correlation table for QC; "+" and "-" mean synergetic and contradicting effects

ECQFD Phase Ⅱ	Relative weighting from Phase I	Front of the tenon	Transparent cylinder	Rear of the tenon	Plastic sheet	Serrated strip	Spring	Pressing the handle	Holding the handle	Pastry tube
The amount of ingredient containing	0.021		9							
stability	0.057				3	9	9	9	1	
visual measurement	0.083		9			3				
weight	0.041	1	3	1	3	3	3	3	3	1
volume	0.060	3	9	3	1	3	3	3	3	1
number of parts	0.051	1	1	1	1	1	1	1	1	9
disassembly	0.106	9	3	9	1					9
strength	0.107	9	1	9	1	9	3	9	9	1
rate of recycled materials	0.054	1	1	1	1	3	3	1	1	1
physical life time	0.102	9	3	9	1	3	3	9	9	3
repairability	0.053	1		1		3				
functionality	0.008	3	3	3		3				9
energy consumption	0.037					3	3	3		
sound	0.016	1		1		9	9	9	3	
materials used	0.012	1	9	1	1	3	3	3	3	1
number of types of materials	0.039	1	1	1	1	1	1	1	1	1
production technolog	0.070	3	1	3	3	9	9	3	3	1
packaging	0.018		3							3
biodegradability	0.066	3	3	3	3			3	3	3
	Raw score	3.495	2.956	3.495	1.236	3.635	2.675	3.439	2.766	2.328
	Relative weight	0.134	0.114	0.134	0.047	0.140	0.103	0.132	0.106	0.089

Figure4. Phase Ⅱ of ECQFD

4.2.3 TRIZ

The contradictions that we obtain from phase I and phase II are shown in Table 2.

In addition, there is a PC exist in “QC: Disassembly”, as shown in Figure 5, the condition with “Easy to clean” and “Operation safety”. It is safer to operate a product under lower disassemble (stability of entire product). In the other hand, if disassembly gets lower, them the product will be worsened to clean up.

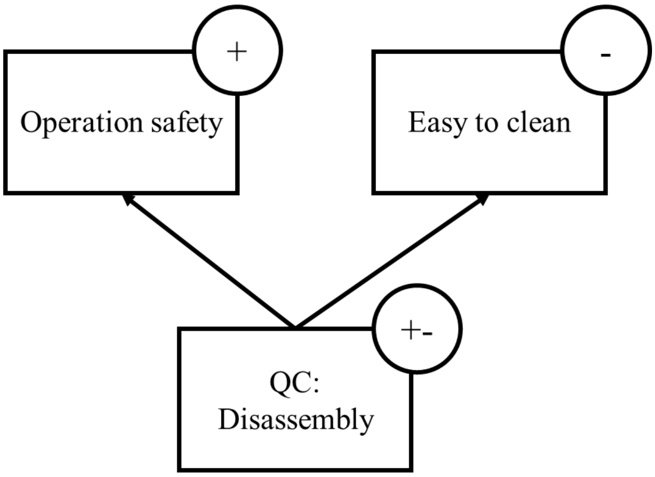


Figure 5. PC in Disassembly

By using the inventive principles "14. Curvature" from Separation in Space to verify the components between disassemble and assemble parts. For instance, the components are locked/dismantling through screw type, so that it can simultaneously satisfy “Easy to clean” and “Operation safety”.

Table2. Contradictions and related inventive principles

Decision	Contradiction of QC	Improving parameter	Worsening parameter	Related inventive principles	The trigger solution
D1	Q7: Disassembly and Q8: Strength	#14 strength	#32 Ease of manufacture	#11-Beforehand cushioning #3-Local Quality #10-Preliminary action #32-Color changes	#11-not applicable #3-spring is locked by rivet, in order to enhance quality of strength #10-not applicable #32-not applicable
		#32 Ease of manufacture	#14 strength	#1-Segmentation #3-Local Quality #10-Preliminary action #32-Color changes	#1-not applicable #3-spring is locked by rivet, in order to enhance quality of strength #10-not applicable #32-not applicable
D2	Q8: Strength and Q10: Physical life time	#14 strength	#39 Productivity	#29-Pneumatics and hydraulics #35-Parameter changes #10-Preliminary action #14-Spheroidality	#29-not applicable #35-change the friable degree of material #10-not applicable #14-not applicable
		#39 Productivity	#14 strength	#29-Pneumatics and hydraulics #28-Mechanics substitution #10-Preliminary action #18-Mechanical vibration	#29-not applicable #28-not applicable #10-not applicable #18-not applicable
D3	Q4: Weight and Q7: Disassembly	#32 Ease of manufacture	#1 Weight of moving object	#28-Mechanics substitution #29-Pneumatics and hydraulics #15-Dynamics #16-Partial or excessive actions	#28-not applicable #29-not applicable #15-not applicable #16-not applicable
		#1 Weight of moving object	#32 Ease of manufacture	#27-Cheap disposables #28-Mechanics substitution #1-Segmentation #16-Partial or excessive actions	#27-not applicable #28-not applicable #1-not applicable #16-not applicable
D4	Q5: Volume and Q7: Disassembly	#32 Ease of manufacture	#8 Volume of stationary object	#35-Parameter changes	#35-Change the appearance of the product, using a combination of elements in a spiral fashion
		#8 Volume of stationary object	#32 Ease of manufacture	#35-Parameter changes	#35-not applicable

5 Conclusion

This paper developed an eco-design methodology that integrates ECQFD and TRIZ. It has been verified through application to a pastry decorating set. Design options were identified using ECQFD, which translate VoC into required design attributes, components then establish the design model of environmental-friendly product. TRIZ was applied to improve the performance and realize the function. This methodology has a bigger benefit than using both tools alone. The study finally solves TCs by inventive principles and contradiction matrix, besides it also proposes PCs and solves through separation.

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Paper ID: 39

Patent Analysis on Low Flow Detector and Unmeasured Flow Reducer

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Abstract

Patents WO2006/134593 and WO2004/025229 from Water Flow Tech and A.R.I. respectively will be discussed separately. These two patents tackle the measuring problem of low volume fluid flow which is an important issue for water supply companies. In the article, the function, way, result of these patents will be discussed in the extended abstracts. The result and function of these two patents are the same which are to minimize measurement errors with a conventional flow meter and to accumulate water and release it in a pulsating way at low volume flow, respectively. However, their ways are different. The way for WO2006/134593 is to use a magnetic valve, whereas for WO2004/025229, a pressure responsive sealing assembly is placed in a control chamber to control the fluid flow.

Keywords: Function, way, result, minimize measurement error, low volume fluid flow.

1. Introduction

Water is an important natural resource. Every year about 12 trillion cubic meters of water are consumed worldwide (Worldometers, 2016). One of the ways to conserve the water is to meter the water consumption precisely. Measuring water consumption with water meter often faces a challenge with low volume fluid flow when leaking occurs in the building. As the leaking continues, the unmeasured leaking waste can go up to 15% of the total water supply to that building. The problem of low volume fluid flow is described in the Figure 1 (Zakay and Bar-Or, 2004) where four curves are depicted with the axis of abscissa representing the actual consumption and the axis of ordinate representing the measured consumption. Curve I is a theoretical 45 degree line indicating that the measured consumption is identical to the actual consumption. Curve II is typical for ordinary flow meter where there is a significant portion of the unmeasured leaking waste. In addition, even when the actual consumption is above the minimum threshold Q_{start}, the measurement error is still large until it reaches a nominal quantity, $Q_{nominal}$. The Q_{start} and $Q_{nominal}$ are shown in Figure 2 (Dana, 2006) where measurement error between measured consumption and actual consumption is the function of the actual consumption rate. Upon installation of a valve in accordance with some embodiments, the flow meter will yield an "over efficient" performance by curve III. This phenomena takes place due to occurrences of closing and opening the valve, involving inertia forces on the rotor of the flow meter. In order to keep the consumers, it is better to devise a valve providing the performance of curve IV extended below the theoretical curve I.

There are two companies from Israel, Water Flow Tech (WFT, 2016) and A.R.I. (A.R.I. valve, 2016), releasing two devices to combat the challenge, low flow detector (LFD) and unmeasured flow reducer (UFR) respectively. The artifacts are shown in Figures 3 (Rochman, 2016) and 4 (Sustainable city network, 2016) respectively. These two devices accumulate the low volume flow into large quantity of water to a certain threshold, then release the water at a time so that the water quantity can be measured by regular flow meter with a minimum amount of measurement error. However, different ways are used by them. The Water Flow Tech uses a magnetic valve to accumulate the water, and the technique is described in patent publication WO2006/134593 (Dana, 2006), and its corresponding artifact is LFD. Whereas A.R.I. uses spring with a plunger admitting flow through the fluid supply system for only measurable fluid flow and the technique is disclosed in patent publication WO2004/025229 (Zakay and Bar-Or, 2004), and its corresponding artifact is UFR. In this paper, function, way and result are used to analyze these two patents. The goal of this research is to understand the patents in the perspective of patent circumvention. Once the function, way and result are constructed in the patents, it becomes easy to apply TRIZ tool to circumvent the patents.

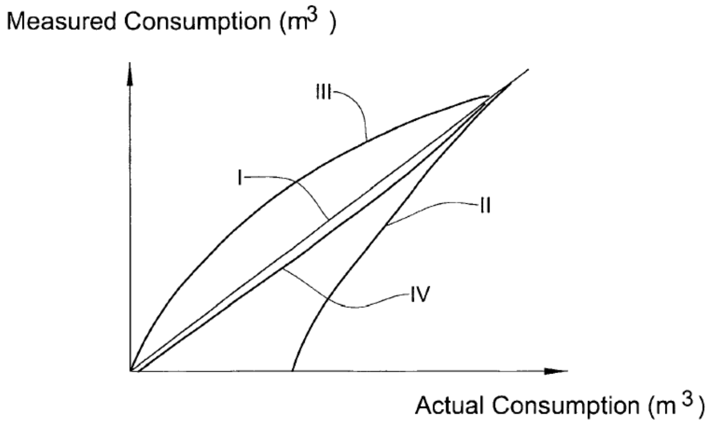


Figure 1. A schematic graph representing actual flow VS. measured flow at four conditions

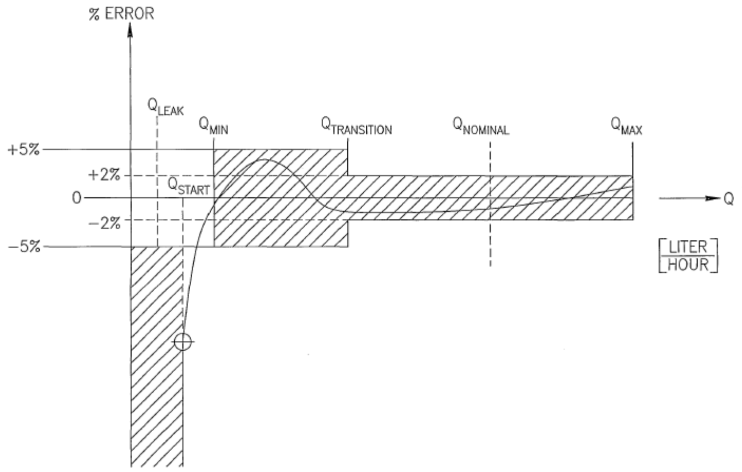


Figure 2. Measurement error over flux Q of a conventional meter

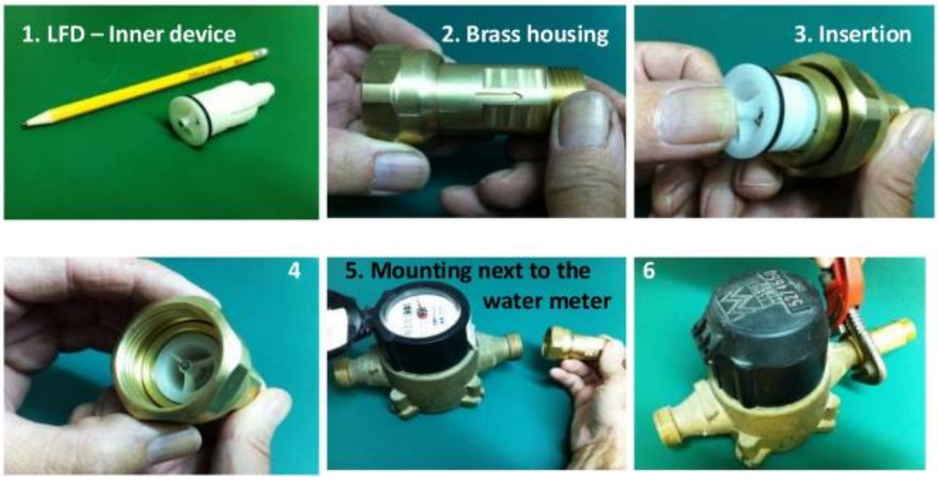


Figure 3. Low flow detector, LFD

Figure 3. Unmeasured flow reducer, UFR

2. Literature Review

Patent WO2006/134593 relates to a magnetic flow controller which transforms a slow reduction in pressure of fluid flow over time to a measurable fluid flow. Once a threshold pressure differential is reached, a flow passage through the flow controller opens rapidly to a relatively large opening, thereby generating a volume of fluid at high flux flowing through the passage, particularly to permit the measurement of the volume of fluid in a conventional flow meter.

Accordingly, the invention provides a magnetic f1ow contro11er including a body defining a f1uid f1ow passage having an inlet and an out1et; a displaceable magnetic sealing member disposed in the passage; an inlet stop member mounted across said inlet; an annular seal member mounted in said body, said seal member having internal walls having a portion of constant diameter; an out1et stop member disposed near said fluid out1et. Said inlet stop member inc1udes a ferromagnetic portion, so as to create a magnetic force, acting on said displaceable member, sufficient to cause the displaceable member to engage said inlet stop member so as to close and seal the flow passage; and a return element adapted and configured near the outlet stop member causing the displaceable member to return towards the magnet.

The disp1aceab1e member and the f1uid flow passage being shaped to remain sealed during a first movement of the displaceable member through the f1ow passage, thereby to gradua11y bui1d up f1uid vo1ume and pressure acting on the disp1aceab1e member, and shaped to rapid1y fully open the sea1, so as to generate a measurab1e vo1ume of fluid through the passage. The extended abstract of the patent is shown in Table 1. Notice that the inventor and assignee of the patent is Yossi Dana who is the CEO of the Water Flow Tech (WFT, 2016).

The content of Patent WO2004/025229 is as follows. A flow responsive valve for a flow metering system comprises a fluid meter having a minimum measuring flow threshold. The valve is able to shift between an open position and a closed position depending on flow rates whether above the minimum measuring flow threshold or not. The pressure pulsating position depending on pressure differential over an inlet port and an outer port of the valve. The pressure pulsating position alters between a closed position essentially prohibiting fluid flow there through at flow rates below the minimum measuring flow threshold, and an open position admitting fluid flow into the supply line at a measurable flow rate above the minimum measuring flow threshold. In that way, an average f1uid flow through the system remains constant over time in spite of flow rate fluctuations imparted by the system. The main part of the flow responsive valve is a pressure responsive sealing assembly which is received within the housing. It comprises an axially displaceable plunder and a stationary cup member. A coiled spring is formed between the plunger and the cup member. A sealing sleeve, made of a resilient material, is applied over the cylindrical extension of the plunger and of the cup member, to thereby restrict liquid flow into the confined space. The extended abstract of the patent is shown in Table 2.

Table 1. **Extended Abstract of WO2006/134593 (US8365753)**

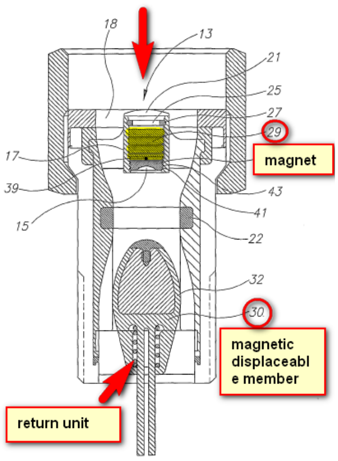
<table>
<tr><td>Title</td><td colspan="4">FLUID FLOW CONTROLLER</td><td>Legal Status</td><td colspan="2">Valid</td></tr>
<tr><td>Pat. No.</td><td colspan="2">WO2006/134593 (US8365753)</td><td>Date of Filed</td><td>2006/06/14</td><td>Date of Issued</td><td colspan="2">2013/02/05</td></tr>
<tr><td>Assignee</td><td colspan="4">Yossi Dana</td><td>Inventors</td><td colspan="2">Yossi Dana</td></tr>
<tr><td>Analyzer</td><td>Jyhjeng Deng</td><td>Tech Keywords</td><td colspan="3">Threshold pressure differential, a displaceable magnetic sealing member, a stop member at inlet with ferromagnetic portion</td><td>Date of analysis</td><td>2016/04/13</td></tr>
<tr><td>INT. PAT. CL.</td><td colspan="2">A61B 8/00 (2006.01)</td><td colspan="2">Reference Cited</td><td colspan="3">GB2083, EP925465, US5,320,136, US5,218,346</td></tr>
<tr><td colspan="8">Problem to be solved:
In many buildings there are leaks and other water demands at low volumes which are too small to be measured by the meter. However, since these flows continue all day long, the unmeasured usage can reach up to 15% of the total water supplied to that building.</td></tr>
<tr><td colspan="8">Functions:
Accumulate water and release it in a pulsating way at low volume flow.</td></tr>
<tr><td colspan="8">Results:
Minimize measurement errors with a conventional flow meter.</td></tr>
<tr><td colspan="8">Ways:
Use a ferromagnetic stop member and a magnetic displaceable member to close and seal the flow passage. The displaceable member is urged through the flow passage towards the out1et by a force created by a pressure differential between a pressure at the inlet and a pressure at the out1et. Then a return element adapted and configured near the outlet stop member causes the displaceable member to return towards the magnet.

</td></tr>
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Table 2. **Extended Abstract of WO2004/025229 (US7640944)**

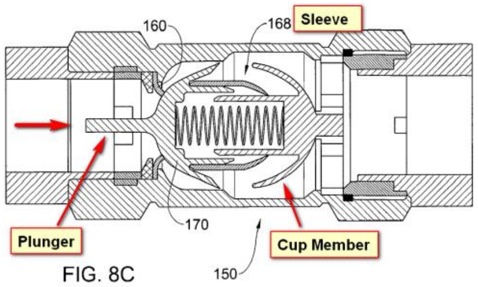
<table>
<tr><td>Title</td><td colspan="4">VALVE FOR PREVENTION OF LOW FLOW RATES THROUGH FLOW METER</td><td colspan="2">Legal Status</td><td colspan="2">Valid</td></tr>
<tr><td>Patent No.</td><td colspan="2">WO2004/025229 (US7640944)</td><td>Date of Filed</td><td>2003/09/04</td><td colspan="2">Date of Issued</td><td colspan="2">2010/01/05</td></tr>
<tr><td>Assignee</td><td colspan="3">A.R.I. FLOW CONTROL ACCESSORIES AGRICULTURAL COOPERATIVE ASSOCIATION, LTD.</td><td>Inventors</td><td colspan="4">Avraham ZAKAY, Jonathan BAR-OR</td></tr>
<tr><td>Analyzer</td><td>Jyhjeng Deng</td><td>Tech Keywords</td><td colspan="3">displaceable plunder, stationary cup member, coiled spring, sealing sleeve</td><td colspan="2">Date of analysis</td><td>2016/04/13</td></tr>
<tr><td>INT. PAT. CL.</td><td colspan="2">F16k 15/02 (2006.01)</td><td colspan="2">Reference Cited</td><td colspan="4">US5,218,346</td></tr>
<tr><td colspan="9">Problem to be solved:
In a water supply system not fitted with a device in accordance with the present invention, any such leaks which are below the minimal measurable flow threshold (a common such minimal threshold is about 10 liter/hour) would not be detected and would not be measurable, i.e. causing the water supplier considerable loss, not to mention the waste of fresh water which in some regions in the world is an acute problem.</td></tr>
<tr><td colspan="9">Functions:
Accumulate water and release it in a pulsating way at low volume flow.</td></tr>
<tr><td colspan="9">Results:
Minimize measurement errors with a conventional flow meter.</td></tr>
<tr><td colspan="9">Ways:
A valve comprising an inlet port and an outlet port; a control chamber extending between the inlet port and the outlet port and a pressure responsive sealing assembly disposed within said control chamber; said pressure responsive sealing assembly having an displaceable plunger, a stationary cup member and a sealing sleeve; and a bleed aperture, between the plunger and the surface of control chamber, determining a minimal flow threshold through the control chamber; wherein the pressure responsive sealing assembly displaces between an open position and a closed position depending on a pressure differential over the sealing member.


FIG. 8C</td></tr>
</table>

3. Methodology

The two patents are found in the database of European Patent Office (European Patent Office, 2016). In the advanced search, keywords such as “A R I Flow control Accessories” are typed in the Applicants field to retrieve 14 patents of the A.R.I.. Then patent title “VALVE FOR PREVENTION OF LOW FLOW RATES THROUGH FLOW METER” is chosen. Within the patent family, patent publication number WO2004/025229 is chosen as its representative. Whereas the search for patent of Water Flow Tech is not that easy. Keywords search is to no avail. The inventor Yossi Dana of low flow detector from Water Flow Tech is identified in Google search. Then “Yossi Dana” are typed in the Inventor field to retrieve only one patent. Click on the patent title “FLUID FLOW CONTROLLER” and its representative WO2006/134593 is chosen.

Function, way and result are the elements used by the Intellectual Property Court to diagnose the patent infringement (Wikipedia, 2016). When a potential infringing case is compared with its infringed patent, function, way and result on both sides are compared. If there is a substantial different between them in any element, then the potential infringing case is saved from the accusation of infringement. Since the purpose of this research is to come out a new design for detecting the low volume flow in residential setting, one of the ways is to describe the function, way and result of the contemporary patents. After that some TRIZ tool may be used to create the new design. Such tools include: Su-Field model (Mann, 2002) and Function Oriented Search (Litvin, 2005).

4. Result and Discussion

Measuring water usage with water meter often faces a challenge with low volume fluid flow when leaking occurs in the building. As the leaking continues, the unmeasured leaking waste can measure up to 15% of the total water supply to that building. The problem of low volume fluid flow is described by curve II in the Figure 1. Curve II is typical for ordinary flow meter where there is a significant portion of unmeasured leaking waste. In addition, even when actual consumption above a minimum threshold Q_{start}, the measurement error is still large until it reaches a nominal quantity, $Q_{nominal}$. Two companies from Israel, Water Flow Tech and A.R.I., released two devices to combat the challenge, low flow detector (LFD) and unmeasured flow reducer (UFR) respectively. The core techniques of these two products are described in patents WO2006/134593 and WO2004/025229 respectively.

The function, way and result of these patents is discussed in the extended abstract described in Tables 1 and 2. The function and result of the two patents are identical. They are “to accumulate water and release it in a pulsating way at low volume flow” and “to minimize measurement errors with a conventional flow meter” respectively. However, ways to perform are different. The way of WO2006/134593 is to use a magnetic valve where aero dynamic shape displaceable member with ferromagnetic portion is interacted with a magnetic inlet stop member. The displaceable member is urged through the flow passage towards the outlet by a force created by the pressure differential between the inlet and the outlet. Whereas the way of WO2004/025229 is to use the pressure responsive sealing assembly with sealing sleeve applied over its cylindrical extension and a coiled spring received within its confined space. The pressure differential between the inlet and outlet disposes the pressure responsive sealing assembly between them. Since the purpose of this research is to come out a new design for detecting the low volume flow in residential setting, one of the ways is to describe the function, way and result of the contemporary patents. After that some TRIZ tool may be used to create the new design. Such tools include: Su-Field model and Function Oriented Search.

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Paper ID: 41

The unexpected contribution of design thinking to technology transfer activities

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Abstract

On a first sight, Design Thinking (DT), which is defined as a method of meeting people's needs and desires in a technologically feasible and strategically viable way (Brown, 2009), can be interpreted by having little or no application on a typical Technology Transfer (TT) process, where technology is on the spotlight and is the promoter of a market application and a new business opportunity. In other words, while the most common technology transfer processes are triggered by the development of a new technology that, after on, searches for available marketplaces where it can generates value; design thinking methodology has human problems, needs or opportunities as starting points to generate, develop and test ideas that will, further on, be implemented in the most viable way. Thus, it is understandable that design thinking have been mostly applied to product and service development, not having had, theretofore, application to scientific and technical research or technology transfer activities.

One of the existing problems of technology transfer activities is considered to be the lack of market knowledge and understanding, which causes the decrease of possible return on investment from the new technologies. Considering this problem and knowing that DT it is a method that uses tools to engage with possible customers/users and understand their needs, aspirations, problems and possible benefits, this paper explores the potential application of DT on TT activities.

Main findings show that the explorative methodology of design thinking can be helpful to unveil less obvious market applications, as well as, bring a better understanding on market dynamics, which will dictate the acceptance of a new technology.

Keywords: design thinking, technology commercialisation, technology transfer, value creation.

1. Introduction

It is stated in every national strategy that investments made on knowledge through the promotion of education, as well as, on research, development and innovation (R&DI) are key to economic growth and countries' development.

However, when it comes to put the generated knowledge to the service of society where they are able to create value and generate the expected return on investment, some challenges arise, mainly when it envolves the product of scientific research or a disruptive breakthrough idea (Fletcher, 2012).

Many authors have been dedicating their attention to the identification of sources which cause the existing challenges on technology transfer activities, such it is presented on the study of Natsheh (2015), where the identified problems rang from patent filling processes, lack of interest, insufficient funds, conflict of interests, bureaucratic disturbance, insufficient test of technology, customer / consumer acceptance, just to name a few. These problems can be grouped in four big topics, namely the issues related with 1) Financials, 2) Market understanding and marketing; 3) Academic and business culture, environment and relationships, and finally 4) Regulations, human resources involved on commercialisation and intellectual property issues (Natsheh, 2015).

Attending to these existing challenges on technology commercialization' activities, and more specifically focusing on the market understanding issues faced by knowledge producers, we searched for methodologies which could master on this task of market understanding and which also involve other important features to help on the development of an innovation.

By doing so, we found a known human-centred approach to innovation called Design Thinking (DT) which seems to fit perfectly the purpose of understanding the market in order to develop results which really create meaning and social-economic impact. And here lies the ground for this work which explores the features of this two processes of Technology transfer and Design thinking, in an attempt to take the most out of both of them for the good sake of technological innovations.

2. The processes of Technology Transfer and Design Thinking

2.1 Technology Transfer activities

A technology transfer process is a way how to bring a technology form the lab to the marketplace, in order to create value and generate the return on investment.

Independently on the chosen strategy for technologies’ commercial exploitation, there is a common path for value creation processes, which is organized in three main phases. Whether we are looking to a new business creation or to license a technology, one must start by identifying an opportunity, i.e. the product/process/service - market combination, or in cases of technological platforms, the identification of, at least, one technology-product-market opportunity. This phase of opportunities identification is followed by an evaluation stage and finally the process ends with the phase of exploitation per se (Grichnik, Smeja, & Welpe, 2010; Shane & Venkataraman, 2000).

Figure 1. r’ stages

This process starts with the identification of what is considered to be an opportunity by having a specific technology in mind. Most of the times, due to confidentiality issues, these opportunities are screened by those who are directly involved on the technology production and commercialization, who will use their background and past experiences not only to identify possible market places for the technology, but also to perform the evaluation between different possible opportunities and also choose among exploitation strategies.

2.2 Design thinking and its approach

Design thinking is defined by Brown (2009) as a method of meeting people’s needs and desires in a technologically feasible and strategically viable way. Still using the definition given by Tim Brown, design thinking method takes a design challenge through three iterative phases, namely the Inspiration Phase - to find the problem or opportunity that motivates the search for solutions, the Ideation Phase - the process of generating, developing and testing ideas, and the Implementation phase - the path that leads from the project room to the market (Brown, 2009).

This human-centered approach to innovation consist on the following steps (Johansson-Sköldberg et al, 2013):

- Empathize;
- Define the problem;
- Ideate;
- Prototype;
- Test.

If we take a carefully look on the previous mentioned steps, we can clearly highlight some direct features of this process, such as the alert to deeply understand and define the problem, in a way that calls our attention to the fact that, now more than ever, our way of understanding the world and its challenges can not be global and universal. This is very important not only to put on the final users' shoes and see and feel the things how they see and feel it, but also to engage with the way how the matter we are dealing with can be meaningful to the customers and the society in general.

The steps of design thinking also confers to the process an experimental profile, since we are encourage to prototype whatever is the outcome of the ideation phase, either a product, a process, a new business concept, or other.

Traditionally, design thinking - empathetic, intuitive, explorative and empowering methodologies (Brown, 2008 and Kelly, 2001) - have seen their primary application in product and service development, and little or no application in scientific and technical research (Simons, 2011), an approach that is theoretically explored on this paper.

3. Comparing stages of Design Thinking and Technology Transfer

If we take it generally, these two processes are very different in the way how they drive innovation.

While Design thinking has its starting point in a human-centred challenge that serves as the motif to empathise and search for insights which will lead to the understanding and definition of a challenge - the inspiration stage; Technology transfer processes do not explore market insights before the development of an idea, mostly looking for the feasibility aspects of a new technology.

Right after the inspiration phase of design thinking, this process searches for solutions to fit on the spotted problems, while technology transfer has a solution which searches for market opportunities where it can create value. Although the ultimate goal of both, ideation (in design thinking) and opportunities' identification (in technology transfer), is considered to be, the same goal of generate innovative and meaningful solutions, they are faced differently by this two processes. Either they can use the same tools to came up with new ideas or opportunities, they are driven by different purposes, using different raw materials and many times involving different actors in the process.

Either way, when both processes have a solution or typically a poll of different solutions, they engage in an evaluation stage, which is more analytical in the case of a common technology transfer process, where metrics as market dimension, competition, among others, are analyzed, and more experimental and welcoming of failures, in case of a design thinking process, where prototypes are built and tests with end-users or other stakeholders are performed, to learn fast and cheap, incorporate feedback, evolve and if needed iterate. Another important aspect is that design thinking, due to the way how evaluate solutions, involve end-users or other stakeholders, or by another words, involve the “voice of the market” on this stage of decision, whether this is not so common on a typical evaluation occurred on a technology transfer process.

Since design thinking searches not only for a way how to generate feasible solutions which meet human needs, but which also makes it in a viable way, aspects related with business viability of the solutions are also taken into account during the final stage of implementation, and while testing the prototypes. In a different way, technology transfer process ends with a stage called “exploitation”, which is specifically tailored to analyze and decide on the business model’s components and the general strategy to move the technology to the marketplace.

4. Applications of Design Thinking’ mindset and features on Technology Transfer activities

The mindset and features of design thinking may offer an higher chance of success on TT activities and help to reduce the existing gap between technology production and corresponding market applicability. This higher chance of success is directly related with the human-centred and participatory approach of design thinking, which helps knowledge producers and those in charge of technologies’ commercialization to better understand the market and the possible customers/consumers. The experimental mindset of design thinking, also brings value to TT processes, such as stated by Norman (2004) “sometimes the value of the end product could obviously be improved through the appropriate application of design” (p. 15).

When applied during the research and development phase, Design Thinking may help to invert one common approach to innovation taken by engineering-driven companies looking for a technological breakthrough, as it was stated by Brown (2009), “In this scenario teams of researchers will discover a new way of doing something and only afterward will they think about how the technology might fit into an existing business system and create value”.

Nevertheless, the applications of DT mindset and features on TT activities need to be further studied and tested, and by doing so, some attention need to be putted on possible constraints.

6. Conclusions

This work discusses the possible application of DT mindset and process into TT activities. Design thinking was introduced, mainly due to its human-centerd approach, and in an attempt to face the identified challenges of market understanding commonly present at TT activities.

Having some knowledge on Technology transfer processes and on the stages involved in this technology commercialisation activity, and at the same time understanding the philosophy which underpins the design thinking methodology, such as its main features, it is possible to conclude that, although both processes have a different setting and different starting points, they can in fact work together to take the most out of new technologies and other science-based knowledge. Mainly the empathetic and explorative intrinsic concepts of DT, showed to be of great help to unveil less obvious market applications, as well as, bring a better understanding on market dynamics, which will dictate the acceptance of a new technology.

Nevertheless, further research is required to test how it is better possible to apply the mentioned design thinking principles and tools, in order to increase the value and effectiveness of a technology transfer process.

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Investor Group's Perceptions of Ecosystem Builders in European Startup Ecosystems

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Abstract

Currently the world's economies are facing great challenges in the creation of employment, especially due to the transformation of the employment structure associated to the technological progress and globalization of organizations. To address this issue, entrepreneurship has been increasingly used by policy-makers in developed economies as a central element in their policies to promote economic growth. While entrepreneurship is now considered to be a key element in growth-oriented policies, there exists a need for a larger foundation of knowledge about how to develop successful entrepreneurship ecosystems. This paper aims to characterize the investor groups' perceptions towards ecosystem builders in European startup ecosystems, with particular attention to the aspects of the ecosystem builders' contribution to startups and to the cooperation between ecosystem builders and investor groups. This investigation is composed by an extensive literature review to startup ecosystems and ecosystem actors, and by an empirical study to investor groups' perception concerning to this subject. To acquire empirical data it was conducted an online questionnaire directed to a sample of investor groups located in Portugal, U.K. and Germany. Our findings suggest that the aspects of the ecosystem builders' contribution towards startups that investor groups most value are startup screening, entrepreneurial education and access to mentoring. As for the cooperation between ecosystem builders and investor groups the results showed that there exists room for improvement, especially with regard to communication and information sharing.

Keywords: Ecosystem Builders, Entrepreneurship, European Startup Ecosystems, Investor Groups

1. Introduction

Throughout recent history entrepreneurship has gradually become a vital element of modern societies. As highlighted by several researchers (Peng, 2001; Audretsch, 2003; OECD, 2009; Kane, 2010), SMEs and entrepreneurs play a crucial role in all economies, being inclusively hailed as the sole source of new net job growth over the last 28 years in the U.S.A. (Herrmann *et al.*, 2015). This escalation in the importance of entrepreneurship in the world economies has led governments to start shifting from traditional enterprise policies to growthoriented enterprise policies, in order to promote the creation of favorable environments for business startups to thrive (Mason & Brown, 2014).

While creating supportive framework conditions alone is insufficient to drive the promotion of entrepreneurship (Mason & Brown, 2014), nowadays it's possible to witness a conjugation of factors which, combined with appropriate approaches to the entrepreneurial ecosystem, explain today's entrepreneurial explosion on the global scene (Herrmann *et al.*, 2015). According to Steve Blank (2013), there are four key factors which explain the current startup burst:

1) Startups can now be built for thousands, rather than millions of dollars;
2) Access to financing has decentralized from its clusters and expanded worldwide; 3) Entrepreneurship developed its own management science and tools; 4) Speed of consumer adoption of new technology has increased.

As a significant part of the global economic future lies on the performance of high-growth firms, society must be prepared to nurture entrepreneurs and support the growth of startups through their development stages. While several approaches to support new ventures have been attempted, most proved to be of limited effectiveness (Herrmann *et al.*, 2015). Currently however, several researchers (Neck *et al.*, 2004; Isenberg, 2011a; Mason & Brown, 2014; Herrmann ate al., 2015) have to come recognize the importance of supporting entrepreneurial ecosystems as whole, in order to better provide support to entrepreneurs and startups.

In the last few years Europe has been showing considerable commitment about promoting innovation and sustainable growth within its region, putting great efforts in developing supportive entrepreneurial ecosystems that encourage innovation, research and development, and entrepreneurship (European Commission). Such commitment can be verified by the implementation of supportive programs like Horizon 2020, which aim to encourage the development of new ideas and businesses through the providence of financial support to entrepreneurs and companies. Similarly to the funding, many other variables within an entrepreneurial ecosystem play equally crucial roles to the entrepreneurial success of a region. Being comprised by a diversity of actors, roles, and environmental factors that interact to determine the entrepreneurial performance of a region (Spilling, 1996), entrepreneurial ecosystems are dynamic, and complex systems that need careful assessment by policy-makers, both at a micro and at a macro level, when developing regional initiatives dedicated to foster entrepreneurship.

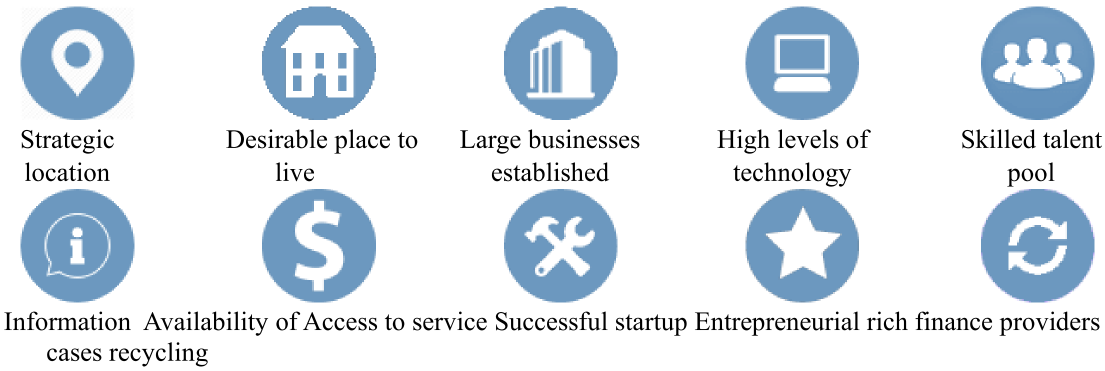
This paper aims to provide some insights about entrepreneurial ecosystems at a micro level, by focusing on two ecosystem actors which we regard as being extremely pertinent to the success of new ventures: ecosystem builders and investor groups. Focusing on the relationship between these two ecosystem actors, we aim to understand the investor groups' perceptions towards ecosystem builders concerning to how they interact with each other to create value to the community. This study is based on a literature review to startup ecosystems and ecosystem actors, as well as on an empirical study to a population of 25 investor groups located in Portugal, U.K. and Germany.

2. Startup Ecosystems and Ecosystem Actors

Behind the scene of innovative businesses there exists a multitude of dynamic processes, resources and entities focused on entrepreneurship, that interact with the purpose of making startups thrive and of boosting the entrepreneurial performance of a region. Such framework, denominated of "startup ecosystem", consists on the combination of factors that promote the entrepreneurship spirit, assist and support the startup process, and play a role in the development of entrepreneurship (Gnyawali & Fogel, 1994).

Startup ecosystems are structures composed by entrepreneurial actors, institutions, and processes, where the entities interact through formal and informal connections, with the purpose of supporting the creation and development of startup companies. These ecosystems can be industry specific, or may evolve from a single industry to several industries, they may be bounded but not limited to a geographic scale (e.g. campus, city, region), and they are not related to the particular size of its city. They generally emerge in locations that have place-specific assets (e.g. Oxford's strategic location close to London and to the airport, as well as its university and its unique cluster of U.K. government laboratories), being typically desirable places to live, with at least one or several 'large established businesses', generally associated to high levels of technology, that serve as 'talent magnets' to the ecosystem, attracting skilled workers to the area, and thus contributing to develop their regional ecosystems. Startup ecosystems are also characterized for being 'information rich' – individuals can access information about new buyer needs, new and evolving technologies, component and machine availability, etc. –, having availability of finance and the presence of service providers – lawyers, accountants recruitment agencies, and business consultants –, living under the 'law of small numbers', i.e. a small number of entrepreneurial successes can be responsible for igniting an entire ecosystem and greatly benefit the entrepreneurial community, and also for having its growth driven by a process of 'entrepreneurial recycling', in which former successful entrepreneurs remain involved in the cluster, reinvesting their wealth and/or experience to create more entrepreneurial activity (Isenberg, 2011b; Mason & Brown, 2014). Figure 1 provides an illustration of the generic characteristics of startup ecosystems.

Figure 1. Generic characteristics of startup ecosystems.



According to Mota *et al.* (2016), startup ecosystems are encompassed by six ecosystem actors who interact to support the creation and development of new startup companies: Entrepreneurs; Support organizations and individuals; Government; Service providers; Large companies; and Educational institutions.

» **Entrepreneurs:** People who identify an opportunity, and create an organization to exploit and pursue the opportunity. These persons undertake innovative activities and promote job creation and economic growth through the commercialization of the innovations (Bygrave & Hofer, 1991; Heirman & Clarysse, 2004; Johansson, 2010).

» **Educational institutions:** Institutions who possess the abilities to enable the initiation and promotion of the venture-creation process. These institutions, especially universities, are particularly important during the early development stages of startups, as they build capabilities and provide a diverse range resources, such as infrastructures, mentoring and support, that promote the development of young entrepreneurs and nascent startups. Universities are also a rich source of skilled people, possessing a large pool of diverse, talented people, as well as a source of innovative technological opportunities, with basic research being conducted in these institutions. However, despite being a source of high potential scientific discoveries, universities often possess weak capabilities for the development of commercial applications, thus explaining the reduced number of university-based spin-off firms. This actor's main contributions to the ecosystem are the scientific advancements that originate new businesses, and the skilled personnel that such institutions attract to the region (Rasmussen & Borch, 2010; Bathelt *et al.*, 2010; Mason & Brown, 2014).

- **Government:** Governments represent the political system that controls a region. Due to its inherent powers to create and enforce policies, governments can have a very influential role in the development of successful startup ecosystems. From a policy perspective, by implementing growth-oriented enterprise policies and incentives, governments can help to democratize the entry of new entrepreneurs to the ecosystem. Such policy approach include fiscal policies (e.g. tax rates), public procurement policies, direct subsidy and insurance schemes, bureaucracy reduction, etc. Governments can also create and encourage entrepreneurship activity through other mechanisms, such as by the establishment of infrastructures and "innovation hubs" to attract early-stage startups, or by promoting network building and developing connections between the entrepreneurial actors. By supporting and financially fund such initiatives, governments can strengthen the entrepreneurial talent pool in those markets, and hence create a favorable environment for the creation and scale up of startups (Neck *et al.*, 2004; Isenberg, 2011a; Mason & Brown, 2014).
- **Service Providers:** Organizations that support startups on non-core activities that they are not prepared to deliver in-house. These entities, such as venture-friendly lawyers, accountants, business consultants, investment bankers, recruitment agencies, among others, are seen as important actors in the entrepreneurial scene, as they understand the needs of entrepreneurial businesses, and focus on assisting these ventures. These organizations are often willing to offer their support to startups at very affordable prices or even at no charge, either with the expectation that long-term business relationships emerge from such cooperation, or due to being paid by other entities, such as the government or large companies, who sponsor specific entrepreneurship programs, or even the entire ecosystem (Isenberg, 2011a; Mason & Brown, 2014; Mota *et al.*, 2016).
- **Large Companies:** Large companies play a major role in developing startup ecosystems, especially in peripheral regions, being able to impact regional ecosystems in several different ways. First and foremost, they are seen as "talent magnets" within the ecosystem, as they recruit large numbers skilled people from outside the region, thus strengthen the workforce talent pool in their regions. Large companies are also sources of new businesses, as typically some staff from those organizations come to feel motivated to leave their jobs in order to start their own ventures. This motivation is often justified by the technological base that large companies set in theirs regions that, by offering to entrepreneurs the opportunity to take advantage of their local environment to get insights about specific technologies, and increase awareness about emerging trends, reduces uncertainty on entrepreneurs, and hence stimulates the creation of companies within those areas. Large companies can also contribute to the ecosystem by supporting entrepreneurs with space and resources, or by directly sponsoring entrepreneurship programs, such as accelerator programs within their areas of expertise (Feldman *et al.*, 2005; Mason & Brown, 2014).

» **Support organizations and individuals:** Entities focused on developing, supporting and encouraging entrepreneurial activities. This is by far the most diverse actor, being comprised by several different organizations and individuals, who support startups at different stages of development, with different goals and different needs. Given the large number of different entities encompassed by this actor, we will consider two different groups: Ecosystem builders; and Investor groups.

Ecosystem builders are those entities whose main focus is about encouraging and supporting new-business developing, and hence about building a successful ecosystem. These organizations support entrepreneurial ventures with high-growth potential, whether technology based or non-technology based, by providing business support intervention (i.e. not just passive space or investment), and access to financial support by introduction to investors, pitching opportunity, prize/grant, or equity investment. This group includes the following startup programs: Incubators; Accelerators; Coworking spaces; Courses; and Competitions (Isabelle, 2013; Dee *et al.*, 2015).

Investor Groups are comprised by the individuals or organizations who invest in highgrowth potential startups, with the expectation that they earn a high rate of return from their investment. These investments may occur throughout the different stages in a startup's lifecycle, and they are seen as an essential source for the development of innovative businesses. The entities encompassed by this group are the following: Venture capitalists; and Business angels (Davila *et al.*, 2003; Wiltbank, 2009).

a) **Incubators:** Business incubators are programs designed to accelerate the creation and development of innovative businesses, typically focusing on technology based startups. According to Hackett & Dilts (2004), a business incubator is a shared office space facility that seeks to provide to its incubatees with a strategic, value-adding intervention system (i.e. business incubation) of monitoring and business assistance. The primary goal of traditional business incubators is to promote economic development, by encouraging and supporting entrepreneurship and the creation of new business, in the expectation that those new ventures will later develop into self-sustaining, successful organizations, that are able to generate innovation, employment opportunities and growth within the local community (CSES, 2002; Lesáková, 2012; Bruneel *et al.*, 2012).

This program emerged for the first time in 1959 in Batavia, New York, in the U.S.A., having become widespread throughout the 1970s and the 1980s. During this period, the so called business incubators of the first generation, primarily centered on job creation and real estate appreciation, by providing affordable office space, agglomerating carefully selected entrepreneurial companies under the same roof, and guiding them through their growth process. Later, throughout the 1990s, it was recognized the need for business incubators to develop their value proposition beyond resources and infrastructures, and to supplementing the office space with business counseling, skills enhancement, and networking services to access professional support and seed capital, hence leading to the second generation of business incubators. Finally, by the late 1990s a third generation of business incubators emerged. This third generation focused on new technology-based firms, and intended to stimulate the ICT industry, and provide a support framework, towards creating high growth-potential ventures (Lalkaka, 2001; Aerts *et al.*, 2007; Bruneel *et al.*, 2012).

Although incubators' resources and services are rather important to entrepreneurs, their benefits to startups go far beyond those elements. According to Smilor's research work (Smilor, 1987), incubators are recognized for creating value to its incubatees in four broad dimensions: development of credibility; shortening of the entrepreneurial learning curve; quicker solution of problems; and access to an entrepreneurial network. Given how little credibility new ventures often possess, mainly due to its newness, incubator's role on validating and providing legitimacy to startups can prove to be incredibly valuable, particularly with regard to gaining access to entrepreneurial networks, as an incubator's association to a new venture can be seen as the proof of quality deemed necessary by investors to earn their attention. In addition to that, incubator's role concerning counseling and access to business services is also seen as quite relevant elements to the entrepreneurial education of new ventures' founders, contributing to shortening of their entrepreneurial learning curve, as well as to their skills' improvement, and consequent ability to solve problems.

b) **Accelerators:** Similarly to incubators, accelerators are programs built to accelerate the creation and development of early-stage businesses. While the formal definition of accelerator programs remains somewhat discordant due to its similarity to incubators (Cohen & Hochberg, 2014), broadly speaking, accelerators were designed to assist innovative ventures throughout their lifecycle early-stages, using a lean startup approach. Unlike incubators, which primarily focus on providing physical resources or office support services, accelerators aim to offer a full partnership with its cohorts of ventures, by assisting them on building the company, define and build their initial products, identify highpotential customer segments, secure resources (e.g. capital and employees), guide through the interview and hiring process, and by lending its own management expertise (Fishback *et al.*, 2007; Cohen & Hochberg, 2014; Clarysse *et al.*, 2015). Based on Miller & Bound (2011), Clarysse in its report for Nesta (Clarysse *et al.* 2015) defined accelerators as having the following characteristics:

○ Possible offer of upfront investment, usually in exchange for equity;
○ Time-limited support comprising programed events and intensive mentoring;
○ An application process that is open to all, yet highly competitive; ○ Cohorts or classes of startups rather than individual companies; ○ Mostly a focus on small teams, not individual founders; ○ Periodic graduation with a Demo Day/Investor Day.

The first accelerator program was founded in 2005, when Y Combinator was launched in Cambridge, Massachusetts, in the U.S.A. This program invested in a small batch of promising startups – including one of Y Combinator's most prominent success cases, Reddit. Using a lean startup approach – a method for developing businesses and products that focus on minimizing the product development cycle – it worked intensively with the startups for three months to prepare them for pitching to an invite-only audience of venture capitalists. (Nesta, 2014). Following the success of this format, a notable proliferation of accelerator programs started all over the world, with Seed-DB (2016) having identified 235 accelerator programs spread throughout the world. While initially accelerator programs were rather generalist, accepting entrepreneurs from a wide range of industries, this proliferation also led to a diversification of programs, with several accelerator programs now aiming to focus on specific industry sectors (Cohen & Hochberg, 2014).

From a startup's perspective, there are several aspects in which accelerators can provide value to the entrepreneurs they support. According to Miller & Bound (2011), accelerator programs provide value to their participants in the following elements: funding; business and product advice; connections to future investment; validation; peer support group; and pressure and discipline. With regard to early stage funding, while it is not rated as the most important feature in accelerator programs, it is identified as being important, as it allows entrepreneurs to concentrate on their startups in a full-time regime without having to work on the side. As for business and product advice, the opportunity for startups to meet experts in their fields, and get feedback about their product and company through mentoring is seen as one of the most invaluable contributions from accelerator programs, being very difficult to replicate outside such programs. Connections to future investment are also seen as quite valuable to startups, particularly for first-time founders, which often face difficulties to connect with potential investors and customers. Pressure and discipline can also be rather important to startups, as having the opportunity to develop their idea in an intense work environment often compels startups to thrive and achieve their goals. The startup's validation by the accelerator itself is considered to be a major benefit of these programs, particularly to first-time founders, as being acknowledge by a group of successful founders and investors provides the reassurance on the startup that investors and potential clients need. Finally, having the opportunity of providing and receiving meaningful support and feedback from other founders is rated as invaluable to many entrepreneurs, with peer support groups, such as alumni networks, being considered one of the biggest added value points of accelerator programs.

c) **Coworking spaces:** Coworking spaces are workplaces conceived to promote inter-firm collaboration (Capdevila, 2014). According to Gandini (2015), coworking spaces are shared places used by different types of knowledge professionals, typically freelancers, working in various degrees of specialization within the knowledge industry. Reputed for being "serendipity accelerators", i.e. promoting unexpected discoveries entirely by chance (Moriset, 2013), coworking spaces are characterized by the co-location of economic actors, where independent professionals work share resources and are open to share knowledge with the community (Capdevila, 2014). These spaces are designed as office-renting facilities, where the tenant companies or individuals rent a desk and a Wi-Fi connection to the internet (Gandini, 2015), and pay in return membership fees for the access to the space. The payment of membership fees explain the tendency for coworking spaces to have as tenants ventures that already have revenue sources (Dee *et al.*, 2015). Coworking spaces are considered to offer optimal research contexts for several reasons, namely for their reduced physical scale, for the micro-organizations involved, for the intensity of the social interaction and also for the predisposition towards collaboration of all involved agents (Capdevila, 2014).

d) **Courses and competitions:** Among the broad range of ecosystem builders within a startup ecosystem, there are several actors, such as universities and accelerators, who develop programs whose purpose mainly aims at providing entrepreneurial education to future entrepreneurs and at supporting entrepreneurs from their pre-startup stage to their early stages of development. Such programs can be classified into two major categories: entrepreneurship courses and competitions.

Entrepreneurship courses are time-limited programs (Dee *et al.*, 2015) usually run by business schools, designed to teach the theoretical basis of entrepreneurship (Nesta, 2014), and to provide students with a wide range of valuable skills, such as business-plan development, marketing, networking, creating "elevator pitches", attracting financing and connecting with local business leaders (U.S. Department of Commerce, 2013), and also to develop students' self-efficacy, confidence, achievement motivation and nonconformity (Florin *et al.*, 2007). Among the wide variety of entrepreneurship courses, some of the most popular courses include introductory courses such as introduction of entrepreneurship and new venture creation, as well as courses about more specific topics of the business such as entrepreneurship strategy, technological entrepreneurship and finance for entrepreneurs (Sá *et al.*, 2014).

Entrepreneurship competitions are time-limited programs, often promoted by other ecosystem actors such as universities, the government, or corporates, whose aim is to provide organizational efficiency, a sense of urgency as well as a feeling of camaraderie and peer-to-peer learning from being in a cohort (Dee *et al.*, 2015). Through these programs the contestants, typically in teams, present a venture idea before a panel of judges for the chance of winning awards and cash prizes (Sá *et al.*, 2014). According to Miller & Stacey (2014), the typical features of a competition include:

○ Widespread publicity for the prize and its aims; ○ An online application process; ○ Shortlisting by the competition organizers; ○ A pitch or face-to-face "final" where ventures meet a group of judges; ○ Follow-up support and publicity for the winners.

These competitions are also characterized for possessing a structure which not only offers a chance to identify potential winners, but also to highlight trends illustrated by the contestants. Like entrepreneurship courses, typically competitions do not need to rely on startups for income, usually assuring their revenues from sponsorships, although sometimes a fee may be charged directly to individuals, especially in the case of courses (Dee *et al.*, 2015).

e) **Venture Capitalists:** Venture capitalists are a source of funding to startup companies, being particularly focused on early to later stage businesses (Wilson, 2011). According to Gompers and Lerner (2001), venture capitalist are an important intermediary in financial markets, that typically focus on providing funding to small and young firms. While these investments are considered to be extremely risky, as they are plagued with high uncertainty and information asymmetry, the potentially high returns on investment lead these firms to purchase equity or equity-linked stakes at such ventures. Venture capital firms dedicate significant amounts of resources on understanding new technologies and markets, and on finding investment opportunities within those sectors (Davila *et al.*, 2003). Their screening and selection processes are considered to be intensive and often lengthy, where variables such as market size, strategy, technology, customer adoption and competition are exhaustively analyzed (Kaplan & Lerner, 2010). Following the investment consummation, venture capitalists look to proactively support the development of their portfolio companies, particularly throughout their early stages of growth, by coaching them and providing financial resources and expertise, access to contacts and help in the recruitment of senior management (Davila *et al.*, 2003; Wilson, 2011). Typically venture capitalists also undertake an active board role in their portfolio companies (Preston, 2011), with venture capitalists exerting control in their companies if the results are not according to the investor's expectation (Kaplan & Lerner, 2010). Venture capitalists' contribution to the development of their companies is reported to be benefic, with venture-backed companies showing faster growth rates (Davila *et al.*, 2003), increased sales, employment, investment, R&D expenditure and exports (EVCA, 2002).

With regard to the structure of the venture model, venture capital firms, also denominated of General Partners, establish investment funds and invite institutions and individuals with particular expertise or significant wealth, known as Limited Partners, to subscribe to them. These investment funds are set for a determined period of time (on average of 10 years), and are applied in equity stakes at high-potential companies compliant with the defined investment strategy (EVCA, 2007). As stated by Zider (1998), venture money is not longterm money, as venture capital firms aim to grow their investments fast, so that they reach sufficient size and credibility to be sold and earn a high rate of return on their investments (Davila *et al.*, 2003), or to be further invested in public-equity markets and receive additional funding (Zider, 1998). For the services provided to the LPs, venture capital firms typically receive management fees of 1% to 2,5% of the capital raised to cover the operating costs, being additionally entitled to 20% of the profits if the startups achieve successful exits (EVCA, 2007; Marcus *et al.*, 2013).

f) **Business angels:** Business angels are a type of investor reputed for often being the first source of significant outside funding of startup companies (Wiltbank, 2009). Although there exists extensive research and literature about business angels, a uniform, definitive definition of angel investors is yet to be found (Avdeitchikova, 2008; Preston, 2011). For the purpose of this study, we will adopt Mason & Harrison's definition, according to whom business angels are individuals, acting alone or in formal or informal groups, who invest their own money in unquoted businesses in which there exists no family relationships in the hope of financial profit and who, after making the investment, actively involves in the company, in active roles such as mentor, adviser, or member of the board (Mason & Harrison, 2010).

Like venture capitalists, business angels invest in startups with the aim of earning a financial return on their investments. However, angel investors distinguish from other types of investors for seeking to invest in early stage companies, where although they face higher risks of failure, they have the potential to achieve highly profitable returns on their money (Preston, 2011). Angel investments also contrast from other types of investment on several other aspects, such as: their investments usually comprise relatively small investments, typically up to £250.000 (Mason & Harrison, 2010); angel investors adequate better to the needs of SME owners, as they have lower rejection rates, longer exit horizons, and target profits similar to the ones from venture capitalists, even though angel investments involve much more risk; and finally, they typically invest in their local economies (Riding, 2008). In addition to providing financial support to new ventures, business angels are also acknowledged for being a source of “smart money” to early stage startups, investing not only money, but also time, and operational and strategic guidance (Aernoudt, 1999; Mason & Harrison, 2010). According to research (Wilson, 2011; Preston, 2011), this input of time in their investments, as well as their longing to be actively involved, relates to angel investor’s desire to “give back” to other entrepreneurs. As most business angels have entrepreneurial and managerial experience, and had successful ventures of their own which they sold under advantageous conditions (Aernoudt, 1999; Wilson, 2011), angel investing is seen as both an effective mean for former entrepreneurs to remain engaged to the challenge of succeeding in a new venture, without the typical time trade-off of running a business, as well as an opportunity for angel investors to support young entrepreneurs prosper in their community (Preston, 2011). Business angels’ close involvement with their investments explains why they typically opt to invest in sectors they understand, usually coinciding to their former ventures as entrepreneurs (Aernoudt, 1999), enabling them to benefit from their previous developed network of potential customers, vendors, and other resources, including additional financial sources (Preston, 2011). Angel investors typically tend to invest in a portfolio of companies, instead of only one or two (Wilson, 2011), and their investments are often regarded as signalers of high quality ventures (Chahine *et al.*, 2007).

3. Background

Theoretically, the relationship between ecosystem actors assumes greater relevance in the specific case of investor groups and ecosystem builders, as they play complementary parts in the role of supporting new ventures throughout their development (Callegati *et al.*, 2005). As acknowledged by Klonowski (2010), ecosystem builders and investor groups have many common characteristics with regard to their activity. Firstly, they share a common interest in successfully growing entrepreneurial ventures, with both actors being characterized for providing hands-on assistance to the young firms. Secondly, ecosystem builders and investors groups share similar application processes, with both processes being multistage, even though the one used by investor groups is regarded as being more comprehensive and exhaustive. And thirdly, ecosystem builders and investor groups seek the same goal of achieving measurable business success by the end of their collaboration with an entrepreneurial venture, where ecosystem builders aim to successfully graduate their tenant companies into viable, long-term businesses, whilst investor groups measure their success based on their internal rate of return. In addition to the characteristics shared by both actors, some authors (Callegati *et al.*, 2005; Klonowski, 2010; Miller & Bound, 2011; Wilson, 2011) have emphasized that the relationship between both parties can be positive and mutually beneficial. With regard to investor groups, the main reasons pointed out as the rationale behind this relationship center around three elements: locating new technologies; monitor startups' development; and exposure to earlystage ventures. Concerning to ecosystem builders' rationale to nurture a relationship with investor groups, three main reasons are highlighted: network and business-oriented experience; access to funding; and business model sustainability.

However, in spite of the apparent solid basis of understanding for both ecosystem actors to develop and maintain a fruitful relationship, that does not seem to be the case as empirical data shows that, especially in immature markets, ecosystem builders' collaboration with investor groups is not always working efficiently (Gullander & Napier, 2003). While several factors can explain this troublesome relationship, such as the general intrinsic mistrust of stakeholders when it comes to early-stage investments or the lack of reciprocal information sharing between ecosystem builders and investor groups, the main issue pointed out by investor groups, particularly venture capitalists, relates to their reduced interest in nurturing such relationship due to their lack of concern towards pursuing companies in their early stages of development (Callegati *et al.*, 2005). Other reasons mentioned by investor groups with regard to their lack of interest in collaborating more with ecosystem builders relates to their limited knowledge of ecosystem builders' activities and perception of low value on their interventions, startups' reluctance towards investors' financing and the scarce number of sources of capital (Callegati *et al.*, 2005; Klonowski, 2010). Albeit investor groups show reduced interest in collaborating with ecosystem builders, the opposite cannot be said, with ecosystem builders showing commitment towards accessing capital sources. Yet, despite their best efforts towards collaborating with investor groups, that has been proving to be challenging, mainly due to the struggle on the follow-up activities with investors, which are difficult because investment decisions take long time to realize for investors (Callegati *et al.*, 2005).

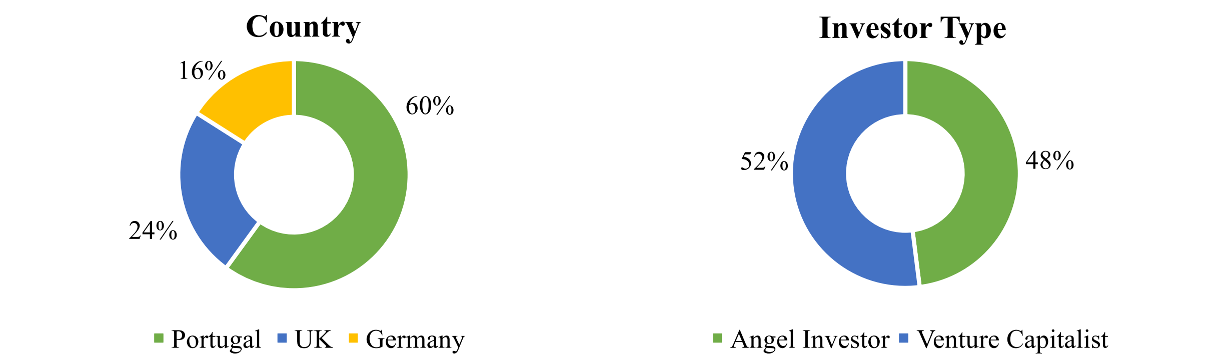
Such discrepancy between the theoretical scenario and what the real-world showed us, led us to ask ourselves two questions: How do investor groups' perceive ecosystem builders' added-value? And, where do investor groups believe that their relationship with ecosystem builders could be improved? The absence of data with regard to this topic, which assumes such prominent importance in nowadays' entrepreneurship ecosystems, suggests that there might exist some lack of awareness about these issues, being the main motivation behind this research work.

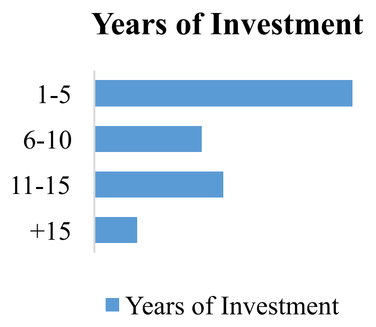
4. Methods

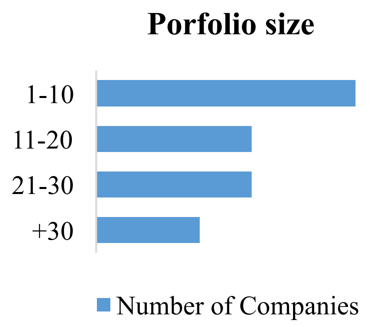
This study consisted on the conduction of an online questionnaire, in which we sought to acquire quantitative data in order to answer the research questions. This questionnaire was fully conducted in English, and consisted of 23 questions divided into four main sections. The first section, aimed to analyze the investor profile of the respondent, was composed by 9 questions. These questions were used to understand certain aspects related to the investor's profile such as their preferred sectors to invest, most used sources to search for startups and funding stages where they typically invest. The second and third sections were composed by 4 questions each, and their objective was of collecting data about the investors' perception of ecosystem builders. The questions comprised in these sections focused on assessing the respondent's perspectives and past experience on topics such as the importance of ecosystem builders to startups, their role in helping investors finding better investment opportunities and ecosystem builder's focus on the respondent's priority investment sectors. Finally, the fourth section aimed to measure the cooperation between ecosystem builders and investor groups, being encompassed by 6 questions. In this section not only we analyzed the respondent's cooperation with ecosystem builders, but we also aimed to collect their opinion about how to improve such cooperation through two open-ended questions on that topic.

As for our data sources, the data collection of this study was gathered from a sample composed by two investor groups: business angels and venture capitalists. Since this research was partly developed in collaboration with Beta-i, an organization based in Portugal focused in entrepreneurship and innovation, and our network of contacts was somewhat geographically limited to Portugal, the core of our sample was composed by Portuguese respondents. However, with the aim of providing conclusive recommendations that might be valid not only to Portugal but to the overall European region, we also included in our sample some respondents from two of the most important countries in the European entrepreneurship landscape, U.K. and Germany. In Figure 2 is presented a detailed overview to this questionnaire's respondents.

Figure 2. Characterization of the questionnaire's respondents.







5. Findings

Throughout this section an analysis to the collected data will be presented. Firstly, the results concerning to the investor groups' perception of the importance of ecosystem builders in the promotion of good investment opportunities will be analyzed. Secondly, the analysis to the investor groups' perception of ecosystem builders' added value to startups will be presented. And finally, the results concerning the investor groups' perception of their cooperation with ecosystem builders will be bestowed.

5.1 Investment opportunities

With regard to the first subject under study, we have assessed 4 different questions concerning to ecosystem builders' role on helping investor groups finding good investment opportunities and on promoting the emergence of startups within investor groups' priority sectors of investment.

The assessed questions and collected data on each of these questions (i.e. absolute value, percentage and average) are following presented in Table 1.

Table 1. Detailed analysis on investment opportunities' results.

	Variable	Absolute frequency	Percentage	Average score
How would you classify the difficulty of finding good investment opportunities?	1	6	24%	2,76
	2	5	20%	
	3	5	20%	
	4	7	28%	
	5	2	8%	
What is your opinion concerning ecosystem builders' importance to help investors find	1	4	16%	3,72
	2	0	0%	
	3	3	12%	

better investment opportunities?	4	10	40%	
	5	8	32%	
From the following list, in which sectors would you like to invest on?	Software	22	88%	-
	Cloud computing/Saas	17	68%	
	Fintech	16	64%	
	Healthcare IT and services	16	64%	
	Analytics/Big data	15	60%	
	Mobile	13	52%	
	Medical	12	48%	
	E-commerce	11	44%	
	Enterprise Software	11	44%	
	Hardware	9	36%	
	Cleantech	9	36%	
	Communications	8	32%	
	Edtech	8	32%	
	Media	7	28%	
	Manufacturing	7	28%	
	Consumer business	7	28%	
	Tourism	6	24%	
	Food/Drink	6	24%	
	Fashion	5	20%	

Table 1. Detailed analysis on investment opportunities' results (Continuation).

	Variable	Absolute frequency	Percentage	Average score
	Advertising	5	20%	
	Music/audio	4	16%	
	Legal	3	12%	
	Social ventures	2	8%	
	Other	0	0%	
Based on your answer to the previous question, do you think ecosystem builders are currently focusing on your priority sectors?	I strongly agree that ecosystem builders are focusing on my priority sectors	4	16%	-
	I agree that ecosystem builders are focusing on my priority sectors	15	60%	
	I neither agree nor disagree that ecosystem builders are focusing on my priority sectors	5	20%	
	I disagree that ecosystem builders are focusing on my priority sectors	1	4%	

I strongly disagree that ecosystem builders are focusing on my priority sectors	0	0%
I don't think ecosystem builders should focus on specific sectors	0	0%

Concerning to the respondents' perception on the difficulty to find good investment opportunities, the results show that the respondents perceive this subject as being mildly difficult, with the average score of 2,76 backing this conclusion. While we were expecting results slightly more accentuated towards a lower score, pointing out an increased difficulty on finding good investment opportunities, such results are plausible given that we are analyzing different ecosystems and different investor groups.

As for the perceived impact of ecosystem builders in helping investor groups finding better investment opportunities, the overall results show a positive overview on the influence of ecosystem builders, with the average of 3,72 illustrating such conclusion. These results are in line with our expectations, as according to theoretical evidence this is one of the main reasons behind the relationship between investor groups and ecosystem builders.

With regard to the investor groups' sectors of future investment, the collected data show that the major trends in the investor landscape focus on software, cloud computing/SaaS, fintech, healthcare IT and services, and analytics/big data. These sectors show a great focus on tech startups by investor groups, which confirms our initial expectations on the current trends of investment.

Finally, our study on ecosystem builders' focus on investor groups' priority sectors illustrated great contentment by investors, with the results showing that 76% of the investor groups perceive that their priority sectors are being given the appropriate attention by ecosystem builders. Such results show that ecosystem builders are meeting investor groups' expectations with regard to this subject.

5.2 Ecosystem builders' added value to startups

Concerning to the second subject under study in our questionnaire, we assessed 4 questions related to the added value generated to startups by ecosystem builders.

The assessed questions and collected data on each of these questions (i.e. absolute value, percentage and average) are following presented in Table 2.

Table 2. Detailed analysis on ecosystem builders' added value to startups' results.

	Variable	Absolute score	Percentage	Average frequency
Considering your personal experience, how do you perceive ecosystem builders' role in the creation of successful startups?	1	2	8%	4,04
	2	1	4%	
	3	5	20%	
	4	3	12%	
	5	14	56%	
Based on your experience, how relevant was the role of accelerators with regard to the following aspects?	Startup screening	3,96	1,00	5
	Entrepreneurial education	3,72	0,96	3
	Access to mentoring	4,08	1,06	5
	Business advice	3,32	1,09	3
	Product/Service development	3,36	1,20	4
	Financial advice	2,88	1,24	3
	Legal advice	2,84	1,08	3
	Post-program support	2,6	1,02	2
Based on your experience, how relevant was the role of incubators with regard to the following aspects?	Startup screening	3,48	1,20	4
	Entrepreneurial education	3,40	1,02	3
	Access to mentoring	3,24	1,11	4
	Business advice	2,96	0,96	2
	Product/Service development	2,64	1,16	3
	Financial advice	2,60	1,20	2
	Legal advice	2,48	1,06	2
	Post-program support	2,24	1,03	2

Table 2. Detailed analysis on ecosystem builders' added value to startups' results (continuation).

	Variable	Average score	Standard Deviation	Mode
Concerning the following areas, where would you like to see greater help from ecosystem builders?	Startup screening	4,88	2,42	5
	Entrepreneurial education	4,08	2,35	2
	Access to mentoring	4,40	1,85	3
	Business advice	4,32	1,95	3
	Product/Service development	4,80	2,23	4
	Financial advice	4,40	2,19	3

	Legal advice	4,52	2,19	6
	Post-program support	4,60	2,88	8

Concerning to ecosystem builders' role in the creation of successful startups, the collected data shows that investor groups perceive great importance in the role of ecosystem builders, with the average score of 4,04 reflecting such opinion. While we expected a positive result expressing the perceived value of ecosystem builders, we weren't expecting an evaluation this positive due to the theoretical evidence that pointed out to a perception of low on ecosystem builders' interventions by investor groups.

With regard to the elements where accelerator programs add value to startups, the results show that the elements where accelerators' intervention are the most valuable are Access to mentoring, with an average score of 4,08, followed by Startup screening and Entrepreneurial education, with an average score of 3,96 and 3,72 respectively. As for the elements where accelerators add the least value, Post-program support, Legal advice and Business advice were highlighted as the elements where accelerators' intervention was the least valuable, with average scores of 2,60, 2,84 and 2,88 respectively. Such results illustrate that accelerator programs' are mainly designed to first-time entrepreneurs, with investor groups stating a more valuable intervention by accelerators in introductory and general elements when in comparison with more specific elements.

As for the elements where incubators add value to startups, similarly to our assessment to accelerators, the elements where the respondents perceive the most value in incubators' intervention are Startup screening, with an average score of 3,48, followed by Entrepreneurial education and Access to mentoring, with average scores of 3,40 and 3,24 respectively, while Post-program support, Legal advice and Financial advice were highlighted as the elements where incubators add the least value, with average scores of 2,24, 2,48 and 2,60 respectively. These results indicate that, like accelerators, incubators are mainly designed to first-time entrepreneurs, with investor groups stating a more valuable intervention by incubators in introductory and general elements when in comparison with more specific elements.
Additionally to this conclusion we can also observe that, while investor groups highlighted the same set of elements as the most valuable and least valuable in both assessments, the overall average scores of incubators' elements of intervention are significantly lower than the ones registered by accelerators, thus emphasizing the increased overall value that investor groups perceive in accelerators when in comparison to incubators.

Following the individual assessment on accelerators' and incubators' added value, we conducted an analysis to the elements where the respondents would like to see greater help by both these ecosystem builders in their interventions. The collected data showed that Entrepreneurial education, Business advice and Financial advice were highlighted as the elements where investor groups would appreciate to see a greater focus by ecosystem builders, with average scores of 4,08, 4,32 and 4,40 respectively. With regard to the elements where respondents perceived the least need to see improvements, Startup screening, with an average score of 4,88 was outlined as the element where investor groups find the current interventions to be the most adequate, followed by Product/Service development and Post-program support, with average scores of 4,80 and 4,60 respectively. Based on these results and on the ones previously analyzed we can conclude that investor groups don't perceive the need to see Postprogram support and Product/Service development being addressed by investor groups', while Entrepreneurial education is seen as a major element of ecosystem builders' intervention on startups, being among the ones which generate the most value in both accelerators and incubators, and being the element which the respondents reported to expect ecosystem builders to continue devoting the utmost attention. As for Business advice and Financial advice, the results show that investor groups perceive the need to see these elements being better addressed, with the collected data illustrating a mismatch between the expectations of ecosystem builders and investor groups with regard to these elements.

5.3 Cooperation between ecosystem builders and investor groups

The last subject under study on the questionnaire related to the cooperation between ecosystem builders and investor groups, having being conducted 6 questions on that topic.

The assessed questions and collected data on each of these questions (i.e. absolute value, percentage and average) are following presented in Table 3.

Table 3. Detailed analysis on the cooperation between ecosystem builders and investor groups' results.

	Variable	Absolute frequency	Percentage	Average score
Do you currently support (e.g. mentoring, financial support, awards, etc.) any ecosystem builder?	Yes	23	92%\	-
	No	2	8%	
If you replied "yes" to the previous question, please specify how you support the ecosystem builders.	Guest speaker	18	72%	-
	Mentoring to startups	18	72%	
	Financial support	6	24%	
	Resources	4	16%	
	Sponsor awards to startups	6	24%	
	Part of final pitch jury	19	76%	

Based on your experience, how do you rate the cooperation between investors and ecosystem builders concerning information sharing on startups?	1	0	0%	4,04
	2	3	12%	
	3	4	16%	
	4	7	28%	
	5	11	44%	
From the following list, please indicate the kind of information that ecosystem builders typically share with investors.	Startup one-pager	23	92%	-
	Startup business plan	9	36%	
	Investment recommendation	11	44%	
	Updates on startups' progress	9	36%	
	Other	3	12%	

	Summary of responses
How do you believe cooperation between investors and ecosystem builders could improve?	Promote more entrepreneurship events
	Prioritize national investors in favor of foreign investors
	Promote a closer cooperative work between ecosystem builders and investor groups more often
	Include investors earlier in the programs, and at a deeper level throughout every stage of the programs
	Focus on sharing more relevant information to the investors about promising prospects of investment
	Improve the communication levels between ecosystem builders and investor groups, and between the ecosystem builders themselves
	Better address the needs of investors, with particular focus on startup scouting and post-program support to startups until they reach proper investment readiness levels
	Work together with investors to better understand the critical factors behind the investors' most successful startups, and focus on improving education and mentoring in those areas

Table 3. Detailed analysis on the cooperation between ecosystem builders and investor groups' results (continuation).

	Summary of responses
How do you believe cooperation between investors and ecosystem builders concerning information sharing could improve?	Create a common platform to share information specifically with investors
	Share information with investors more proactively and on a more regular basis
	Filter the information shared with investors, so that it better fits each investor's profile
	Promote meetings between investors and startups that might match the investor's criteria
	Share more information with investors concerning the development of their startups, and provide their insights on future prospects of investment

With regard to investor groups' support to ecosystem builders, 92% of the respondents confirms to currently support ecosystem builders. These results are quite positive and back our expectation that the level of cooperation between these two entities concerning the provision of support would be effective. From our assessment to the collected data we were also able to conclude that the support provided to ecosystem builders is mainly comprised by three services: participating in the final pitch jury (76% of the respondents), guest speaking and providing mentoring to startups (both confirmed by 72% of the respondents). These three services show that investor groups' contribution to ecosystem builders consist primarily in the provision of knowledge and on experience sharing, thus concurring with the theoretical evidence previously presented in this dissertation.

Concerning to the cooperation between ecosystem builders and investor groups regarding information sharing, the majority of the inquired investor groups considered it to be important, with 72% of the responding rating this elements as being important or very important, against only 12% of the respondents who disagreed on their importance. This opinion is further emphasized by the average score of 4,04 which leaves no margin for doubts on the perceived importance of information share. Although such evaluation was not unexpected, given that the key in any successful cooperation is communication, oddly, according to the collected data, it coincides with the most troubled component in the interconnectivity between these two entities. Such claim is backed by the following presented assessment to the cooperation between ecosystem builders and investor groups.

Analyzing the type of information shared by ecosystem builders, startup one-pagers come clearly highlighted as the primary information being shared between these two entities, with 92% of the respondents indicating to typically receive this information. Following startup onepagers, the second most shared type of information are investment recommendations, with 44% of the respondents claiming to receive such information, a value which represents less than half of the startup one-pagers' value. In third and fourth place come startup business plan and updates on startups' progress, with only 36% of the respondents stating to receive these information. This analysis to the results show that although information share is considered to be important to investor groups, the cooperation between ecosystem builders and investor groups is not being efficiently conducted by both parties, with relevant information not reaching its interested parties, thus resulting an underwhelming relationship that doesn't live up to its potential.

Also concerning to the cooperation between ecosystem builders and investor groups, we have conducted 2 questions that aimed to understand investor groups' opinions on how to improve the cooperation and the information share with ecosystem builders. The summarized results presented in Table 3 further emphasize the current shortcomings in the interconnectivity between these entities. With regard to the overall cooperation with ecosystem builders, the respondents' suggestions mainly focused on the need to promote a closer cooperative work between ecosystem builders and investor groups earlier and at a deeper level, the need to improve the communication levels, promoting more entrepreneurship events and also of better addressing investors' needs. As for the suggestions on how to improve the information share between these entities, the most referred suggestions were to create a common platform specifically designed to promote information share with investors, to share information more regularly and proactively, and finally to filter the shared information by investor so that it better fits each investor's profile.

6. Conclusions

The development of this research work allowed us to acquire knowledge about the investor groups' perceptions towards ecosystem builders in European startup ecosystems, with particular attention to the aspects of the ecosystem builders' contribution to startups and to the cooperation between ecosystem builders and investor groups.

Based on the analysis to the results, it was discovered that concerning to the aspects of the ecosystem builders' contribution towards startups which are most valued, investor groups perceive Startup screening, Entrepreneurial education and Access to mentoring as the elements through which ecosystem builders generate the most value to entrepreneurs. It was also discovered that the cooperation between these two ecosystem actors could be improved, with investor groups highlighting the existence of diverse shortcomings in their collaboration with ecosystem builders, particularly in terms of communication and information sharing.

Based on the collected data and on the analysis to the results, we suggest some recommendations about how can ecosystem builders generate greater value to startups, and about how to improve the cooperation between ecosystem builders and investor groups, namely:

» ***Promote a closer cooperative work between ecosystem builders and investor groups:*** While ecosystem builders focus on promoting entrepreneurship and on supporting startups throughout their development stages, their contribution often lacks the hands-on and business-oriented experience that investor groups possess, thus limiting the added value of their intervention. In that sense, cooperating more closely with investor groups could lead to a more meaningful impact on ecosystem builders' intervention in startups.

» ***Promote a clearer understanding between ecosystem builders and investor groups with regard to the expectations about each other's role:*** As illustrated in our questionnaire results, there exists a slight mismatch between the ecosystem builders' contribution to startups and the elements where investor groups believe they should focus on adding value to startups. Such disparity might result from the lack of understanding and knowledge about each other's role and perspectives. By means of a greater communication and mutual understanding between both entities, ecosystem builders and investor groups could come to an agreement about how to add the most value to startups, and hence improve their contribution to the emergence of higher quality startups.

» ***Create a common platform specifically for information sharing between ecosystem builders and investor groups:*** One of the most referred suggestions on how to address the existing liabilities in information sharing between ecosystem builders and investor groups was the creation of a common platform designed specifically for the purposes of information sharing between these two entities. The intent behind the creation of such platform would be of facilitating the information sharing between ecosystem builders and investor groups, and also of promoting a more proactive and regular sharing of relevant information according to individual profile of each investor group.

Throughout the development of the study we were faced with some limitations on the nature of the research which might affect the applicability of the results. These limitations are mainly comprehended by the sample size, which we found to be reduced and rather limited with regard to the analyzed countries, and also by the fact that we only investigated investor groups' perception, thus confining the scope of the dissertation to the point of view of only one of the involved entities.

In spite of limitations on the nature of the study, we consider this research as having been successfully conducted, with the results hereby presented constituting a significant contribution to the global effort of possessing a greater understanding on the intricacies of the entrepreneurial ecosystems in Europe, particularly with regard to interconnectivity between ecosystem builders and investor groups. Although the collected data lacks the proper dimension to attest the validity of the results, this research work provides an interesting assessment on this specific topic, which may possibly contribute to stimulate the development of future research that addresses the limitations that we have previously identified.

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Using Systematic Innovation Techniques to find Solutions for the impact of Distance Education on Higher Education in Taiwan

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Abstract

This study employs Michael E. Porter's Five Forces Model and TRIZ-based systematic innovation methodology to analyze the competitiveness of distance education in conventional education in Taiwan. First, this study discusses the competitiveness of Taiwan's distance education and conventional education industries based on Porter's Five Forces Model. Second, this study explores the influence of distance education on conventional education in Taiwan. Third, this study applies the TRIZ-based systematic innovation methodology to analyze the effect of distance education on conventional education in Taiwan and search for solutions. Finally, based on the solutions, this study incorporates distance education into conventional education to meet learners' needs and improve the competitiveness of Taiwan's distance education in higher education.

Keywords: Porter's Five Forces Model; conventional education; distance education; competitveness of industries

1. Introduction

While Taiwan's education industries have evolved with the demand for convenience, variety, and autonomy, most learners remain used to conventional learning modes. With the immense quantities of information in this ever-changing era, conventional education seems unable to fully meet learners' needs. Since higher education provides different ways of instruction and learning, its learners may emphasize convenience, variety, and autonomy in the pursuit of knowledge. Simonson et al.(2008) describes Dan Coldeway's taxonomy of ways of learning: conventional learning which occurs in the same time and place, synchronous distance learning, which occurs in the same time but different places, and asynchronous distance learning, which occurs in different times in the same place or in different times in different places. Under Coldeway's taxonomy, distance learning, either synchronous or asynchronous, is more flexible than conventional education in time and space.

Distance education in higher education in Taiwan began with the establishment of National Open University in 1986. At present the university uses multi-media and internet to implement distance learning. In addition to conferring degrees, it also offers professional training for certificate seekers. With little spatial and temporal restriction in learning, National Open University has matriculated nearly 290,000 students to date.

Because distance education is free from time-space restrictions and autonomous in its nature, it is becoming more popular and accepted among learners. Recently, institutes of higher education have established distance education centers and promoted distance learning courses to on- and off-campus students in order to reform conventional education and attract learners.

2. Literature Review

Relatively systematic distance education dates back to the mid-19th century, when Isaac Pitman invented both Pitman Shorthand and a prototype distance education program(Simonson et al., 2008). This enabled people to use symbols (e.g. dots/lines) to represent English phonetic sounds. Isaac Pitman taught this rapid handwriting system to learners through correspondence. In the late 19th century, an American educator Anna Eliot Ticknor founded “The Society to Encourage Studies at Home” as a pioneering correspondence school in the United States, in which teachers conducted correspondence studies with guided lessons on a monthly basis and administered tests to learners (Simonson et al., 2008).

With more attention paid to the field of distance education, remarks from the academia have come to outline the general picture of distance education. Keegan (1996)[11] argued that distance education is characterized by separating teaching from learning in terms of time and space and by intersubjectivity between teachers and learners, which makes “learning from teaching” a feasible practice. Moore et. al. (2011) stated that distance education provides distant learners with convenient access to learning. Bruder (1989) indicated that distance education can be performed by learners using electronic communication equipment.

In addition to the spatial-temporal flexibility of distance education, Moore (1989) explored the interactions among learners, content, and instructors, defining three types of interactions: learner-content interaction, learner-instructor interaction, and learner-learner interaction. Learner-content interaction refers to learners’ cognitive structural changes as they learn the content (Moore, 1989). Learner-instructor interaction, to some extent, is favored by learners probably because in this type of interaction instructors attempt to maintain learners’ interest in learning and present content materials for them (Moore, 1989). Learner-learner interaction is viewed as a precious experience for learners in which learners obtain information conducive to learning by interacting with peers whether or not the instructor is present during learning activities (Moore, 1989).

With the advance of technology, the concept of distance learning has been more popular and accepted among many higher education institutions and private enterprises. Institutes of higher education such as the Open University (UK), the University of Essex (UK), the University of Florida (USA), and the University of Phoenix (USA) offer distance education through the internet and/or audiovisual resources and award degrees to geographically faraway learners.

Currently, many higher education institutions in Taiwan use classroom-based teaching as the principal way of learning. In conventional classroom-based teaching, the teacher-to-student interaction is often unilateral and face-to-face. Nevertheless, the rapid development of technology has fed a growing demand for convenience, variety, and autonomy in learning. Distance education appears to be the solution to these concerns. Taiwan's conventional higher education must transform its way of implementing education into a more adaptive approach to address learners' requests.

3. An examination on the competitiveness of Taiwan's Distance Education based on Porter's five forces model

3.1 Porter's five forces model

Porter's introduced his five forces model in "The Competitive Advantage: Creating and Sustaining Superior Performance" (Porter, 1985) which argued that the internal structure of and external competition for an industry are critical factors to its operating performance. The five competitive forces in Porter's model are "threat of new entrants", "threat of substitute products or services", "bargaining powers of buyers", "bargaining powers of suppliers", and "rivalry among existing firms", all of which help to analyze the competitiveness of industries. Since the competition between industries is becoming more complex, a sixth force, "complementors" proposed by Nalebuff and Brandenburger (1996), has supplemented Porter's original model. The extended six force model is shown in Figure 1.

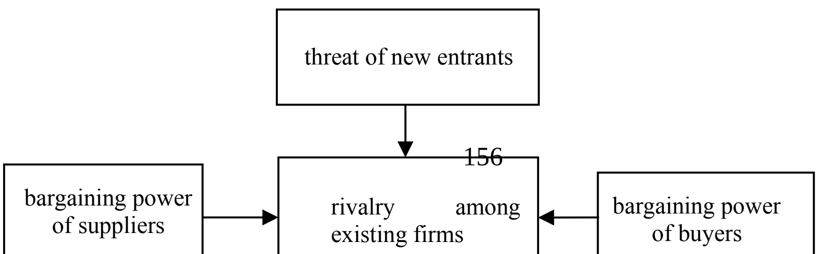

Figure 1: Six Forces Model

Source: Adapted from Porter (1985) and Nalebuff and Brandenburger (1996)

3.2 A six-forces-model-based analysis of Taiwan's distance education in conventional higher education

This study applies the six forces model to reveal potential issues confronting distance education when it enters the domain of higher conventional education. The analysis is made in terms of six forces as follows:

1. Threat of new entrants

Taiwan's education industries have recently been impacted by declining birth rates. For Taiwan's higher education institutions, which treat conventional classroom-based teaching as the primary way of learning, distance education industry is viewed as a new entrant. An increasing number of higher educational institutions have designed digital courses and learning materials for distance learning. Facing the invasion of distance education, conventional higher education must take "product differentiation" into account to keep learners loyal. Thus, from the aspect of "threat of new entrants", an issue faced by Taiwan's conventional higher education as distance education is being introduced is how to maintain the variety of distance education using the internet without sacrificing mutual learning goals in conventional education.

2. Threat of substitute products or services

Recently the dynamic development of educational industries has contributed to learning reforms. Learners desire more convenience, autonomy, and variety in learning, which makes fixed-time-and-place conventional education an "underdog".

Computers and equipment for internet use are ubiquitous among Taiwanese. They can easily connect to the internet and start distance learning courses. Thus, from the aspect of "threat of substitute products or services", an issue faced by Taiwan's conventional higher education as distance education is being introduced is how to immerse individual learning in the cohort learning environment as learners shift their preference from cohort-based learning (conventional education) to individual learning (distance education).

3. Bargaining powers of buyers

In the present phase, some higher education institutions offer tuition-free distance courses for study online. However, learners are charged fees to use the distance learning platform created by the schools and to have the earned credits reviewed. These extra costs are shifted to learners. If conventional education is converted to a distance format with higher switching costs, learners are obligated to pay extra miscellaneous fees, let alone the circumstance that some distance courses are pay-per-use. This suggests that the bargaining powers of learners (buyers) are weak. Thus, from the aspect of “bargaining powers of buyers”, an issue faced by Taiwan’s conventional higher education as distance education is being introduced is how to elevate the rate at which distance courses are taken but reduce extra derived expenses.

4. Bargaining powers of suppliers

Because Taiwanese prefer to go abroad to study if they can, many higher education institutions in Taiwan have sought collaboration with overseas academic units to implement joint-degree programs that save time and money for learners by allocating the time of study partly in their home countries and partly abroad. If more of this inter-institutional study is completed by distance coursework, learners may come to prefer it. Since such joint-degree programs are highly differentiated, they offer schools (suppliers) good bargaining power against learners. Thus, from the aspect of “bargaining powers of suppliers”, an issue faced by Taiwan’s conventional higher education as distance education is being introduced is how to uphold quality learning for degrees in a shorter period of time.

5. Rivalry among existing firms

If distance education can provide customized courses to suit learners’ needs, it can diminish the possibility that the prescribed curriculum turns learners off. However, highly tailor-made curricula often result in extra costs in designing courses. Thus, from the aspect of “rivalry among existing firms”, an issue faced by Taiwan’s conventional higher education as distance education is being introduced is how to provide more customized curricula but reduce the expenses for course design.

6. Complementors

Before learners take distance courses, computers, laptops, webcams, and internet equipment should be ready. These technology devices are, to some extent, complementors to distance education and help teachers monitor learner-learner interaction online.

The more learners become used to distance education, the more complementary and indispensable the technology devices become. Therefore, when such devices are unavailable or break down, learners are unable to receive distance education. Thus, from the aspect of “complementors”, an issue faced by Taiwan’s conventional higher education as distance education is being introduced is how to continue distance learning even if the complementary technology devices fail to function.

4. Using the TRIZ Method to generate solutions to the six issues

This study examines the six issues from each facet of the six forces model and suggests solutions in the following paragraphs.

4.1 Facet 1, Threat of New Entrants

The issue is how to maintain the variety of distance education via internet without sacrificing mutual learning goals in conventional education. This issue belongs to the realm of "separation upon conditions" in which the corresponding inventive principles are Principle 12, 28, 31, 32, 35, 36, 38, 39, and 40. Among the 9 principles, this study adopts Principles 38 and 40, which underlie the proposed solutions. The remaining 7 principles are set aside due to inapplicability.

Principle 38, "Accelerated Oxidation", activates the system environment via intensified stimuli and makes the system work in a timely and effective way. According to the issue in Facet 1, the solution proposed is to establish a network teaching assistant system. When learners encounter bottlenecks in distance learning, the schools that offer distance education should immediately assign network teaching assistants to help learners. This assistance initiates on student request and will be implemented in two stages. In Stage 1, network teaching assistants provide guidance on the computer screen for individuals. If the guidance is not understood, learners enter Stage 2 where the teacher or network teaching assistants schedule a meet-up with learners and offer them instructions in person. This way, learners could achieve the pre-set mutual learning goals. The two-stage network teaching assistant system is shown in Figure 2.

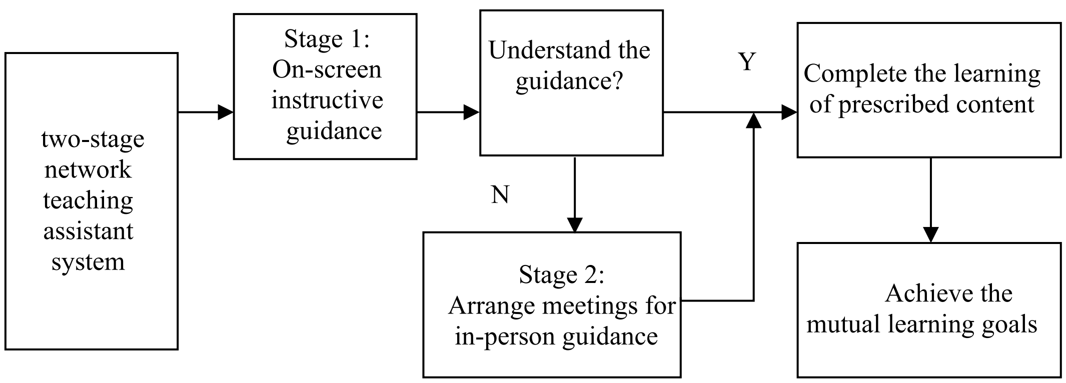

Figure 2: Two-stage network assistant system

Principle 40, “Composite Materials”, replaces homogeneous materials with heterogeneous materials to improve system performance across a variety of conditions. Based on the issue in Facet 1, the proposed solution is “conduct evaluations on learning in group-based class and provide remedial instructions to failing individuals or the group.” For distance English classes, learners can achieve weekly learning goals by watching selected English movies or listening to the English radio. After a period of time, the teacher administers tests to evaluate whether the distance learners demonstrate a solid understanding of the learning content. In this threshold-based evaluation system, those who pass the test will continue distance learning, and those who do not will receive conventional remedial instruction in meetings and discontinue distance learning until they pass the tests, as shown in Figure 3.

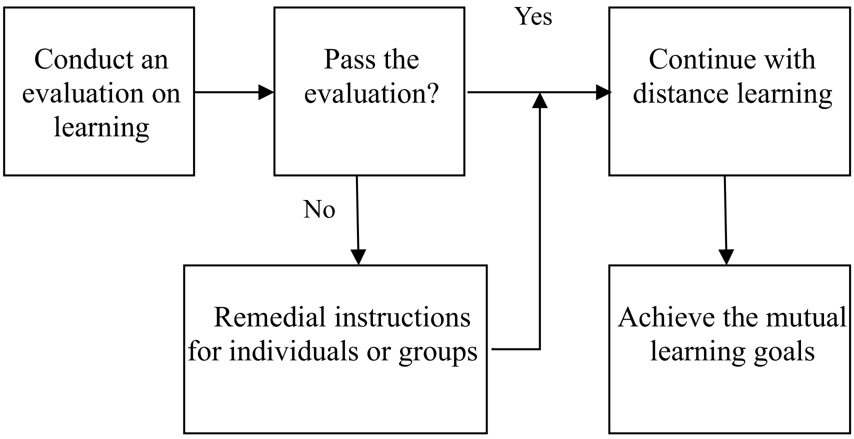

Figure 3 A threshold-based evaluation system

4.2 Facet 2, Threat of substitute products or services

The issue is how to immerse individual learning in the cohort learning environment as learners shift their preference from cohort-based learning to individual learning. This issue belongs to the realm of “separation upon conditions” in which the corresponding inventive principles are Principles 12, 28, 31, 32, 35, 36, 38, 39, and 40. Among the 9 principles, this study uses Principle 12, 36, and 39 to formulate its solutions. The remaining 6 principles are set aside due to inapplicability.

Principle 36, “Phase Transitions”, draws on the effects derived from the process of phase transitions. Based on the issue in Facet 2, the solution proposed is “form a learning organization”. Before each distance course, schools that offer distance learning could survey distance learners for information on their residential locations or workplaces, and use that to create learning groups. Members of each learning group are required to assume the responsibility of helping his or her peers accomplish in-class learning tasks. The teacher can observe the degree of assistance each member renders online as one of the primary criteria for scoring. If these help students succeed in completing in-class tasks, the teacher will view the assistance as effective. Learners will not be alone in the cohort learning environment.

Principle 39, "Inert Atmosphere", replaces the normal environment with an inert one to make the system work as anticipated. Based on the issue in Facet 2, another solution proposed is "create an online platform for the conveyance of messages among learners". Schools that offer distance education can create an e-platform simulating a conventional class discussion room, and furthermore this e-platform is exclusive for members only. Distance learners of this class are then required to log into the discussion room online at a designated period of time and they can feel safe and private when they exchange opinions and thoughts with other peers they target.

Principle 12, "Equipotentiality", alters the system environment to make the system work better. Based on the issue in Facet 2, the solution proposed is "provide incentive bonuses to boost teamwork." Schools that offer distance education can provide extra benefits to enhance learners' will to collaborate as a team in class, such as reduced tuition or awards. In this way, individual learners can enjoy a sense of achievement by collaboration in the cohort learning environment.

4.3 Facet 3, Bargaining powers of buyers

The issue is how to elevate the rate at which distance courses are taken but reduce extra derived expenses. To deal with the issue, this study refers to the contradiction matrix. Among the 39 engineering parameters, this study identified item 26, "quantity of substance/the matter", and items 23 and 30, "loss of substance" and "object-affected harmful factors" respectively, as being able to address the problem. Improving item 26, "quantity of substance/the matter", refers to the number of distance courses taken, Worsening item 23, "loss of substance", refers to the derived costs imposed on distance learners, and Worsening item 30, "object-affected harmful factors", refers to the situation in which the rising derived costs commensurate with the increasing number of distance courses taken, curbs learners' will to continue with distance courses. Thus, in Facet 3, the constructed contradiction matrix shown in Table 1 suggests 8 inventive principles, among which Principles 3 and 33 are adopted due to significant applicability.

Table 1. Contradiction Matrix for Facet 3

parameters that may be changed \ parameters that cannot be changed		loss of substance	object-affected harmful factors
		item 23	item 30
quantity of substance / the matter	item 26	3 6 10 24	35 33 29 31

Principle 3, "Local Quality", changes the structure of an object or system, turning it into a heterogeneous entity to make the object or system work. Based on the issue in Facet 3, the solution proposed is "make a tuition rate schedule with different levels of discounts". Schools that offer distance education could waive partial derived fees for distance learners if distance courses are free or provide discounts on credit-hour tuition for those who take a certain number of pay-per-use distance courses. For example, distance learners who take 2 or 3 pay-per-use distance courses can receive 10% discounts on credit-hour tuition.

Principle 33, "Homogeneity", adds the quality of homogeneity (or similarity if applicable) to the interplaying objects or systems. Based on the issue in Facet 3, the solution proposed is "implement a distance education work study program". Schools that offer distance education provide opportunities for work study at schools or at affiliated companies. At school, student workers help collect teaching resources and in-class assignments to mitigate the burden of the distance learning instructor. While at affiliated companies, student workers help deal with the educational training affairs. Owing to the work study program, the role of distance learners shifts from pure customers (that receive educational service) to service suppliers. Moreover, the hourly wage obtained from the work study could offset a portion of the distance learning tuition and fees.

4.4 Facet 4, Bargaining powers of suppliers

The issue is how to obtain quality learning for degrees in a shorter period of time. This study then refers to the contradiction matrix and among the 39 engineering parameters, identifying item 25, "loss of time", and items 24 and 7, "loss of information" and "reliability" respectively, as being able to address the problem. Improving item 25, "loss of time", refers to the time taken for learning, Worsening item 24, "loss of information", refers to the situation in which some of the learning content is overlooked in a shorter time of study, and Worsening item 27, "reliability", refers to the situation in which in condensed time, learners may not acquire adequate research skills or sufficient knowledge. Thus, in Facet 4, the constructed contradiction matrix shown in Table 2 suggests 7 inventive principles, among which Principles 26, 28, and 10 are adopted due to significant applicability.

Table 2. Contradiction matrix for Facet 4

parameters that cannot be changed / parameters that may changed		loss of information	reliability
		item 24	item 27
loss of time	item 25	24 26 28 32	4 10 30

Principle 26, “Copying”, uses cheap and simplified copies to improve flawed objects or systems. Based on the issue in Facet 4, the solution proposed is “create a cloud-powered online database of curriculum resources”. Schools that offer distance education can create such online databases for learners to access curriculum materials, downloadable or for on-screen-viewing, to enable them to conveniently and autonomously preview or review the materials where computers and internet are available.

Principle 28, “Replacement of Mechanical System”, replaces the existing system with other kinds. Based on the issue in Facet 4, another solution proposed is “grant the right to record online instructions by digital means when taking distance courses”. In order to shorten the time of study, distance learners can be permitted to record in-class teaching with recording pens (audio) while taking distance courses (visual and audio). Thus, distance learners will be able to review what is learned. With constant review, learners should need less time to master the knowledge.

Principle 10, “Prior Action”, introduces effective actions to the system in advance. Based on the issue in Facet 4, the proposed solution is “take prerequisites for advanced learning”. To reduce time spent on the degree, distance learners are advised to take prerequisites to acquire sufficient knowledge and skills prior to taking advanced courses. After being officially registered, distance learners will find such classes helpful throughout their future studies.

4.5 Facet 5, Rivalry among existing firms

The issue is “how to provide more customized curricula but reduce expenses for course design.” This study refers to the substance-field analysis of the issue, as shown in Figure 4, where F represents the development of distance education curriculum, S_1 the customized curriculum, and S_2 the development costs thus derived. To diminish these costs, substance-field analysis suggests Standard 1.2.1 “introducing S_3 to eliminate the detrimental effects in the substance-field system” out of 76 standard solutions, as shown in Figure 5.

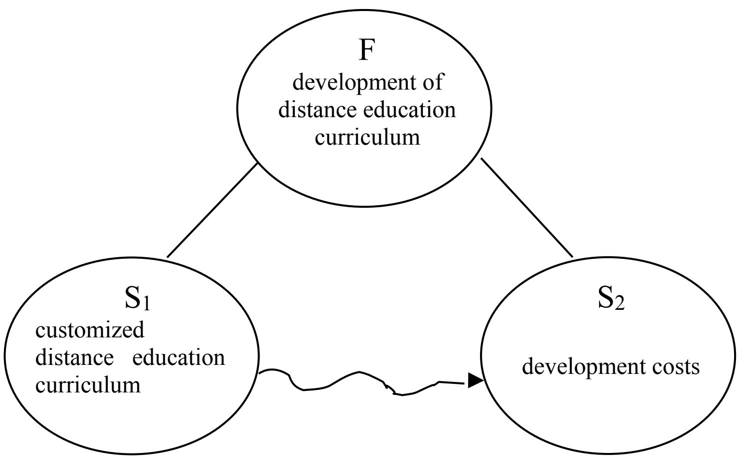

Figure 4 The substance-field model of the issue in Facet 5

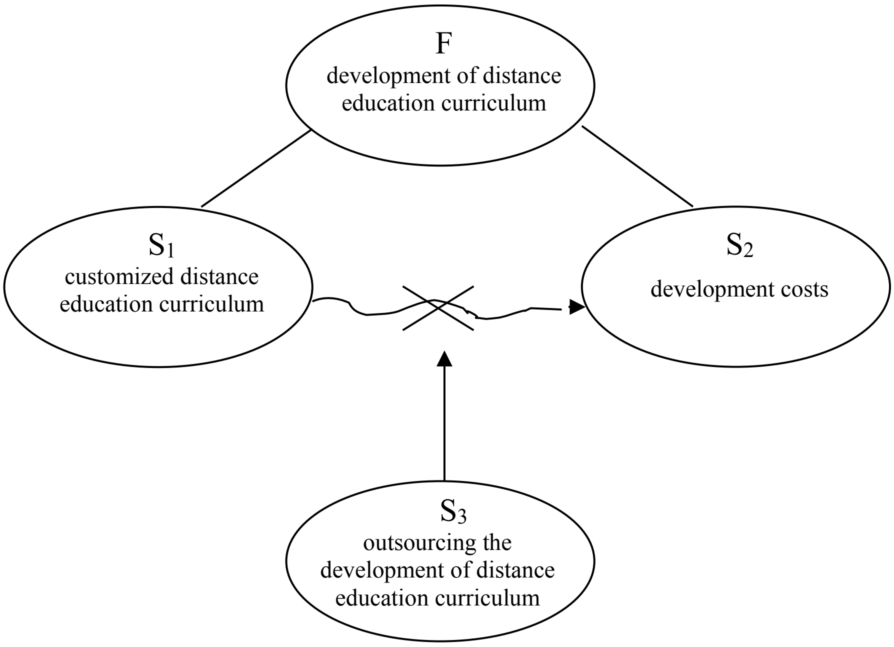

Figure 5 Substance-field model of the issue in Facet 5 with S_3 introduced as a solution

In Figure 5, the solution to the issue here is “outsource the development of the distance education curriculum in part or its entirety to other educational service suppliers”. Other educational service suppliers provide the curriculum, and schools that offer distance education provide facilities and services (such as classrooms or computer labs) for distance learning and are responsible for reviewing the outsourced curricula for conformance to curriculum regulations. This should reduce development costs for schools.

4.6 Facet 6, Complementors

The issue is “how to continue distance learning even if the complementary technology devices fail to function.” To deal with the issue, this study refers to the contradiction matrix. Among the 39 engineering parameters, this study identified item 31, “Object-generated harmful factor”, and item 27, “reliability” as being able to address the problem. Improving Item 31, “Object-generated harmful factor”, refers to unwanted influences from malfunctioning technology devices used in distance learning. Worsening Item 27, “reliability”, refers to the situation in which distance learners are unable to continue with distance courses when technology devices fail. Thus, in Facet 6, the contradiction matrix as shown in Table 3 suggests 4 inventive principles, among which Principle 24 and 2 are adopted due to significant applicability.

Table 3 Contradiction matrix for Facet 6

parameters that	reliability

cannot be changed parameters that may changed		item 27
object-generated harmful factor	item 31	24 2 40 39

Principle 24, “Mediator”, uses mediators between objects or systems to prevent harmful effects from occurring. After the mediator performs its function, it vanishes automatically. Based on the issue in Facet 6, the solution proposed is “use mediating technology devices”. When internet equipment malfunctions, distance learners can use other resources, such as smart phones or tablets, to continue with distance courses, as shown in Figure 6.

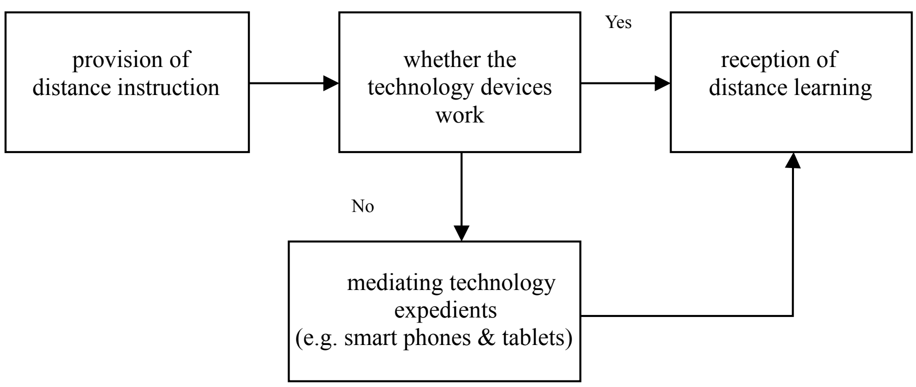

Figure 6 Use of mediating technology devices

Principle 2, “Extraction”, extracts or singles out critical parts in objects or systems. Based on the issue in Facet 6, the solution proposed is “provide an off-line learning mode”. When the computers and internet equipment fail unexpectedly, schools that offer distance education have to inform distance learners of this incident and send them the distance learning materials stored in CDs or other portable data storage devices by postal services. Thus, distance learners could continue learning at home. Though interactive elements are lacking in the off-line learning mode, distance learning does not have to stop.

5. Conclusion

Transformation of modes of learning has been a hot issue in recent years. The primary concern is whether conventional education can meet learners’ needs effectively. That is also the reason the educational paradigm has shifted from teacher-centered learning to learner-centered learning. Tailor-made curriculum, time-and-place flexibility in learning, and auxiliary technology devices all bring the variety, autonomy, and convenience to distance learning that learners are increasingly seeking.

Based on the six forces model, this study analyzes the six issues confronted by Taiwan’s conventional higher education as distance education is being introduced. TRIZ Method is then employed to identify solutions for these issues.

To sustain the development of education, educational administrators and practitioners must examine their own institutions and adopt effective strategies. This study explores the impact brought by Taiwan's distance education in higher education when it is introduced to Taiwan's conventional higher education. With the adoption of the suggested solutions in this study, the overall competitiveness of Taiwan's higher education institutions may be enhanced.

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Systematic Mold Flow Analysis for Propeller Blade

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Abstract

Today's plastic products have been widely used in daily life, like the shell of the locomotive, car bumpers, lights, connectors, mobile phone housing, shell of LCD screen, and many plastic products. The above products are mostly completed by the injection molding process products. However, in order to ensure the product a good quality, it is necessary to conduct a computer-assisted simulation prior to the following manufacturing process. In this paper, we adopt mold flow analysis software to systematically analyze a propeller blade product. A detailed process was used to illustrate the endeavors of this work. The result showed an effective improvement on deformation by way of adequate modifications of input parameters. Moreover, the production efficiency was also raised because of the reduced cooling time.

Keywords: Propeller Blades, Computer-Assisted Simulation, Mold Flow Analysis, Systematic Analysis.

1. Introduction

The propeller of aircraft is promoted by the air, and the propeller of ship is promoted by the water. They all using propellers to move, but they both use the different type of propeller to meet the different needs. Propellers are used in many types of ways. We can find propellers in land vehicles, aviation, navigation, aerospace and even in daily props. The main structure of the propeller has the blade to provide thrust and suction, and the central hub that connected to the engine. The propeller is one of the most important parts in the thruster. It determines whether the aircraft can fly, whether boat can move, and whether the fans have winds. The research of the propeller blade has a long history outside oversea with marine engineering, materials science engineering, chemical engineering, aquaculture engineering and, aeronautical engineering. There are many studies for propeller shaped like modeling (Long, 2001), Rudd et al. (1999) had the molded composite study, Hong and Dong (2010) had the numerical analysis of the distribution of the propeller blades, Rossgatterer et al. (2012) had the inside of the ship propeller blade design, Ye et al. (2012) had the study of propeller cavitation propeller numerical predictions blade, Zeng and Kuiper (2012) had a marine propeller blade design and maximum cavitation inception speed, Lin et al. (2012) had optimization and composite marine propeller.

2. Propeller blades Injection Molding

In this comparative study, we are focus on some fixed injection conditions. The table 1 shows the plastic material features used in the experiment as Chi Mei PC + ABS. The table 2 shows the pressure's setting and packing, etc. will be set with the same value. As for the size of the gate and the flow channel is immobilized to facilitate comparison. Therefore, it is rely on the software's setting to do the filling flow analysis, packing analysis and warpage analysis to see what kind of the section makes the minimal impact on the propeller. The flow channel is set shown in Figure 1.

Table 1. Injection Molding Conditions.

Injection Molding Conditions	
Material temperature	230（℃）
Mold temperature	75（℃）
Injection pressure	142（MPa）
Injection volume	718.363（cc）
Compress time	5（sec）
Holding pressure	142（MPa）
VP switching	98（%）
Mold opening time	5（sec）

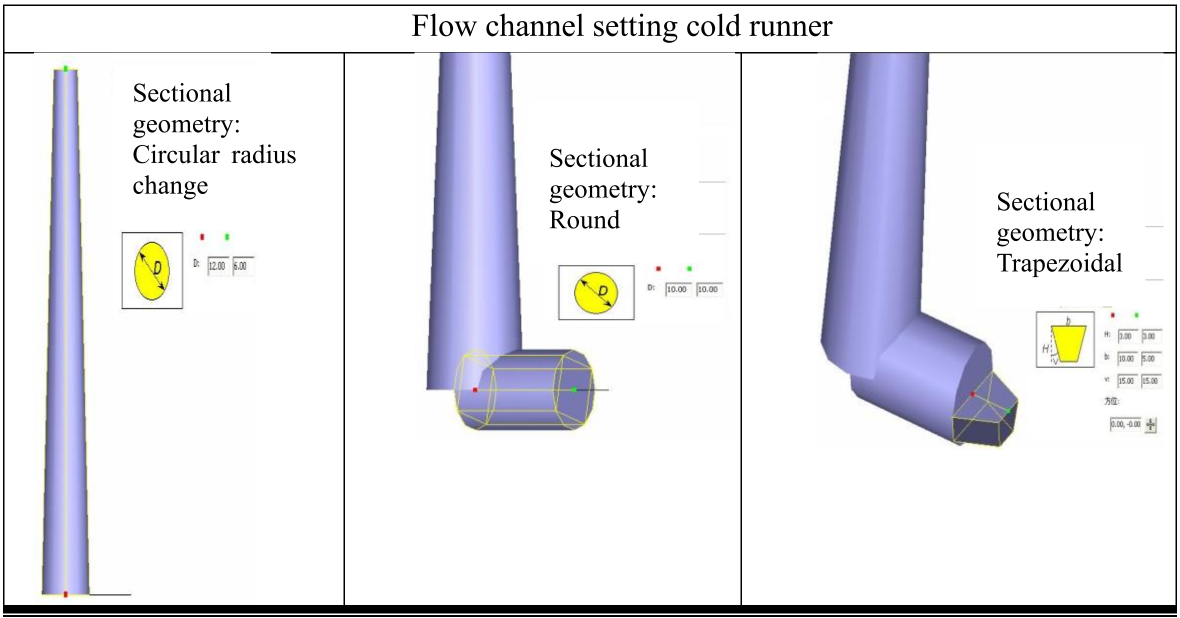
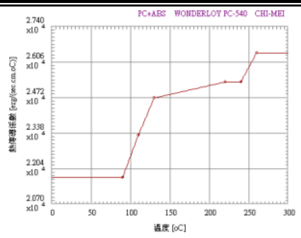
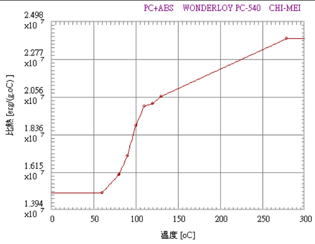
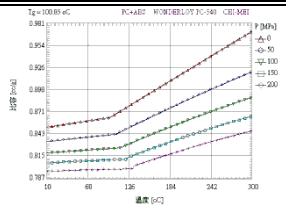
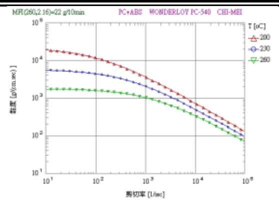


Figure 1. Flow channel setting.

3. Results and Discussion

Different water pipeline filling flow analysis, sutures, volume shrinkage, and warpage results in Figure 2.

Table 2. Plastic properties.

Plastic properties	
 Thermal conductivity	 Specific heat
 PVT	 Viscosity

After the analyzing of the flow of filling, pressure holding, and warpage; the difference between two of them shows in the Figure 3.

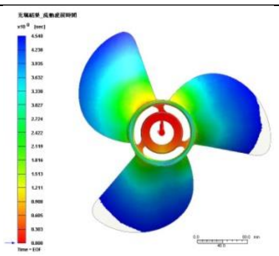
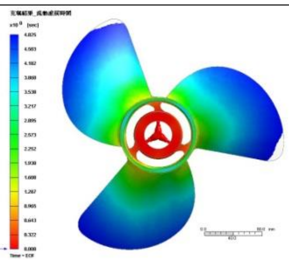
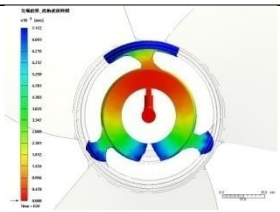
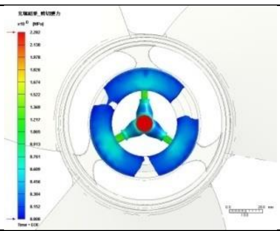
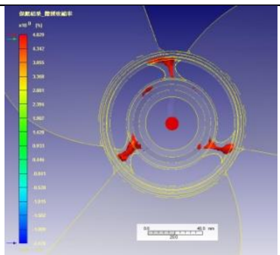
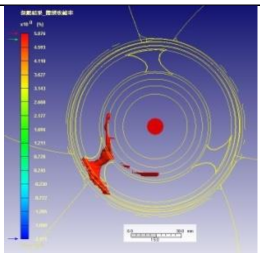
The experimental result shows that only one flow channel will make flow channel to be uneven. Because of the strength at the part of the central hub, one bonding line can let only one part of damage may occur in the hub. The degree of shrinkage at the surface is very average. It can make the propeller have a smooth surface to control effectively when injection molding is working. The accuracy of the total deformation also is less 0.3mm than three flow channels. Therefore, one flow channel design can effectively improve the accuracy and strength of the propeller.

Next, the paper will focus on the using one flow channel to do several cooling water channel design and comparison. When make designs, must take into account for the mold parting surfaces can't leave the products and parting surfaces too close. The design of the cooling water pipeline also can't design too complicated, because if the design is too complicated will increase relative costs. A good cooling water pipeline design can save the cooling time and let the product to be more efficient, and less cost. A balanced cooling also can decrease the Deformation of the product to let the shrinkage average. The water pipeline can be designed on the CAD software or mold flow design software. Figure 3 shows the cooling water pipeline 1, the results of cooling water pipeline 1 shows in the Figure 4, and the Figure 5 shows the warpage cooling water pipeline 2 shows in the Figure 6, cooling water pipeline 2 result shows in the Figure 7, and cooling water pipeline 2 warpage result shows in the Figure 8. After the experimental test, the second design obvious shows the surface temperature drop 3.7 ℃ and the total amount of deformation is also decrease 0.112~0.098mm than first design. However, most of the cooling water pipeline designed at the periphery of the propellers and blades.

The design makes the central hub limited with the scope and cannot use the drilling way to design the water pipeline cycle. The design also cause the internal temperature up to about 216 ℃, which would make cooldown longer. Therefore, the design will switch to use the insert mode to insert beryllium copper (Beryllium + copper + cobalt alloy) in the gaps and some other parts. Beryllium copper has properties of high strength, high thermal conductivity, non-magnetic permeability and fatigue resistance can be quick to absorb heat and eliminating the need for replacement of trouble. With this way, we can improve the heat problem of central hub, decrease the cost, avoid complicated water pipeline design, and let the deformation of the propeller can highly decrease the cooldown to increase the production efficiency.

Table 3. The difference between two different flow channels.

	One flow channel	Three flow channels
Time before fluctuations	Uneven when filling	Can fill average in every part of the channel
Suture	Only a single junction entire central hub preferred strength	Have three bonding wires, so make the damage appear at the junction and strength rather poor.
Volume contraction	The area between the hub and blades have a balanced contraction. It make the injection easily to control the surface contraction.	It is not quite balanced and usually concentrated in one area.
Warpage	The total warpage amount is 3.097mm	The total warpage amount is 3.353mm

Filling Flow Analysis	
 The status when filling time is 4.54 sec	 The status when filling time is 4.825 sec
Suture line	
	
Volume shrinkage	
 When the Volume shrinkage is 4.68%	 When the Volume shrinkage is 4.86%
Warpage	

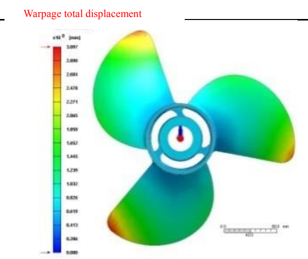
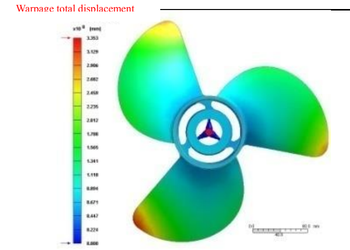
 The total amount of warpage is 3.097mm	 The total amount of warpage is 3.353mm

Figure 2. Different water pipeline analysis result.

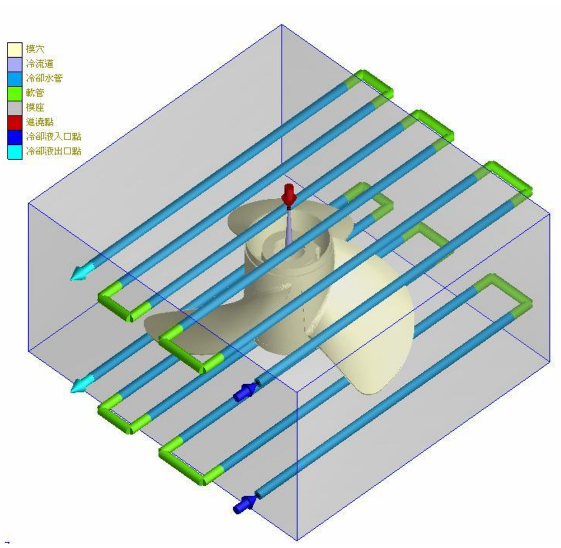
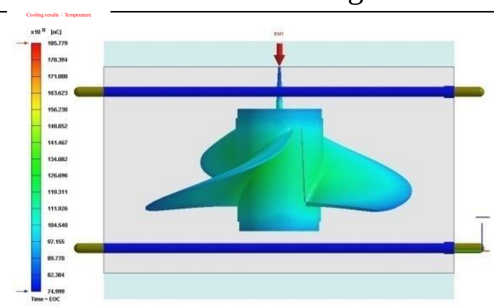
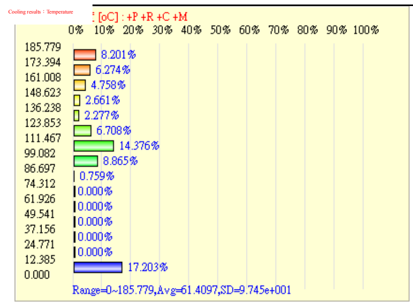
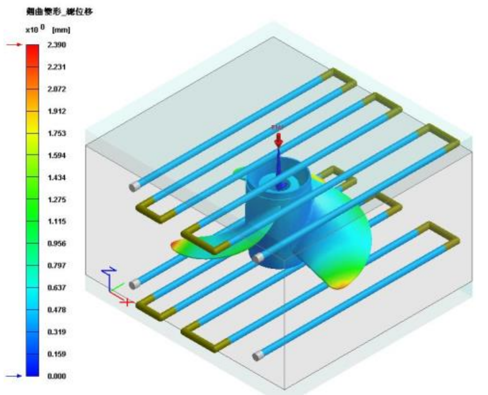
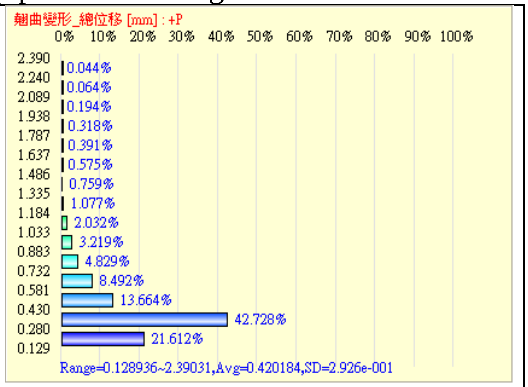


Figure 3. Cooling water pipeline 1.

- The maximum temperature is about 185.8℃
- Most of the temperature range is between 99~111.5℃
- The surface temperature is about 125℃ after cooling down

Figure 4. Cooling water pipeline 1 cooling result.

●Most of the deformation is about 0.28~0.43mm，accounts for about 42.728%

Figure 5. Cooling water pipeline 1 warpage result.

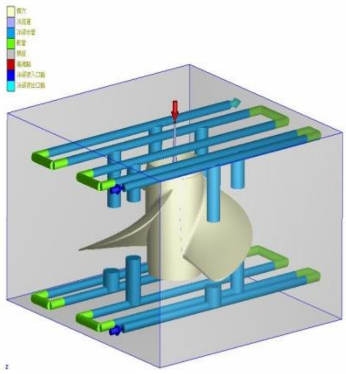
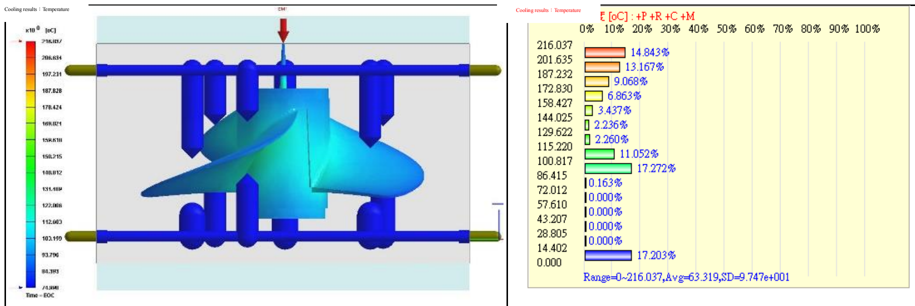


Figure 6. Cooling water pipeline 2.



● The maximum temperature is about 216 ℃

● Most of the temperature range is between 86.4 ~ 100.8 ℃

● The surface temperature is about 121.3 ℃ after cooling down

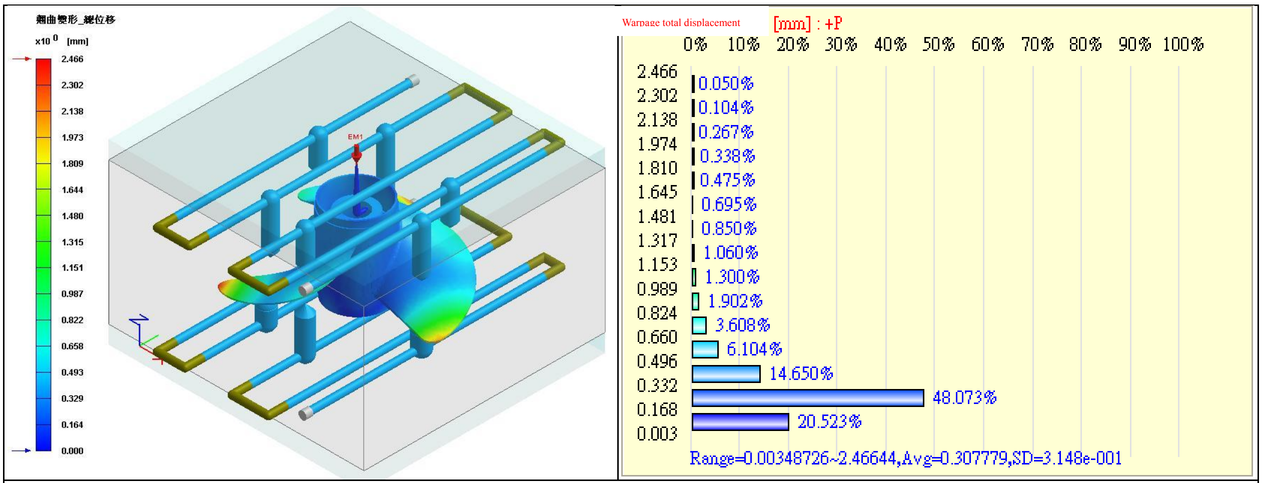
Figure 7. Cooling water pipeline 2 cooling result.

Figure 8 shows central hub with higher temperature. Figure 10 and Figure 11 show that after installed beryllium copper can improve the heat problem. Table 4 shows the cooling result when after install the beryllium copper, and table 5 is the result of warpage after install beryllium copper. Table 5 shows the cooling result when after install the beryllium copper, and table 5 is the result of warpage after installs beryllium copper.

4. Conclusion

Mold flow analysis includes water pipeline, flow channel, gate, and product analysis to improve the product. Therefore, analysts must have the experience of mold design. For example, there are more than one way to design a gate. If we need to increase the accurate, choose people who has the experience in using the injection molding machine will be more perfect. In addition, the person with the experience in using the injection molding machine also can avoid the simulation results different from the actual situation.

Warpage total displacement



●Most of the deformation is about 0.168 ~ 0.332mm, accounts for about 48%

Figure 9. Cooling water pipeline 2 warpage result.

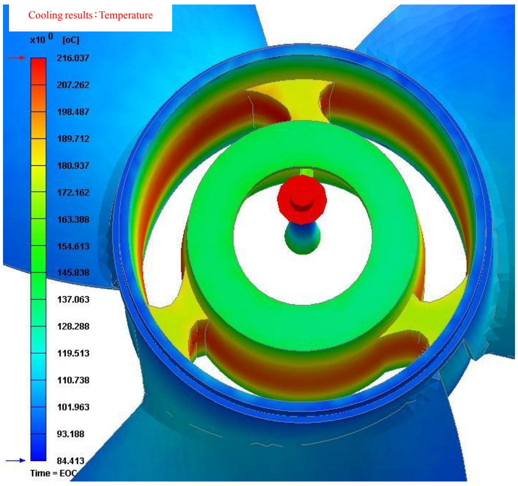


Figure 10. Central hub has higher temperature.

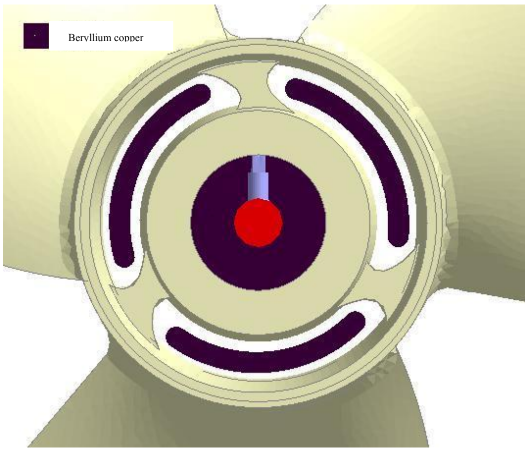


Figure11. Install beryllium copper.

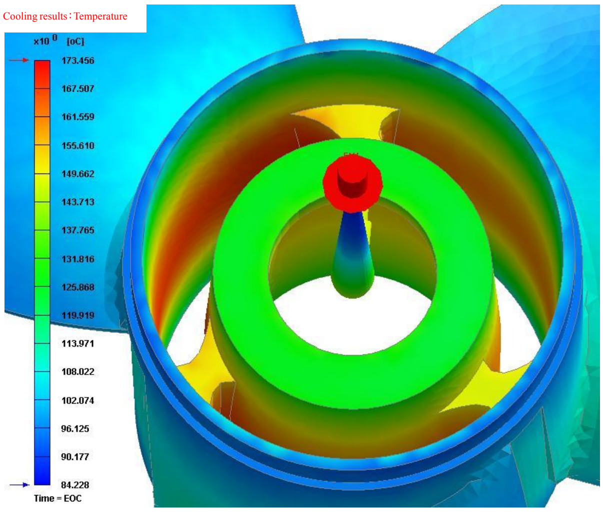


Figure 12. Improve the heat dissipation of Central hub.

Table 6. The cooling result that after installing beryllium copper.

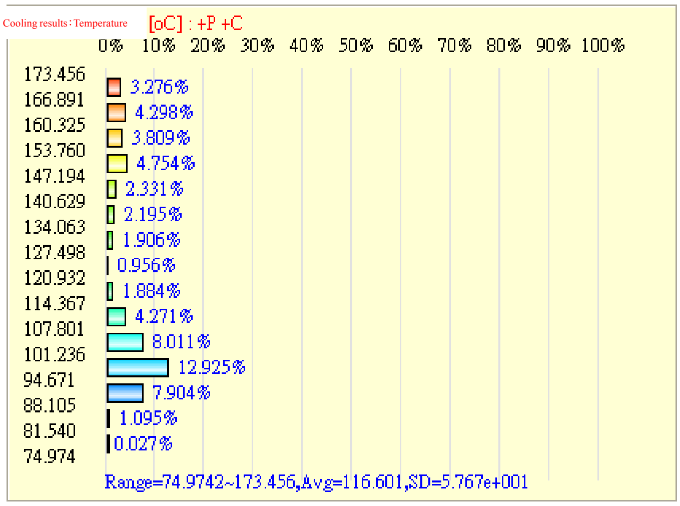
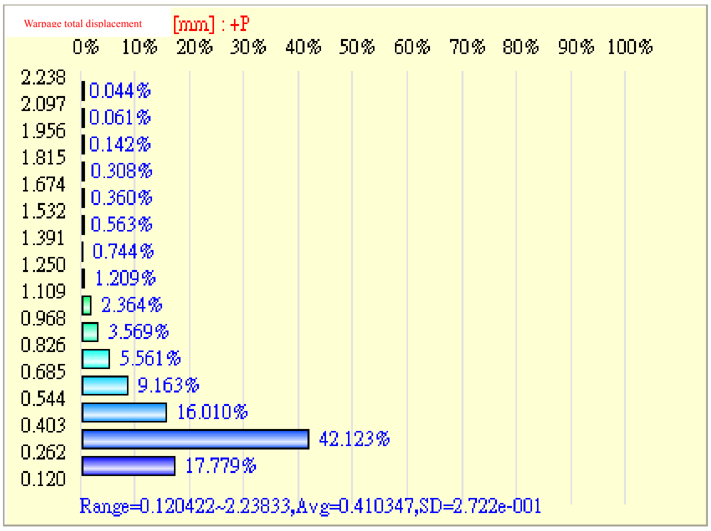


Table 7. The warpage result that after installing beryllium copper.



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Integrating Systematic Innovation Method and Industry 4.0-based Concepts on the Problem Analysis and Opportunity Identification of Fastener Industry

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Abstract

Screw manufacturing industry is an important industry in Taiwan. In 2015, Taiwan is one of the three largest fastener exporting countries in the world. The export quantity was 1.57 million metric tones. The exporting value was 2.8 billion US dollars. Many of the leading factories are capable of manufacturing massive quantities. However, as the global economic growth slows down recently, customers do not want to keep large inventory in the warehouse. As the batch quantity reduces, the production lines need to be adapted. Many problems will arise due to small batch quantity. In order to adapt to new order tends, we have to use Industry 4.0 concepts to quickly respond to the changing demands. As we solve the problems, we will find new business opportunities.

In this paper, we use a systematic innovation approach to demonstrate how to find problems when applying Industry 4.0 concepts. Then we use TRIZ problem solving tools to solve the problems and suggests a new business model. The research processes in this paper are problem definition, Function Analysis and 40 inventive principles. In this paper, we showed systematic innovation approach of opportunity identification with a case study on a suggestion to new business model for tooling shops. The procedures we proposed in the paper can be used as general opportunity identification procedures. Therefore, it contributes a feasible reference method to search for a new business model in fastener industry or other industries.

Keywords: Systematic Innovation, Industry 4.0, Opportunity Identification, Fastener Industry.

1. Introduction

The screw manufacturing industry is an important industry for Taiwan. In 2012, the production value was more than 420 Million US Dollars. 93% of production is for export worldwide. The export quantity was 1.38 million metric tones. There are more than 1,300 factories and 24,000 Workers in the industry. The market shares were 40.66% to the USA, 8.96% to Germany, 5.22% to the Netherlands, 4.78% to Japan, 4.04% to the UK and 36.34% to other countries (Chen, 2012). Most of the screw manufacturing companies in Taiwan are small and medium enterprises and own abundant manufacturing experiences. However, as the global economic growth slows down recently, customers do not want to keep large inventory in the warehouse. As the batch quantity reduces, the production lines need to be adapted. Many problems will arise due to small batch quantity. In order to adapt to new order tends, we have to use Industry 4.0 concepts to quickly respond to the changing demands. As we solve the problems, we will find new business opportunities. In this paper, we use a systematic innovation approach to demonstrate how to find problems when applying Industry 4.0 concepts. Then we use TRIZ problem solving tools to solve the problems and suggests a new business model.

2. Literature Review

2.1 Industry 4.0

Industry 4.0 has become an important trend for manufacturing industry. It proposed many perspectives such as intelligent manufacturing, cyber-physical systems, object networking, high efficiency, and sustainable management of green energy (Adeyeri et al., 2014; Brettel et al., 2015; Lee et al., 2015). It provides a solution to face the more competitive global manufacturing environment. The enables of Industry 4.0 include information and communication technology, sensor technology, and big data analysis. By way of Industry 4.0, small and medium enterprises may find the breakthrough and some new opportunities to conquer current dilemma.

2.2 Business Model

Currently, the research issue on business model has attracted more and more attention of academia and industry (Timmers, 1998; Linder and Cantrel, 2000; 2008, Teece, 2010, Pereira & Caetano, 2015). It relates a wide range of multi-disciplinary knowledge. Osterwalder and Pigneur (2010) presented a compact architecture, called Business Model Canvas (**Figure 1**). This architecture consists of nine elements: customer segments, value propositions, channels, customer relationships, key resources, key activities, key partnerships, revenue streams and cost structure. The business model canvas provides enterprises a global view to investigate internal and external problems and a distinct opportunity target.

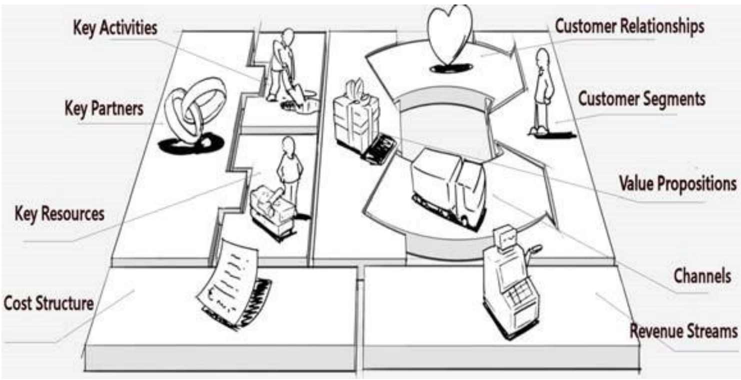

Fig.1. Business Model Canvas (Osterwalder and Pigneur, 2010)

2.3 TRIZ-based Systematic Innovation

TRIZ has been developed over six decades (Altshuller, 1996) and attracted a great deal of interest for industry and academy (Sheu and Hou, 2013, Yang and Chen, 2012, Yeh et al., 2011). It can provide a systematic approach to analyze problems where innovation is needed and to provide strategies and methods to solve the problem. Mann (2007) proposed a hierarchical view of TRIZ that is shown in Fig. 2. In this figure, TRIZ is an integrative system that includes a set of tools, a method, a way of thinking and a philosophy. At its highest level, TRIZ may be seen as the systematic study of excellence. At the philosophy level, there are five key elements in TRIZ— Ideality, Resources, Space/Time/Interface, Functionality, and Contradiction. The method level, located between the philosophy level and the tool level, is the main research interest of many scholars.

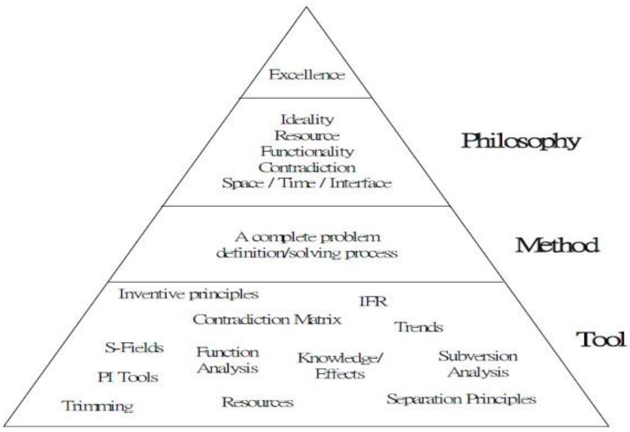

Fig. 2 Hierarchical view of TRIZ (Mann, 2007)

3. Methodology

The research stages in this paper were shown in Fig. 3. This paper is a preliminary study. We only focus on the first three stages of the problem solving of systematic innovation method. The research tools adopted in this paper are flowchart diagram, function analysis diagram and 40 inventive principles.

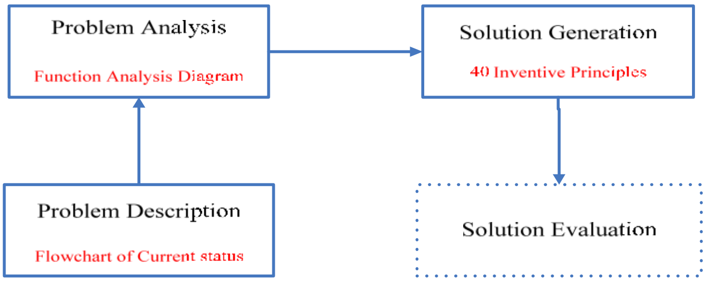

Fig. 3 Research stages in this paper

4. Case Study

4.1 Problem Description

This research focuses on fastener manufacturing industry to investigate possible problems that may arise from using industry 4.0 concepts. One possible manufacturing problem is that the tooling costs increase significantly when production quantities reduce and production ranges increase. For each screw type and size, the mass production quantity has to be over 500 thousand pieces to manufacture screws economically. As there are hundreds of screw types and hundreds of sizes, one screw factory will only make certain type of screw and certain size ranges to minimize the use of tooling and increase the production quantity. Fig. 4 shows the flowchart of order decision making.

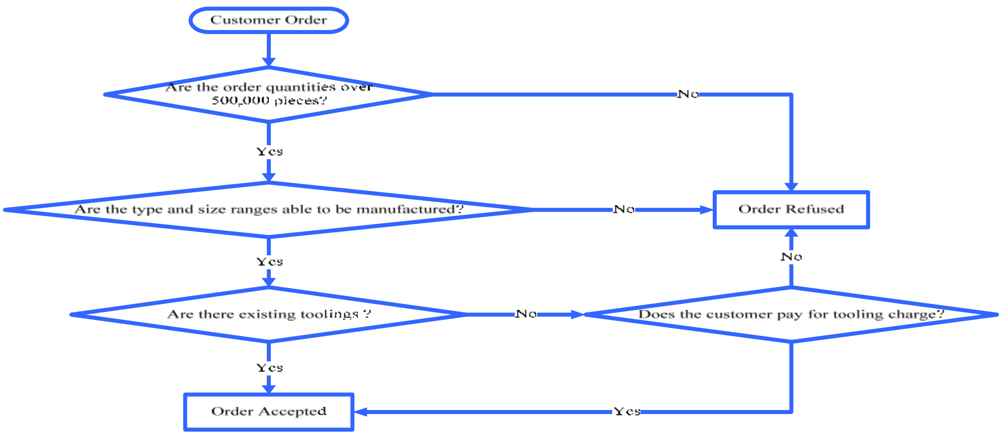

Fig.4 Flowchart of order decision making

4.2 Problem Analysis

In this paper, we adopted functional analysis tool to analyze the current scenario and found the problem. Fig. 5 shows the functional analysis of current screw manufacturing process. In Fig.5, we can find out where the problems occur and focus some target problems.

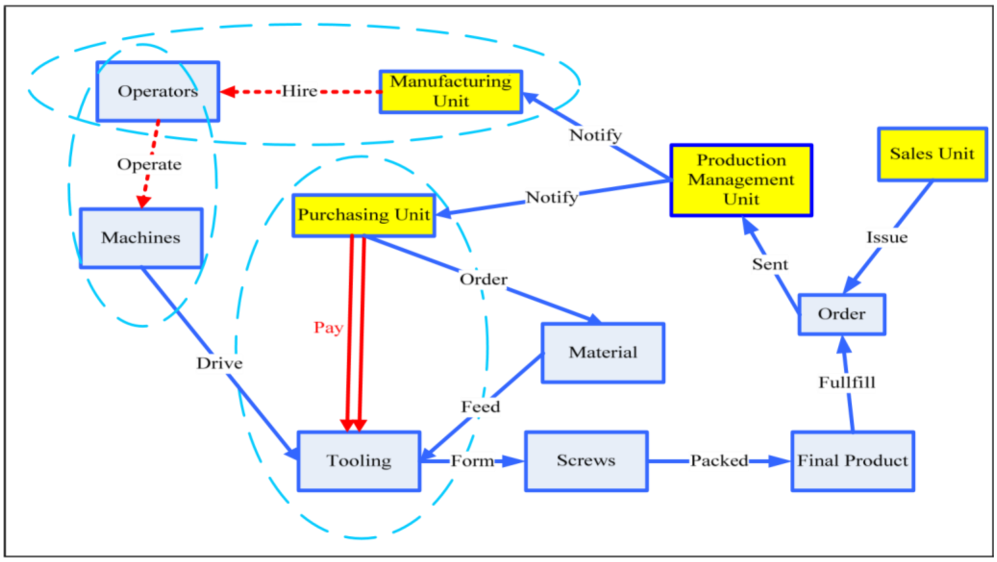

Fig. 5 Functional analysis diagram of current screw manufacturing process

4.3 Solutions Generation

Based on the aforementioned target problems, we adopted business inventive principles proposed by Souchkov (2015) to generate trigger solutions. In the last column Table 1, we also propose suggestion based on industry 4.0 or business model innovation concepts. Therefore, it might provide an approach from problem to opportunity identification for small or medium screw manufacturing enterprises.

5. Conclusion

In this paper, we showed systematic innovation approach of opportunity identification with a case study on a suggestion to new business model for tooling shops. The procedures we proposed in the paper can be used as general opportunity identification procedures. Therefore, it contributes a

feasible reference method to search for a new business model in fastener industry or other industries.

Table 1 Solution Generation with Systematic Innovation Method along with and Industry 4.0-based Concepts and Business Model Innovation

Problem	**Inventive principles** (Souchkov, 2015)	**Suggestion (trigger solutions) based on industry 4.0 or business model concepts**
Too High Tooling Cost	#1 Segmentation: Pay per use (time) #8. Separate conflicting properties between parts and a whole (Souchkov, 2015) 12. Merge or share resources (Souchkov, 2015)	1. Rent tooling 2. Several small companies purchase (share) an expensive tooling 3. Use the readily available tooling in the warehouse
Insufficient Experienced Operators	#5 Move to a radically new technology principle of a function delivery #7 Use an inverse action or an inverse process	1. Distant training and education 2. Intelligent machine (operator learn from machine)
Difficulty for Hiring Operators	#5 Move to a radically new technology principle of a function delivery #10 Create a preliminary condition to prevent from the occurrence of a conflict 11. Merge or share resources	1. Automated manufacturing peocess 2. Maintaining a pool of potential seasoned employers 3. The same operators works for cooperative companies

▪Reference

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Paper ID: 50

Understanding if and how TRIZ is used in the Portuguese reality

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Abstract

TRIZ is a methodology that promotes systematic innovation through its principles and tools. At the same time, it is a methodology that fits well with others methodologies such as Lean Production. TRIZ support continuous improvement efforts of Lean companies by helping to design and develop nature-friendly products and saving resources (energy, raw material, water). Even so, few companies in Portugal know this methodology or are aware of its strength. With the Industry 4.0 at our doors, it is crucial to have the knowledge of this kind of methodologies. Additionally, it is compulsory for the new engineers to acquire competences on these.

Based on a content analysis of written text works (papers, case studies, projects, master dissertations and/or similar) produced and developed in Portugal, the main objective is to identify the Portuguese reality in the use of TRIZ methodology. The collected data will be coded into categories according to the type of work developed (in an academic or industrial environment), the company type where the project was developed, the type of the approach to the problem (just using TRIZ or combining TRIZ and Lean or others), the TRIZ and/or Lean principles and tools used, the problem(s) solved in the project developed. Building on the results, the authors want to systematize the Portuguese reality and infer about the enablers and barriers to TRIZ use.

Keywords: Content analysis, Lean Production, Systematic innovation, TRIZ.

1. Introduction

Lean Production is an organizational management and production methodology that have been implemented in companies of goods and services by all of the world (Bhamu & Sangwan, 2014; Jasti & Kodali, 2014). After the best-seller book of Womack, Jones, & Roos, (1990) publication, the Lean journey never stopped and the influence of this methodology, which was transformed in a paradigm by the Lean Thinking principles of Womack & Jones (1996), has been always evolved, spread and growth (Samuel, Found, & Williams, 2015). The reason behind this is the simplicity, universality and truth in the Lean objectives: reduce cost and improve productivity through wastes elimination, being wastes all activities that the customer is not willing to pay for. These objectives are transversal because all companies are always working to achieve them.

Attending to this transversality, currently it is common to find Lean Thinking principles applied from operations to education (Alves, Kahlen, Flumerfelt, & Siriban-Manalang, 2014). These applications have been called Lean Office (administrative areas) (Lareau, 2003), Lean Education (Flumerfelt, Alves, Leão, & Wade, 2016; Murman, McManus, & Weigel, 2014), Lean Healthcare, (Mazzocato, Savage, Brommels, Aronsson, & Thor, 2010), Lean Supply Chain (Azevedo, Carvalho, Duarte, & Cruz-Machado, 2012), Lean Product Development (Mascitelli, 2007), among others. At the same time, Lean is a perfect partner for other initiatives undertaken in companies like sustainability (Lean-Green) (Moreira, Alves, & Sousa, 2010; Aguado, Alvarez, & Domingo, 2013; Alves, Moreira, Abreu, & Colombo, 2016), ergonomics (Arezes, Dinis-Carvalho, & Alves, 2015), or Lean and TRIZ (Maia, Alves, & Leão, 2015; Navas & Machado, 2015; Toivonen, 2015).

It is known and based in some recent works and authors' experience (e.g., Ikovenko & Bradley, 2004; Hsieh, Chen, & Do, 2015; Maia et al., 2015) that TRIZ can be used as a Lean tool since it use all the Lean Thinking principles (knowledge and innovation). So, and tailing this awareness, in this paper the partnership Lean & TRIZ is discussed as a healthy and symbiotic relationship that when explored could conduce a company in a continuously journey of systematic innovation. To achieve this a literature review of papers, case studies, projects, master dissertations and/or similar is undertaken. This literature is only focused in works developed in Portugal in order to characterize the Portuguese reality of using TRIZ methodology. It is intended to achieve the four following objectives: 1) to identify the companies where the project were developed, 2) to identify the type of the approach to the problem, 3) to identify TRIZ and/or Lean principles and tools used, 4) to identify the type of problem solved in project developed. Based on the results, the authors want to systematize the TRIZ Portuguese reality use and infer about the enablers and barriers to TRIZ practice.

This paper is organized in five sections. After this first section that introduces the themes and objectives, the authors present in section 2 a brief literature review about Lean and TRIZ methodology. The section 3 presents the research methodology. The fourth section presents the results of the literature review, analyzing and discussing these results. Finally, section 5 presents the main findings founded with this research.

2. Literature review

Formally the concept of Lean Production appear for the first time in the article 'Triumph of the lean production system', written by Krafcik in 1988 (Krafcik, 1988) to describe Toyota Production System (TPS), a production system that increases productivity and reduces costs by eliminating waste (Monden, 1998; Ohno, 1988). Waste are all activities of customer point of view and that he/she is not willing to pay for.

Ohno (1988) identified and categorized seven major wastes: 1) Overproduction: Producing more that what is needed by the next process or customer; 2) Waiting: Operators standing idle as machines cycle, equipment fails, needed parts fail to arrive, etc; 3) Transport: Moving parts of the products or products unnecessarily, 4) Over-processing: Performing unnecessary or incorrect processing, 5) Stocks: Having more stocks than necessary; 6) Motion: Operators handling and moving parts; 7) Defects. One more waste and considered the worst of the wastes is non-used talent of the collaborators (Liker, 2004). Nevertheless, this is a pillar of TPS referred as creative thinking because without people nothing can be done. Other pillars that sustain TPS are JIT production, autonomation (*Jidoka*) and flexible workforce (*Shojinka*) (Monden, 1998).

Popularity of Lean Production was achieved with the book of Womack, Jones, & Roos (1990), researchers of MIT and mentors of Krafcik. With this popularity came the companies' interest in implementing Lean Production. This was the mote for the second book of the same authors that published six years later the *"Lean Thinking: banish waste and create wealth in your corporation"* (Womack & Jones, 1996).

Lean Thinking is nowadays accepted as philosophy (Bhasin & Burcher, 2006) that helps the management of an organization, ruled by certain principles. These principles are five: 1) Value: characteristics identified by the customer, that each product or service offers and which the customer is willing to pay for; 2) Value Stream: define a process or a set of process steps, that each product or service has to go through to be complete; 3) Flow: refers to the flow of people, materials, information or capital, 4) Pull system: means that the production of a product or providing service should be initiated only when requested by the customer; and 5) Pursuit Perfection: meaning being always searching continuous improvement (*kaizen*) and being unsatisfied with *status-quo*.

This human condition (being always unsatisfied) is what makes Lean different requiring a mind-set and a culture not understood by many companies (Yamamoto & Bellgran, 2010). Also, it is this state that pulls for creativity, for innovation in attempt to identify and solve problems in its roots, even if this demands new or different tools. TPS was known to apply simple tools like PDCA, 5Why, root cause-analysis, or more complex tools that came from all kind of sources. What it is important is to solve the problem definitively. So, even with a lot of tools that were developed in TPS and with this development that continues in evolution, Lean embraces all tools that serve this purpose, being TRIZ one of these tools.

Genrich Altshuller (Lerner, 1991) is the father of TRIZ methodology, Russian acronym *Teoria Rechenia Izobretatelskih Zadatchi* (TRIZ) for Theory of Inventive Problem Solving (TIPS) (Altshuller, 1995). More than 3,000,000 patents have been analyzed to discover the standards, which provide innovative solutions to problems, and these were encoded within the TRIZ. From various sources, namely, (Altshuller, 1995), Mazur (1995) and (Chechurin, 2016), TRIZ could be defined as:

- A methodology for solving problems based in logic, data and research, not intuition;
- It is based on past knowledge and ingenuity of many thousands of engineers and brings the ability to accelerate the project team to resolve issues in a creative way;
- It brings repeatability, predictability and reliability;
- It is a process of solving problems with an approach structured and algorithmic;
- It is an international science of creativity that is based on study patterns of problems and solutions, not spontaneity and intuitive creativity of individuals or groups; It is a toolkit of methods to support systematic creativity.

According to Nakagawa (2012) the essence of TRIZ (in 50 words) is: *"Recognition that technical systems evolve towards the increase of ideality by overcoming contradictions mostly with minimal introduction of resources. Thus, for creative problem solving, TRIZ provides with a dialectic way of* *thinking, i.e., to understand the problem as a system, to make an image of the ideal solution first, and to solve contradictions".*

The TRIZ Body of Knowledge (Litvin, Petrov, Rubin, & Fey, n.d.) assumes that TRIZ is based in the premise: *The evolution of successful technological systems is not random, but is governed by certain laws or prevailing trends. Contemporary TRIZ is both a theory of technology evolution and a methodology for the effective development of new technological systems. It has two major subsystems based on the laws (prevailing trends) of technological system evolution: a set of methods for developing conceptual system designs and a set of tools for the identification and development of next generation technologies and products.*

TRIZ could be applied in a transversal way by all types of companies because it could be applied to solve technical engineering problems but also science and knowledge content (Chechurin, 2016; Spreafico & Russo, 2016). Also could be applied with already known other tools like Quality Function Deployment (Domb, 1995; Ulwick, Zultner, & Norman, n.d.), Six-Sigma (Wang & Chen, 2010), Toyota Kata (Toivonen, 2015), among others (Chechurin, 2016).

Basic tools of TRIZ methodology are the 40 inventive principles, Table 1 (Altshuller, 2001). These are combined with Altshuller's Contradiction Matrix (Mazur, 1995) based on these 39 technical parameters to find solutions for the technical contradictions (Mazur, 1995).

Table 1. The 40 Principles of TRIZ, based on Altshuller (2001).

The 40 Principles of TRIZ			
1. Segmentation	11. Beforehand cushioning	21. Skipping	31. Porous materials
2. Taking out	12. Equipotentiality	22. Blessing in disguise	32. Colour changes
3. Local quality	13. "The other way round"	23. Feedback	33. Homogeneity
4. Asymmetry	14. Spheroidality-Curvature	24. Intermediary	34. Discarding and recovering
5. Merging	15. Dynamics	25. Self-service	35. Parameter changes
6. Universality	16. Partial or excessive actions	26. Copying	36. Phase transitions
7. Russian dolls	17. Another dimension	27. Cheap short-lived objects	37. Thermal expansion
8. Anti-weight	18. Mechanical vibration	28. Mechanics substitution	38. Strong oxidants
9. Preliminary anti-action	19. Periodic action	29. Pneumatics and hydraulics	39. Inert atmosphere
10. Preliminary action	20. Continuity of useful action	30. Flexible shells and thin films	40. Composite materials

Meanwhile a lot of tools were developed and refined (Institution of Mechanical Engineers, 2012) in order to design problem solving with systematic innovation. There are ten tools in the Oxford Creativity TRIZ toolkit: 1) Thinking in Time and Space; 2) Eight Trends of Technical Evolution; 3) Contradictions; 4) Forty Principles; 5) Seventy-six Standard Solutions; 6) Resources; 7) Ideality; 8) Functional Analysis; 9) Smart Little People; 10) Size-Time-Cost. Additionally, is available in a web site a effects database provided by Oxford Creativity (Oxford Creativity, 2015). Other could be find in (Product Inspiration, 2015).

TRIZ has been taught in many universities and implemented by the entire world, but, probably because of its Russian origin, it seems it is more known in Eastern Europe. As an example of teaching and applying TRIZ, Bušov, Žídek, & Bartlová, (2015) reviewed the last 35 years in Czech Republic universities and companies. Additionally, Spreafico & Russo (2016) developed a survey of industrial cases studies of TRIZ application exposing the reasons why companies needs TRIZ, which tools were the most used, how TRIZ has been integrated with other methods, and how industries and academies communicate their success. Among others findings, they highlight that in spite of TRIZ continues evolving, its spread did not reach the capillarity expected.

Elimination of waste, in all its forms, in some way, has been recognized as one of the main challenges that both Lean and TRIZ as methodologies, attempt to overcome and implement solutions. Previous studies that explore the synergies between Lean and TRIZ have emerged around 2000 as described by Anosike & Lim (2013). However, and nevertheless TRIZ applicability in different areas growth, ranging from 23% to 47% in the last years (Goldense, 2016), Portugal has not been mentioned and it is not clear how the synergy of TRIZ and Lean has been applied in Portugal. Hence, the importance of this work in locating and identifying the application of these methodologies, by Portuguese companies.

3. Research methodology

Based on the four main objectives that this work is willing to attend to, the following research questions were stated: 1) Where project have been developed (which company)?, 2) what type of approach to the problem was chosen?, 3) what TRIZ and/or Lean principles and tools were used?, 4) which was the problem solved in the project developed?. The answers were obtained focused on the Portuguese reality. In this regard, a search on published work was made based on the authors' knowledge and expertise. The search was conducted in two phases. The first, for the brief literature review as previously described (see section 2) lied within international journals, conference proceedings and books. The second, within thesis and/or dissertations works, serving as a basis of reflection and analysis presented here.

The search was performed on the Online Knowledge Library, b-on (http://www.b-on.pt/), that allows searchers to filter full texts from a larger number of scientific international publications from different publishers. With the terms "TRIZ" & "Lean", not limited to the search filed, were retrieved 538 records. A third term "Portugal" were considered since this work wants to described the Portuguese reality. The number of records decreased to 59. Notice that, and in this stage, language restriction was not applied to the search. From these 59 records a total of 46 were excluded: 13 were not in English or Portuguese, 24 were books or eBooks and not designed for the study purpose, and 9 were others types of sources considered to be outside the scope of the search. Since, the search developed did not provided many results, a new search was performed in an academic repository. At the end, master dissertations and some papers published as an outcome of the masters, in a total of 17, were the studies considered valid for the presented study and for the content analysis.

4. Results presentation, analysis and discussion

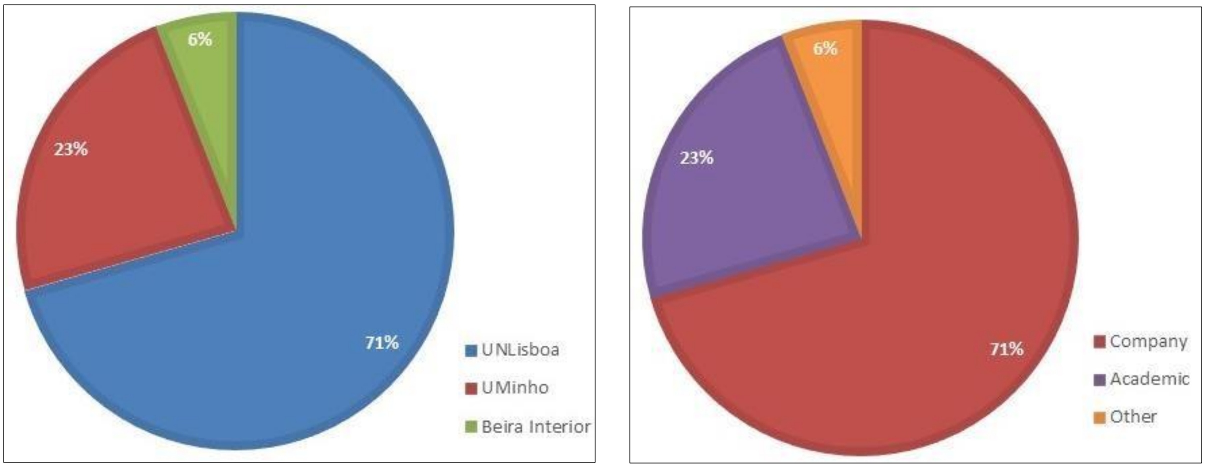
Table 2 presents the results based on 17 master dissertations founded. The table displays the reference of the work, the year, and the university where it was developed and if it was in a company or academic context.

Table 2. Master dissertations developed in Portuguese universities.

Reference	Year	University	Company/Academic
(Almeida, 2008)	2008	UBeira Interior	Academic
(Carneiro, 2013)	2013	UMinho	Company
(Fernandes, 2013)	2013	UNLisboa	Company
(Molina, 2013)	2013	UNLisboa	Company
(Silva, 2013)	2013	UMinho	Academic
(Correia, 2014)	2014	UMinho	Company
(Gomes, 2014)	2014	UNLisboa	Academic
(Marques, 2014)	2014	UNLisboa	Academic but applied to case studies
(Castro, 2015)	2015	UNLisboa	Company
(G. H. N. Lopes, 2015)	2015	UNLisboa	Academic
(Pombo, 2015)	2015	UNLisboa	Company
(Ramos, 2015)	2015	UNLisboa	Company
(Sameiro, 2015)	2015	UNLisboa	Company
(David Soares Vilamariz, 2015)	2015	UNLisboa	Company
(Guimarães, 2016)	2016	UNLisboa	Company
(Pádua, 2016)	2016	UNLisboa	Company

It is evident from the Table 2 that the number of dissertations using TRIZ methodology is growing, particularly, in University Nova de Lisboa (UNLisboa) that seems to be a promotor of the teaching and researching of this methodology. Additionally, recent works show an increased concern in practical application and in collaboration with companies.

Most dissertations were developed in UNLisboa (71%) (Figure 1). Also, from this it is possible to see that most of dissertations are developed in a company context (71%). The “Other” category means that the dissertation was developed in academic context but using data from case studies in companies.



a) b)

Figure 1. a) Number of dissertations by university; b) Number of dissertations developed in academic vs company context

▪4.1 Industry type of companies of the projects

Relating to the companies where the projects were developed, Figure 2 presents the type of industry of these companies, with Metalworking and Consulting the two areas with higher representation.

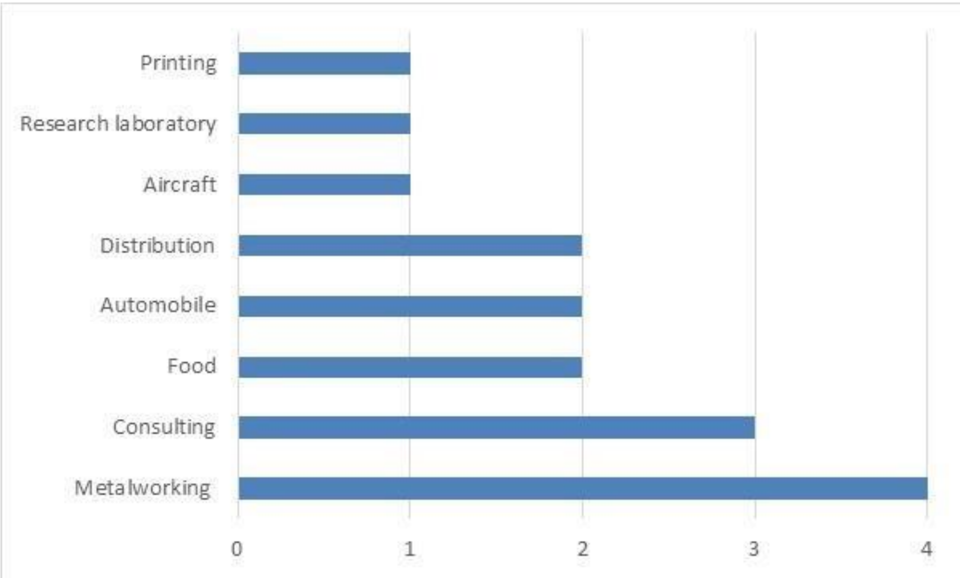


Figure 2. Industry type of companies where the projects were developed

TRIZ methodology could be applied from distinguished goods (from food products to electronics components) and areas (distribution and productive) which is corroborated from the literature (Chechurin, 2016). Even in the area of consulting there are projects applying TRIZ to improve, for example, project management processes (Navas, Tenera, & Cruz Machado, 2015).

▪4.2 Approach type

The second question is related with the approach used to solve the problem and/or used in the project. All projects used TRIZ because this was the criterion used to select them. Almost 50% also use Lean methodology and tools and almost 30% used, beyond TRIZ and Lean, others knowledge areas and/or tools, namely, Ergonomics, Autonomous Maintenance, Six-Sigma, FMEA, Kano model, Quality Function Deployment and Project Management. This is also corroborated by the literature, showing the symbiotic nature of the two methodologies (Campbell, 2004; Ikovenko & Bradley, 2004; Iyer, 2006; Bligh, 2006; Navas & Machado, 2011; Maia et al., 2015; Navas & Machado, 2015).

▪4.3 TRIZ and/or Lean Principles and tools

TRIZ tools more used in the dissertations are the ones presented in Figure 3. Inventive principles, contradiction matrix and substance-field analysis were the most used.

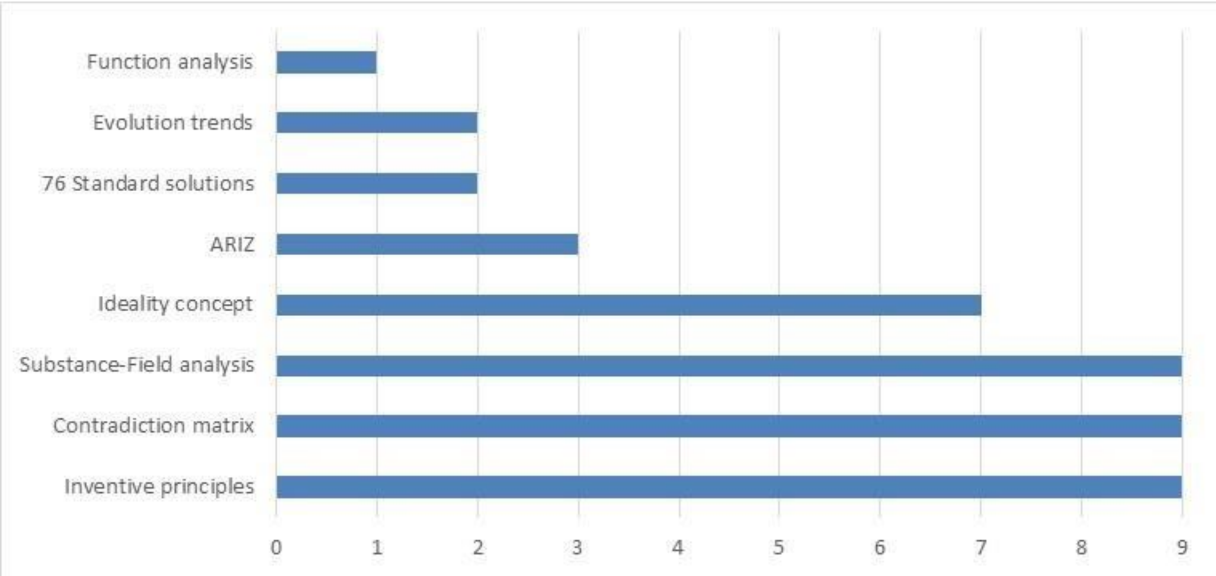


Figure 3. TRIZ tools used in dissertations

The inventive principles used were according the need to solve the problem and it was not a standard in this use (there were not the same). The dissertations authors used more than one and less than eleven principles, being the number of principles used in average five.

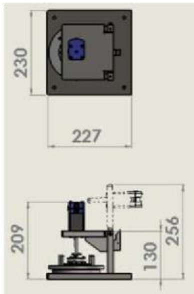
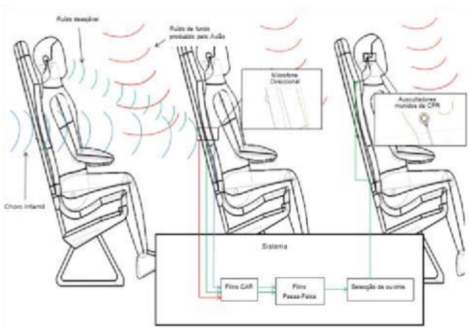
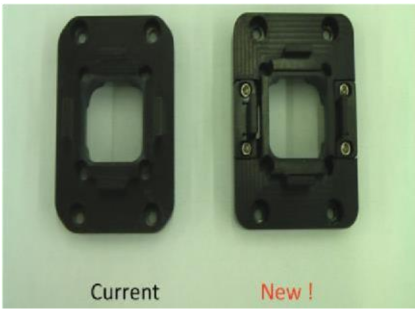
Lean tools used were the Single Minute Exchange of Dies (SMED), Overall Efficiency Equipment (OEE), Kaizen, 5S, Hoshin-Kanri, Visual Management and Standard Work. Other tools were Pareto diagram, brainstorming, project charter, Ishikawa diagram, SIPOC model that are useful to identify, categorize problems and organize work.

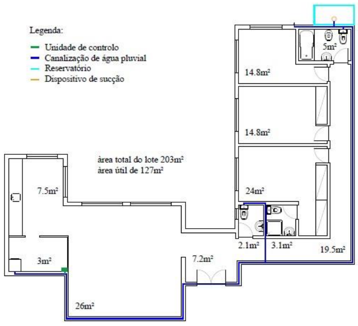
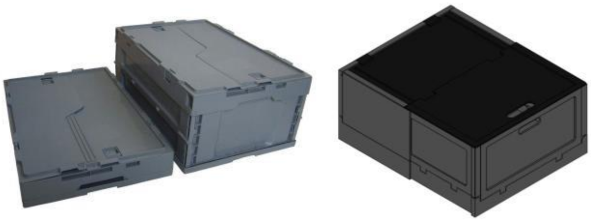
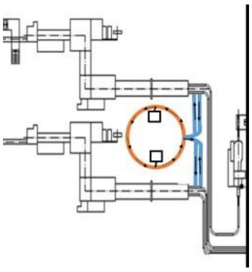
▪4.4 Problem(s) solved in the project developed

TRIZ and Lean methodologies were used to solve usual problems of companies: products and equipment and/or process improvements. Table 3 presents some of these equipment (nine of twelve projects in industrial environment) and respective references. Eight equipment and/or products were just improved and four were designed.

Some of projects, beyond the improved equipment (product), also included the new process plan for the production of the new product. This was the project of Correia (2014) (fifth project in the Table 3) that achieved the main objective of reduce the noise in tableau caused by the sensor and obtain a more simplified assembly sequence which reduced the need of a component, eliminated some non-value added activities and reduces the cost of material investment (by eliminating one component). At the same time, one machine could be removed from the production line because no longer is needed (Correia, Alves, Barbosa, Seabra, & Silva, 2015). The advantages of using TRIZ with Lean and other tools according to this master students was the reduced time to develop the new product, the improved product quality and the reduced costs.

Table 3. Equipment improved and designed in the context of the projects.

Product/equipment	Image (left: initial; right: final)	References
Improvement of a test equipment to measure friction coefficient of fabrics and other 2D non-rigid surfaces	 	(Carneiro, 2013; Carneiro, Silva, Seabra, Alves, & Lima, 2014; Carneiro, Silva, Seabra, Lima, & Alves, 2013)
Improvement of an industrial sterilizer	 	(Fernandes, 2013)
Design of a noise filtration system to reduce noise in aircraft Simplified scheme of studied system (to the left)		(Molina, Navas, & Nunes, 2014; Molina, 2013)
Improvement of a contactor chuck/mandrel nest to reduce changeover time.		(Silva, 2013)

Improvement of an steering angle sensor to reduce noise of the car tableau		(Correia, 2014; Correia, Alves, Barbosa, Seabra, & Silva, 2015) Some sensors tested (to the left)
Scaling a recovery system of rainwater		(Gomes, 2014)
Design of a supply kit to reduce ergonomic problems		(Alves, 2015)
Design of a new package for sports distribution to transport products of different dimensions		(Castro, 2015)
Design of a conveyor to increase a production line capacity		(Ramos, 2015)

In the project of improvement of an industrial sterilizer (the fourth project in the Table 3), the master student also applied TRIZ to two case studies that involved processes improvement (Fernandes, 2013). It was an improvement of a welding process in a metalworking company and to find a solution to make the implementation of the predictive maintenance most attractive.

The remaining projects (nine) were all related with processes improvement being two of them more generic: about applying TRIZ to the design of the product (Almeida, 2008) and about developing a model to apply Lean and TRIZ (Lopes, 2015; Lopes & Navas, 2015). The others seven are the application of Lean to improvements processes, for example, Marques (2014) applied Lean and TRIZ and Maintenance autonomous to industrial maintenance activities to decrease non-conformities in products, to increase service level and to increase efficacy of maintenance plans. Sameiro (2015) used

TRIZ, in particular, ARIZ to improve the project management processes in a consulting company. This application was also experienced in another work (Navas, Tenera, & Cruz Machado, 2015). A project developed in an important national company of energy distribution was also about processes improvement (Vilamariz, 2015) and involved a lot of others tools to achieve this objective (Vilamariz, Navas, & Paulos, 2015). The two most recent projects were developed in partnership with Portuguese Institute of Quality (IPQ) and hospital units because involved the metrology processes improvement in health equipment. “Improvement” is the word that lead and that well represents the main objectives of these projects.

▪4.5 Discussion: enablers vs barriers

The figures presented above shows that a lot need to be done for Portuguese companies know TRIZ methodology and its advantages. An effort has been made by one of co-authors of this paper but this does not seem to be sufficient. According to the experience of this co-author, companies in Portugal know, at least by name, some other methodologies, such as Lean or Six Sigma. It is much easier to convince a company to implement Lean than TRIZ, because they have heard about Lean, even if they do not implement Lean (Maia, Alves, & Leão, 2016), but they know nothing about TRIZ. So a good strategy has been the joint application of Lean with TRIZ in companies and institutions. This combination of TRIZ with others methodologies for a better acceptation and simplification is corroborated by (Spreafico & Russo, 2016) study. TRIZ comes into organizations like a Lean supplement and little by little begins to gain followers and his own space as an autonomous methodology.

Companies seek easy methods to apply and with almost immediate results. It is a very important task to explain to decision-makers in companies that TRIZ has techniques very easy to learn and apply. Companies usually are afraid to apply techniques that require large investments, while TRIZ has some analytical tools and techniques that can ensure significant gains and virtually no additional investment. Both TRIZ as Lean can be seen as a set of quantitative techniques or as a different way of being in an organization.

In Portugal the media, practically, do not speak of TRIZ even in publications with a technical or scientific disclosure content. Thus, the authors of this paper are working on the dissemination of TRIZ whenever there is any opportunity. For example, one of the authors published a paper on systematic innovation and Lean maintenance in a special edition dedicated to Lean maintenance of the Portuguese Journal "Maintenance" of APMI (Portuguese Association of Industrial Maintenance) (Navas, 2011). The TRIZ has been taught with Lean in the this author university, contents of this course could be find in a chapter to be published by a Springer book (Alves, Flumerfelt, & Kahlen, 2016).

One of the authors has organized a seminar at the Portuguese Engineers Association dedicated to the Systematic Innovation and TRIZ methodology. They were invited several responsible for innovation in large organizations in Portugal who told their experiences in innovation. It was clear that they lack a methodology, a scientific basis to guide their work better. Attendance to the seminar largely surpassed expectations. There were people, from companies and organizations across the country, which have moved on purpose to Lisbon to attend the seminar. Some conferences have been organized with this purpose.

One of the authors was invited to be a columnist in the Portuguese monthly newspaper "Innovation & Entrepreneurship" published by the Economic Life group. The column allows publish monthly information on TRIZ and other related topics. Till now, 23 columns (since may of 2014, (Navas, 2014)) were published. However, all the work done is still little, there is still a lack of knowledge about TRIZ.

5. Final remarks

This paper intends to inform about TRIZ knowledge and implementation in Portuguese reality based on a systematic search. For this, the authors search scientific publications (like, papers or other materials) about this subject, having as basis the Portuguese reality. Most material were master dissertations mainly from Universidade Nova de Lisboa (university that one of the co-authors belong to) and conferences papers. This was not a surprise since TRIZ teaching and knowledge has been promoted by research team of this university. Other efforts have been made as such offering optional courses in the university of other co-author of this paper and integrating in a Product Design Master course one module about TRIZ. In the final of semester students opinion about TRIZ learning was positive, seeing this methodology as very useful in the development phase of the product.

The findings from the master dissertations identified, and mainly from the literature, show an enormous potential of TRIZ for companies that want to innovate, generate innovative solutions based on reliable methods. Being "innovation" one word in agenda, it is crucial to divulgate and to teach this methodology in the academic environment.

The study herein, presents as the main limitation, the recent master dissertations have embargoed access not allowing a detailed analysis. Also, the search will be extended to cover and considering more academic repositories. However, there is no guarantee that this extension will corresponds to more scientific works.

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Case Study of Relative Importance Perception on Firefighting Service Missions with AHP Method

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Abstract

The firefighting service missions have become more complex and diverse due to the intense desire of citizenry in current democratic society. To realize the relative importance perceptions on firefighting service missions will be helpful for improve the service quality and raise the satisfactory degree for firefighting service units. Moreover, it is useful as a reference to allocate rational human and equipment resources for the administrative government units. In this paper, we presented the procedures of a multi-criteria decision making method for evaluating the relative importance perceptions of different firefighting service missions such as disaster rescue, emergent aid and care, guidance of fire accident prevention and miscellaneous citizen service. We adopt the analytic hierarchy process (AHP) method to conduct this research. We invite the heads of a subdivision district at Xinshi District, Tainan City, Taiwan as the subjects of the AHP questionnaire as they have the abundant service experience for the citizen's affairs. The research method and results in this paper provide a useful reference and base for administrative government units to allocate reasonable resources and for firefighting service unit to realize the citizen's perception on the diverse firefighting service missions.

Keywords: Firefighting Service Missions, Analytic Hierarchy Process (AHP), Service Quality, Resource Allocation.

1. Introduction

The firefighting service missions have become more complex and diverse due to the intense desire of citizenry in current democratic society. To realize the relative importance perceptions on firefighting service missions will be helpful for improve the service quality and raise the satisfactory degree for firefighting service units. Moreover, it is useful as a reference to allocate rational human and equipment resources for the administrative government units. In this paper, we presented the procedures of a multi-criteria decision making method for evaluating the relative importance perceptions of different firefighting service missions such as disaster rescue, emergent aid and care, guidance of fire accident prevention and miscellaneous citizen service.

2. Literature Reviewe

The analytic hierarchy process (AHP) method (Saaty, 1980) has be proposed and popularly applied in many disciplines over three decades. Many scholars consider that AHP is very practical quantitative method (Tsai et al., 2012; Li, 2010), however, they also suggested various improved methods such as Delpi AHP (Vidal et al., 2011), fuzzy AHP (Im & Cho, 2013; Wu et al., 2010), ANP (Niemira & Saaty, 2004) to enhance the decision quality. The AHP was developed by Saaty (1980) and it is a robust and flexible multi-criteria decision-making method with the capability converting decision-maker's preference into quantitative analysis. AHP method consists of several steps such as identifying problem definition, searching criteria from literature and experts, determining criteria and establishing AHP hierarchical model, designing questionnaire, evaluating criteria and alternatives from experts, implementing data analysis and explaining implication. Besides industrial application, it has been applied as a practical evaluation tool in many new areas such as course website quality (Lin, 2010), government-sponsored R&D project selection (Huang & Chiang, 2008), and patent valuation (Chiu & Chen, 2007).

3. Research Method

We adopt the analytic hierarchy process (AHP) method to conduct this research. The AHP hierarchy shown in **Fig. 1**, is divided into three levels: the first level (goal), the second level (main criteria), and the third level (sub-criteria). The criteria consist of four categories: disaster rescue, emergent ambulance, fire advocacy, and miscellaneous service. Based on this hierarchy, we transform this hierarchy diagram into an AHP questionnaire.

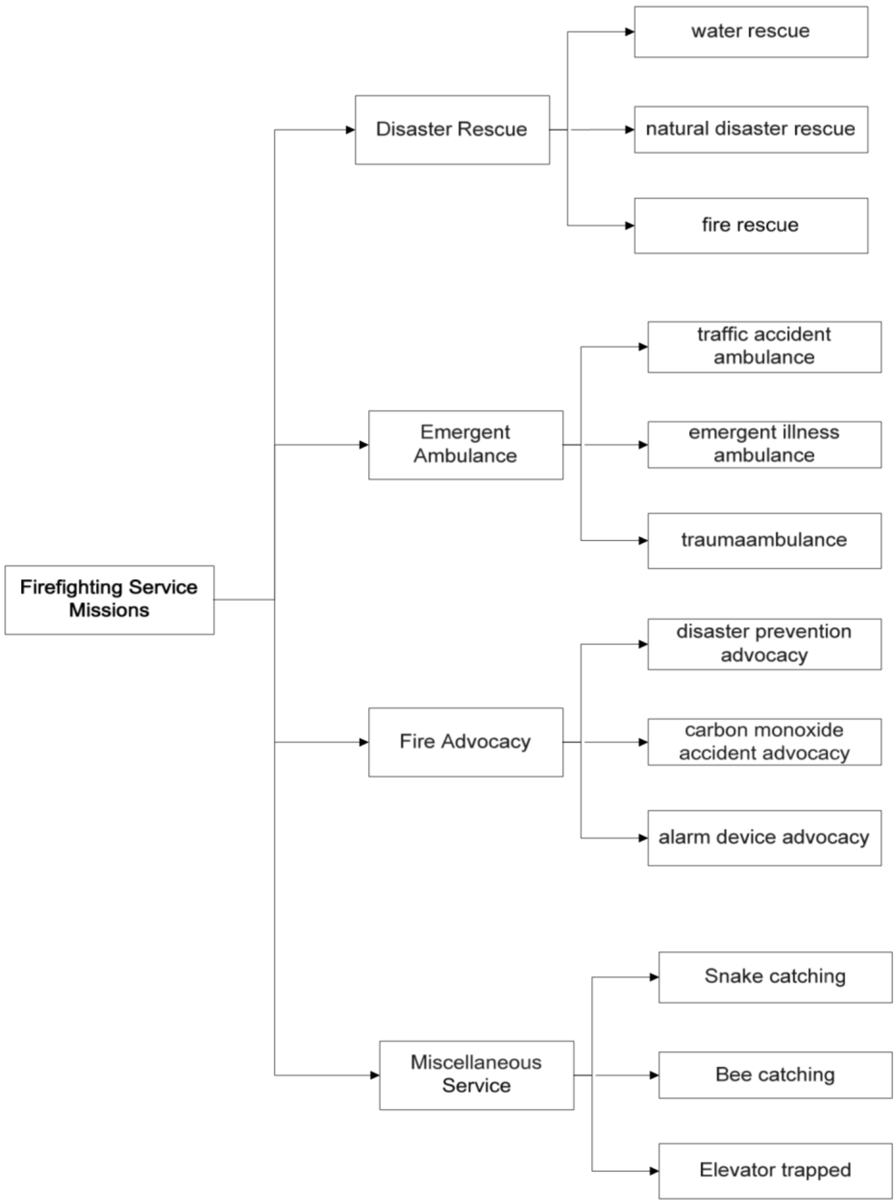

Fig. 1 The AHP hierarchy of firefighting service missions in this paper

4. Research Results

In order to realize the relative importance of the criteria of the firefighting service missions, we invite the heads of a subdivision district at Xinshi District, Tainan City, Taiwan as the subjects of the AHP questionnaire as they have the abundant service experience for the citizen's affairs. As most of people don't familiar with the AHP questionnaire, respondents were informed to join a face-to-face meeting so that authors could explain the objectives of this research and how to fill out the questionnaire. The relative weights and the overall results for each alternative were obtained by the commercial software package Expert Choices (http://www.expertchoice.com/). **Fig. 2** shows some operating interfaces of the case study.

Table 1 shows the arranged research results. The rank of the all the sub-criteria in terms of the global weight were shown in **Table 1**. For the main criteria, the rank in decreasing of representativeness is: disaster rescue, emergent ambulance, miscellaneous service, and fire advocacy. Trauma ambulance has the highest overall preference value and the overall value for the other alternatives in decreasing of representativeness is: fire rescue, traffic accident ambulance, emergent illness ambulance, water rescue, natural disaster rescue, elevator trapped, disaster prevention advocacy, carbon monoxide accident advocacy, alarm device advocacy, bee catching and snake catching.

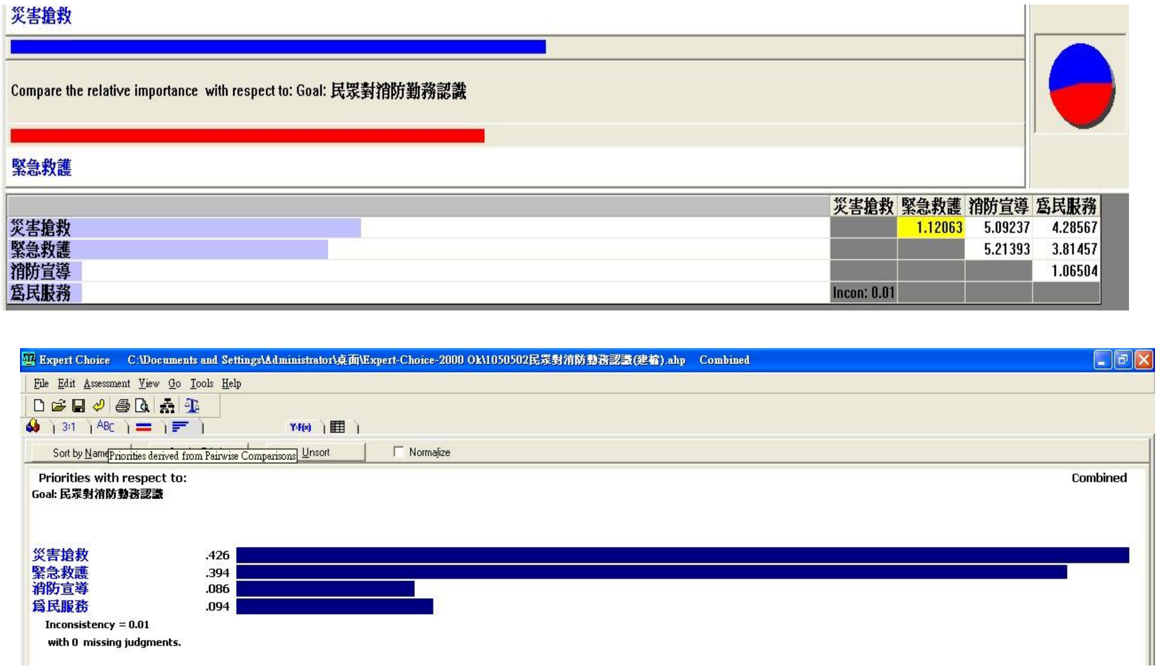

Fig. 2 Snapshots of some operating interfaces of Expert Choice in the case study

5. Conclusion

The research method and results in this paper provide a useful reference and base for administrative government units to allocate reasonable resources and for firefighting service unit to realize the citizen's perception on the diverse firefighting service missions.

Table1. The rank of the all the sub-criteria in terms of the global weight

Criteria & Sub-criteria	Weigh	Rank
Disaster Rescue	0.426	
water rescue	0.087	5
natural disaster rescue	0.061	6
fire rescue	0.278	2
Emergent Ambulance	0.394	
traffic accident ambulance	0.212	3
emergent illness ambulance	0.142	4
trauma ambulance	0.404	1
Fire Advocacy	0.086	
disaster prevention advocacy	0.040	8
carbon monoxide accident advocacy	0.024	9
alarm device advocacy	0.022	10
Miscellaneous Service	0.094	
Snake catching	0.019	12
Bee catching	0.022	10
Elevator trapped	0.053	7

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Use of Presumptions of Neuro Linguist Programming to Keep an Innovation Mindset

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Abstract

The innovation process begins with the goal to create strategic advantage in the marketplace. To get an ideal product need lots of brain effort, and failure cause the innovators to feel frustration. TRIZ help people create good products, but it cannot help people eliminate unpleasant feeling, however Neuro Linguist Programming can. In this paper, presumptions of Neuro Linguist Programming are introduced to help keep an innovation mindset. An innovation process with TRIZ and NLP can help innovators to create good products with pleasant mood, and get better results.

Keywords: NLP, Neuro Linguist Programming, TRIZ.

1. Introduction

Most people assume innovation is a hard work. It needs lots of effort to screw a brand new idea that is qualified to make up a good product. It also needs to be identical in order not to be a copycat. However, TRIZ introduced a set of power tools (Altshuller, et al. 1999). Obtaining a high quality innovation result without power tools is hard. A good idea would not pop up, if the inventor does not put much effort. TRIZ help people to think systemically. It models and catalogs the nature of innovation so that people can follow the model to proceed with innovation processes (Altshuller 1984). Despite this, innovation stills need lots of mental efforts, because people must face their emotions. Good emotions can help produce good products, but bad emotions can lead to waste people's effort. TRIZ is good at the process of invocation, but not good at deal with people's emotions. However, NLP (Neuro-Linguistic Programming) is good at deal with people's emotions. It also like TRIZ models good invention process to model successful people's strategy (Dilts, et al. 1991). Becker and Domb (1998) reveal that NLP and TRIZ can accelerate creativity for product designers. Bridoux and Mann (2002) and Bridoux, et al. (2002) show how NLP can help TRIZ evolve and compare NLP and TRIZ in many ways. Mann and Dewulf (2001) show extension of TRIZ system operator into 3-Dimensions by using NLP. So, NLP and TRIZ work together can really help creative works.

2. The Presuppositions of NLP

Like the four pillars of TRIZ, NLP also have the presuppositions to support its philosophy theory (Bridoux and Mann 2002, Bridoux, Halifax and Mann 2002). The effective of NLP is based on its presuppositions about human's nature (Dilts and Delozier 1993). NLP is good to many aspects, including social activities, therapy, and business. The presuppositions are also the pillars of NLP, and are the basic beliefs and assumption to NLP. There are 12 rules in the presuppositions of NLP. These beliefs are as follows:

1. The map is not the territory.
2. Having choices is better than not having choices.
3. People make the best choice available at any given time.
4. People work perfectly.
5. Every behavior has a positive intention.
6. People have all the resources they needed.
7. Mind and body are connected, and form a system.
8. Modeling successful performance leads to excellence.
9. The person or element with the most flexibility in a system will gave the most influence.
10. The meaning of communication is the response you get.
11. There are no such thing as failure only feedback.
12. All actions have a purpose

3. Presuppositions and Mindset

TRIZ introduces many excellent tools to help innovation. Most tools make contributes to two aspects, one is to overcome Psychological Inertia, and the other is Cognitive Reframing. People cannot make innovation is that they always think the same way. Psychological Inertia is a block to keep people from innovating. TRIZ introduces many tools to overcome Psychological Inertia and Cognitive Reframing. System operators help people think from different positions and time. Problem Hierarchy

Analysis keeps problems from dead end. Smart little people and STIC (Space Time Interface Cost) make people overcome Psychological Inertia.

Overcoming Psychological Inertia and Cognitive Reframing are also the NLP's contributions. Thinking in terms of time/space/interface makes people think from different aspects. Meta-Model and Meta-State can help people find their inner requirement (Knight 2012). Time-Line models of communication can change people's perception so that old trauma can no longer hurt people. Chunking and Reframing patterns can reframe people perception just like TRIZ's tools do.

Though, NLP introduces so many good tools to regular our minds. These tools are all based on the presuppositions of NLP, the core beliefs. To get a better job needs a good mindset.

Belief 1: The map is not the territory. Every one uses his knowledge to explain the world. Because their knowledge is different, their responses to the world are different. So, a bad idea in innovation may be a good idea to others. It also introduces the concept of reframe.

Belief 2: Having choices is better than not having choices. For an inventor, he should always give a widest and richest number of choices to achieve a goal. It also can be applied to problem hierarchy analysis.

Belief 3: People make the best choice available at any given time. People make the best choice at any time even it is so unreasonable and bizarre. Take smoking as an example, smoking is bad to health, but it is the easiest way to relax at that time. So, ideal final result might be change by times, and so S-curve does.

Belief 4: People work perfectly. It is about people talents. Everyone can work perfectly according his strategy. In spite of his strategy is not good enough, he can perform it well. So, everyone can work well according his past training. If he can learn more training, he can work better with his training. It is like that systematic innovation does. People follow the systematic innovation method to get better result.

Belief 5: Every behavior has a positive intention. Every behavior always combines a positive intention even it is not a good behavior. Consider smoking for example. Most people smoke for social reason. So, when an inventor looks at a work, good or bad, he should consider the positive intention behind. It is the same that Systematic innovation also asks people to consider the higher value.

Belief 6: People have all the resources they needed. It says everyone is resourceful, but sometimes he is at un-resourceful state of mind. So, keep a resourceful state of mind during innovation process is needed.

Belief 7: Mind and body are connected, and form a system. People who learn NLP always treat mind and body as a whole thing. It likes that TRIZ consider user experience as a subsystem of whole system. When one is changed, the other will be affected.

Belief 8: Modeling successful performance leads to excellence. TRIZ also has the same belief. Both NLP and TRIZ model successful performance and leads to excellence.

Belief 9: The person or element with the most flexibility in a system will gave the most influence. It is the same to design a multifunction product.

Belief 10: The meaning of communication is the response you get. This belief is very important to anyone, of course, including the inventor. People always know the important of communication. They always learn how to communicate but forget the meaning of communication is the response they get. With this belief, the inventor can focus on the content instead of temperamental speaking.

Belief 11: There are no such thing as failure only feedback. It is a good reframing thought. Bearing this belief, the inventor can obtain the courage when he does not get the ideal result. He can reframe the negative emotional into positive one.

Belief 12: All actions have a purpose. This can help the inventor to analyze the requirement deeper and find hidden values.

4. Conclusion

Even in the processes of invention, people can success or fail. This paper suggests that people had better bear NLP's presupposition in mind. Though he is not familiar with NLP's presumptions yet, he can also benefit from TRIZ's philosophy. As time passes, he can use the tools more precisely and powerfully, because he knows the humanity behind TRIZ's tools. How to keep an aggressive mind to work is not an easy thing. But if people keep these presuppositions of NLP in minds, people can work more energy. If one understands TRIZ's tools to invent and stick NLP's presuppositions in his mind to adjust his feeling, he will speed his invention process and enjoy his invention process.

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Resource and Energy Efficiency for Process Industries – the MAESTRI Project

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Abstract

The MAESTRI project aims to contribute to the implementation of sustainability in European manufacturing and process industries, by providing a management system, in the form flexible and scalable platform, to promote and simplify the implementation of an innovative Efficiency Framework, the "Total Efficiency Framework". The overall aim of the Total Efficiency Framework is to promote improvement culture within process industries by assisting decision-making process, supporting the development of improvement strategies and helping on the definition of priorities to improve the company's environmental and economic performance. Its development and validation will be achieved through its implementation in 4 real industrial settings across a variety of activity sectors.

The Total Efficiency Framework concept will be based on four main pillars to overcome the current barriers and promote sustainable improvements: a) an effective Management System targeted for process and continuous improvement; b) Efficiency assessment tools to define improvement and optimisation strategies and support decision making process; c) integration with Industrial Symbiosis concept focusing material and energy exchange; d) a software Platform, based on "Internet of Things" concept, to simplify the concept implementation and ensure an integrated control of improvement process.

Over a period of 4 years, the project aims to reach a wide range of relevant exploitable results, which can be mainly clustered into technological outputs, including eco-innovative products, processes and services tailored to industrial end-users; and structured solutions - involving technical, economical, legislative and policy solutions synergistically combined.

Keywords: Eco-efficiency, Industrial Symbiosis, Internet of Things, Management System, Total Efficiency Framework.

1. Background

Europe was the cradle of the manufacturing industry and it has traditionally led important industrial changes. Process industries represent the foremost part of the manufacturing base, around 20% of the total European manufacturing industry, which include more than 450,000 individual enterprises (EU27), having over 6.8 million employees and generating more than 1,600 billion € turnover. On other hand, process industries are largely dependent on resources imports from international markets that are hampering the industry's access to globally traded raw materials, due to the increased political instability in many regions of the globe, which is perfectly visible from a sharp increase in raw material prices during recent years. Moreover, European industry has also accounted for more than a quarter of total energy consumption in 2014 in Europe (EU 27) (Eurostat, 2016) with a significant portion of that used within the process industry.

The pursued impacts reflected in the EUROPE 2020 flagship initiative "A resource-efficient Europe" aims to deliver smart, sustainable and inclusive growth. By, for instance, reducing fossil energy intensity up to 30% from current levels and up to 20% reduction in non-renewable, primary raw material intensity versus current levels, by increasing chemical and physical transformation yields and/or using secondary and renewable raw materials. Moreover, the importance of technology leadership in production technologies does not only impact on the competitiveness of manufacturing in Europe, it also sustains Europe as an export leader. For instance, the European share of world machine tool production is 31 %, of which 45 % is exported outside Europe.

Regarding manufacturing, the trend is to contribute in a qualitative sustainable growth of the manufacturing industry by implementing the strategic shift from 'quality-cost-delivery' competition, which reduces the production cost per good, towards 'value-added production' (including i.e. product individualisation and life cycle orientation). This represents both an opportunity and responsibility of this sector contribution to the sustainability challenges of European societies, being imperative to drastically reduce the environmental footprint and increase competitiveness and production systems efficiency by "doing more with less". However, to successfully implement sustainability in manufacturing and process industries, a holistic, multidimensional and systematic approach is required.

2. MAESTRI vision

MAESTRI is a four-year project funded by the European Commission through the Horizon 2020 programme. The project, which started on September 2015, brings together 15 organisations from 5 different countries to advance the sustainability of European manufacturing, specifically focusing in the process industries.

The MAESTRI project aims to advance the sustainability of European manufacturing and process industries by providing a management system in the form of a flexible and scalable platform to promote and simplify the implementation of an innovative approach, the Total Efficiency Framework. Based on a holistic approach which combines different assessment methods and tools, the overall purpose of the Framework is to generate improvement on a continuous basis and increase eco-competitiveness by fostering sustainability in routine operations.

Its conceptual approach is based on a life cycle perspective (Figure 1), centred on models for dynamic simulation and optimization, of both individual and complex systems, to better understand processes and the opportunities to add value. This life cycle approach is important to avoid problems shifting from one life cycle stage to another.

In order to develop more resource and energy efficient processes, utilize waste streams and improve recycling in a sustainable manner, modelling and assessing all the interacting value chains is essential. However, despite the environmental, economic and social improvement potentials by sharing resources (e.g. energy, water, waste and recycled materials), it is essential to understand and assess resource and energy efficiency in order to optimize production systems.

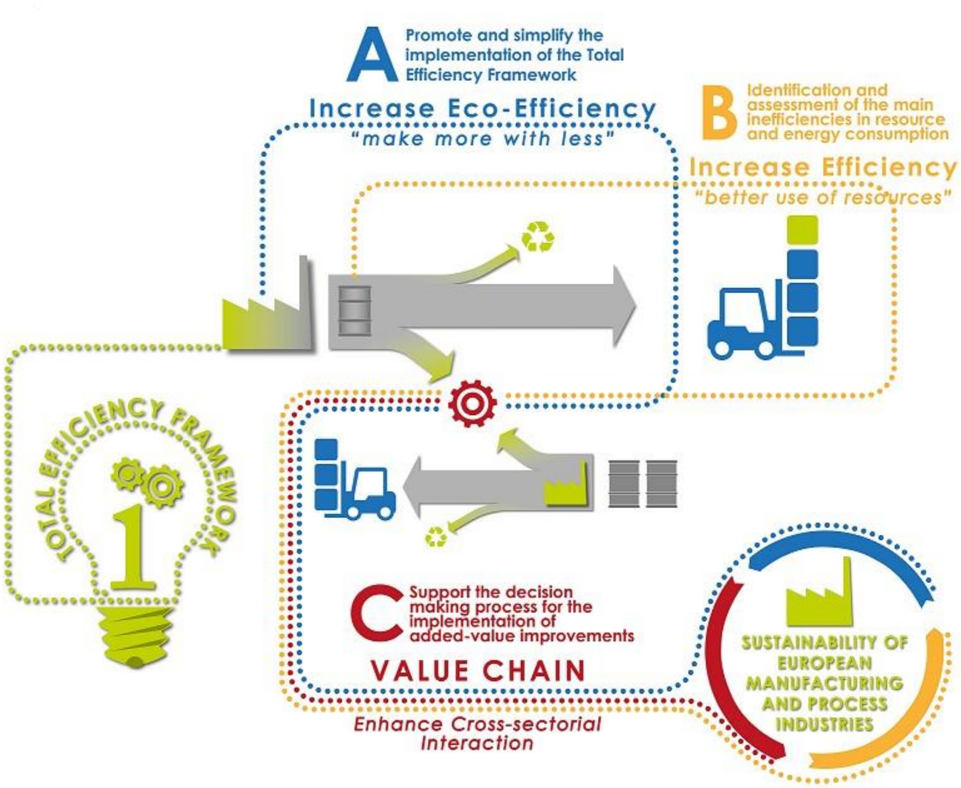

Figure 1 – MAESTRI project vision

Moreover, the increased availability of ultra-modern technologies for process monitoring and optimization should be carefully adapted and integrated for a wider and facilitated adoption of state-of-the-art tools and methodology for efficiency and eco-efficiency. Such methodologies and tools should support wastes and cost reductions in industry (large or small).

The following gaps on the effective implementation of energy and resource management were identified:

Technical/Technological Gaps

- Lack of flexible, scalable and holistic tools to support decision making process regarding resource and energy efficiency;
- Lack of simple and integrated tools to assess and optimize resource and energy efficiency, crossing the different environmental and economic operational aspects;
- Deficient knowledge to identify the potential use of wastes as resources (energy, resources, man-power, etc.);

Management Gaps

- Non-incorporation of sustainability aspects in company strategy and objectives;
- Non-implementation of structured management systems targeting resource consumption and energy efficiency;
- Dispersion of process efficiency relevant data and information across different departments of the company;
- Difficulty on the definition of clear and consistent KPIs, and their follow-up;

Organisational Gaps

- Poor means for sharing resources (e.g. plants, energy, water, residues and recycled materials) through the integration of multiple production units of a single company or multiple companies on a single industrial production site;
- Difficulty to collect and share information about all process flows (resource and energy inputs as well as waste and pollutant outputs).

To address these gaps, an innovative and integrated platform, combining holistic efficiency assessment tools, a novel management system and an innovative approach for industrial symbiosis implementation will be developed.

3. Total Efficiency Framework

The main concept of the MAESTRI project consists of the development of a flexible and holistic integrated Framework to foster sustainability in process industry, the "*Total Efficiency Framework*". The overall aim of the *Total Efficiency Framework* is to promote an improvement culture within process industries by assisting decision-making process, supporting the development of improvement strategies and helping on the definition of priorities to improve the companies' environmental and economic performance. The *Total Efficiency Framework* will be based on four main pillars (Figure 2) to overcome the current barriers and promote sustainable improvements:

- An effective Management System targeted for process and continuous improvement;
- Efficiency assessment tools to define improvement and optimization strategies and support decision making process;
- Integration with Industrial Symbiosis concept focusing material and energy exchange;
- An IoT Platform to simplify the concept implementation and ensure an integrated control of improvement process.

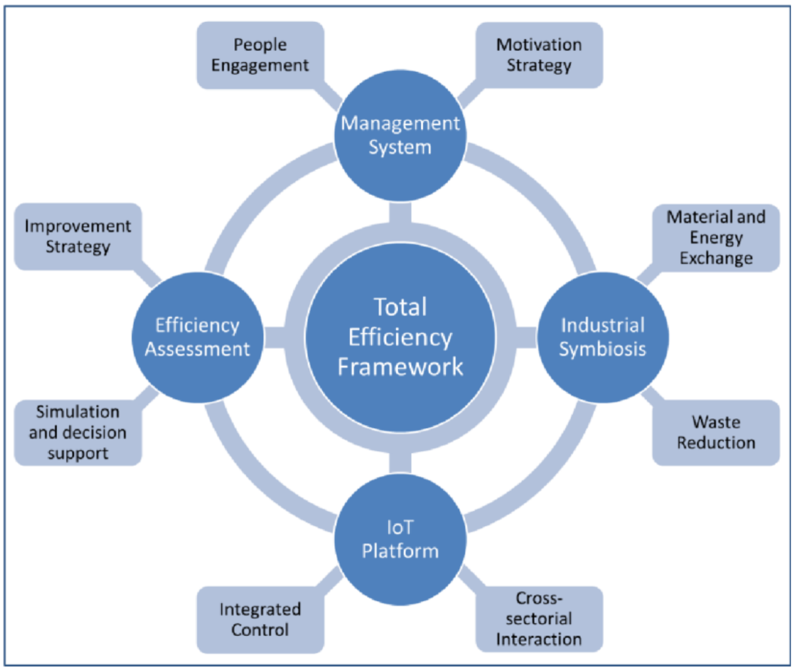

Figure 2 - Concept of Total Efficiency Framework

2.1 Management System

A 2011 survey on attitude towards eco-innovations within small and medium enterprises (SMEs) from a variety of sectors revealed that around 30% of EU companies had introduced a new or significantly improved eco-innovative production process or method in the past two years and around 25% had introduced a new or significantly improved eco-innovative organizational methods.

At the same time among the main barriers to accelerated eco-innovation uptake and development by companies were: uncertain return on investment, or too long payback periods for eco-innovation and lack of funds within the company (Flash Eurobarometer 315, 2011). Therefore, it seems reasonable to provide manufacturing companies with management system and improvement methods, which will enable improving eco efficiency without significant investment as this kind of activity will help omit the barriers mentioned by European entrepreneurs.

In the last two decades Lean Management has become a commonly used approach in the manufacturing industry to organize and manage the production and supporting processes. The basis of Lean Manufacturing is adding value to the customer by the elimination of all items, actions, deliverables that do not add value to products (from customer perspective) and that are called wastes. This approach is based on small increments, everyday improvements in value delivery and waste elimination and their sustainment rather than large and costly innovations that require large efforts to maintain. Therefore, Lean Manufacturing approach can be considered as a low-cost approach.

Although Lean Management is used in more and more sectors and companies, it seems that companies tend not to fully explore its potential in term of improving eco efficiency, reduce energy consumption and residues production. Companies are utilizing Lean-based techniques in order to improve some of their environmental-related metrics, e.g. reducing natural gas consumption by 50% in 1 year (Jacoby, 2009), energy consumption by 30% (Łukasiewicz et al., 2011) and totally eliminating scrap loss within 1 year (Murugaiah et al., 2010). However, it is still missing a holistic approach for eco efficiency management and a broader methodology supporting this systemic perspective.

The management system to be developed in MAESTRI embraces the development of management tools that encompass LEAN strategies related to sustainable continuous improvements. Apart from the definition of specific procedures, as commonly applied for any other Management System, continuous improvement will be promoted by the implementation of efficiency assessment tools. Its flexible and holistic approach will allow the definition and monitoring of relevant KPIs, on an appropriate time scale, aiming the identification of potential improvement initiatives and decision support making process. Integration with strategy, management system and managers' behaviours will ensure the proper motivation and people engagement on every level of the company. Synergies with other Legal (e.g. REACH, IPPC, etc.), Management (e.g. ISO standards 9001, 14001 and 50001) and Communication (e.g. GRI, ETS, Ecolabel, etc.) instruments, will be also evaluated and taken into account, in order to support decision and stimulate competitiveness.

Hoshin Kanri will be used in MAESTRI management system to promote Continuous Improvement (CI) and to deploy improvement goals regarding economic issues, energy efficiency and other important environmental topics to all levels of organisation. Eco Lean Management boards will be based on principles of Lean Management system and encompass the following elements: long term improvement goals, visualised targets for KPIs (key performance indicator) and KEPIs (key environmental performance indicator) (corresponding with improvement goals) and standard procedures for problem solving and quick improvements used each time KPIs do not reach the predefined level. An important aspect of the management system will be embedding continuous improvement into daily improvement routines. This will ensure people engagement to be an integrated element of the system.

The developments will also include a set of low cost eco improvement methods aimed for cost-saving optimization of energy and resources used for production processes without the need for significant investment. They will be used each time when Lean Management boards indicates there is a gap between monitored KPI and the agreed target (targets come from long term improvement goals, which in turn come from strategy). Low cost improvement methods are based on Lean Management approach in particular: 1) small incremental improvements 2) root cause analysis 3) problem solving 4) standardization.

2.2 Efficiency Assessment

Sustainable development based on a vision that aims to maximize value creation and minimize environmental burdens, will enable companies to seek solutions to improve the economic and environmental aspects of their production systems (Lehni et al., 2000). Eco-efficiency has assumed a key role for this objective, since its "practical and theoretical importance lies in its ability to combine performance along two of the three axes of sustainable development, environment and economics" (Ehrenfeld, 2005). Eco-efficiency relies on the quantified information concerning environmental and economic development of activities as sustainability aspects that evidence more value from lower inputs of material and energy and with reduced emissions. The state-of-art of eco-efficiency analysis will be based on current namely ISO 14044:2010 and 14045:201 (ISO 14044:2006, 2006). Data collection is one of the most important tasks, since the quality of the input data will influence the final results considerably. The Environmental Performance Evaluation (EPE) defined by ISO 14031:2005 can be applied to any organization, and is perfectly integrated with the current management practices. When assessing eco-efficiency, the Life cycle impact assessment (LCIA) methodology provides assistance on understanding environmental influence and supports the creation of the environmental profile, and the more complete methodologies and tools should have this component (ISO 14040:2006 defines the life cycle assessment (LCA) methodology). Having in mind an easy interpretation of the economic value created, simple and direct monetary indicators are usually suggested, e.g. Gross value added (GVA), EBITDA (earnings before interest, taxes, depreciation and amortization), Production Cost, etc. (Verfaillie et al., 2000, Michelsen et al.,2006). Besides monetary values, Life Cycle Cost (LCC) can be used as a value related quantity, since it integrates all the cost associated with a product throughout the product' life from "cradle to grave.

The ecoPROSYS© approach (Baptista et al., 2014) presents an integrated decision support tool based on eco-efficiency principles, decoupling economic growth from environmental burden and using of an organized set of indicators which are easy to understand/analyse.

Regarding efficiency assessments, recently new tools and approaches are being developed in order to assess/measure sustainability of production systems. For instance, Paju et.al. (2010) presents the Sustainable Manufacturing Mapping approach that focuses on the application of a Value Stream Mapping (VSM) based assessment as an integrated visualization and monitoring method for environmental impacts and production control. Li et. al. (2012) presents an eco-efficiency approach to evaluate energy as well as resource efficiency of manufacturing processes. Despite the progresses, both approaches lack the assessment of efficiency performance of the overall system, and don't identity KEPIs.

In current state-of-art there is no articulated and integrated approach that relates between eco-efficiency assessment, including both KPI for operations and resource management, cost analysis, KEPI for assessing environmental impacts with an LCA methodology, LCC analysis, an overall efficiency assessment, and LEAN principles integration.

One main innovation of MAESTRI is to achieve such integration namely by the study of articulating the innovative and complete analysis of ecoPROSYS© with the strong capabilities and innovation of the MSM® Multi-Layer Stream Mapping (Lourenço et al., 2013), a method that was developed with strong LEAN basis to achieve an overall efficiency assessment for systems. This integration enables an overall efficiency performance assessment both from environment, including energy efficiency, and value and cost perspectives. Such integration encompasses Environmental Performance Evaluation with Environmental Influence and Cost/Value assessment models through a life cycle perspective. Its aim is to optimize all process elementary flows via cost-saving optimization by clearly assessing resource and energy usage (valuable/wasteful), and each flow efficiency.

The decision support model will be composed by: (a) simulation models for assessing scenarios, (b) predictive models to identify consumption patterns and emission projections, and (c) optimization models for energy and resources efficiency. These methodologies are aligned with the best state-of-art approaches, thus, their combination will assure that project MAESTRI will provide technical outputs for Total Efficiency Assessments beyond the state-of-art and provide the most complete methodologies and tools for increased sustainability of process industries.

2.3 Industrial Symbiosis

Turning waste into a resource has been identified as a key strategy in the Roadmap to a Resource Efficient Europe (COM (2011) 571). The concept of reusing waste as a resource through the exchange of waste streams between processes and companies is known as industrial symbiosis (IS). As a sub-field of industrial ecology (Graedel, 1994), it is a practical approach to apply the ecological metaphor whereby organisms are maximizing their own functions and benefits through synergistic exchange of waste and resource flows. IS enables similar cyclic circulation of waste by promoting cooperation between companies as demonstrated in industrial eco-parks such as the famous example of Kalundborg in Denmark (Ehrenfeld and Gertler, 1997). Such example shows that the collective benefits of engaging in industrial symbiosis, is greater than the benefits a single entity could achieve by itself (Chertow, 2004). The reuse of waste as a resource has a direct effect on the efficiency of the whole system and enables the decoupling between the value created through material processing or products' manufacture, and the environmental impact associated to natural resource intake and waste/pollutants assimilation. IS does not only enable this reduction of natural resource intake, pollutant emissions and waste discharges, but it can also be a source of increased revenue and new employment, as well as create a safer and cleaner natural and living environment (Van Berkel et al., 2009).

There are many examples of industrial symbioses across the world, from small-scale, local reuse of waste to large-scale, wider regional exchange between companies and industries. These examples are demonstrating the feasibility and benefits of "waste2resource" conversions, and potentially inspire companies in engaging in activities enabling the emergence of industrial symbioses. Examples and practical information on how to engage with IS activities are required to help companies make the required mind-set and behaviour shift to see waste as a potential resource and identify synergies within and outside their operations. This shift can only occur through the provision of a better understanding of IS.

Based on the understanding of theoretical characteristics (Chertow and Ehrenfeld, 2012) and practical characteristics of IS, categories of possible challenges have been identified (Tao, et al., 2014):

- Finding embedded norms of exchange, culture and structure of enterprises
- A lack of information on waste exchange
- A lack of technical and financial support
- Increased cost incurred during the process of waste exchange (e.g. transaction costs, opportunity cost, labour costs, etc.)
- A lack of guidance in institutional arrangements
- A lack of inter-firm trust and unstable cooperation between participants

Industrial Symbiosis, within the scope of sustainable manufacturing for process industries, fosters the sharing of resources (energy, water, residues and recycled materials etc.) within the different processes of a single company or between multiple companies. This association enables companies to reduce raw material and energy consumption, and waste disposal costs, promoting the efficient use of resources.

In order to develop industrial symbioses, it is fundamental to identify the waste (energy or material) sources, demands and potential synergies. It is necessary to understand the success factors associated with implementations and attempted implementations of industrial symbiosis in order to establish the principles for the toolkit development and its integration with the Total Efficiency Framework and Management System into the IoT platform. IS examples will be collected to build a library of case studies and then analysed to extract key success factors, which will provide the foundation for the toolkit development. In addition, the library of case studies will be used to initially populate the waste database by providing example of wastes which have been converted into resources. Through the development of a database architecture – an open platform for value-laden wastes available to companies across the EU – increased availability of information will be enabled and potentially provide inspiration for companies to identify reuse opportunities for their own waste. This is essential to expand the uptake of industrial symbiosis practice across the EU.

With an understanding of the success factors and challenges (technical, organizational, behavioural and regulatory) associated with implementations of industrial symbiosis, 'how-to' guides will support the process of learning how symbiosis might be best applied to one's own circumstances, catalysing the search for internal and external opportunities. The toolkit and database developed in the MAESTRI project will encourage a greater appreciation and retention of the value embedded in waste streams as well as encourage collaboration and exchange between processes, sites, companies and across industrial sectors. Furthermore, the knowledge and insights from new understanding of industrial symbiosis application will be developed to provide a user guide supporting the toolkit and platform.

2.4 IoT Platform

The Internet of Things (IoT), accordingly with the ITU (International Telegraph Union) and IERC (IoT European Research Cluster) definition, is "a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual things have identities, physical attributes and virtual personalities, use intelligent interfaces and are seamlessly integrated into the information network". This definition sounds today much more concrete than few years ago since IoT vision, including research activities and product development, is constantly growing and IoT applications are innovating the way of life and work. The IoT potential benefits are recognized as "unlimited".

Due to the nature of SPIRE programs, the integration of IoT topic is not of course centred in development of ICT specific components, but rather to get the best capabilities and functionalities of this powerful technology in order that processing industries are aligned and benefited with these high-level technologies application and usefulness.

<u>IoT and the Smart Factory</u> - Thanks to the growth of the industrial Internet services, today's production environment is living a new era of innovations and changes that have the potential to bring higher efficiency, flexibility and interoperability among industries, even if belonging to different production ecosystems. A vast number of IoT development already exist in the industry fields, namely for oil and gas level monitoring, automated stock calculation, explosive and hazardous gases detection, machine auto-diagnosis and assets control, etc. The main characteristic of these developments is that are vertically designed, since mainly leveraging on specific technologies to handle specific problems.

Also other systems, SCADA (Supervisory Control and Data Acquisition), MES (Manufacturing execution systems), ERP (Enterprise Resource Planning) and EAI (Enterprise Application Integration), provide limited vision on the status and performance of the production systems from both the economic and environmental perspective. Within the business environment, vertical and horizontal integration is the key condition for seamless information flows from different business units as well as between business partners. Unfortunately, there is still a huge gap to achieve this integration, and the MAESTRI project proposes a vision for filling this gap.

The proposed approach is based on the deeper integration, in the production environment, of the IoT paradigm, envisioning a seamless interconnection of heterogeneous devices, systems and subsystems in order to achieve higher degree of interactions between the shop floor, the legacy management systems and the end users, supporting end-to-end business optimizations addressed by MAESTRI. The full integration of the IoT allows managing assets, optimizing performance, and developing new business models. The IoT is an innovative and important instrument that acts as generic enabler of the hyper-connected factory, to improve energy efficiency and to optimize all kinds of resource management and savings.

For the purpose of MAESTRI project, to assess and improve the overall efficiency and eco-efficiency performance of process industry in an innovative way, (i.e. monitor process data, most of it in continuum, for energy and resource efficiency, eco-efficiency, optimization and for parameters currently not taken into account for plant engineering, process monitoring and to connect to the value chain information with a life-cycle approach), an "open source" platform will be developed.

The LinkSmart Middleware - The MAESTRI project will advance the open source project LinkSmart (LinkSmart® Middleware Platform Portal), an IoT designed middleware that combines a service-oriented architecture, peer to peer networking technologies and semantic Web Services, addressing the resource sharing and the interoperability of available services. This middleware addresses the need of an interoperable platform that facilitates the creation of cost-effective, high-performance cyber-physical systems and Internet of Things applications.

Smart Decision Support - The envisaged MAESTRI platform shall include the device and sensor integration as described before as well as a context and energy efficiency related decision support for industrial workflows.

Platform Modelling Tools - The MAESTRI project aims to create a platform that shall be usable for a variety of businesses (large of small) and as such is based on a middleware that is designed to be a Service Oriented Architecture (SOA) and also support Model Driven Development (MDD). As such, it is necessary to make the tools for the configuration and deployment of the platform to be usable by non-ICT experts as well. Especially the business process based monitoring is an innovative approach that enables the companies to not only look at aggregated numbers but to pick selected process steps and analyse the data in order to identify areas for potential optimization.

Mobile context aware applications - The envisaged MAESTRI platform shall include the device and sensor integration as described before as well as a context and energy efficiency related decision support for industrial workflows. Together with the user-centered requirements engineering results the applications will be tailored specifically to the end users need. An important aspect if the usability and adaptability of the user interfaces.

These vectors of the platform will be developed in order to ensure a scalable and flexible scope of application, namely into three main perspectives:

- **Single companies** – supporting decision making in order to improve the efficiency of any product, process, or service system.
- **Multi-companies** – promoting cross-sectorial interactions by identifying residues/ wastes sources, demands and potential synergies.
- Following a **value chain approach** – promoting an integrated overall resource and energy management system to facilitate information flow among the participating companies (both in material supply chains and equipment supply chains). This will assure a complete overview of the mutually tightly connected stages in a product production chain.

The platform should promote and support the Total Efficiency Framework implementation, encompassing the three above mentioned modules. This will allow better support management decisions within companies (both Large and SME) for improvement actions and also to capital investment on new efficient technologies.

4. Conclusion

The MAESTRI project ambition is to be able to provide a complete framework that allows the analysis of process systems, both in strategic level (high level KPI and management tools, for instance in Management System, Motivation Strategies, Eco-Efficiency assessment for company profile definition in economic, environmental and eco-efficiency, by applying LCA and LCC approaches), but also in operational level (total efficiency assessment, lean improvement and follow-up actions) that can greatly increase the efficiency of processes and reduce wastes and costs (both for energy and resources).

The adoption of an optimization tool, which allows fast generation of optimized scenarios of improvement, is ambitious, but very useful for enterprises (particularly SME), since improvement scenario design optimization can be very time-consuming and unmanageable task a “trial-error basis”. The introduction of innovative mechanisms to acquire information from MAESTRI subcomponents and state of device (inline in the "Internet of Things" trend), to feed data from the pilot demonstrators, together with ERP and MES links, will provide a leap of progress in the way we see management systems for processing industries. The very time consuming process of data collection, even requiring external audits, will be simplified (both for large, but specially for small companies), while allowing a faster assessment in terms of total efficiency analysis, faster decision supported improvement actions and more sustain achievements.

Finally, the ultimate aim of project MAESTRI is to became, with all the integrated methodologies and technologies, a reference inside A.SPIRE by providing extensive gains in resource and energy efficiency, and related costs reductions, thus improving competitiveness and sustainability in European process industry (for large, medium and small companies). The industry transversal mind-set for the construction of the key methods can also allow, by derivation, its application to other sectors and domains of European Industries (such as capital goods, construction, automotive, aeronautical, etc.) what should be also consider an extra ambition for the project towards the increase of European competitiveness and leadership.

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The use of DFSS Tool / Design for Six Sigma in the Innovative Process of New Product Development: A Case Study

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Abstract

The SS methodology is being widely used as a quality management model. Focusing on "Zero Defects" production, the tool that support DNP used in the planning phases, that precede manufacturing is DFSS methodology, suitable for production processes with SS requirement. There is a contradictory question regarding the differences and complementarities between DFSS tool and the SS methodology: to conclude about what is the best strategic decision by two companies, in which one uses the SS and the other uses the DFSS; else more, if it would be a competitor at a higher level with regard to the experience and knowledge, by using both. The case study indicates that given the intrinsic characteristics of the company, common to other Portuguese Small, Medium Enterprises (SMEs), it is clear that the use of DFSS tool turns out to be the most effective, especially when the client is a big company.

Keywords: New products development; Six Sigma (SS); Design for Six Sigma (DFSS).

1. Introduction

Motorola enterprise faced a problem in the past. The company was losing market and needed to find the cause of such problem. Even after testing several tools already used by other companies, still couldn't be competitive enough. However, after several studies, it became possible to confirm that the stock of waste, material, time and manufacturing defects, were generating high costs. Then Bill Smith, a Motorola engineer, in 1986, created the Six Sigma methodology (Suski and Maukiewicz, 2010), which replaced the program TQM (Total Quality Management). This methodology has brought very positive results and after its release, it has been implemented worldwide in many organizations such as: General Electric, Ford, Caterpillar, Microsoft, Raytheon, Siemens, Citybank, and others. The SS methodology has this name because, according to Cone (2001, p.31) the letter sigma is the Greek letter that represents the statistical unit of measurement that defines the standard deviation of a population. It measures the variability or data distribution. The higher the sigma, better are the products produced or services, and from another point of view, the less are the defects presented by these products and services. So with the application of this methodology, it is possible the realization of products and services with only 3.4 defects per million of the units produced.

The SS methodology (Six Sigma) is used for strategic changes. It is an organizational approach to the excellence of performance, the persistent search of perfection to answer the customer needs, decision making driven by data and facts, process improvement, strict alignment of actions with the strategies and the measurement the ultimate impact. (Pande, 2001). In this conditions, the design and develop of new products with this goal of perfection offered by SS philosophy, is essential to its success in the market and for the achievement of its effectiveness (Dias, 2015; p 128.). The DFSS tool is an alternative to this, it is an approach to product development that integrates effective analytical methods, to ensure that the design is: oriented to the customer (voice of customer); innovative; robust against the causes of variation and have a minimum total cost. (Mader, 2003) The approach based on DFSS becomes more suitable to the creation and development new products, services and processes, not so much in the improvement of existing ones, getting this aspect and the curative nature of interventions for the SS (Dias, 2015). In this research directed to the DNP, the right tool for the design phase, is the DFSS and instrumental tools that are DMAVD cycle (Define, Measure, Analyze, Design, Verify), and all that have developed from this one. These cycles represent the various methodological ways through which DFSS theory can be used, and allow each company to follow its methodological approach because each company is unique and has intrinsic characteristics.

2. Six Sigma Production

Since the movement that quality began a few decades ago, many improvement models were created, adapted and applied to processes over the years. Most of them are based on the steps introduced by W. Edwards Deming, the PDCA cycle (Plan, Run, Check, Act) which describes the basic logic process improvement based on data (Fioravanti, 2005).

Motorola developed the MAIC cycle (Measure, Analyze, Improve, Control) as an evolution of the PDCA cycle. Later, this cycle was adopted by the company G.E. which included an initial phase called the letter D in order to recognize the importance of defining a project, calling it the DMAIC (Define, Measure, Analyze, Improve, Control) (Fioravanti, 2005). The DMAIC method became the base of Six Sigma philosophy for business, it is fundamental to its success. It is a revolutionary methodology for the improvement of business processes, which gives improvements in quality and productivity gains due to the reduction of costs. It uses the application of statistical methods to business processes, to eliminate defects. There are several benefits such as operational efficiency increased, costs reduced, quality improved, and customer satisfaction and profitability both increased.

▪2.1 DFSS (Design for Six Sigma) Methodology

According to Treichler et al. (2002), DFSS is a culture change that occurred in the organization design and product development, from deterministic to probabilistic. People are trained to incorporate statistical analysis of failure modes in products and processes. The goal is to incorporate changes which eliminate design features with a statistical probability of failure within a predefined range of conditions and operating systems. According to Dias, (2015), the methodology or methodological tool, DFSS (which integrates DMAVD cycle) is directed to:

- Create new products that motivate the purchase by customers in order to obtain higher profits;
- Detect and prevent the occurrence of failures before they occur in the product (prevent them from occurring during or after the production phase).

There are several tools that can be useful when related to the DFSS and DNP. Between the beginning of the development creative design and creative solution, is expected that it should use some instrumental tools such as: Pugh analysis; DOE (*Design for Excellence*) and/or DFX (*Design of Experiment*). DOE is used to support the planning optimization, implementation and analysis of an experiment in order to obtain solutions to DNP problems. DFX is suitable to quality improvement during the production phase. It is expected the achievement of creative solutions by the creative design, for the respective problems of DNP projects (Dias, 2015). It is possible in the same problem of DNP, associate several tools such as tolerance design that sometimes is use in combination with DFSS and robust design; and the axiomatic design with robust design and both with DFSS.

▪2.2 SS vs. DFSS

The Design for Six Sigma, at first analyze, appears to be an extension of the Six Sigma methodology. It should be noted that this is not a reality. The DFSS and Six Sigma methodologies are independent, however, DFSS has many characteristics that make the Six Sigma methodology known worldwide. Having in account the differences between these two methods, it can be concluded that the DMAIC cycle is used in production processes and services that are in need of significant improvements in its sigma level performance. First of all, it is important to understand which are the parts of the process that are underperforming and must need an improvement, for after applying Six Sigma in these specific parts, the performance in general, improve an satisfactorily way. The application of the DFSS is different. It is applied when is wanted to do a new process. So it is studied and designed (Design for Six Sigma) to start its activities having a Six Sigma level performance. (Dias, 2015).

All the tools that are applied in Six Sigma methodology can also be applied in DFSS methodology, but the opposite is not true, some tools are specific to the DFSS because they are applied specifically to the development of new products (Fioravanti, 2005). Figure 1 shows a diagram that explains the integration of Six Sigma methodology (improvement of product performance and process) and DFSS (design of new products and processes) based on the procedure for design selecting.

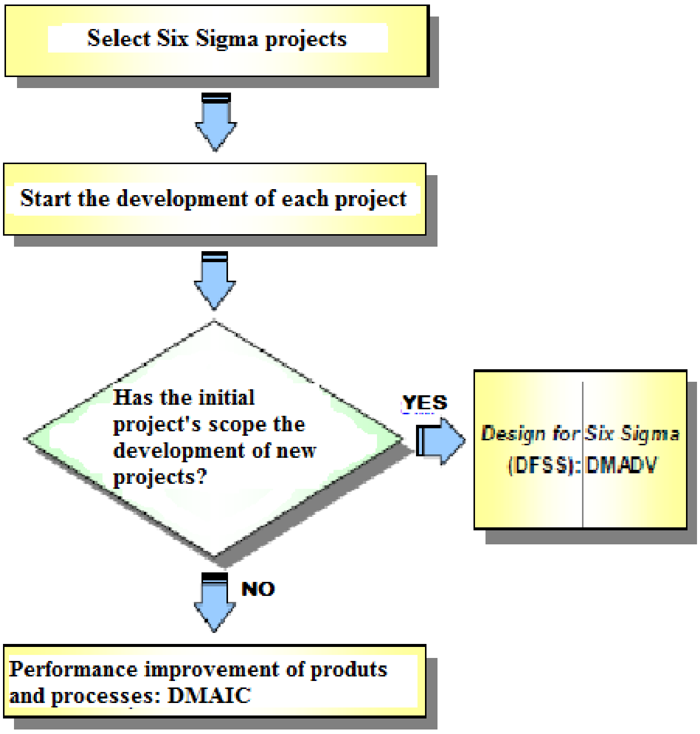

Figure 1. Decision of the best methodology to use, Six Sigma (DMAIC) or DFSS (DMADV). Adapted from FioravantiI (2005)

The approach based on DFSS is suitable to the creation and development of new products, services and processes, not so much to the improvement of ones that already exist, taking this aspect and the curative nature of interventions linked to the SS methodology (Dias, 2015).

Sometimes the best solution isn't start over. Often improve the current situation can be necessary and the best option in financial terms. The development of a new product depends on a several factors like the stage of the current product life cycle, its competitive position in the market, its projection to the following years, etc. So, DFSS and Six Sigma are presented like complementary and independent methodologies (Werkema, 2002). On the other and, Treichler et al. (2002) are stringent in their affirmation that diverges from the above idea exposed by

Werkema (2002), wich Treichler quoted: “The DFSS is a much more effective way in financial terms of obtaining Six Sigma quality levels rather than trying to fix problems after the product finds it’s place in the market”.

As shown in Figure 2, it’s in the DFSS operating area that the costs associated to the correction of non-conformities are lower. However, these non-conformities are harder to detect, which is why it’s necessary to use several analytical tools, in order to anticipate potential anomalies (Dias, 2015).

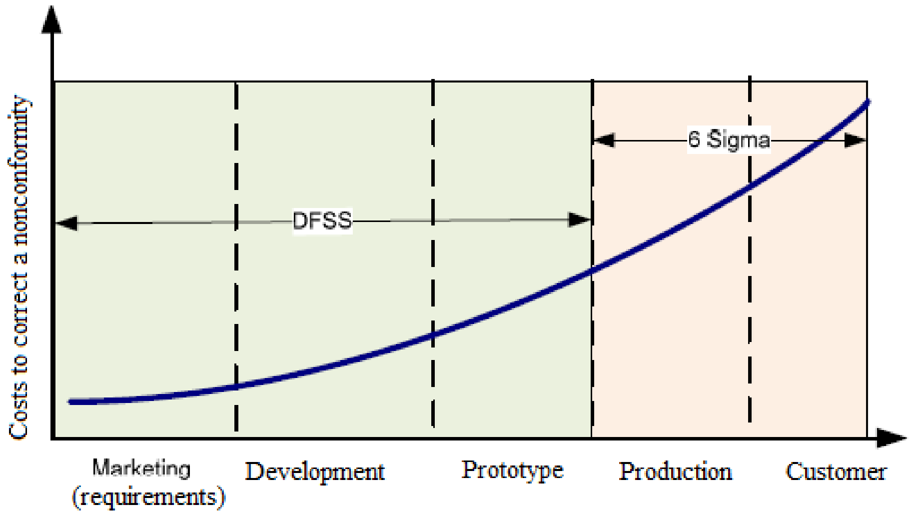

Figure 2. Operating area of the DFSS and SS, concerning the product life cycle. Adapted from Dias, (2015).

Concerning the present investigation focused on DNP innovative process, the most adequate tool to be used in the design phase is DFSS theory and its instrumental tools: the DMAVD cycle and the ones that developed from this. These new cycles, were born, in alternative to the DMAVD, to answer the unique characteristics and special needs of each company, in a way that ensures the creation of an effective and efficient culture to the DNP (Dias, 2015).

3. Case study

▪3.1 Company 1

The following case study, concerns to a company that will be designated from now on as enterprise 1 due to issues concerning confidentiality.

The enterprise 1 is a SME of the industrial maintenance sector. Works for other companies and provides electrical maintenance services, maintenance of rotating and static equipment.

Usually do the replacement, repair or calibration, and especially in rotary do the conditioned maintenance because it has this valence. Concerning the DNA, the company mostly does continuous improvement actions of products that exist, so there is no substantial innovation.

It is a company with about 15 permanent employees and at the work peaks can reach 100. The correspondent in terms of time, to have 40 people working (100 floating employees and 15 permanent ones gives the equivalent of 40 working per day). Only when the company has about 30 or 40 people working permanently, it becomes possible to make a routine that allows applying the DFSS tool. The approximate turnover is about 3 million euros per year.

The enterprise 1 doesn’t have implemented the Six Sigma program, but this program is known by it. It is periodically updated and is certificated by the standards ISO 9001, ISO 14001 and OHSAS (18001).

It doesn't have a quality department but has a responsible person in this area. It is common in SMEs not to have a specific department for quality. The system is structured from bottom to top, it can not be done by the book (implemented from top to bottom), involving the participation of all employees in the implementation of operational and technical procedures. All the basic part of the quality structure is mounted from the participation of all people, therefore the person responsible for the quality, translates what people do in a procedure, so that there is uniformity, where the spirit of the people is evident. This happens in a later stage, when crossing other levels of procedures, in company's senior management or business management, people are prepared to receive training or awareness, because they participated in the bases of the system. Thus, it becomes easier to judge the introduction of a given system. One of the people interviewed, Eduardo Dias Lopes, quoted: "When you want to apply something that was previously done to someone who has an education or more basic training, this only brings waste time for the person, rest or nap and isn't useful for nothing."

Enterprise 1 has used the DFSS tool and recognizes that it would be beneficial to use more this tool, although it is not possible to do in a permanently way. The major problem of the company, which is common to most portuguese SMEs, is the reduced number of employees and the lack of technical qualifications, so it is difficult to make this implementation. In a theoretical and organizational point of view, the use of DFSS tool would be important to the companies, but as they are "crushed" by the market, they focus on meet established plans. Often quality programs are introduced in order to release the pressure imposed by customers. Sometimes, companies are required to present the security and environment procedures that must be in accordance with the large company for which they work, whether the operating place is or where large companies operate. There is a wide variety of mechanical equipment, because of that, the company is being restricted to implement DFSS tool.

In enterprise 1 there are situations where it's not necessary to use the DFSS tool like when there is a very specific contract to a particular project, with a specific thing or a simple project. There are two types of SMEs: the companies like enterprise 1 with intensive production and capital-intensive, which produce a large number of units. These companies can apply to DFSS tool, just do not have the technical ability to use the tool when the project has few dimension; and small but technology-based companies with highly qualified people, focused on project development, and these are the companies that are emerging too in Portugal. To implement DFSS system and to involve more qualified people, it's easier for a company like enterprise 1 that has manufacturing units, answer the needs of a large company like Autoeuropa, for example.

According to the interviewed Eduardo Dias Lopes, the costs of using the DFSS tool in a management system should be considered as investments. That will result in efficiency and improving the quality of a production process. As in the area of quality, when it made the implementation of a system, it can first be seen as a cost, but when it's start to find what was the cost of production of a company before and after applying that system, it's found that the company that is organized according to this methodology (six sigma program) starts to produce better, cheaper and with deadlines, which is very important.

When there is a need for training, people take courses that have a short term, in which the person leaves the company, makes the course and is suitable in terms of knowledge to use DFSS tool property. Usually this kind of people must have good knowledge in the quality area as a whole, in order to use DFSS tool. Otherwise, the course will not be worth it. There're two main problems for the companies: one, is the lack of capacity of the managers, and two, the low-skilled people, therefore when there is no organization and people do not have training, companies do not work. First people must be sensibilized and only then can be trained.

Also, according to the interviewed Eduardo Dias Lopes, the DFSS tool forces the company to retain a client, and with this, the company knows that the project will bring profit, usually a margin of 5% or so. The profit on the work that was done is not very high, but can be certain in order to know exactly the margin. There are situations which because of the urgency to perform a job, the work is much better paid, so the margin is higher. The margin variability depends on the urgency of the delivery of the work or service (corresponding to shorter deadlines). The company over the years managed to get better, even lowering the value of the contract. This is possible with the observation, which is a very important factor when working with a large company, see the progress of work, see whether there are delays and try to find a way and tools to produce faster and at lower cost. This process of improvement could be made using the innovation, but this has never been done in the enterprise 1. A large volume (e.g. half a million), can give a margin of 2 to 3 percent to the company, which in the industrial maintenance area, which is very good.

As a conclusive note, after the interview, is concluded that the companies that provide services can be considered as production companies, as enterprise 1. They repetitively do a series of activities and jobs. To use the DFSS methodology tool, the first step is to see, within the company, which is identical and different in order to arrange like the methodology asks. The essential is the dimension. It is a concern if the company does not implement ways to work well, according with deadlines and being competitive in market. There were a several improvements over the years in this company, that have been implemented until now, but with these improvements, the margins can be "crushed" because often the large companies, year after year, when jobs are repeated, try to see if it can "squeeze" the kind of service that is done by the SMEs, reducing the cost, the value of the contract and see if they can do the same thing for less money. There are cases where the work that was done ten years ago, nowadays can be made by three quarters of the price. As margins decrease is necessary to look for other ways to overcome this situation, and the solution for a particular job is not the DFSS tool, it should look for another similar that best suits the type of service. As the large diversity of works that are made by the company, it must have a very accurate idea of the company's own value chain to be able to see in whitch situation it can use the DFSS tool.

4. Final Conclusions

It was possible to demonstrate that the application of DFSS, through it's strongly structured methodology, achieves significant gains in terms of the quality of product optimization already in it's development process, to avoid higher costs of further product modifications when it's already in a production phase and answering the consumers needs (voice of costumer).

The enterprise analyzed in the case study uses, punctually, the DFSS tool in order to attend their customer's needs, which in most cases are big named companies that can have the Six Sigma program implemented. The fact that the DFSS and the Six Sigma methodologies are independent, however complementary, makes possible the punctual use of DFSS in some companies, like the one studied. Therefore the DFSS tool presents itself as a good way to help SMEs in order to make these capable of integrating themselves in client companies that present high standard project requirements.

In another point of view, it's possible to a company that uses DFSS in the DNP context, to substantially decrease the costs associated to the product, service or process life cycle, since that DFSS presents a preventive approach that looks for failure occurrence to prevent errors due to these failures. For this reason and for the complexity of some instrumental tools used and its connection, DFSS projects can be time-consuming and of higher risk compared to SS projects, which are contemplated in the production phase in course. This being the only disadvantage associated with the use of DFSS.

Lastly, it's possible to assert that the implementation of Six Sigma methodology is a benefit to some companies, although it's not affordable to most of portuguese SMEs given that in Portugal, companies of high technological level and qualification, are increasing. The use of DFSS it's a good alternative to answer the high standard levels of potential clients.

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The use of the theory of inventive problem solving (TRIZ) method in NPD processes: A Case Study

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Abstract

The theory of inventive problem solving or TRIZ is a modern innovative tool used to systematize the creative process decreasing the trial-and-error method. It's based on a large list of innovative principles and solutions that can be applied in new product (or process) development. This paper presents the methodology for the preparation of TRIZ in different fields that this can emerge applying the instrumental tools proposed for three levels of innovation according to Altshuller – the contradictions matrix, the substance - field method (S-Field) and the algorithm of inventive problems solving (ARIZ). This tool is also capable of interact with other innovative procedures like Axiomatic Design, that will be shown in this paper. The Axiomatic Project is a methodological tool that synthesizes tools decomposing in functional requirements and design parameters. For assembling the information is presented a case study of TRIZ application in the Sandometal's organizational process. This case study shows perfectly how TRIZ methodology can be applied and present good results on industrial companies inserted in markets increasingly demanding, dynamic and challenging, as they are nowadays.

Keywords: Axiomatic Design; Case Study; New Product Development; TRIZ.

1. Introduction

The acronym TRIZ origins from the Russian sentence (cyrillic) "Теория решения изобретательских задач" and was adapted to English as the theory of inventive problem solving (Almeida 2008). It was developed by Altshuller (1999) and his team in the USSR from 1946 to 1985 in order to systematize the process of recording and analyzing patents developed until then. More than 3 million patents were analyzed to discover the patterns which provide innovative solutions to distinct problems.

TRIZ is a methodological tool that promotes the systematization of the innovation process and the reduction of trial and error method. The tool is based on the assumption that there are several principles of creativity essential for creative innovations that make the technology evolve. If these principles are identified and codified, they can be taught to employees to make the most predictable creative process (Dias, 2015). The reduced version is:

"Somebody someplace has already solved this problem (or one very similar to it.)
Creativity is now finding that solution and adapting it to this particular problem.

Source: Sreebalaji and Saravanan (2009)

Following this, any incentive problem can be reformulated in a general pattern of TRIZ corresponding to a general solution. This solution is then applied to the specific problem according with the following scheme (Figure 1).

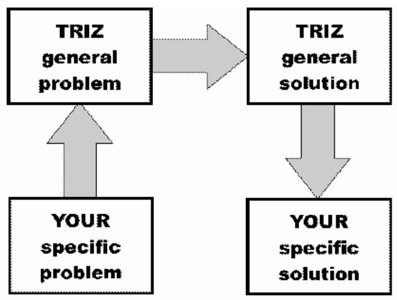

Figure 1 - TRIZ process scheme (Domb and Dettmer, 1999).

According to Carvalho (2004), TRIZ is useful in particular supporting the development of design innovations, products or process engineering or technology even though it´s possible reference other authors who have applied this tool to other areas such as Wang and Chen (2010), Pin et al (2011) and Berdanosov and Redkolis (2011).

In order to make the application of TRIZ, innovation types are divided into 5 different levels (Almeida, 2008):

Level 1. Inventive problems consisting of a simple improvement or a modification of a characteristic of the system without solve any problem. Among patents verified by Altshuller et al. (1999), 32% were of this type;

Level 2. Innovation considered a small improvement which resolves technical contradictions between two product features. Among patents verified by Altshuller et al. (1999), 45% were of this type;

Level 3. Innovation designated as a major improvement or an elimination of a physical contradiction. These level innovations require expertise in various technical and industrial areas proceeding to changes in the physical, chemical and geometric level. Among patents by Altshuller et al. (1999), 18% were of this type;

Level 4. Innovations that require development of new technologies replacing the oldest. It is created an improvement, but not solved by any particular technical problem. Among patents verified by Altshuller et al. (1999), 4% were of this type;

Level 5. Innovation from technical or scientific discoveries. These types of innovations do not come from any inventive problem. Among patents verified by Altshuller et al. (1999), 1% were of this type;

The following graph represents the distribution of patents analyzed by Altshuller (Figure 2)

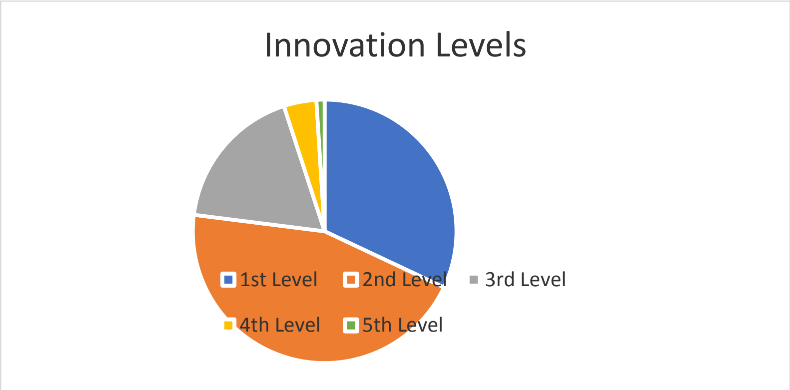

Figure 2 – Analyzed Patents percentage by innovation level.

For each of these levels of innovation, Altshuller (1999) assigned an instrumental tool[1] to support TRIZ such as the matrix of contradictions, the S-Field model and ARIZ model being distributed according to figure 3.

[1] Tool instrument is a type of tool used as support of a methodological tool (Dias, 2015).

1st Level	TRIZ 2nd Level	TRIZ 3rd Level	TRIZ 4th Level	5th Level
Existing Products	Small improvments Contradiction matrix	Major improvement • Contradiction Matrix • S-field	Major improvement • Contradiction Matrix • S-field • ARIZ	New Discoveries

Figure 3 – TRIZ instrumental tools for each innovative level (Dias, 2015).

However, TRIZ tool doesn't only interacts with the instrumental tools proposed by Altshuller. In the doctoral thesis of Dias (2015) it's presented a graph (Figure 4) which was obtained by analysis of 11.671 articles that reported one or more new product development (NPD) tools. In this graph the circles represent the importance of each tool in NPD, since the largest circles correspond to more tools mentioned searched articles. The lines between the circles correspond to the strength of interaction between different tools, methodologies and instruments of NPD, since the variation of lines thickness was provided by the quantity of article with this interaction.

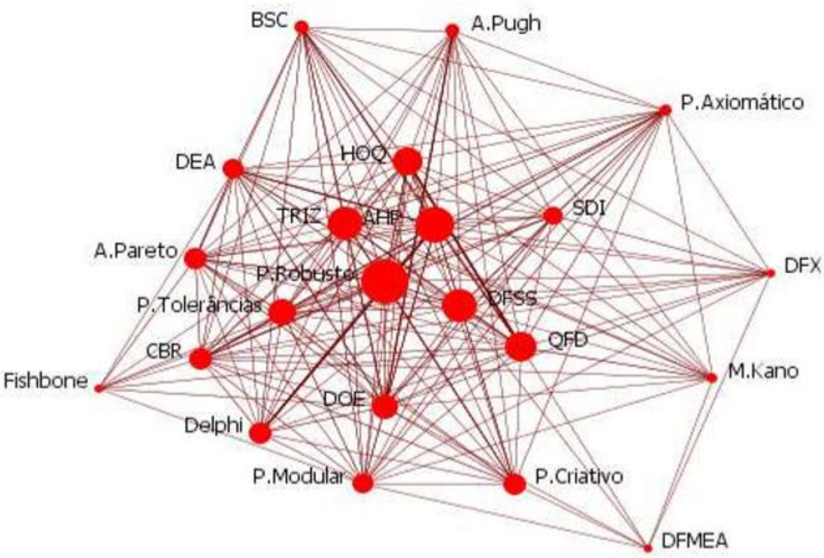

Figure 4 - Graph showing the importance of tools and their inter-relationship in NPD (Dias, 2015).

After analyzing the figure 4 and table used to perform the same (Dias, 2015) is found it's possible to confirm that TRIZ inter-relates to various tools, however the most relevant are the creative design, the axiomatic design, quality function development (QFD) and Kano's model.

2. TRIZ instrumental tools

According to what was mentioned above, there are three instrumental tools proposed by Altshuller et al. (1999) - The matrix of contradictions, the S-Field model and the ARIZ model.

2.1 Contradiction matrix

The contradiction matrix is mainly applied to first level innovations, simple improvements, however, is likely to be applied to innovations in second and third level.

The contradiction matrix is presented as a tool that sets out the indicated inventive principles (Table 1) for each of the contradictions formed by 39 engineering parameters (Table 2).

Table 1 – 40 principles of innovation (Altshuller, 1999).

1. Segmentation	11. Be prepared, Cushion in advance	21. Rushing Through	31. Porous Material
2. Extraction	12. Equipontentiality	22. Convert Harm into Benefit	32. Color Changes
3. Local Quality	13. Reverse (The Other Way Round)	23. Feedback	33. Homogeneity
4. Asymmetry	14. Spheroidality	24. Mediator	34. Rejecting and Regeneration
5. Merging (Consolidation)	15. Dynamicity	25. Self-Service	35. Transform the physical/chemical properties
6. Universality	16. Partial or Excessive Action	26. Copying	36. Phase Transition
7. Nesting (Nested Doll)	17. Another Dimension (Transition to New Dimension)	27. Dispose (Cheap Short-living Objects)	37. Thermal Expansion
8. Counterweight	18. Mechanical Vibration	28. Replace a Mechanical System	38. Accelerated Oxidation
9. Prior Counteraction	19. Periodic Action	29. Pneumatic or Hydraulic Construction	39. Inert Environment
10. Prior Action	20. Continuity of Useful Action	30. Flexible Shells and Thin Films	40. Composite Materials

Table 2 – 39 engineer parameters (Hsieh and Chen, 2010).

1. Weight of moving object	11. Tension, pressure	25. Waste of time
2. Weight of nonmoving object	12. Shape	26. Amount of substance
3. Length of moving object	13. Stability of object	27. Reliability
4.Length of nonmoving object	14. Strength	28. Accuracy of measurement
5. Area of moving object	15. Durability of moving object	29. Accuracy of manufacturing
6. Area of nonmoving object	16. Durability of nonmoving object	30. Harmful factors acting on object
7. Volume of moving object	17. Temperature	31. Harmful side effects
8. Volume of nonmoving object	18. Brightness	32. Manufacturability
9. Speed	19. Energy spent by moving object	33. Convenience of use
10. Force	20. Energy spent by nonmoving object	34. Reparability
	21. Power	35. Adaptability
	22. Waste of energy	36. Complexity of device
	23. Waste of substance	37. Complexity of control
	24.Loss of information	38. Level of automation
		39. Productivity

In order to use this tool it is necessary to start by generalizing the inventive problem and determinate which intended improvement parameter and consequent damaged parameter.

Subsequently should be consulted the contradiction matrix where the columns represent damaged parameters and the lines represent improved parameter. Table 3 demonstrates a piece of matrix contradiction.

Table 3 – Contradiction matrix (Robles et al., 2009).

Improved Parameter	Damaged Parameter									
	1	2	3	4	5	6	7	8	9	10
1			15, 8 19, 34		29, 17 38, 34		29, 2 40, 28		2, 8, 15, 38	8, 10, 18, 37
2				10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2		8, 10, 19, 35
3	8, 15, 29, 34				15, 17, 4		7, 17, 4, 35		13, 4, 8	17, 10, 4
4		35, 28, 40, 29				17, 7, 10, 40		35, 8, 2,14		28, 10
5	2, 17, 29, 4		14, 15, 18, 4				7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2
6		30, 2, 14, 18		26, 7, 9, 39						1, 18, 35, 36
7	2, 26, 29, 40		1, 7, 4, 35		1, 7, 4, 17				29, 4, 38, 34	15, 35, 36, 37
8		35, 10, 19, 14	19, 14	35, 8, 2, 14						2, 18, 37
9	2, 28, 13, 38		13, 14, 8		29, 30, 34		7, 29, 34			13, 28, 15, 19
10	8, 1, 37, 18	18, 13, 1, 28	17, 19, 9, 36	28, 10	19, 10, 15	1, 18, 36, 37	15, 9, 12, 37	2, 36, 18, 37	13, 28, 15, 12	

Principles to use

2.2 S – Field Method

When it's proposed a kind of innovation corresponding to a major improvement (third level), one of the instrumental tools proposed by Altshuller is the S-Field model, or substance field model. This model explains that all technological systems can be decomposed into a set of subsystems, each one is composed of an object, a tool and a certain function or interaction (Almeida, 2008). The type of function displayed varies with the field in which it is applied. According to Belski and Iouri (2007) the six major fields of interactions are:

Table 4 – Interaction fields of s-field method (Belski and Iouri, 2007).

Fields	Interations including
Mechanic	Gravitation, collisions, friction, vibration, resonance, gas/fluid dynamics, wind, compressing, deformation, etc.
Acoustic	Sound, ultrasound, infrasound, cavitation
Thermic	Heating, cooling, thermal expansion, convection, burning, etc.
Chemical	Reactions, catalysts, polymerization, ph indicators, etc.
Electric	Electrostatic charges, insulators, superconductivity, electric field, ionization, piezo-electrics, etc.
Magnetic	Magnetic fields, induction, electromagnetic waves, optics, etc.

An example (Figure 5) of the application of the substance field model is the application of a nail in a wooden block (Prakasan and Goolya, 2008).

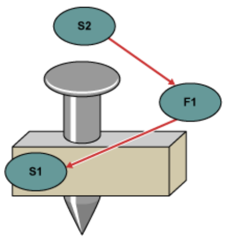

Figure 5– Example of S-field application (Prakasan and Goolya, 2008).

In this example the object is portrayed by wood block (S1), the tool by the nail (S2) and the function in question (F1) is the force required to preach the nail on the block. For this system work correctly it is necessary apply force to the nail (now as object) by the hammer which proves that a system is always subdivided by various sub-systems. The figure 6 represents this great system.

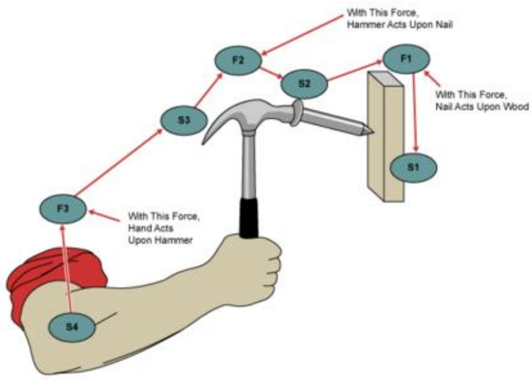

Figure 6 – Expansion of S-field Model (Prakasan and Goolya, 2008).

This expansion is needed to understand all interactions, however is still necessary classify them by different levels as shown in figure 7.

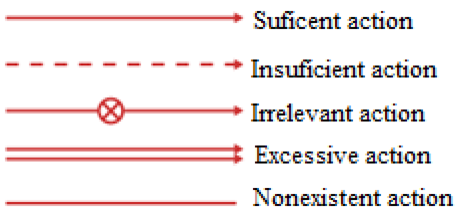

Figure 7 – Relevant interactions (Prakasan and Goolya, 2008).

The final result of the model is shown in figure 8a) in which the arm (S4) apply an excessive force on the hammer, consequentially and applying the Third Newton Law, the nail will in excessive speed and the wooden block will react deforming the screw. It appears then that the power generated by the arm is not sufficient to perform the intended function. The system is in failure (Figure 8b).

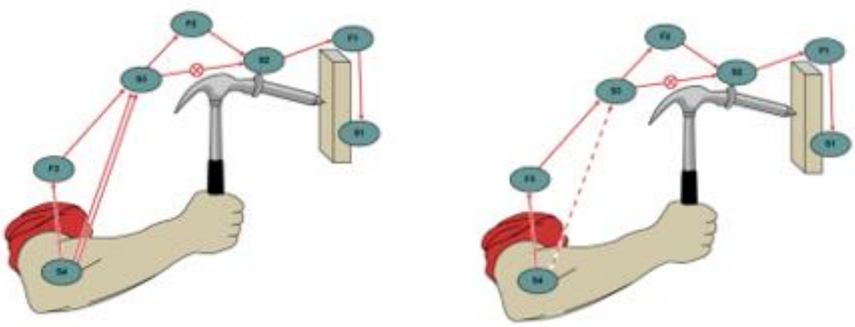

Figure 8 – a) System representation and b) Failure System (Prakasan and Goolya, 2008).

To troubleshoot failures, the sustenance field model presents, according Terninko et al. (1999), 76 standard solutions which should be interpreted and applied to the system failure in study.

2.3 ARIZ

According to Altshuller and his colleagues, the fourth level of innovation corresponding to the new concept completely eliminates the technical and physical contradictions and can be solved by applying the instrumental tool of TRIZ called by ARIZ.

ARIZ is an acronym in Russian for *алгоритмрешенияизобретательскихзадач*, or algorithm of inventive problems solving (Altshuller, 1999). This algorithm is a logical structured process, which evolve incrementally a problem with high complexity to a point at which simplifies to be easier to resolve (Pombo, 2015).

This method was redone countless times presenting different versions. The most recent version contains about 100 distinct steps despite the most widely used version is the 85C (Hanik, 2005) mainly driven by the following steps (Dias, 2015):

"1. Identification and formulation of the problem;

2. S-Field Method Application to the problematic parts of the system;

3. Formulation and definition of the ideal final result (IFR);

4. Listing of resources available at the level of systems, subsystems and supersystems;

5. Resolution of technical or physical contradictions using the principle of contradiction;

6. Generation of possible solutions concepts from the S-Field model;

7. Implementation of solutions simply using available resources in the system in question;

8. Analysis of the system changes to verify weaknesses."

It is necessary to notice that the ARIZ is an incremental and iterative process which may require a review of the initial problem to be able to proceed to the final solution.

3. Iteration of TRIZ with Axiomatic Design

The axiomatic design is a methodological tool of innovative process which is essentially based on the characterization of synthesized tools (Dias, 2015) by iterative decomposition of functional requirements (FR's) and design parameters (DP's) and the connection of this decomposition with the axioms of project.

Two of axioms most used in axiomatic design are independence and information.

In the first axiom, independence, maximum independence is required between RP’s and DP’s. The relationship between the two can be proven using the independence matrix "A" expressed by the equation 1:

$$FR_i = \sum(A_{ij} \times DP_j) \tag{1}$$

The way that the independence matrix displays matches the type of project that is being implemented:

- Diagonal matrix - uncoupled design
- Triangular matrix - semi-coupled design
- Full matrix - coupled design

For the independence of the axiom the ideal is to have an uncoupled or semi-coupled design.

The second axiom information is used an expression in logarithmic form which analyzes the probability of a given FRn be satisfied by the corresponding DPn. The expression has the following form (equation 2):

$$I = -\sum_{i-1}^{n} \log_2 p_i \tag{2}$$

Dias (2015) concludes that "the systems with low probability of success have a high content of information, have high complexity" so "the project information content should be minimized, due to the negative influence.

The axiomatic design has many similarities with the TRIZ innovation tool. Yang and Zhang (2000) present an article with the interaction between these two with a case study using the ampoule sealing process.

The ampoules submitted for studies are designed to: accommodate a drug in the same sealing process is combusted causing the formation of a toxic atmosphere.

To solve this problem was used the tools, axiomatic design and TRIZ. The axiomatic design was characterized as:

- FR1 - sealing of ampoules
- FR2 - the protection of the product during the sealing process
- DP1 - heat transmitted by the flame

In this system that there is only one design parameter for two functional requirements which indicates that the system is coupled - which is not ideal for the independence axiom. A review of the system by adding a DP to match the existing FR number and to annul the effect of the heat produced by the flame was necessary. It was added a water tub to the system to negate the heating effect (DP2).

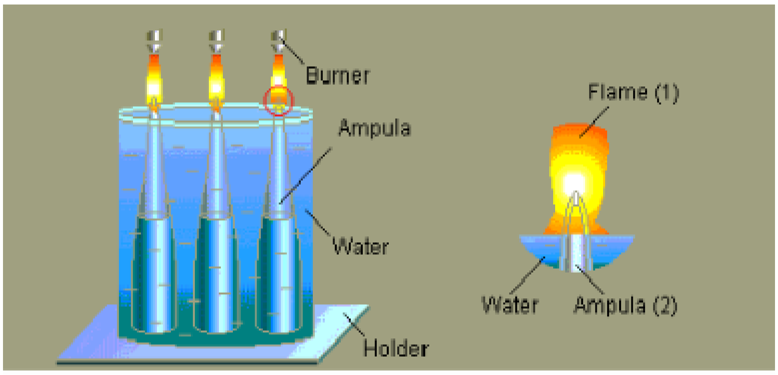

Figure 9 – Sealing ampoules process (Yang and Zhang, 2000).

The problem of the ampoules was easily solved by independence axiom of axiomatic design. When the TRIZ tool checks that the couple system from axiomatic project corresponds to the contradiction of TRIZ, it is necessary to increase the heat to seal the ampoules, but it is also necessary to decrease it to prevent deterioration of the drug.

This contradiction is easily overcome by using innovative principles and concluded that the best solution is the same as that indicated on the axiomatic design.

4. Case Study

According to the statement in the introduction of this paper its present a case study about the application of TRIZ in innovative processes in Sandometal.

In this case the TRIZ was applied due the necessity of improving existing process such as warehouse organization, materials supply, defected and no defected materials and limitations of ERP software (Pombo, 2015).

To solve some of these problems was applied S-Field method and the contradictions matrix.

4.1 S-Field application tool

During the process materials query was verified the following contradictions in software:

- The user limit on the same server was limited to 20 users to work simultaneously;
- The software processing time was quite high and is not practical for tasks such as, for example, stock query.
- Thus it was generated system representation, according to the sustenance tool field (Figure 10).

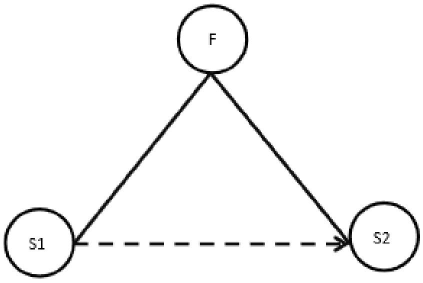

Figure 10 – Inefficient System (Pombo, 2015).

In this representation the substance S1 is the description of the products, the substance S2 is the consulting products and the F field is the storage software data.

Analyzing the representation of the system and checking the 76 standard solutions it was found that to solve the problem in a better way is necessary to replace the S1 enabling to reduce or eliminate inefficiencies. The follow scheme (figure 11) was obtain.

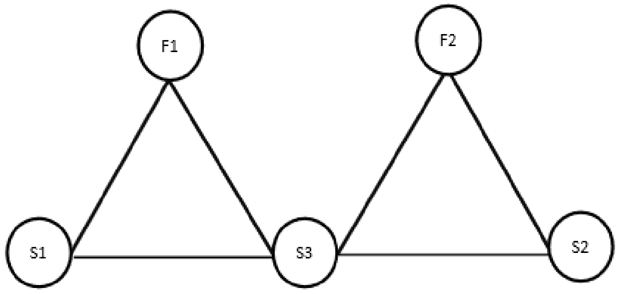

Figure 11– Inefficient System (Pombo, 2015).

The above scheme represents an expansion of the chain system. In this case S1 corresponds to the product definitions, F1 to analysis software, the new substance S3 to a server internally created, the new field F2 to a data base and finally S3 to the intermediate products query on software.

4.2 Contradictions matrix application

As mentioned above, there was a need to improve warehouse organization processes and eliminate stock ruptures combining with the appropriate use of the software. The application of TRIZ would increase the stock control without involve a significant investment leveraging existing resources.

To solve this problem was used the contradictions matrix in which it is intended to achieve an improvement in the loss of information (engineering parameter number 24) and this involves a waste of time (25). The innovative principles obtained were:

- 24. Mediator;
- 26. Copying;

- 28. Replace a mechanical system;
- 32. Color Changes.

Proceeding of these innovative principles, were applied solutions as the introduction of a new intermediary device – an optical scanner bar code - which made connection between the code and the product data base in the computer and the organization of the database in the computer with a color system.

5. Conclusion

This paper provides the importance of this innovation tool and how it is necessary to apply more often these useful tools to improve and develop the creative and innovative methods. The tool gives the advantage to systematize and synthesize methods that normally are seen as abstract and irrational.

Similarly as exemplified in this paper, the TRIZ conjunction with the axiomatic design, also other innovation processes can be combined with this tool, allowing the opening of fields and improving innovation methods.

The analyzed case study presented demonstrate that the application of TRIZ has been quite successful in improving existing processes and the development of new processes, administrative, operational or others despite the main use for new product development.

However, this application requires the implementation of a thought of permanent continuous improvement. This mentality and concept were incorporated into the company implementing new processes as a positive result of this study improving and optimizing those processes generating more income for it.

The application of TRIZ was so cost effective and functional way to the company that it is planed the implementation of this innovation tool in other sectors and departments inside Sandometal.

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Case Studies in TRIZ: A Clothes Horse

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Abstract

People are always busy in working from day to night. They do not have time to do regular work like putting clothes on clothes horse to dry it under sun. If a device can help people dry clothes automatically, it is very useful. In this paper, a climate-controlled clothes horse is introduced. It can automatically dry the clothes when sun is strong, and take clothes in when it is raining. TRIZ tools, including 40 inventive principles and contradiction matrix, help design the device. The product can save people time to let people do some more valuable work.

1. Introduction

People in modern society are always busy in working. Single people especially have no time to take care of themselves, because they usually get up early, and sleep late. Wash clothes is a problem for these people. They go out so early that they cannot put clothes on clothes horses when it is a sunny day. If the weather becomes worse, they cannot pack clothes in time when they are outside. So, this research introduces a clothes horse that can automatically operate according to the state of the weather by TRIZ tools.

2. TRIZ

TRIZ (Theory of Inventive Problem Solving) is a set of tools that originate from study of global patent literature and the identification of the most inventive patents (Altshuller 1984). These tools help people innovate in a systematic way, thus people can conduct innovations more effectively. TRIZ includes man tools such as 40 inventive principles (Altshuller 1997, Domb and Mann 1999, Zhang, et al. 2003) , Su-field

Analysis (Terninko 2000), Substance-Field Models (Haijun 2009, Kim 2012), Ideal Final Result (Mishra 2013).

3. Clothes Horse development process

When applied TRIZ to this inventive process. A problem hierarchy analysis was conducted. Problem hierarchy analysis helps this research clarify which problem needs to be approach. Figure 1 reveals the flowchart of this research. First, problem hierarchy analysis was conducted [Figure 2]. This process is to focus on the problem to be solved. Second a formal problem definition was introduced.

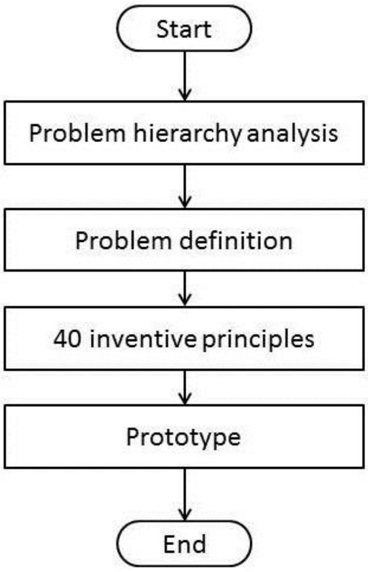

Figure 1 Research flowchart

According Figure 2, the formal definition is to solve the problem that busy people who need to go out early and have not enough money or room to buy a dryer machine. An approaching solution is to design an automatic clothes horse controlled by weather. Surely, there are some other solutions. On the grounds that research teamer's strength is at mechanic and electrical fields. So, an automatic clothes horse is a better choice.

On designing the functional block, sensors of light and rain are introduced in this system. A decode IC to judge the priority of rain and sun is introduced in this system, too. The decode IC is the brain of this system, and it can control activation of the motor to move the clothes horse [Figure 3]. A relay isolates the small current for IC and large current for motor. Water and light sensors control the rotation of motor. With all the functional blocks, the clothes horse can function very well.

On developing the clothes horse, several inventive principles were applied. Table 1 shows these inventive principles and examples. Finally, a prototype was built. The prototype prove that the idea is workable.

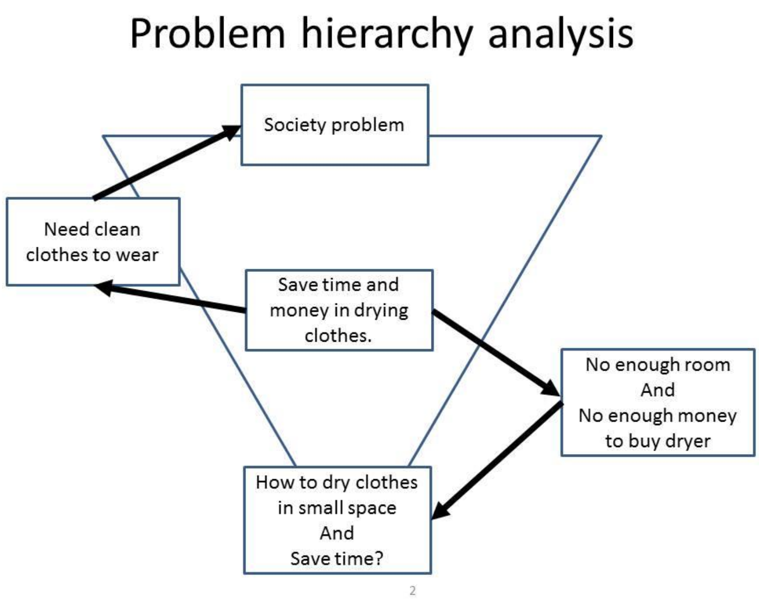

Figure 2 Problem Hierarchy Analysis

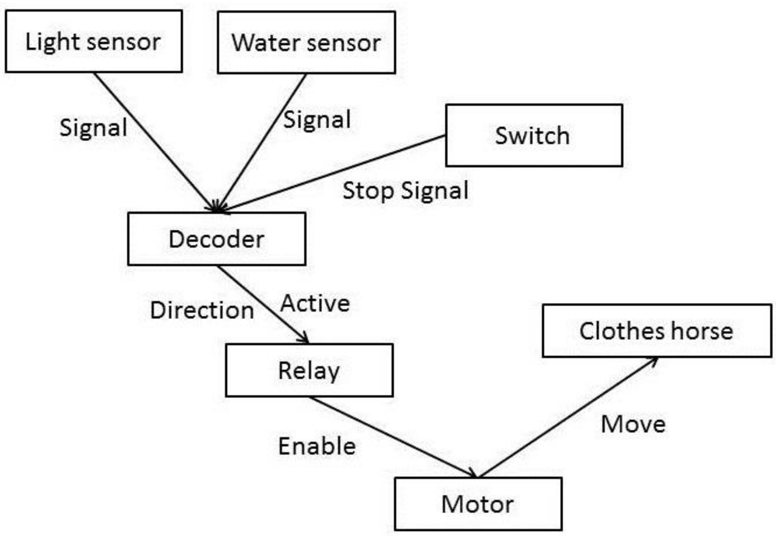

Figure 3 Functional Block

Table 1 Applies 40 Principles

Applied principle	Rule	Example
Principle 5 Merger	A. Bring closer together (or merge) identical or similar objects or operations in space	Combine sensor, clothes horse and remote-control
Principle 13 The Other Way Round	B. Make movable parts (or the external environment) fixed, and fixed parts movable	Move clothes horse in and out
Principle 15 Dynamics	C. Change from immobile to mobile	Move clothes horse
Principle 17 Another dimension	A. Move into an additional dimension - from one to two - from two to three	Move clothes from one-dimension to two
Principle 28 Mechanics substitution	B. Use electric, magnetic and electromagnetic fields to interact with the object	Use sun, water to interactive the clothes horse

Figure 4 shows the prototype of the clothes horse. Its installation is in room, thus can save more space, and is fitted in the apartment. It needs extend out through window in sunny day. Because it is automatic, people can put clothes on the clothes horse and go out to work. After they come back, they can have dry clothes. The clothes horse is controlled by sunshine and rain. If it is a sunny day, the clothes horse can extend out through the window to dry clothes. If is start to rain, the clothes horse can shrink in to avoid clothes being splashed.

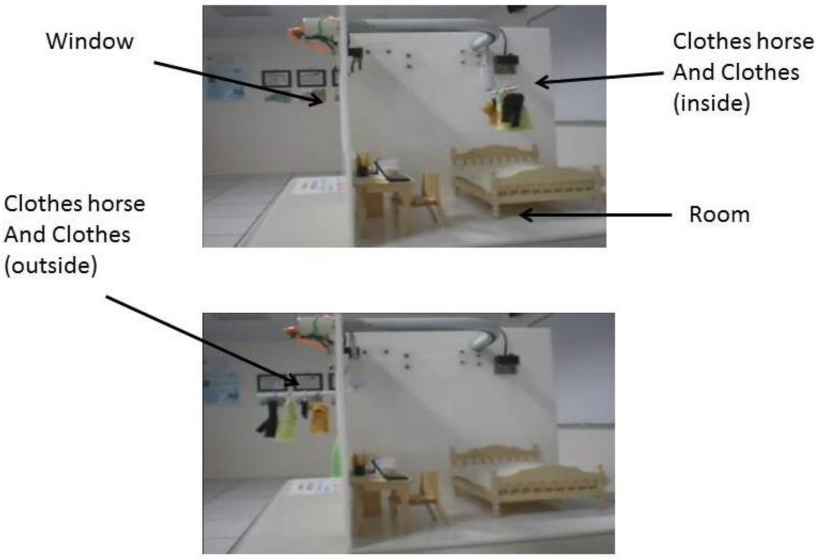

Figure 4 Prototype of clothes horse

4. Conclusion

This clothes horse can help people to dry their clothes, but there is still something to overcome. Price and installation are not discussed in advance. The TRIZ tools help the project very much, and shorten the time of developing. If people are familiar with the TRIZ tools, they can produce more ideal products. Too much elementary are in the clothes horse may cause some problems, and it need a trim to increase its availability.

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TRIZ and MACBETH in Chemical Process Engineering

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Abstract

The Chemical Process Industry (CPI) is facing an increasing pressure to develop new or improved chemical processes. The major challenges experienced by CPI is related with sustainability namely economic, social and environmental issues reason why innovation in chemical process design is becoming more challenging. However innovative chemical process design needs the support of a systematic innovation approach to guide engineers in the creation of new or improved chemical processes. The objective of this work is to present an approach that integrates the theory of inventive problem solving (TRIZ) and a multicriteria decision analysis method MACBETH for the selection of an improved chemical design among different options. The objective is to establish a systematic innovation approach to assist engineers or decision makers through the idea generation with TRIZ theory, and use MACBETH to perform the selection of the best-generated concept. The use of a combine approach in chemical process improvement may increase the efficiency of concept selection avoiding time waste. An illustration is presented in order to show the simplicity and applicability of the approach.

Keywords: Theory of inventive problem-solving (TRIZ), M-MACBETH, innovative process, chemical process engineering, creativity.

1. Introduction

Sustainability has become a key agenda for chemical process industry (CPI) in face of the increasing environmental challenges, growing awareness of social responsibility and shortages of natural resources (Bonini and Görner, 2011). The chemical process industry (CPI) involves the extraction of raw materials such as crude oil, gas and minerals, processes which are highly energy intensive, and also the handling of large volume of toxic, flammable, and hazardous chemicals involving different sectors (e.g. oil/petro-chemicals, bulk/specialty chemicals, pharmaceuticals, and consumer products). The study of sustainability trends in process industries performed by Liew et al. (2014) revealed that the top sustainability issues of chemical process industries are very similar and related to health and safety, human rights, reducing GHG, conserving energy/energy efficiency, and community investment. Innovation in chemical product and process design needs to respond effectively to society's challenges by providing solutions for future generations reason why innovative chemical process design requires the introduction of new methods and tools for generation of technological and organizational solutions. Some of the methods usually applied for creativity enhancement used in chemical industries are brainstorming, brainwriting, lateral thinking, morphological analysis, etc. These methods usually have the ability of identifying or uncovering the problem and its root cause, but lack the capability to actually solve those problems because they do not point clearly to ways of solving problems, or highlight the right solutions (Savransky, 2001). The use of a systematic process for invention, with a logical formal structure covering the different aspects of the systems, will accelerate the problem solving in a creative way and give the confidence that a wide range of possibilities of new solutions have been covered, breaking up the psychological inertia to innovation and inventive problem solving (Gadd, 2011). A systematic process for invention leads to problem solving methods based on logic and data, not intuition, which accelerates the project team's ability to solve problems creatively. The TRIZ theory is based on scientific sound tools that allow the generation of innovative ideas and facilitates the design of new and improved product and processes, no matter the technology field. TRIZ is based on the premise that creativity means finding a standard solution based on the fact that somebody somewhere has already solved the problem or one similar to it, and adapting it to the current problem. The application of TRIZ in chemical process engineering is somewhat recent and the aim of this paper is to present an approach that integrates TRIZ and MACBETH for the selection of an improved chemical design among different options. Section 2 briefly describes what is the theory of TRIZ, the contradiction matrix and its solving process as well as the applications of TRIZ in chemical process industries. Section 3 describe the MACBETH a multiple criteria decision analysis (MCDA) method that allows the evaluation of options against multiple criteria, as well as the main steps of the approach. Section 4 presents the case study, and describes the procedure used to combine TRIZ and MACBETH in order to select the best option. The last section of the paper summarizes the relevant results as well as the main conclusions of the work.

2. What is TRIZ?

2.1 General presentation

TRIZ is the Russian acronym for Teoriya Resheniya Izobreatatelskikh Zadatch and is a systematic process for invention, also called theory of inventive problem solving (TIPS) and was developed in the late 1940s by Genrich Altshuller and his colleagues in the former USSR (Yang and El-Haik, 2009). Genrich Altshuller, a Russian scientist and engineer, studied a large amount of technology patents, and from them drew out certain regularities and basic patterns, which governed the process of solving problems, creating new ideas and innovation. Using the knowledge from the analysis of patents the approach solves technical problems and presents innovative solutions meaning that creativity for innovation may be seen as a structured systematic method. The TRIZ problem solving process is based on five key different fundamental concepts (i.e. ideality, functionality, resource, evolution and contradictions). Based on these key concepts TRIZ developed a system of methods. These concepts are the pillars of a variety of tools used in TRIZ and these elements make TRIZ distinctively different from other innovation and problem solving strategies.

According to TRIZ a challenging problem can be expressed as either a technical contradiction or physical contradiction. A technical contradiction takes place when there are two parameters of the system in conflict, and the improvement in the value of one parameter worsens the value of the other. Technical contradictions are solved by the application of the contradiction matrix, by the identification of the contradictions between the technical parameters (Srinivasan and Kraslawski, 2006). Another kind of contradictions, physical contradictions, takes place when a parameter should simultaneously have two different values occurring when two incompatible requirements refer to the same element of the system. Physical contradictions are removed by applying the four principles of separation, which are separation in space, separation in time, separation within a whole and its parts, as well as separation upon conditions (Orloff, 2006).

When in presence of technical contradictions TRIZ identify, and eliminate them in technical systems instead of trying to find a compromise or making the trade-off between the objectives. In fact, when analysing the vast amount of patents Altshuller detected that the best engineering solutions were obtained by the removal of trade-offs between the objectives. According to TRIZ, a problem is solved if a technical contradiction is recognized and eliminated. The TRIZ approach for problem solving is described in Figure 1.

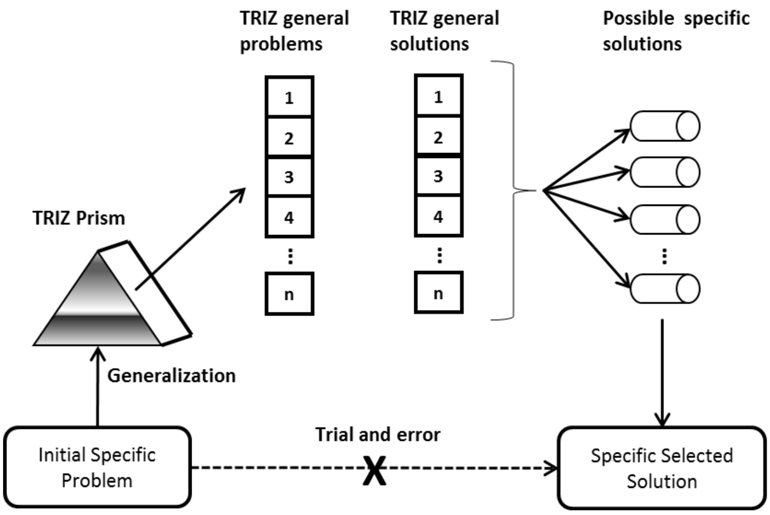

Figure 1. TRIZ approach to problem solving.

The application of the basic principles is made as shown in Fig. 1. The first and main task, step 1 is to identify the specific factual problem, and then step 2 comprises the formulation of the problem in the terms of a technical contradiction that is the basis of the TRIZ contradiction method. Step 3 is devoted to the search for a previously well-solved problem based in the matrix of contradictions.

Altshuller identified 39 technical characteristics, which cause a conflict and named them the 39 engineering parameters. A 39 x 39 matrix is defined by the 39 engineering parameters that shows which of the 40 inventive principles other engineers and scientists have previously successfully used to solve contradictions similar to the ones being analysed. Step 4 consists in looking for parallel general solutions where G.S. Altshuller extracted 40 inventive principles, which are hints to find specific solutions to the technical problem to solve. The solutions to any contradiction are all the ways Altshuller discovered to eliminate technical contradictions. Therefore, based on the TRIZ method, one can easily find a number of potential solutions to the problem (Mann, 2002). Based on the TRIZ general solutions it is possible to envisage different specific solutions in order to pick the right solution to the problem. This is somewhat different from the trial and error procedure usually used by intuitive methods where the searching for problem solutions depends on a large quantity of possible ideas and the quantity of possible ideas the premise for the possibility of finding solutions with good quality.

2.2 Solving Technical Contradictions

The contradiction matrix and the 40 inventive principles offer clues to the solution of the problems. When using the contradiction table and the 40 principles the following simple procedure may be helpful:

1. Set the contradiction to solve;
2. Decide which feature to improve, and use one of the 39 engineering parameters in the contradiction table to standardize or model the feature. To use the table, one must go down the left hand side of the table until identify the standardized property to improve.
3. Then think about the features that degrade or get worse when you try to do this, and find this feature on the X axis.
4. For this two features (or more) identify the inventive principles in the intersection of the row (attributes improved) and column (attribute deteriorated) to resolve the technical contradiction.
5. Traduce the inventive principles into specific solutions, operational solutions that will solve the problem.

The contradiction matrix maps the most promising principles to contradictions in any pair of attributes. A section of the classical contradiction matrix is displayed in figure 2.

Improving Feature \ Worsening Feature		Weight of moving object	Weight of stationary object	Length of moving object	Length of stationary object	Area of moving object	Area of stationary object	Volume of moving object	Volume of stationary object
		1	2	3	4	5	6	7	8
Weight of moving object	1	+		15, 8, 29 ,34		29, 17, 38, 34		29, 2, 40, 28	
Weight of stationary object	2		+		10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2
Length of moving object	3	8, 15, 29, 34		+		15, 17, 4		7, 17, 4, 35	
Length of stationary object	4		**35, 28, 40 ,29**		+		17, 7, 10, 40		35, 8, 2, 14
Area of moving object	5	2, 17, 29, 4		14, 15, 18, 4		+		7, 14, 17, 4	

Figure 2 – Section of a classic contradiction matrix

For example, if one needs a static object to be longer without becoming heavier, this is a contradiction that according to the contradiction matrix can be solved with inventive principles 35 – parameter changes, 28 – mechanics substitution, 40- composite materials and 29-pneumatics and hydraulics.

It is usual to formulate several contradictions for one problem and form a set of recommended principles and use those principles which were identified more than once. The application of a pareto analysis allows the identification of a small number of principles that were recommended more times allowing to separate the vital few from the trivial many. The approach helps to understand and to document the technical contradictions in the system that may be of high importance for problem analysis.

2.3 The application of TRIZ in chemical process industries

The applications of TRIZ are abundant in industry and TRIZ continues to be universal method and used for many different applications (Spreafico and Russo, 2016). Poppe and Gras (2002) highlight that TRIZ is and will be successfully applied in the process industry and that its adoption for solving problems in the process industry would benefit a lot if more case studies would be published. Ferrer et al. (2012) refer that despite significant achievements and several success stories and technological developments in quite a lot of industries TRIZ is still not well established in chemical engineering. Some chemical engineering successfully examples, applied on specific problems of the chemical process industry, include a multi drum filter used in a textile application (Carr, 1999), a novel heat exchanger (Busov et al., 1999) the fluidized bed combustion boiler (Lee et al., 2002), the application of physical-chemical properties of bentonite (Teplitskiy et al., 2005) or the conception and development of a chemical product (Mann, 2005) among others.

Some authors refined the generic principles of TRIZ and enriched them with specific domain knowledge. That is the case of Srinivasan and Kraslawski (2006) who illustrate the application of the modified TRIZ to the design of inherently safer chemical processes. Since the book of Altshuller et al. (1998) with the list of 40 principles with technical examples for an explanation of the 39 engineering parameters, some authors give examples of the principles in various domains. Some authors presented the 40 inventive principles for chemical engineering (e.g. Grierson et al, 2003; Hipple, 2005; Robles et al., 2005) with the main goal of overcoming some difficulties experienced by chemical engineers due to the abstract level of the original inventive principles. Kim et al. (2009) developed a modified method of TRIZ to improve safety in chemical process design justified by the difficulty to access chemical process safety. The topic of innovation is of vital interest for chemical industries not only to improve competitiveness and increase benefits but also to account for the new challenges of sustainable production (Klatt and Marquardt, 2009)

3. MACBETH

Measuring the attractiveness of options by a Category-Based Evaluation Technique is the goal of MACBETH. The key distinction between MACBETH and other Multiple Criteria Decision Analysis (MCDA) methods is that it needs only qualitative judgements about the difference of attractiveness in order to help the decision maker quantify the relative value of the options and to weight the criteria. MACBETH relies on a pairwise comparison questioning mode to compare the options, two at a time, and introduces seven qualitative categories of difference of attractiveness. Is there no difference or is the difference very weak, weak, moderate, strong, very strong, or extreme? The MACBETH value elicitation procedure is comprised of an input stage to elicit a consistent set of qualitative pairwise comparison judgements of difference in attractiveness and an output stage to construct an interval value scale from the set of judgements which numerically measures the relative attractiveness of options (Bana e Costa et al., 2011). When a certain judgement is inconsistent with previous ones, MACBETH detects the problem and gives suggestions to overcome it (for details see Bana e Costa and Vansnick, 1999 and Bana e Costa et al., 2005). The key stages in a multicriteria decision aiding process supported by the MACBETH approach can be grouped in three main phases: structuring, evaluating and recommending. After the identification and clarification of the criteria, i.e. those objectives that will be used to evaluate the options, it is possible to use the MACBETH to appraise the options in terms of difference of attractiveness in each one of the criteria.

MACBETH uses a simple additive aggregation model

$$v(A) = \sum_{i=1}^{n} w_i v_i(A) \tag{1}$$

$$\sum_{i=1}^{n} w_i = 1, w_i > 0$$

With

$$\begin{cases} v_i(good) = 100 \\ v_i(neutral) = 0 \end{cases}$$

where $v(A)$ is the global score of the option A, $v_i(A)$ is the score of the option A according to criterion *i* and w_i (*i=1,2,…, n*) are the weights or scaling constants. Equation (1) allows to obtain the scores of different options by multiplying the scaling constant of each criterion *i* by the value of the option according to the same criterion and summing up all the weighted partial values in order to select the option with higher score. In a multiple criteria evaluation context scoring the options on an interval scale within each criterion is important because it permits one to meaningfully take a weighted average of each option´s scores on the criteria. The weights of the criteria can also be derived applying the MACBETH procedure (Bana e Costa and Vansnick, 1997). M-MACBETH is the multicriteria decision support software that implements the MACBETH approach. The software allows model structuring through a representation module where the criteria are commonly organized in a tree structure normally referred to as a "value tree". It also permits the construction of criteria descriptors, the development of value functions, the weighting of criteria, the scoring of options in relation to criteria, and extensive sensitivity and robustness analysis about the relative and intrinsic value of the options in face of several sources of uncertainties (http://www.m-macbeth.com).

4. Combining TRIZ and MACBETH in systematic innovation

In this work we propose the use of a systematic innovation approach that combines the theory of inventive problem solving (TRIZ) and a multicriteria decision aid method MACBETH for the selection of an option solution among different option concepts. The goal is to highlight the possibilities of the synergy between TRIZ and MACBETH with a mere chemical engineering example. The objective is to convert the chemical engineering problem into a contradiction matrix and solving the contradictions through the TRIZ inventive principles. This might lead to various different options or different specific solutions. In order to evaluate the different options against multiple criteria the MACBETH will be used as a selection method for the specific solutions obtained through the TRIZ approach to problem solving. The combined approach is depicted in figure 3 and includes the following main steps:

Step 1 – Identification of the specific chemical engineering factual problem that is of concern.

Step 2 – Looking at the problem through the TRIZ prism and making the generalization in order to formulate the problem in the terms of a technical contradiction.

Step 3 – Involves the search for previously well-solved problems based in the matrix of contradictions. In this step the general problems are identified as well as the improved features and features that get worse. At the end of this step the contradictions for the problem are identified.

Step 4 – Look for the general solutions based on the 40 inventive principles.

Step 5 – Based on the general solutions some specific solutions are developed (options to evaluate) and after they must be evaluated for the selection of the best specific solution among different specific concepts.

Step 6 – Structuring consists in the identification of the evaluation criteria, used to appraise the options, that usually are represented in a tree structure normally referred to as a "value tree".

Step 7 – Evaluating involves the determination of the criteria weights and the aggregation procedures to use in order to score the options or specific solutions to evaluate.

Step 8 – Recommending is the last step in order to select the best specific solution. It includes the exploration of the model results, analysing the results and performing sensitivity and robustness analysis of the model results.

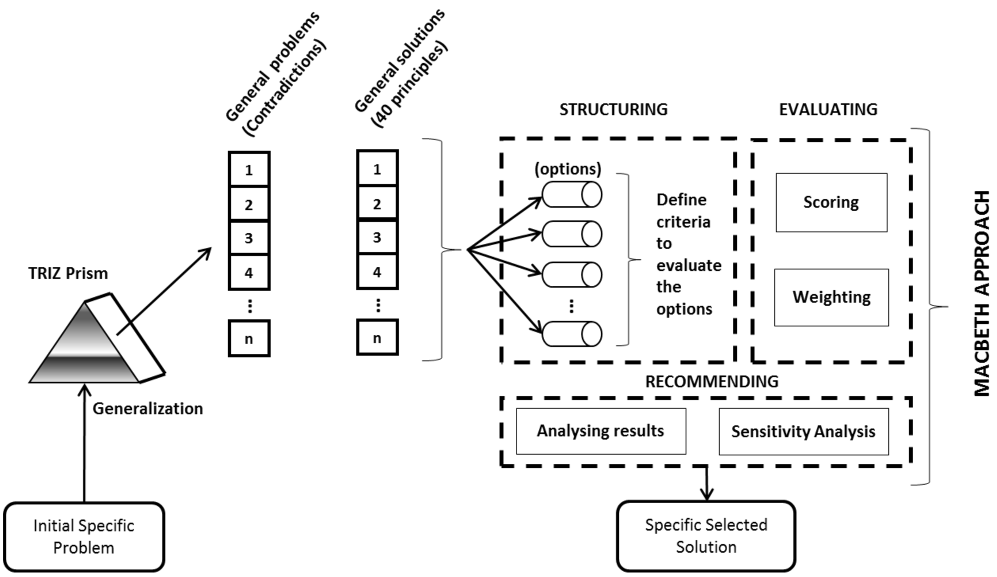

Figure 3 – Framework for combining TRIZ and MACBETH in systematic innovation

5. The case study

Distillation processes involve mass transfer between a liquid phase (or two liquid phases) and a vapour phase flowing in counter current fashion. The vapour and liquid phases are generated by vaporization of a liquid stream and condensing a vapour stream, which in turn requires heating and cooling. Distillation is thus a major user of energy in the process industries and globally. A "simple" distillation column is defined as one in which a single feed is separated into two products, where the column has a single reboiler and a single condenser. A number of operational problems can reduce energy efficiency of a distillation process (Jobson, 2014). In the design of continuous distillation columns one of the things that is crucial for a good operation is the selection of the type of reboiler. During the normal operation of a distillation column, depending of the type of products to evaporate, it is usual to have some type of fouling in the reboiler that can reduce heat transfer rates, increasing steam demand or requiring steam at higher temperatures. A high pressure drop may indicate fouling of the reboiler with an associated increase in heating and cooling duties.

In the design of the reboiler is common to consider some extra heat exchanger area to account for this type of problem, and during the time of operation the amount of steam used to maintain the same rate of boiled products need to be increased. After some point, it is impossible to maintain the rate of boiled products and it is necessary to stop the operation in order to clean the reboiler. One possibility to maintain the column in operation requires backup redundancy in the reboiler, meaning the need to have an identical secondary reboiler to back up the primary unit implying investment costs in a reboiler that usually is out of service.

When choosing the configuration of the reboiler we can start from the simplest and less expensive reboiler, the thermosiphon horizontal reboiler (TSH-Reb), a very common type of reboiler used in refining applications. This reboiler is a horizontal mounted shell and tube exchanger, with the boiling fluid on the shell side. Traditionally the TEMA type X, G or H shells have been used for this purpose. The principal advantages are the multi-pass arrangements for the heating fluid and a differential expansion that can be easily accommodated. Considering a process fluid with propensity to fouling, and having in attention the fact that the process fluid pass in the shell side, the cleaning process will be difficult and the mechanical cleaning can only be done by removing the bundle. This operation can take some time due to the difficulty of the cleaning process.

The problem here consists in finding a solution that allows longer operation of the reboiler, when the process fluid have tendency to form a fouling, maintaining the same rate of boiled products without the need to stop for maintenance.

What is the goal of the system? Increase the time of operation; Improve the ebullition rate; Reduce the number of maintenance stops; and reduce the energy consumption (steam).

There are several degrading parameters associated with each improvement that need to be identified. In the table 1 we present the parameters that degrade (worsening feature) when a parameter (improved feature) is improved, retired from the TRIZ contradiction matrix, and the corresponding inventive principles used to reduce the contradiction. The information was taken from the intersections of the relevant parameters on the contradiction table, the 39x39 matrix of engineering parameters.

Table 1. Resume of the analysis of the TRIZ contradiction matrix.

Improved feature	Worsening Feature	Inventive principles
16. Duration of action by a stationary object	30. Object affected harmful factors	17;1;40;33

22. Loss of energy	6. Area of a stationary object	17;7;30;18
	25. Loss of time	10;18;32;7
25. Loss of time	6. Area of stationary object	10;35;17;4
	19. Use of energy by moving object	35;38;19;18
	22. Loss of energy	10;5;18;32
	27. Reliability	10;30;4
	30. Object affected harmful factors	35;18;34
	31. Object generated harmful factors	35;22;18;39
	33. Ease of operation	4;28;10;34
39. Productivity	6. Area of a stationary object	10;35;17;7
	30. Object affected harmful factors	22;35;13;24
	31. Object generated harmful factors	35;22;18;39

The identification of the contradiction allowed the enumeration of the inventive principles to take into considerations. A tally of the principles suggests looking at those that occur most frequently. The top inventive principles are presented in figure 4.

The analysis of the inventive principles of figure 4 shows that the inventive principle 18 (Mechanical vibration/oscillation) and 35 (Transformation of the physical and chemical states of an object, parameter change, changing properties) have the higher frequency of occurrence (seven times). Principle 10 (Prior action) is chosen six times, the principle 17 (Moving to a new dimension) is mentioned four times while the inventive principles 4 (Asymmetry), 7 (Nesting) and 22 (Convert harm in to benefit) are recommended three times.

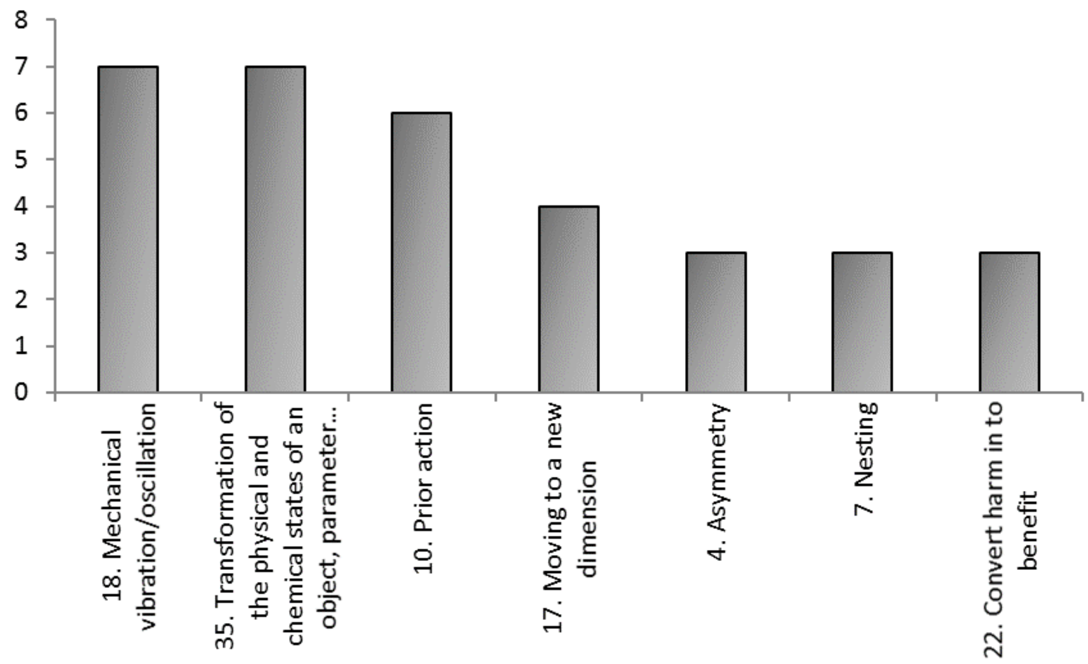

Figure 4 – The frequency of inventive principles recommendations

Based on the general solutions extracted from the list of inventive principles it is possible to identify some specific solutions that improve the performance of a reboiler.

According to the interpretation of the inventive principle 17 – "Moving to a new dimension", one of the solutions pointed out is the tilt or reorientation of the object. That means, if we change from a horizontal thermosiphon reboiler (TSH-Reb) to a vertical thermosiphon reboiler (TSV-Reb) the formation of fouling would be reduced. This transformation also implies that the process fluid pass inside the tubes instead of the shell side to improve the heat transfer coefficients and the speed of the process fluid is increased compared to the horizontal one. This situation implies also a single pass in the tubes that contributes to an easier mechanical cleaning. In a vertical thermosiphon reboiler (TSV-Reb) the mechanical cleaning of the tube side is more easy than the cleaning of the horizontal one.

The inventive principle 18 – "Mechanical vibration/oscillation" suggests the use of a type of dispositive that promotes some type of vibration contributing to the reduction of the fouling formation. In recent years we can find in the literature some devices used in heat exchangers to reduce the formation of fouling (Hasanpour et al., 2014, Sheikholeslami et al., 2015, Zhang et al., 2016). Thus, tube inserts are used to simultaneously carry out two functions: enhancing the turbulence in the throughput flow (increase the Reynold's number), and inhibiting the rate of deposition through mechanical action as well as restricting it to a lower level. This means that the use of tube inserts improves the heat transfer efficiency by cleaning up the existing fouling and avoiding the fouling formation making possible the improvement of heat transfer efficiency. A forced circulation vertical reboiler with inserts (FCVI-reb) is a specific solution that could be obtained making use of the principle 18.

According to the inventive principle 4 – "Asymmetry" the suggestion is transforming the design of the reboiler in a way that the symmetry is changed. Nowadays some reboilers manufacturers (ex. Koch Heat Transfer Company) suggest the use of reboilers with twisted tubes. The twisted tubes reboiler (TTH-reb) is a specific solution that could be obtained making use of principle 4. The special arrangement of this tubes avoid the use of baffles in the shell side. By this way the turbulence of the fluid is maximized in the tube and shell sides, improving the heat transfer coefficients and reducing the fouling formation.

According to the inventive principle 10 – "Prior action" the suggestion is to resolve the cause of the fouling before the reboiler, i.e. before the process fluid enters the distillation column. In some cases, this approach can resolve partially the problem of fouling, but in other cases the fouling formation is directly related to the operating temperature of the reboiler.

After looking for the general solutions based on the 40 inventive principles and having decided on the specific solutions that overcome the problems the next step consists on the evaluation of the solutions and the selection of the best specific solution among different specific concepts. The selection of the solutions can be viewed as a multicriteria decision problem where the options are evaluated against multiple criteria.

The options to evaluate are: the thermosiphon horizontal reboiler (TSH-Reb), the thermosiphon vertical reboiler (TSV-Reb), the forced circulation vertical reboiler with inserts (FCVI-reb) and the twisted tube reboiler (TTH-reb).

The MACBETH socio-technical approach was used in order to evaluate the options against multiple criteria making use of qualitative judgments about the difference of attractiveness between two elements at a time in order to generate numerical scores for the options in each criterion and also to weight the criteria. The process began with the elicitation of the key aspects that the decision maker considered to be the criteria by which the attractiveness of any option should be appraised. A value tree was then created in the M-MACBETH decision support system along with the introduction of the reboiler options into the model, according to figure 5.

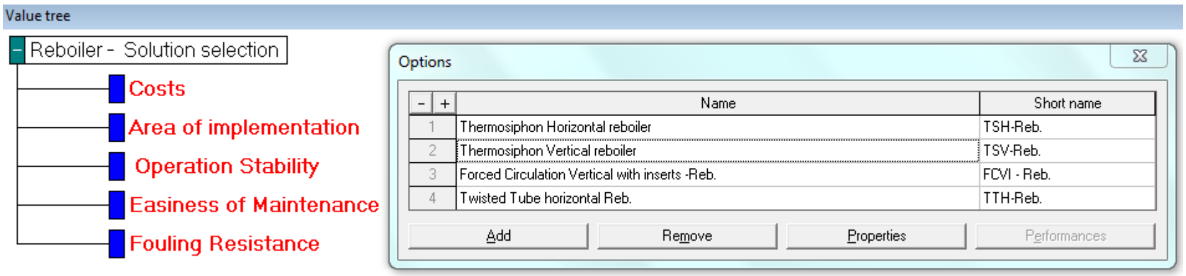

Figure 5 – Value tree and reboiler options

The options were then ranked in order of their attractiveness in terms of costs. Next qualitative judgements regarding the difference of attractiveness between the options were elicited based on the qualitative categories “very weak”, “weak”, “moderate”, “strong”, “very strong” and “extreme” rating. From the completed consistent matrix of judgements MACBETH created a numerical scale (see the matrix of judgements in figure 6)

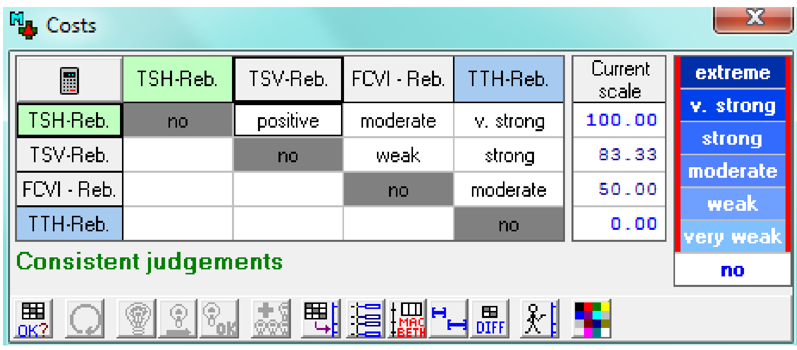

Figure 6 – Matrix of judgements and MACBETH value scale for costs

The process was then repeated to create value scales for the remaining criteria (all of the scores can be found in figure 7). The next step was to weight the criteria in order to allow the calculation, by an additive model, of the overall score for each option. A comprehensive explanation and discussion about the weighting procedure of MACBETH approach is presented in Bana e Costa et al., (2011) and the histogram with the weights of the criteria presented in figure 7. A table with the partial and global scores was then created allowing to see the final results of the model (see figure 7). The most attractive option is the forced circulation vertical reboiler with inserts (FCVI-Reb) given the decision maker´s judgements. The overall scores clearly show that the option twisted tube horizontal reboiler (TTH-Reb) is almost as attractive has the most attractive option.

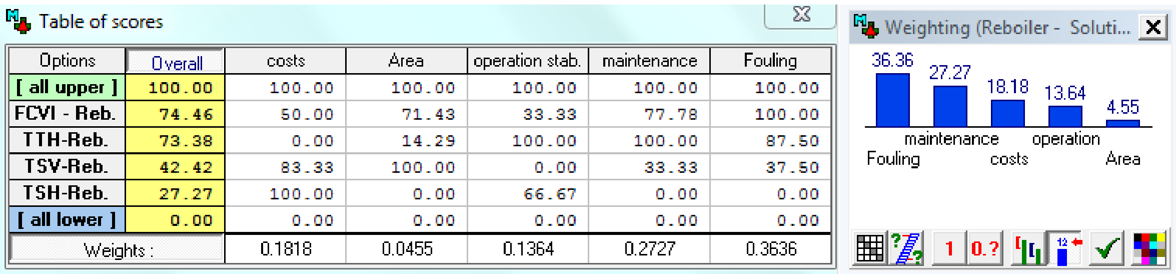

Table of scores

Options	Overall	costs	Area	operation stab.	maintenance	Fouling
[all upper]	100.00	100.00	100.00	100.00	100.00	100.00
FCVI - Reb.	74.46	50.00	71.43	33.33	77.78	100.00
TTH-Reb.	73.38	0.00	14.29	100.00	100.00	87.50
TSV-Reb.	42.42	83.33	100.00	0.00	33.33	37.50
TSH-Reb.	27.27	100.00	0.00	66.67	0.00	0.00
[all lower]	0.00	0.00	0.00	0.00	0.00	0.00
Weights :		0.1818	0.0455	0.1364	0.2727	0.3636

Figure 7 – Table of scores and histogram of criteria weights

The sensitivity analysis on the weight of the criterion fouling (i.e. the criterion with higher weight) shows that if the weight of the criterion fouling goes bellow 30,3% than the option twisted tube horizontal reboiler (TTH-Reb) becomes more attractive than the option forced circulation vertical reboiler with inserts (FCVI-Reb) according to the information displayed in figure 8.

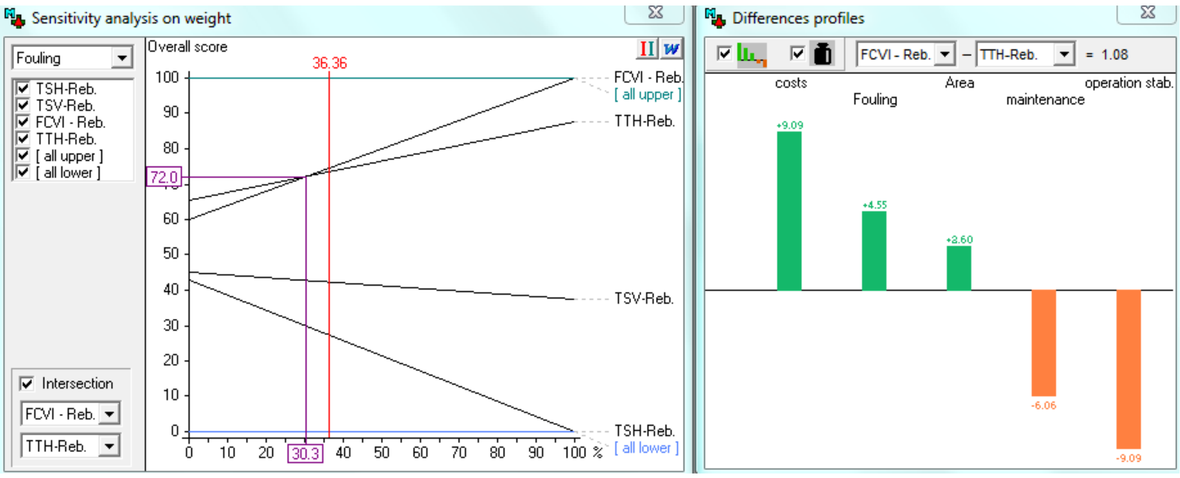

Figure 8 – Sensitivity analysis on weight of criterion fouling and difference profiles of TTH-Reb and FCVI-Reb

Looking at the differences profiles of the options FCVI-Reb and TTH-Reb we can observe that the criteria that punish the option FCVI-Reb is the maintenance and the operation stability while the costs and fouling are the criteria that are in favour of the option FCVI-Reb. The M-MACBETH software allows for numerous sensitivity analysis to be performed. We will not describe them here but for more information about sensitivity and robustness analysis see (Bana e Costa et al., 2012).

6. Conclusions

In order to assist chemical engineers in solving problems effectively a combined strategy using TRIZ and MACBETH was established. The product and process innovation can be achieved in a sound scientific way and the synergies of the combined approach were highlighted with a chemical engineering example. The case study illustrates the effectiveness of MACBETH approach in order to support TRIZ methodology.

TRIZ is very advantageous to promote innovation in a systematic and logic way due to the structured approach but at the same time brings some difficulties due to the abstraction and consequent difficulties in the application. The scheme of TRIZ combined with a multicriteria decision analysis method, such as MACBETH is very useful and can be addressed by engineers as well as researchers interested in creativity research and its practical implementation.

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A Tool to Assign Weights to Customer Requirements in QFD for Service Industries

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Abstract

Nowadays business cannot afford to waste its limited time, human resources, and money on services that customers do not want or need reason why modern quality systems move beyond eliminating poor service to maximize positive quality (e.g. enjoyable, luxurious, comfortable services) creating value. QFD focuses on delivering value by seeking out both spoken and unspoken needs, translating the customer requirements into actionable services and communicating these through the organization. Further, QFD allows customers to prioritize their needs and directs the organization in optimizing those features of the service that will bring the greatest competitive advantage.

The problem of determining the weight of each customer requirement is particularly important in QFD. The traditional QFD methodology evaluates the importance of customer requirements applying methods of direct attribution of weights. Such procedure can become arbitrary in those situations where the customers are not able to give significant evaluation of their requirements and their preference system is not explicitly known. The results of this forcing can lead to a distortion of the design process and the development of products or services that do not match the customer needs and expectations.

We propose a tool that makes use of a modelling approach based on an ordinal regression method with dummy variable regression in order to prioritize customers' needs that overcomes the problems of direct attribution of weights. The method also has the advantage of deriving the customers' requirements weights based on the shape of the value functions. The simplicity of the method as well as its advantages in the determination of the customers´ prioritization of the requirements makes it a good candidate to use in combination with the QFD methodology.

The straightforwardness of the modelling approach as well as the advantages of the method in the assessment of weights to prioritize customer requirements in QFD is pointed out with an example of a service industry.

Keywords: Quality Function Deployment (QFD), ordinal regression, dummy variable regression, customer requirements.

1. Introduction

The industry endeavour for high quality and customer satisfaction must be targeted towards a continuous chain of activities including understanding customers, redesigning or innovating products/services, and improving products/services to fulfil customers' needs delivering products/services that maximize customer satisfaction. Emphasis should be placed in service system design and improvement, in every service quality and satisfaction program. Improvement in service quality and customer satisfaction will occur once the obtained information is successfully incorporated into redesigned services and subsequent service deliveries (Jeong and Ho, 1998).

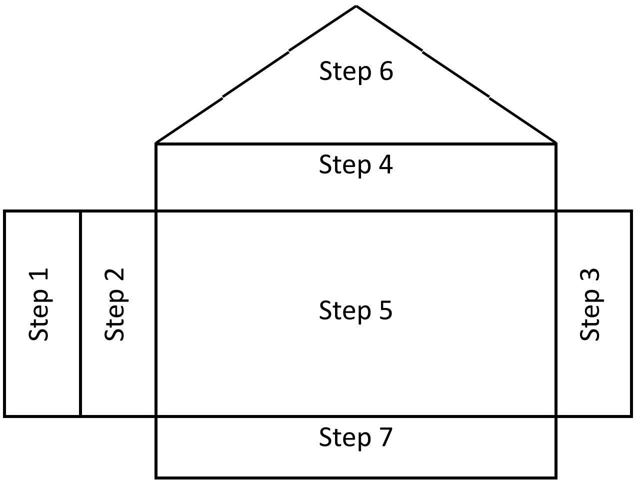
To satisfy customers, we must understand how meeting their requirements affect satisfaction. Quality function deployment (QFD) is oriented to the voice of the customer (VOC) and not to the "thoughts of the developer". With the focus on the customer, all decisions made during the service design and development are targeted at the customer, through collecting and analysing the voice of the customer, to develop products and services with higher quality in order to meet or surpass customers' needs. Quality function deployment has gained a widespread support as a powerful technique to increase customer satisfaction (Matzler and Hinterhuber, 1998; Franceschini, 2001).

QFD started more than forty years ago in Japan as a quality system dedicated on delivering products aimed to satisfy customers. Dr. Mizuno and Dr. Akao and other quality experts in Japan established the tools and techniques of QFD and organized them into a comprehensive system to assure quality and customer satisfaction in products (Kogure and Akao, 1983; Akao, 1997; Akao, 1990).

A well-designed QFD approach is able to link customer requirements, product specifications, target values and competitive performance into a visual planning matrix. In the QFD approach a matrix called house of quality (HOQ) (Hauser and Clausing, 1988) is used to display the relationships between the voice of the customers and the technical characteristics (Chuang, 2001; Chan and Wu, 2002). The HOQ is developed during the QFD process and guide the detailed decisions that must be made throughout the product development process (Cohen, 1995). Quality management and product development and improvement are achieved in QFD through customer needs analysis that, in fact, is always the very first step of a QFD process and thus an important functional field of QFD (Chan and Wu, 2002).

The QFD was firstly used for tangible products but its ideas are by no means of doubt applicable to services. QFD was progressively introduced into the service sector to develop and improve quality services (e.g., Chang and Lin, 1991; Ermer and Kniper, 1998; Harvey, 1998; Kaneko, 1991; Natarajan et al., 1999; Partovi, 2001; Stuart and Tax, 1996; Park et al., 2014; Murali et al., 2016). Chan and Wu (2002) present an extensive literature review of quality function deployment. The great diffusion of QFD is illustrated by thousands of publications with several fields of application (e.g. product and service development, quality management, customer needs analysis, planning, decision-making, engineering, teamwork) showing that there is no definite boundary for the potentials fields of QFD application (Sharma et al., 2008).

The HOQ is central in the QFD system (Hauser and Clausing, 1988) and the foundation of the HOQ is the belief that the products and services should be designed to reflect customers' needs and preferences. As shown in figure 1 seven steps are required to build a typical traditional HOQ.



Step 1 – Customer Needs (WHATs)
Step 2 – Prioritization of customer Needs
Step 3 – Customer competitive assessment
Step 4 – Technical requirements (HOWs)
Step 5 – Relationship matrix (WHATs vs. HOWs)
Step 6 – Correlation matrix (HOWs vs. HOWs)
Step 7 – Technical competitive assessment

Figure 1. Main steps of the product planning HOQ in QFD System

These main steps of the product planning house of quality are described in detail in the literature (e.g.: Franceschini, 2001; ReVelle et al., 1998). Mainly significant are those steps related to the voice of the customer collection and analysis. The first step concerns the voice of the customer (VOC) gathering and exploration, mainly through interviews and questionnaires, and data analysis.

The main purpose of this article is to highlight the issue of customers´ prioritization requirements, i.e. step 2 according to figure 1, within the context of a service industry and recommend a modelling approach making use of an ordinal regression method in order to prioritize customers' requirements (i.e. determination of customers´ requirements weights). The mathematical tool was developed with the purpose of measuring customer satisfaction in circumstances where ordinal measurement scales are used (João, 2009; João et al., 2010) and is suitable to use in step 2 of the service planning HOQ construction process.

2. Customer Requirements Prioritization in QFD

The prioritization of customer requirements (CR) is a very important step that has impact in the next steps of the planning matrix and should be performed according to the customer system of preferences. It is essential to assess the relative weights of the requirements based on the customers´ evaluation of the provided service to be unequivocally certain that it is the customers´ voice and not the designers´ direct experience that are reflecting the weights.

There are many approaches for prioritizing the customers´ requirements in the product planning matrix. The QFD methodology usually solves the issue of assigning degrees of priority to customer requirements by ranking them according to a scale from 1 for a requisite of negligible importance to 5 for an indispensable requisite or with a scale going from 1 to 10 (e.g. Griffin and Hauser, 1993). A usual method consists of directly evaluating the importance of a list of customer requirements or criteria under evaluation, asking customers to express the importance they think they ought to assign to each element, by filling in a questionnaire. It usually comprises the use of some qualitative evaluation scales, which terms used, can be changed according to the type of information expected from the customer or according to how the questions are stated. Since this type of qualitative response scale is ordinal it only allows comparisons like "x is more important than y" but unfortunately a typical abuse is to promote this type of scale to an interval or even a ratio scale. Franceschini et al. (2015) refer that the abuse in customer requirements prioritization in the HOQ is implicitly committed when aggregating preference judgements through their arithmetic average. The arithmetic average, a central tendency measure, should be applied only to variables defined on scales which take into account the "distance" between the objects represented.

Another problem of the direct evaluation of importance is related with the natural tendency to record high importance ratings for all the requisites when the importance of a requisite is explicitly asked. (Deng, 2007; Abalo et al., 2007). This creates a problem because one of the first steps should be to identify the most salient criteria of a product or service.

Applying methods of direct attribution of weights also constitutes a classical problem in the field of decision analysis, known as "*the most common critical mistake*" (Keeney, 2002). For instance, a customer might state that "a requisite x is three times as important as requisite y" but while the sentiment of this statement may make sense, it is useless for understanding values or for building a model of values. Such procedure can become arbitrary in those situations where the customers are not able to give significant evaluation of their requirements and their preference system is not explicitly known. The results of this forcing can lead to a distortion of the design process and the development of products or services that do not match the customer needs and expectations.

Some authors use techniques that integrate Kano model in the QFD environment requiring relatively complex questionnaires to classify the criteria into several categories but the method has also been subject of criticism (Sanchez et al., 1993). Some authors point out the arbitrariness of the weights for the qualitative Kano categories (i.e., basic or must-be (B), one dimensional (O), attractive (A), indifferent (I), reverse (R), and questionable (Q) (Franceschini and Maisano, 2015).

Many authors have suggested the use of Analytical Hierarchy Process (AHP) in combination with QFD in order to prioritize the customer requirements (Akao, 1990; Kwong and Bai, 2003; Aswad, 1989; Li et al., 2009). Techniques based on AHP and also on Analytical Network Process (ANP) require customers´ requirements judgements in the form of paired comparisons assuming a ratio scale (Karsak et al., 2002; Lee et al., 2008). First of all, the respondents may find it difficult to express their judgements using such complex questioning procedure. AHP has also been criticized in decision analysis literature from several other perspectives (Smith and von Winterfeldt, 2004; Belton and Stewart, 2002; Bana e Costa and Vansnick, 2008). The information obtained from the weights assigned to the requirements, or criteria, serves to aggregate the preferences of customers-decision makers, within this context, and must reflect their system of values.

The next section presents a tool that makes use of a modelling approach based on an ordinal regression method with dummy variable regression in order to prioritize customers' needs and overcome the problems of direct attribution of weights. The method also has the advantage of deriving the customers' requirements weights based on the shape of the value functions. The simplicity of the method as well as its advantages in the calculation of the customers´ prioritization of the requirements makes it a good candidate to use in combination with the QFD methodology.

3. A mathematical tool to assign weights to customer requirements

The problem of determining the weights of customers´ requirements can be perceived as a multicriteria evaluation problem. The first step consists in customers´ needs identification followed by a questionnaire based survey method in order to identify the weights (i.e. some needs have higher priorities for customers than others) and managers use these priorities to make decisions that balance the cost of fulfilling a customer need with the desirability (to the customer) of fulfilling that need. Figure 2 presents the schematic representation of the approach to follow, which consists in the identification of customers´ needs (i.e. criteria to evaluate), the questionnaire to infer group decision judgements of satisfaction and determine the criteria weights (i.e. relative importance of customer requirements).

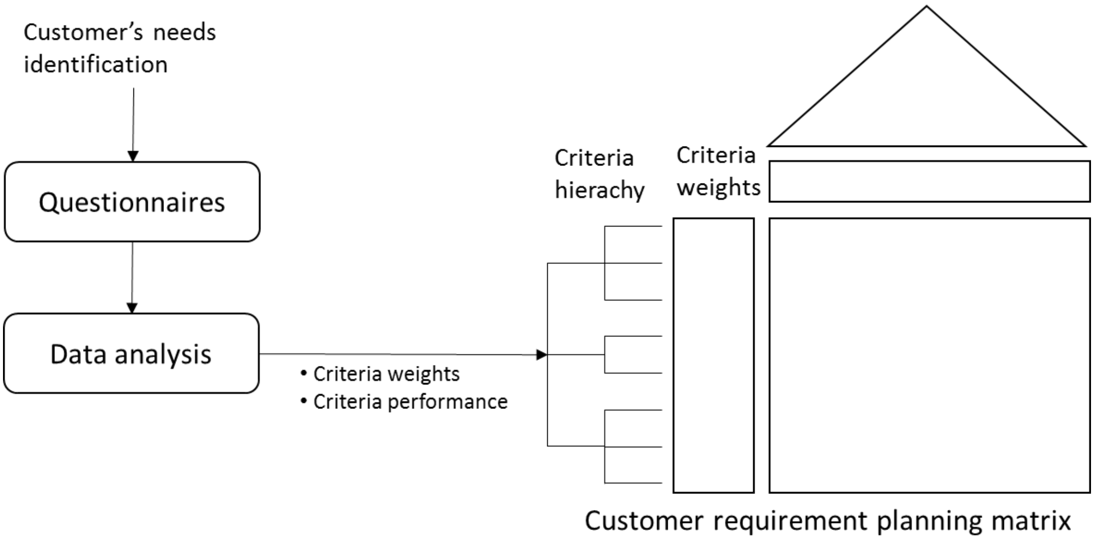


Figure 2. Schematic representation of VOC input into the HOQ

The questionnaire is structured so that each criterion is evaluated with a satisfaction scale ranging from vd (very dissatisfied), to vs (very satisfied), as well as an overall question concerning the global level of satisfaction with the delivered service. The mathematical tool makes use of customer satisfaction questionnaires to collect input data (see figure 3).

Partial questions concerning each evaluation criterion. Please indicate which level better reflects your satisfaction with each criterion by signalling ☒ the appropriate level					
List of criteria to judge the service	vd	d	nd/ns	s	vs
Criterion 1	☐	☐	☐	☐	☐

Criterion 2	☐	☐	☐	☐	☐
…	…	…	…	…	…
Criterion n	☐	☐	☐	☐	☐
Overall question: Globally what is your level of satisfaction with service?	☐	☐	☐	☐	☐

Figure 3. A sample of the customer satisfaction questionnaire.

The mathematical model evaluates the criteria with ordinal satisfaction scales (i.e. overcoming the problem of arbitrarily assume that the words associated to each point of the scale guarantee a scale gradation with constant intervals between adjacent categories). An additive model is used to aggregate the partial evaluations of the customers into a global satisfaction measure making use of a dummy variable ordinal regression approach searching out the value functions and the relative criteria "weights".

The method disaggregates the global satisfaction in a set of partial satisfaction functions concerning each of the criteria under evaluation. The idea is to infer an additive model of customer satisfaction with the criteria under evaluation that is consistent with the overall satisfaction of the customer with the product/ service concept.

In order to measure the customer satisfaction with a product/service as a whole lets' consider the overall satisfaction evaluation of a customer "*a*" by means of an additive aggregation model:

$$V(g(a)) = \sum_{i=1}^{n} v_i(g_i(a)) \tag{1}$$

where,

$V(g(a))$ = value of the overall satisfaction of a customer "*a*" by aggregation of all criteria

$v_i(g_i(a))$ = value of the partial satisfaction of a customer "*a*" concerning criterion *i*

Let´s also consider that $v_i(g_i), i = 1,\ldots,n$ are the partial value functions corresponding to the n criteria, for which we assume increasing monotone functions, as well as $V(g)$ representing the global satisfaction function of the product/service also an increasing monotone function.

The additive aggregation model in its non-normalized form is represented by:

$$V(g)=\sum_{i=1}^{n}v_i(g_i) \tag{2}$$

The essential problem is to estimate the partial value functions corresponding to the criteria $v_i(g_i), i=1,\dots,n$ that best explain the overall satisfaction with the product made by the customers and also the overall value function $V(g)$. The method is based on the premise that respondents assess the satisfaction value of a product/service by combining the separate amounts of satisfaction values provided by each criterion under evaluation and so respondents decompose the overall satisfaction evaluation of the product/service to give the satisfaction value for each level of a criterion composing the product. The objective is to determine the contributions of the various criteria and their respective values to the overall evaluation.

The method allows the estimation of the overall value function $V(g)$ as well as the partial value functions $v_i(g_i), i=1,\dots,n$ for all the n criteria under evaluation.

The set of customers used to estimate the piecewise linear value functions is defined by $A=\{a_j, j=1,2,\dots,m\}$. Each customer $(a_j, j=1,2,\dots,m)$ is asked to express his/her level of satisfaction concerning each criterion under evaluation, $g_i(a_j), i=1,2,\dots,n; j=1,2,\dots,m$ as well as the level of satisfaction with the product/service as a whole $g(a_j), j=1,2,\dots,m$ by answering a customer satisfaction questionnaire with questions concerning to each of the criteria that represent the product/service under evaluation. In order to estimate overall and partial value functions the following regression model is used:

$$\begin{cases} V(g(a_1))=v_1(g_1(a_1))+v_2(g_2(a_1))+\dots+v_n(g_n(a_1))+\varepsilon(a_1) \\ V(g(a_2))=v_1(g_1(a_2))+v_2(g_2(a_2))+\dots+v_n(g_n(a_2))+\varepsilon(a_2) \\ \vdots \\ V(g(a_m))=v_1(g_1(a_m))+v_2(g_2(a_m))+\dots+v_n(g_n(a_m))+\varepsilon(a_m) \end{cases} \tag{3}$$

subject to the following constraints due to the ordinal nature of the satisfaction scales:

$$\begin{aligned} &v_i(g_i^{\alpha+1})-v_i(g_i^{\alpha})\geq 0,\ \ \alpha=0,1,2,\dots,L_i-1 \\ &V(g^{\alpha+1})-V(g^{\alpha})\geq 0,\ \ \alpha=0,1,2,\dots,L-1 \end{aligned} \tag{4}$$

The method to solve the ordinal regression model with constraints is based on dummy variable regression making use of a set of dichotomic variables, usually defined as dummy variables, also designated by binary, instrumental or qualitative variables. The customers´ degree of satisfaction with each criterion and their overall degree of satisfaction measured in ordinal scales are codified with a set of dummy variables.

The dummy variable regression for a customer "a" is represented by:

$$\sum_{i=1}^{n}\sum_{k=0}^{L_i-1} D_{ik} \times X_{ik} - \sum_{k=0}^{L-1} Z_k \times Y_k + \varepsilon(a) = 0 \tag{5}$$

Where D_{ik} and Z_k are the dummy variable regression parameters. Each regression parameter represents the difference of value of a level in relation to the reference level according to:

$$Z_k = V(g^k) - V(g^L),\ k = 0,\ldots,L-1 \tag{6}$$

$$D_{ik} = v(g_i^k) - v(g_i^L),\ k = 0,\ldots,L_i - 1,\ i = 1,2,\ldots,n \tag{7}$$

In order to estimate the regression parameters a least squares procedure is used, with the objective of minimize the sum squares of errors. The final form of the problem is described as follows:

Objective function: $Min \sum_{a_j \in A} \varepsilon(a_j)^2$ (8)

Subject to:

$$\begin{cases} \sum_{i=1}^{n}\sum_{k=0}^{L_i-1} D_{ik} \times X_{ikj} - \sum_{k=0}^{L-1} Z_k \times Y_{kj} + \varepsilon(a_j) = 0,\ with\ j = 1,\ldots,m \\ \sum_{i=1}^{n} \mathrm{D}_{i0} = \text{constant } (<0) \\ \mathrm{D}_{i(L_i-1)} \le 0 \\ D_{ik} \le D_{i(k+1)}, \forall_i,\ with\ k = 0,1,\ldots,L_i - 2 \\ Z_0 = \text{ constant } (<0) \\ Z_{L-1} \le 0 \\ Z_k \le Z_{k+1},\ with\ k = 0,1,\ldots,L-2 \end{cases} \tag{9}$$

The weight of a criterion can be defined as $\left[v_i(g_i^{L_i}) - v_i(g_i^0)\right]$. In order to compare the criteria weights´ it is necessary to normalize the weights of the criteria in order to obtain the relative weight of each criterion:

$$w_i = \frac{v_i(g_i^{L_i}) - v_i(g_i^0)}{\sum_{j=1}^{n}\left[v_j(g_j^{L_j}) - v_j(g_j^0)\right]} \tag{10}$$

The dummy variable regression parameters, Z_k and D_{ik} in global and partial value functions are graphically represented by:

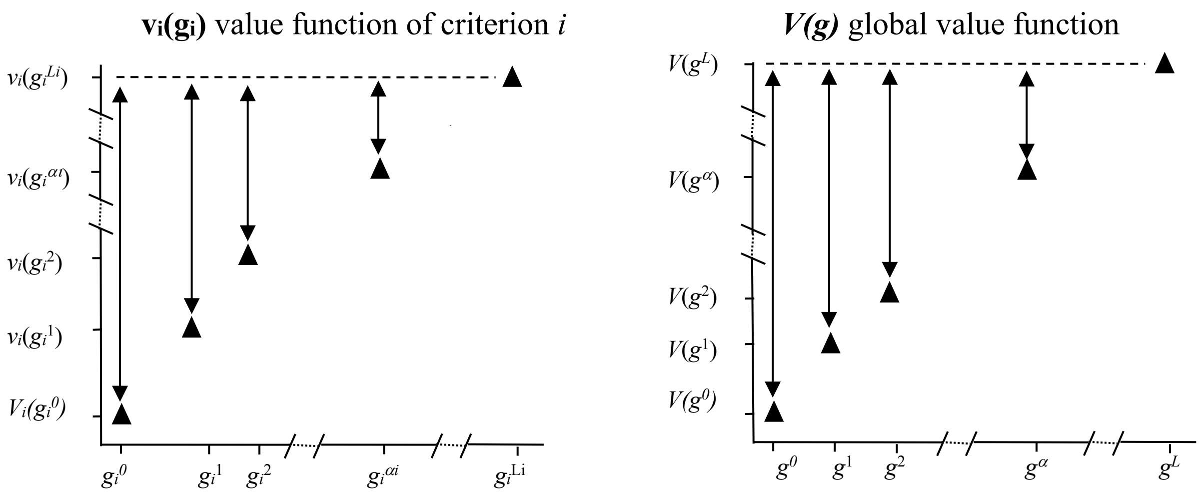


Figure 4. Graphical representation of the dummy variable regression parameters, Z_k and D_{ik} in global and partial value functions

It is also necessary to normalize the partial and global value functions if we want to compare them. The normalized values $\bar{v}_i(g_i^{\alpha_i})$ with $\alpha_i = 0,1,\ldots,L_i$ and $\bar{V}(g^{\alpha})$ with $\alpha = 0,1,\ldots,L$ are calculated as follows:

$$\bar{v}_i(g_i^{\alpha_i}) = \frac{v_i(g_i^{\alpha_i}) - v_i(g_i^0)}{v_i(g_i^{L_i}) - v_i(g_i^0)} \tag{11}$$

$$\bar{V}(g^{\alpha}) = \frac{V(g^{\alpha}) - V(g^0)}{V(g^L) - V(g^0)} \tag{12}$$

According to the normalization procedure the zero value corresponds to the lowest degree of satisfaction, $\bar{v}(g_i^0) = 0$, whereas the value one corresponds to the highest degree of satisfaction

$\bar{v}_i(g_i^{L_i}) = 1$ meaning that the satisfaction functions are normalized in the interval $[0, 1]$ and so the additive aggregation model in its normalized form is the following:

$$\bar{V}(g) = \sum_{i=1}^{n} w_i \bar{v}_i(g_i) \quad (13)$$

In the codification procedure we considered the highest level as the reference level yet we could have considered different schemes of codification as for example differences to the lowest level or differences to an intermediate level considered as the reference level. In order to test if the results depend of the codification procedure different model formulations were tested with real data as presented by João et al. (2010).

4. An Illustrative example

The hospitality industry, hotels included, employs thousands of people and generates high revenues annually in value-added services. Thus, any quality improvement in this industry will have a significant effect on costs and market competitiveness (Oke et al., 2008). In spite of this, the literature regarding the application of the QFD process in hotels, in particular, or the hospitality industry, is limited (Paryani et al., 2010).

A case study was developed focusing on a specific hotel to illustrate the simplicity of the proposed tool that makes use of a modelling approach based on an ordinal regression method with dummy variable regression in order to prioritize customers' needs overcoming the problems of direct attribution of weights.

A sample of a customer satisfaction survey of a Portuguese Hotel&Resort chain (João, 2009) was used as an example to illustrate the approach to the prioritization of customers´ needs in the house of quality matrix. The survey consists of a sample of 1077 answers of customer satisfaction with the service provided by the restaurant of the hotel unit X. The hierarchy of criteria are represented in figure 5.

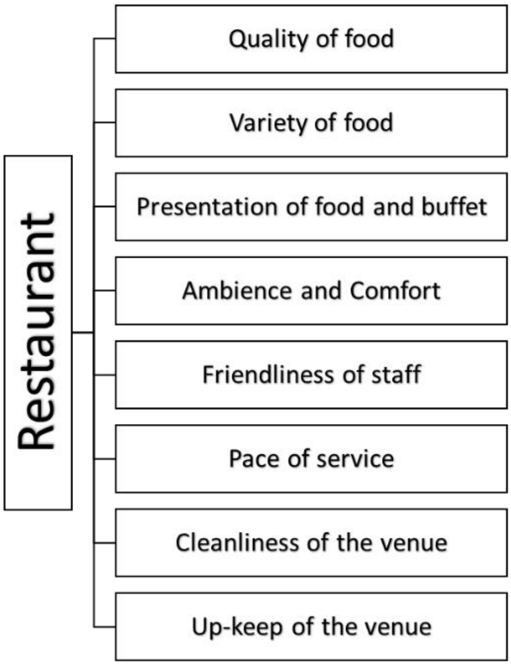


Figure 5. Hierarchy of customer requirements

The customers indicated their level of satisfaction with the criteria described in figure 5 as well as their global satisfaction with the restaurant.

The relative weights of the eight criteria, obtained by equation (10) are represented in figure 6.

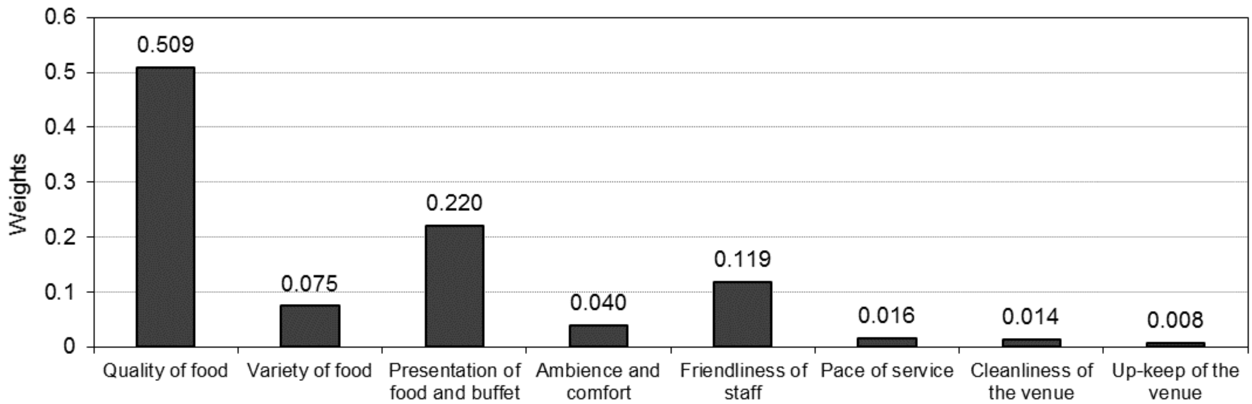


Figure 6. Relative weights of the criteria for the restaurant of the Hotel X

The value functions were estimated according to equations (11) and (12) and are presented in figure 7. The functions are very important because they show the value that the customers attach to each level of the ordinal satisfaction scales.

By combining weights with the average satisfaction obtained with the information provided by the value functions it is possible to develop some action diagrams that can indicate strong and weak points of customer satisfaction and the required improvements to be made. By combining the satisfaction analysis with the criteria weights, the hotel managers also have a strategic tool for identifying those attributes of the service that are most in need for improvement or those that are candidates for possible cost-saving conditions.

According to the shape of the functions is possible to notice which criteria have more than proportional effect on satisfaction, and which criteria are an absolute must in the eyes of the customer. To achieve global customer satisfaction in economic way HOQ users should understand what customers like more and also understand how much attention should be paid to each customer criterion to achieve the desired customer satisfaction level. Looking at the shape of the functions it is possible to see that the criteria have different shapes.

The value functions with a score ranging from 0 to 100, show the real value that the customers give to each level of the ordinal satisfaction scale and from the form of the curve the organization will recognize where to make improvement efforts. The weights assigned to each of the criterion together with the shape of the value functions will be the input information of the VOC to the house of quality.

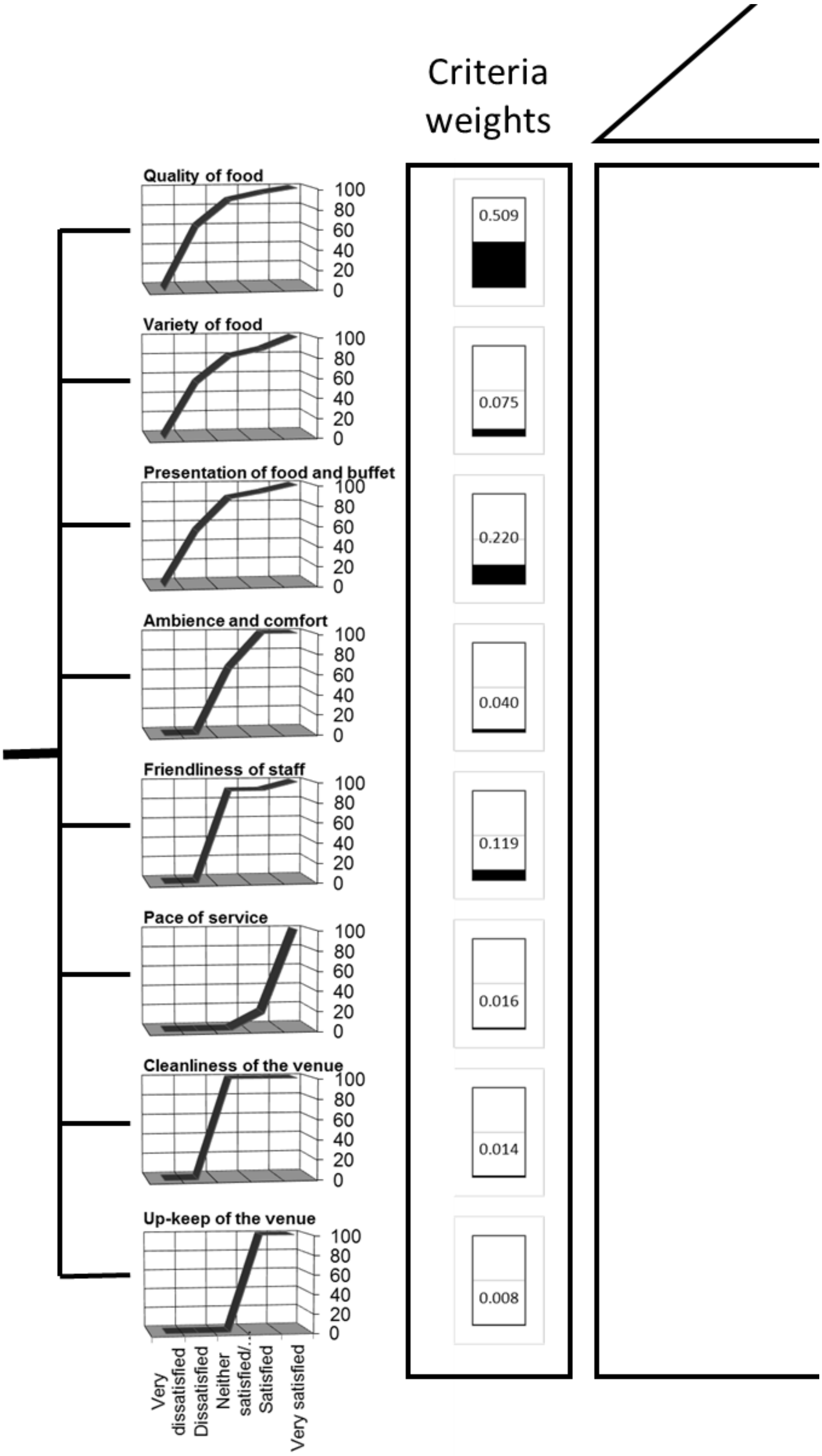


Figure 7. Value functions and relative criteria weights for the restaurant of the Hotel X

5. Conclusions

The tool presented in the paper allows to aggregate the responses of a group of respondents and based on their level of satisfaction with several criteria, determine the criteria weights. Unlike other methods like AHP, ANP or Kano model that require complicated elaborations by the respondents, the proposed method requires simple answers by the respondents having considerable practical advantages over more complicated techniques. The method also has the advantage of deriving the criteria weights based on the shape of the value functions and not by direct attribution of weights where typical abuses (e.g. arbitrary promotion of the scale properties) usually occur. The proposed procedure allows aggregation of the customers´ requirements, generally expressed on ordinal response scales into an interval scale without the abuses of the classical approaches. The simplicity of the method as well as its advantages in the calculation of the customer prioritization of the requirements makes it a good candidate to use in combination with the QFD methodology.

The presented tool represents the first stage related to the VOC in order to deal with ordinal input data in the product planning HOQ. Future research is related to the subsequent steps of the HOQ in order to build a product planning HOQ dealing with ordinal input data without violation of the scale properties. The wok presented concerns only to the prioritization of customer requirements using ordinal input data overcoming the problems of direct attribution of weights.

Future research is needed in order to build a Product Planning HOQ where only ordinal input data is exclusively used (e.g ordinal relationships between WHATs and HOWs, the technical requirements prioritization) without violations of the scale properties concerning the raw data of interest.

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Persistence of innovative activities in the context of a moderate innovator

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Abstract

Innovation is a major determinant of firm performance. The competitive advantage of firms' is strongly connected to their ability to continuously innovate over long periods of time. (Le Bas and Scellato, 2014).

The concept of persistence in innovation is perceived since the early debate on cumulative creation (Schumpeter, 1942). It underlines the influence of past and present innovations on future innovations. There is a positive correlation between past and present innovations which under the correct environment transforms innovation into a routine (Nelson and Winter, 1982).

The analysis of persistence in innovation, his drivers and frameworks can improve the understanding of firm dynamics, anticipate the effects of the different policy actions, correct macroeconomic disequilibria, help in designing the correct policies to boost R&D and consequently generate prosperity.

This paper debates the persistence of innovation using a dynamic panel comprising 1099 firms operating in all economic sectors; firms are observed in three waves of the Portuguese part of the Community Innovation Survey (CIS), covering the time span from 2004 to 2010 (i. e. the CIS 6, the CIS 8 and the CIS 10). Innovation Persistence is analysed using the general concept of having performed any type of innovation during the period and additionally, the concept is broken down into the different types of innovation: product, service, process, organisational and marketing.

The first empirical approach to persistence uses transition probabilities, allowing for a simple understanding of the panel dynamic behaviour in each innovation type as well as the firms' trajectory. This framework depicts the firm behaviour in each period, given its state in the former. The results expressively vary according to the innovation type in analysis, the proportion of firms mentioning the achievement of either product or service innovation is quite small compared to process, organisational or marketing innovations. The last period of observation included in the panel, 2008-2010, non-surprisingly depicts a generalised fall in terms of innovation performance, perhaps caused by the economic crisis, although the difference is emphasised for product or service innovation.

The empirical analysis continues with the construction of two econometric models, using the random effects probit model; Model 1 depicts a general panel and Model 2 differentiates innovative behaviour in a time perspective, in both cases we control for firm-level characteristics and the use of public funds to perform innovative activities. The construction of an alternative model discriminating past innovative behaviour (non-innovative, persistent, new or sporadic) is of particular interest as the persistence hypothesis fails to be corroborated in the general model for most of the innovation types, while the use of innovative behaviour sub-types produces different results.

Former innovation options are in most cases statistically significant in determining present innovative behaviour. The results vary according to the innovation type in analysis, which is of particular interest, as most of the existing studies only consider product innovation, and only a few consider as well organisational and process innovation.

The panel allows analysing persistence of innovation in all economic sectors. Across our models services and industry seem to behave differently towards persistence, this aims at fulfilling some gap as the existing literature mostly provides empirical evidence only for industry.

Persistence of innovation is empirically explored mostly using the case of innovation leaders or followers, which may not apply to countries with poorer performances in terms of innovation. Studying the case of a moderate innovator may shed some light into the different conditions of firms and their attitude towards persistence, as well as the adoption of different policy actions to observe this heterogeneity.

The results sustain the construction of a solid debate in terms of firm strategy in terms of persistency of innovation in the context of a moderate innovator. Moreover, perceived downturn in the innovative performance over time, in line with the results presented for the Portuguese part of the Innobarometer will permit drawing some policy recommendations, and required adjustments in terms of smart policy making.

Keywords: persistence, innovation, community innovation survey

1. Introduction

Several works such as those of Geroski et al. (1997), Dosi (1997), Antonelli (2011), Colombelli and von Tuzelmann (2011) underline the importance of continuity in innovative activities, promotion of R&D, its diffusion, and accumulation processes. Thus, firms are recommended to consistently produce innovative output (Latham and Le Bas, 2006), or to persistently innovate as this determines their competitive advantage

Innovation persistence is defined as the number of consecutive years during which firms report achieving innovative outputs innovate, being the later often measured by patents, R&D outputs or major innovations (Le Bas et al., 2011). Persistence increases the odds of accommodating changes and maintaining the innovative path, it is connected to the innovative behaviour of dynamic firms**,** allowing for the development of competences and resources (Nelson and Winter, 1982, Teece et al., 1997, Latham and Le Bas, 2006, Le Bas and Scellato, 2014).

Geroski et al., (1997) and Dosi (1997) empirically prove continuity, emphasising the role of explicit investment to generate technological and organizational improvements. There might be lock-in effects arising from innovation, which will put the firm in a forefront position to seek new innovations in a continuous path

Persistence is empirically tested in different countries, most notably, the UK (Cefis, 2003; Frenz and Prevezer, 2013); France (Duguet and Monjon, 2004) – France; Duflos (2006) - USA; Peters (2009) – Germany; Raymond et al. (2010) – Netherlands; Antonelli et al. (2012 and 2013) - Italy; Clausen et al. (2013) – Norway; – UK; Le Bas and Poussing (2014) – Luxembourg; Tavassoli and Karlson (2015) – Sweden.

Despite the use of different time periods and empirical methodologies these studies have proved the existence of persistence in innovative activities. Very often, persistence is approached by the report of patents, although, the degree of innovation depends on the indicator that is used (Duguet and Monjon, 2004). Furthermore, recent studies have drawn diverse patterns of persistence combining different types of innovation (e.g. Antonelli et al. 2012, Le Bas and Poussing, 2014).

Stable environments are the underlying condition of empirical papers on persistence. In this context, past actions tend to facilitate subsequent success. However, if market conditions change, firms must redesign their strategy. These models fail to define what to expect.

Pure past or path-dependence is somehow unfeasible (Le Bas and Scellato, 2014), and it will limit the ability to respond to the environmental challenges. Accumulated resources and capabilities will constraint new innovative projects, despite their inadequacy to the new setting, thus, former decisions will stick. Changes in economic or institutional conditions influence the type of profitable innovations. Nonetheless, past innovations may not serve for the present and the innovative strategy will be forced to change.

The exception, with all the differences that may apply, is the study for Argentina (Suárez, 2014). Under this unstable economic environment, the hypothesis of persistence is rejected. Under uncertainty, past-dependence may become worthless as the results of the cumulative process seem inadequate to the altered economic environment causing the disruption of the innovative course. Given the new circumstances, firms rationally consider all the possibilities in terms of (dis) continuity of innovation projects.

Follower countries due to the composition of their industrial structure as well as the nature of their Technological Innovation Systems (TIS) frequently face instability; the conditions arising from the external environment will likely affect their innovative decisions with high importance.

This paper aims at giving the insights of the innovative strategy and the characteristics of the innovation systems to boost the followers' capacity to persistently innovate or to absorb the new technology, creating a favourable environment to become a fast mover and spread the innovations to consolidate new practices.

Empirical evidence will be drawn from the Community Innovation Survey (henceforth CIS), in its different waves. To consider the case of the 2008 crisis a firm panel was constructed comprising data included in CIS6 (2004-2006), CIS8 2006-2008), and in CIS10 (2008-2010).

2. Literature review on persistence of innovative activities in unstable environments

The analysis of the determinants of persistence in innovative activities will allow an understanding of industry dynamics and the monitoring of the effects of the policy actions in terms of the support of R&D and innovative activities.

The effective degree of innovation persistence depends on the indicator considered, when using patents persistence tends to be low, while when considering product or process innovation it is higher (Duguet and Monjon, 2004). Moreover, there are combinations of innovation types which draw different patterns of persistence (Antonelli et al., 2012; Clausen et al. 2013 Le Bas and Poussing, 2014).

The factors affecting persistence can be divided into internal and external. Concerning the first we will consider factors such as the size, success in former R&D activities, availability of internal funds (Cefis and Ciccarelli, 2005; Latham and Le Bas, 2006; Peters, 2009; Clausen and Pohjola, 2013), concerning the second we consider the access to local knowledge stocks (Antonelli et al. 2012).

Le Bas and Scellato (2014) point three complementary frameworks to assess the motivations and spin-offs of persistence, namely; knowledge accumulation, success-breeds-success and sunk cost in R&D activities.

Knowledge is cumulative and non-extinguishable generating a permanent advantage enhancing the probability of persistence. The systematic interaction between the knowledge stock and the productive routines converts innovation in a competitive advantage (Antonelli et al., 2013). Former innovations generate financial availability for the future, as past success will raise profitability and credibility towards external sources (Latham and Le Bas, 2006).

The development of R&D activities tends to be persistent as the investment in an R&D laboratory is considered as sunk, its pay-back requires multiple years; this action, once pursued will force the firm to continue this strategy as well as it will disincentive sporadic actions (Antonelli et al., 2013).

These approaches act as complementary and self-reinforcing; virtuous cycles will emerge from the dynamic interaction between the "knowledge accumulation" and the "success breeds success" in which, the returns from present R&D will retro-feed new ones (Latham and Le Bas, 2006).

The concept of persistence is explained by the continuity on innovative investments (inputs) and not by the results (outputs) (Le Bas, and Scellato, 2014). Firms have to decide, as part of their managerial strategy, to develop innovative activities in a sporadic or a continuous basis. It is likely that innovators continue to innovate as well as non-innovators not changing their strategical view (Cefis and Orsenigo, 2001).

The option for persistence innovations is part of the innovative process thus determining technological change. It is essential for firms to continue investing in these projects in order to respond to the changing economic environment. Hence, a strong cleavage is perceived among firms as persistence will be verified among "great innovators" (Cefis, 2003).

Managers may opt for pursuing innovation in a regular base, perceiving the fact that there is some inertia in the process, the innovative behaviour over time is not a random process, if the firm is targeted to the market (market drive) the propensity to become a persistent innovator will raise, as well as if it is R&D intensive or Science based (Clausen et al., 2011).

Innovation will not behave in the same manner for its different types, the requirements of product and process innovations appear as being more complex therefore weighing the managerial strategy in a different manner. There is strong persistence in what concerns these components, so, we expect firms performing innovations in these areas to be found as persistent innovators, while other innovative actions may be more volatile. Product innovators are more affected by strategic factors and process by market constraints (Roper and Hewitt-Dundas, 2008).

Firms that cut off path dependence and lock-in were able to fully understand the changed environment, figuring out innovations suitable for the new market, thus being successful (Suaréz, 2014).

Throughout unstable periods, where innovation heritage is worthless, present decisions must be disconnected from the past. During these phases, firms perform short term innovations with low impact on capabilities and resources. Therefore, these actions do not retro-feed future persistence. With regards to long term innovations and considering path dependence and lock-in, the past is rescheduling present achievements of results.

The economic crisis is, to many, seen as a major problem in what concerns continuing the innovative activities; however, if firms seize the competences in terms of human factors, technology and structural factors, downturns will not jeopardise the development of innovative activities (Filippetti and Archibugi, 2010).

The sources of persistence can be explained by alternative frameworks such as Knowledge accumulation, success-breeds-success and sunk costs in R&D. These views are complementary and self-reinforcing rather than substitutes. These concepts will explain the micro-mechanisms underlying persistent innovation. Persistence is approached in the literature as: path dependence; virtuous cycles of accumulation and market power dynamics.

Due to strategical option, firms decide to invest in R&D, this cost is considered as sunk, and therefore, it will rationally be supported in the long-run. Innovative firms create a certain stock of knowledge, this process enhances the success-breeds-success hypothesis, and the profits generated with the ongoing innovative process will retro-feed the system, financing new R&D activities enabling the system to continue working. This setting portraits a virtuous cycle in which the learning process will indefinitely continue.

The innovation process itself can be explained by to alternative properties: past dependence or path dependence.

Past dependence claims that the determinants' of the innovative process and its results are fully determined by the initial conditions. Mansfield's (1961) epidemic model of technological diffusion describes this process relying on the number of innovation pioneers, the speed of diffusion foreseeing the contagion process. Persistence will be conditional to the first innovation, and the generation of long-lasting innovative skills.

Conversely, path dependence explains that, in a localized context in which knowledge is planted, an "historical accident" occurs, followed by another in a random process. The success of innovation will depend on the ability of the firm to benefit from the “accident”. Therefore innovation will be strongly tied to existing competences and networking. Persistence will be contingent to the exploitation of complementarities and interdependencies under the proper institutional environment (Collombelli and von Tunzelmann, 2011). The access to knowledge pools, reinforcement of networks, linkages among firms will therefore be strongly recommended.

2.1. Knowledge Accumulation

The dynamics in terms of persistence can be analysed either in terms of the firms' conditions in the past or to the existence of a path.

The development of innovations in the past will enhance the innovative potential at present. The existence of a former innovative path will raise the odds of starting new innovation projects as well as the likelihood of achieving effective innovations. Moreover, the innovative strategies firms pursued in the past will capitalise in the present **(**Antonelli: 1997, 2008, 2010).

The persistence of the innovative activities is based on the combination of both external and internal factors. The availability of a knowledge pool and a competitive market, as well as the structural traits of the firms concerning the R&D policy, the skills and education of the labour force (Antonelli et al., 2013), are all important factors.

Past innovative projects are classified as sunk costs due to their irreversibility and they also generate scale economies due to their indivisibility. Strategic decisions made in the past will produce results in the present and even in the future. Firms will exploit these actions until they are profitable.

Innovation is a dynamic process, characterised by persistence and path dependence. The dynamics of local attractors will determine the innovation success in a continuous base. This process is path dependent rather than past dependent; as the past will not fully determine the present, the shape of the process will be determined by a localised context of action (Colombelli and von Tunzelman, 2011).

Past innovations will positively influence the current ones if their impact is strong enough to transfer the effects to the present. For example, one could expect that market leaders will persist as monopolists, fed by the need to maintain the dominance (Duflos, 2006).

Changing the innovative strategy is also a feasible option, even though it may generate important opportunity costs which must be taken into account when analysing the new innovative projects (Antonelli: 1997, 2008).

Innovative firms have increased means of finance due to their past behaviour and as a result they have resources and capabilities. In the path dependence approach, innovative firms have extended capabilities and important opportunity costs concerning their innovative options. Financial constraints play a major role in what concerns innovation barriers and, therefore. The availability of finance will play a determinant role to the maintenance of the innovative behaviour (Savignac, 2008; Mohen et al., 2008).

2.2. Success breeds success

Persistence emerges from the feedback of past innovations, present investments and future innovations. Innovations are achieved as a result of a regular activity, and when successful, they are repeated. The persistence of routines will impact the innovative outcome, thus reinforcing or obstructing new cycles (Nelson and Winter, 1982).

Firms achieving innovations will be considered as successful, standing out from their competitors due to their abnormal profits which will be reinvested in the development of new innovative activities, hereby forming a virtuous cycle (Nelson and Winter, 1982).

When a firm reaches innovation, it conquers market power, achieves higher profit levels, thus creating an advantage from its competitors. Past innovations will generate the finance to support present innovative activities which are very likely to generate future innovations

2.3. Sunk Costs in R&D

Conversely, due to great uncertainty relating to innovation projects, weak finance availability will discourage the start-up of innovation routines. Furthermore, the cost of external capital for this purpose may be too high or even unavailable.

The hypothesis of persistence is confirmed by deliberate managerial strategies, covering diverse aspects such as investments in physical capital, intangible assets, human capital. Persistence is therefore observed if the organisation does perform these actions in a continuous base to boost the institutional evolution and the improvement of the overall efficiency level (Clausen et al., 2012; Frenz and Prevezer, 2012; Le Bas et al., 2011; Peters, 2009, Raymond et al., 2013).

The virtuous cycle approach considers innovative firms as organisations with innovation routines, gaining extra-profits which generate natural barriers to their potential competitors. Regardless of the approach, there is a positive correlation between past and present innovation. Past innovations will trigger new innovative activities, naturally increasing the probability of reaching innovation again, thereby closing the innovation cycle, Phillips (1971), Mansfield (1962), Geroski et al., (1997).

Firm environment includes the economic actors in the system, establishing a complex set of interactions. The firm may design a new innovation strategy due to the changes in the economic environment and not simply based on former innovation decisions (Freeman, 1982a; Lundvall, 1992).

In sum, in volatile environments, continuity in innovative activities will be an expression of deliberate strategic behaviour rather than sheer time correlation. Persistence generates feedback and accumulation but they are indeed the outcome of continuous innovative strategies. The framework of persistence will be designed by the managerial strategy as well as the dynamic interaction of the firm and its environment (Suárez, 2014).

Thus, in contrast to what one would expect in the context of stable environments, one might find past successful innovative behaviour to have no impact or even a detrimental impact on future innovative behaviour in contexts of unstable (or uncertain) environments.

As noted by Nelson and Winter (1982) this could happen if, for example, past successful innovative behaviour generated from specific problem-solving processes that are not necessarily useful for the new environment. On the other hand, the new environment may create opportunities for previously non-innovative firms. These innovative firms may therefore be more likely to innovate in the future if their innovation process is adapted, from the start, to the new environment.

This same line of reasoning suggests, however that the persistence of different types of innovative behavior may differ according to the types if innovation. For example, past successful innovative behavior may have a positive effect on future innovative behavior if the innovation we are referring to is product innovation, but have a negative effect if the innovation is organizational innovation.

In such instances, any analysis that pools the two kinds of types may find no effect of past behavior on future innovative behavior. To our knowledge, no such analysis by innovation type has so far been done.

Organisational innovation practices such as knowledge management and external partnerships speed up the pace of technological innovation hereby generating persistence (Le Bas et al., 2011).

Strategic behaviour of firms, in some cases, points to non-innovative strategies as being the more effective; conversely, in other cases, the most efficient option is to invest in innovation.

The empirical evidence points to the fact that some innovative actions generate new innovative actions; albeit others fail to boost the virtuous cycle of innovation.

Existing literature usually describes persistence as a pure time dependence between past innovation results and future innovation strategies, modelling persistence as an autoregressive process, independent on the specification model adopted (Duguet and Monjon, 2004). This fact, points up persistence more as serial correlation rather than an independent option taken in each period of time. Apart from time inertia, and if firms reiterate a certain innovative practice, it means that there are strategic advantages in benefiting from feedback and accumulation (Suárez, 2014).

This leads to four possible innovation trajectories in each time threshold: non-innovative, if the firm decides not to innovate in the two time periods; sporadic innovator if the firm stops innovating from one moment to the other; new innovator if the firm commences the innovative process; or persistent innovator if the firm continues to innovate from one moment to the other. This analysis constitutes a further contribution to the persistence literature, discussing the different innovative strategies over time in the context of a moderate innovator. Moreover, it depicts the innovation trajectories dividing the innovative behavior into different innovation types as the literature points to dissimilar perspectives according to the type of innovation in scrutiny.

3. Econometric modelling and methodology

3.1. Hypothesis in test

Under the conventional persistence hypothesis, present innovation outcomes are explained by past innovation achievements, subject to the extension of investments in resources and capabilities (investments in R&D and machinery, skilled human resources) and firm's structural characteristics (size, sector, age, capital ownership), (e.g. Le Bas and Scellato, 2014).

Still, the empirical evidence shows that firms carry on, commence, stop or withdraw innovative processes in an array of patterns to which conventional persistence seems to be insufficient. In addition, innovation strategies over time are different when analysing the different types of innovation.

The analysis of persistence will be divided in two major branches: the first will illustrate the conventional persistence concept (pure time dependence), and will be broken down into the different innovation types; the second will analyse disruptive innovation strategies and it will also detail on the different innovation types.

Given that three time periods are considered, meaning two time thresholds, eight innovation paths may be pursued by firms; the classification will arise from the strategy adopted in the transition from one period to the other.

Table 1 - Alternative innovative strategies

Innovative strategies (3 time periods)	**DESCRIPTION**
Continuous	The firm reports having performed innovative activities in all periods of analysis
Continuous - Sporadic	The firm reports having performed innovative activities in the first and the second period of analysis, and stopped innovating in the third
Sporadic - New	The firm has innovated in the first period, stopped innovating in the second and started innovating in the third
Sporadic - Non innovative	The firm has performed innovative activities in the first period of analysis and stopped in the next two
New - Continuous	The firm did not perform innovative activities in the first period, commenced in the second and continued in the third
New - Sporadic	The firm did not innovate in the first period, has innovated in the second, immediately stopping in the third
Non - innovative - New	The firm did not innovate in either the first and the second period and started innovating in the third
Non - Innovative	The firm did not innovate at all in all periods of analysis

Source: Author's own computation

The first hypothesis [H1] will test pure time persistence ignoring other possibilities than being innovative in the former period of time. According to existing literature, independent of the conceptual framework, having innovated in the past will positively influence the probability of innovating at present, ***continuous innovators*** in the past will continue innovating at present Therefore, under [H1], persistence is confirmed. This hypothesis will be tested in model 1, detailed in the following sections.

The strategic changes will be detailed in three alternative hypotheses:

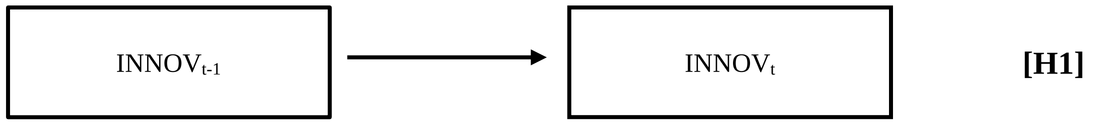
[H2] - Being a ***continuous innovator*** in the past (persistent innovator in t-1 and t-2) will enhance the probability of continuity; therefore, former innovative behaviour will increase the probability of innovation at present. This hypothesis is different from the former, as, we allow the possibility of intermittence in innovative strategies in the past, isolating the effects of past innovative strategies.

[H3] – If the firm is ***new to innovation***, which means that despite not having innovated in the first period, it started during the second, the probability of pursuing an innovative strategy will rise. This means that new innovators have an increased probability to continue innovation.

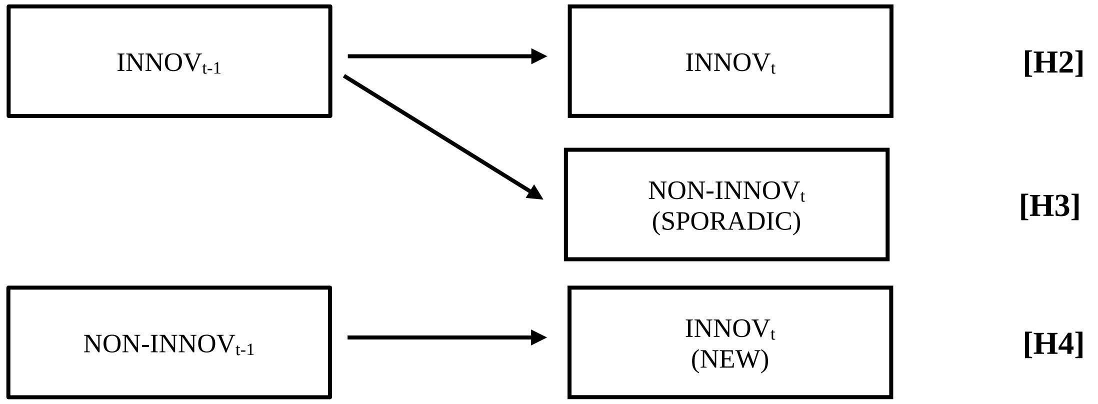
[H4] – ***Sporadic innovators*** have described a strategic option that comprises innovation or not according to the circumstances; these firms have proved to be far from the persistence hypothesis. Being a sporadic innovator in the past will consequently decrease the probability of being innovative at present.

Summarising the major hypothesis in debate we have:

CONVENTIONAL HYPOTHESIS - continuous innovation no firm distinction



(UN) CONVENTIONAL STRATEGIES – discontinuous innovation



3.2. Model specification

As mentioned in the previous section, the conventional hypothesis of persistence does not comprise the alternative choices in terms of innovation strategy in the past. Therefore, this model will illustrate pure past dependence, having innovated in the past will positively influence the innovative behaviour in the present. Moreover, a set of explanatory variables are included, comprising the firm's structural traits and illustrating innovation efforts.

Following a similar procedure than what can be found in Suaréz (2014), we have drawn an_econometric model allowing us to test the conventional persistence hypothesis, which is specified as follows:

$$INNOV_{it} = \beta_1 + \beta_2\, INNOV_{it-1} + \boldsymbol{\beta} W_{it} + \boldsymbol{\delta} V_i + \alpha_i + \varepsilon_{it} \qquad (1)$$

Where innovations at time *t* by firm *i* ($Innov_{it}$) depend on innovations at time *t-1*, a set of time-variant (W_{it}) and time-invariant (V_i) observable characteristics of the firm, and an unobservable firm-specific characteristic (α_i). The variables included in the vectors of control variables will be detailed in the following table.

Evidence in favour of the conventional persistence hypothesis is found if present innovations are positively influenced by past innovations, in other words, a significant and positive coefficient for the lagged dependent variable in the vein for serial correlation. Accordingly, having innovated in the past positively influences the odds of innovating in the present.

However, as previously mentioned, this model may be inadequate to test the persistence hypothesis in unstable environments whose circumstance makes the firm opt for discontinuity in the innovative strategy. .

Following the taxonomy proposed in the European Innovation Scoreboard 2004, also adopted by Suaréz (2014), firms may be broken down in different sub-groups: continuous innovative firms if there is an affirmative answer to innovation in two consecutive time periods (Continuous_Innov); sporadically innovative firms, if one innovative period is followed by a non-innovative (Sporadic_Innov); new innovative firms are those that started performing innovative activities after a period of no innovation (New_Innov); or non-innovative firms if in two periods the firm did not perform innovation.

In this context, the model in equation (1) must be modified as follows:

$$INNOV_{it} = \beta_1 + \beta_2 CONTINUOUS\_INNOV_{it-1} + \beta_3 SPORADIC\_INNOV_{it-1} + \beta_4 NEW\_INNOV_{it-1} + \boldsymbol{\beta} W_{it} + \boldsymbol{\delta} V_i + \alpha_i + \varepsilon_{it} \quad (2)$$

In this case, evidence in favour of the persistence hypotheses could come from a positive coefficient on the $Continuous\_Innov_{it-1}$ variable or from a positive coefficient of the New_Innov_{it-1} variable. Concerning $Sporadic\_Innov_{it-1}$, one would expect a negative effect in the probability.

Concerning the set of other explanatory variables, the operationalisation of performed as follows:

Table 2– Variable description

Variable	Type	Description

RD_intensity	Count	Ratio comparing the expenditures in R&D compared to the total turnover
Mid_tech	Binary	1 if the firm belongs to a SIC code classified as being mid tech [1]
High_tech	Binary	1 if the firm belongs to a SIC code classified as being high tech [1]
Balance	Binary	1 if the firm combines investments in endogenous and exogenous knowledge
Education_intensity	Count	Ratio comparing the number of top educated workers to the total
Openness	Count	Counts for the number of sources of innovation the firm uses
Funds	Binary	1 if the firm uses public funds
Medium_size	Binary	1 if the firm in medium
Large_size	Binary	1 if the firm in large
Group	Binary	1 if the firm belongs to an economic group
Industry	Binary	1 if the firm belongs to the industrial sector
Services	Binary	1 if the firm belongs to the services

[1] Technological intensity defined according to the Pavitt taxonomy in what concerns the manufacturing sector and expended to the other activities as seen in diffused literature from the OECD and the European Commission (exhaustive classification in appendix 6).

3.3. Estimation Methodology

The dependent variable in both of these equations is binary: it takes the value of 1 if the firm *i* innovates at time *t* and the value of 0 otherwise. As is well-known, the nature of the dependent variable dictates that these models are best estimated using a probit (or logit) specification.

Given the panel structure of the data, a choice must be made concerning estimation through fixed-effects or random-effects. Because some of the explanatory variables of interest are time-invariant, the use of fixed effects is unfeasible, pointing to the use of random-effects. However, the use of random effects is only valid if the unobserved time invariant firm effects are uncorrelated to the explanatory variables, which is impossible given that the lagged value of the dependent variable is an explanatory variable.

Fortunately, Wooldridge (2005) developed a solution to relax the independence assumption in random effects dynamic probit models. This solution amounts to replace the α_i in the equations above by a linear function of the firm's observable characteristic's (i.e. the average values of the time-variant exogenous characteristics) plus the value of the so-called "initial condition", i.e., the innovative or non-innovative state of the firm at the start of the period under observation.

Therefore, the estimation of either the model presented in equation (1) and equation (2) will be completed using a dynamic random effects probit model.

4. Data

4.1 Initial considerations

This section details the underlying methodology for the panel construction considering three CIS waves. The Portuguese economy went through one of the most serious crisis of the last decades in 2008, which is still to overcome. The innovative behavior of firms is naturally shaped by the endogenous and exogenous constraints, and we aim at understanding how did firms reacted to this adverse environment.

In order to measure the connection between the past and the present innovations, a panel of firms operating in all economic sectors was constructed. This panel will comprise three biennia, and the information will be collected from the CIS in three waves: the CIS 6, CIS 8 and CIS 10.

The panel will be strongly balanced as only firms that were present in the three inquiry moments are maintained. In doing so, information from 1099 firms was collected. The survey collects information from the former years of operation, in concrete, the CIS 6 gets information from the 2004-2006 period; the CIS 8 collect information from the 2006-2008, and the CIS 10 from 2008-2010. The underlying reasoning is collecting evidence of the firm behaviour before, during and after the financial crisis that started in 2008.

Following the OECD and Eurostat (2005), innovation is the process that develops new or significantly improved products, processes, organisational or commercial techniques. An enlarged overview, presents innovation as part of a general behaviour, in which is found complementarity between product and process innovations Martinez-Ros and Labeaga (2009).

The firm is considered innovative if reporting innovations in terms of product, service, process, organisation or marketing. It is classified as an innovator, in general, if mentioning, at least, one of the possible types.

According to Mohnen and Hall (2013) product innovation consists in the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This type of innovation also includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.

Process innovation consists in implementing new or significantly improved production or delivery methods. Significant changes in techniques, equipments and/or softwares are also considered as being process innovations.

An organizational innovation involves the development of new organizational methods in the firm’s internal or external business practices, workplace organization, communication and hierarchical layouts.

Marketing innovation is based on the implementation of a new marketing-mix and the development new its methods which will involve significant changes in product design or packaging, product placement, product promotion or pricing (the four P's).

The first moment will be considered as being of normal innovative behaviour, the second will capture the immediate effects of the crisis and the final will allow for adjustments to the new adverse environment.

The following table illustrates the total number of firms reporting innovation activities in the different types of innovation considered in the present analysis. This will provide an understanding of the entire picture of innovative activities compared to the constructed panel.

Table 3 - Innovative firms per innovation type (entire CIS sample)

		Product innovation	Service innovation	Process innovation	Organisational innovation	Marketing innovation	Innovation in general
CIS 6	**n**	990	912	1763	2537	1770	3159
	%	20.97	19.32	37.34	53.74	37.49	66.91
CIS 8	**n**	2111	1826	3193	2844	2370	4278
	%	32.02	27.7	48.43	43.14	35.95	64.89
CIS 10	**n**	1818	1422	2846	2694	2431	4161
	%	29.51	23.08	46.2	43.73	39.46	67.55

Source: Author's own computation based on CIS data

4.2. Exploratory analysis of the panel – structural traits summarised

Despite the large number of firms responding to the CIS questionnaire due to theoretical reasons, a balanced panel was constructed, meaning that only firms that have responded to the three waves of the CIS were considered. The fully balanced panel has 1099 firms observed in three time periods, namely, the CIS 6, the CIS 8 and the CIS 10.

The panel is essentially composed by medium size firms (44%); small firms represent 35% and large firms represent 21%. The Portuguese entrepreneurial environment is mainly composed by SME's thus the panel will accurately reproduce the real scenario.

Firms in the secondary sector represent 62%, which include all industries. The primary sector reaches 2%, and the services achieve 36% of the total.

The constructed panel presents an equivalent division of firms not integrating an economic group and firms developing their activities individually.

Nearly half of the panel was classified as belonging to a high tech sector, one fifth to a low tech and one third to a mid tech (following Pavitt's taxonomy (Pavitt, 1984). High tech firms are naturally expected to be far more innovative than others, therefore more prone to rely on the innovative sources to pursuit their projects.

The R&D intensity illustrates the amount of resources devoted to innovative activities compared to the total turnover; 45% of the firms reported not undertaking R&D activities. There are 449 firms with R&D intensity up to 3%.

The number of workers with undergraduates or educational titles is often used as a proxy for education intensity. In the panel, 86 firms have no workers with a top education profile, thus all their workforce is classified as unskilled. Conversely, 53 firms report between 75% and 100% of their workforce as being highly skilled.

Almost 9% of the firms in the panel have reported innovative activities in all the mentioned types, contrarily one quarter of the firms in the respondent panel did mention not performing any innovative activity during the period of analysis. There were 371 firms reported not finding relevant any source of information for their innovative activities.

Three quarters of the firms have mentioned not relying on any type of external funds. It is expectable that during negative phases of the business cycle firms tend to grasp finance from this source.

4.3. Transition frequencies

In each period, firms face binary decisions: whether or not to invest in innovation. In dynamic terms it is transformed into stopping or starting/continuing innovative activities. During the period of analysis, firms may maintain their strategy: persistent innovators or non-innovators, or change their strategy: stopping or starting innovating. For a three period panel, this will produce eight typified outcomes.

There are two major objectives arising from the empirical analysis: the understanding of unchanged strategies - persistent and non-innovative firms; and the determinants of transition. In both cases it is expected to shed some light into the determinants of this strategic behaviour and the role of policy makers in helping firms to take the most accurate decisions.

The respondent panel was divided in several categories according to the nature of the response regarding development of innovative activities. Then, the innovative behaviour of firms in the transition from one period to the following had four possibilities: persistent (a double yes to the performance of innovative activities), non-innovative (a double no to the performance of innovative activities), sporadic (a yes/no sequence) and a new innovator (no/yes sequence).

The transition was operated twice, the firs moving from the CIS 6 to the CIS 8 and the second from the CIS 8 to the CIS 10, which produced eight possible strategies over the six-year period.

The exploratory analysis shed some light into possible differences among firms depending on the innovative type being used. At first, we have decided to analyse the innovative behaviour of the firm under a general perspective, which means that the firm did perform innovative actions in at least one of the possible types.

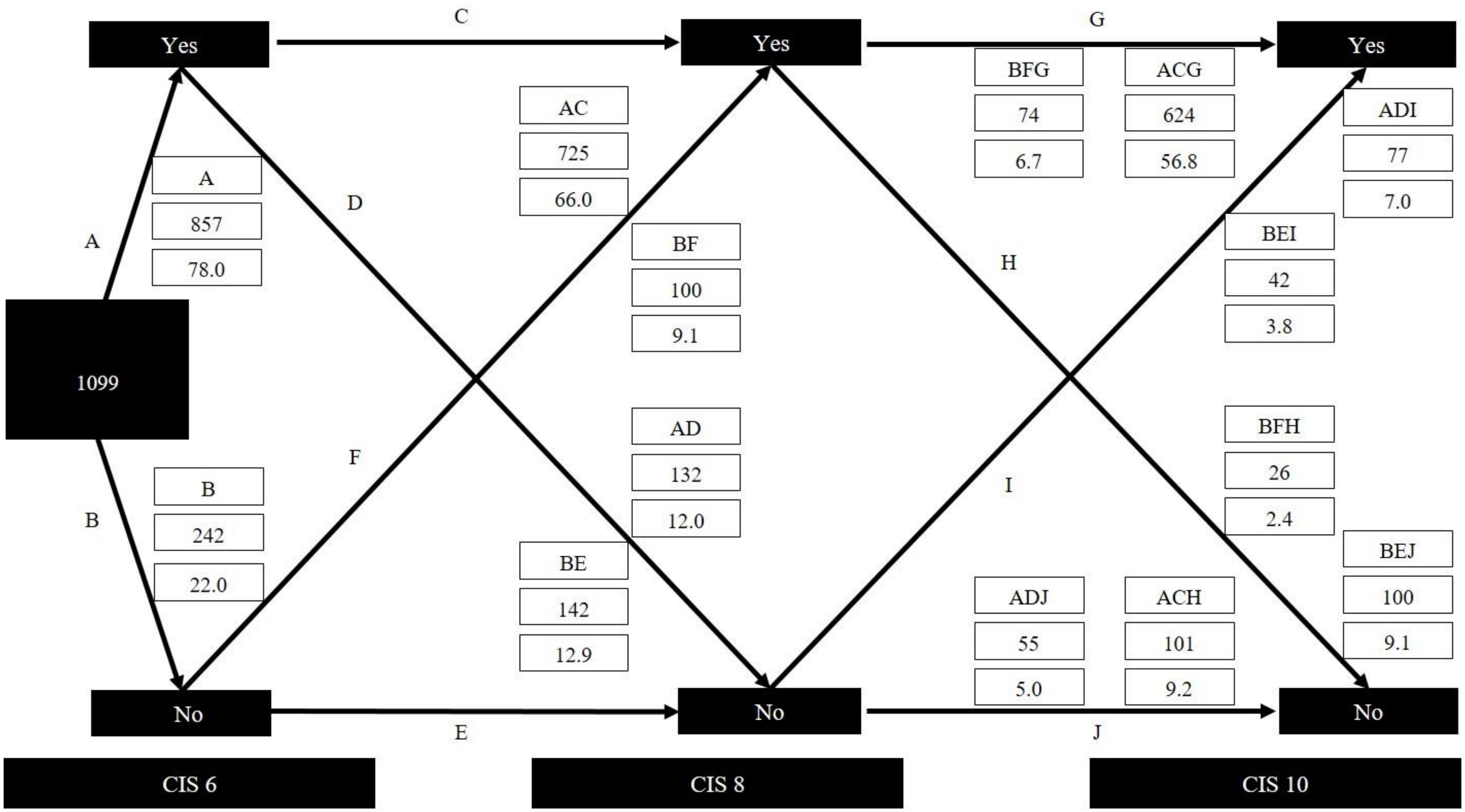
Secondly, we did move forwards analysing each type in separate based on the belief that the difference in the complexity, duration and requirements of the innovation types will naturally influence the innovative strategy of continuing stopping or starting.

The following figures illustrate the transition frequencies reporting the firm's innovative strategy and group the firms accordingly. One can observe that in the constructed panel, almost half of the firms were classified as "non-innovative" concerning product innovation; for service innovation the portion of non-innovative is higher even higher (520). Relating to the other innovation components (process, organisational and marketing), the number of non-innovators falls.

The persistent innovators represent nearly one fifth for product innovation, 130 firms for service innovation and, for process and organisational innovation the number of firms importantly rises (347 and 345 firms). Intermediate strategies present a more homogeneous distribution; there is no important cleavage according to the innovation types.

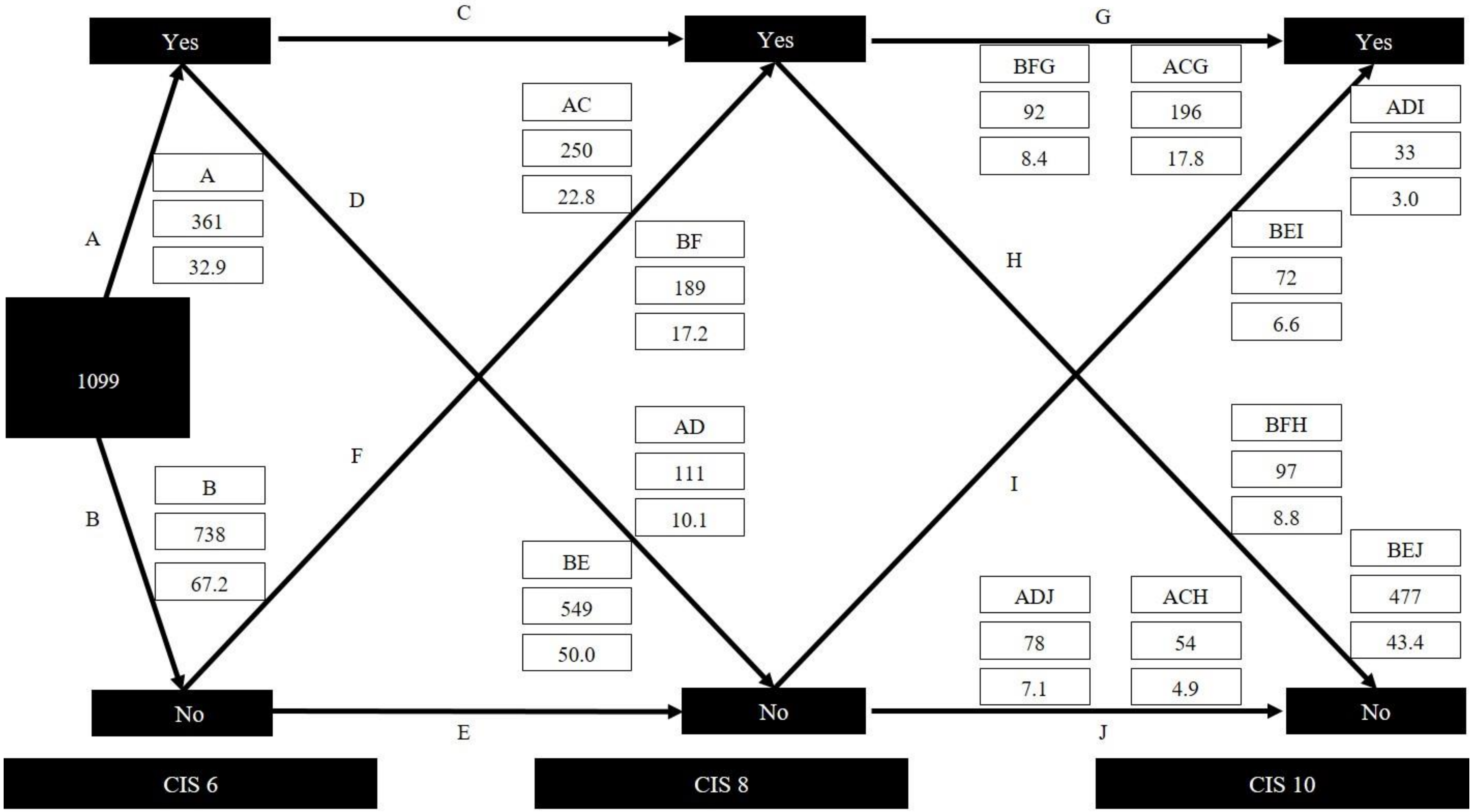
The innovative behaviour of the firm is observed over three periods of time, each one comprises one biennia.

Figure 1 - Transition frequencies: overall innovation



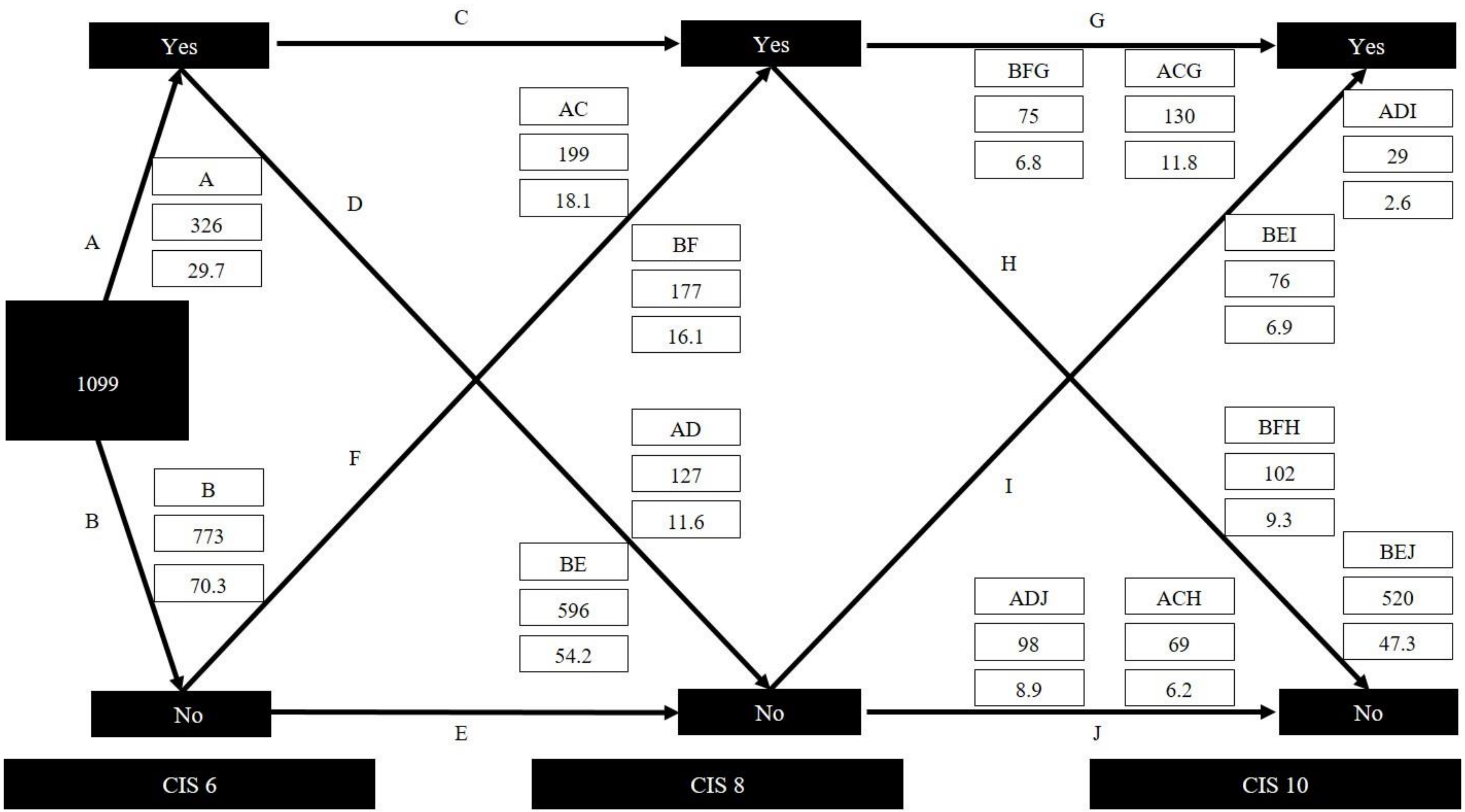
Source: Author’s computation based on CIS data

Figure 2 - Transition frequencies – product innovation



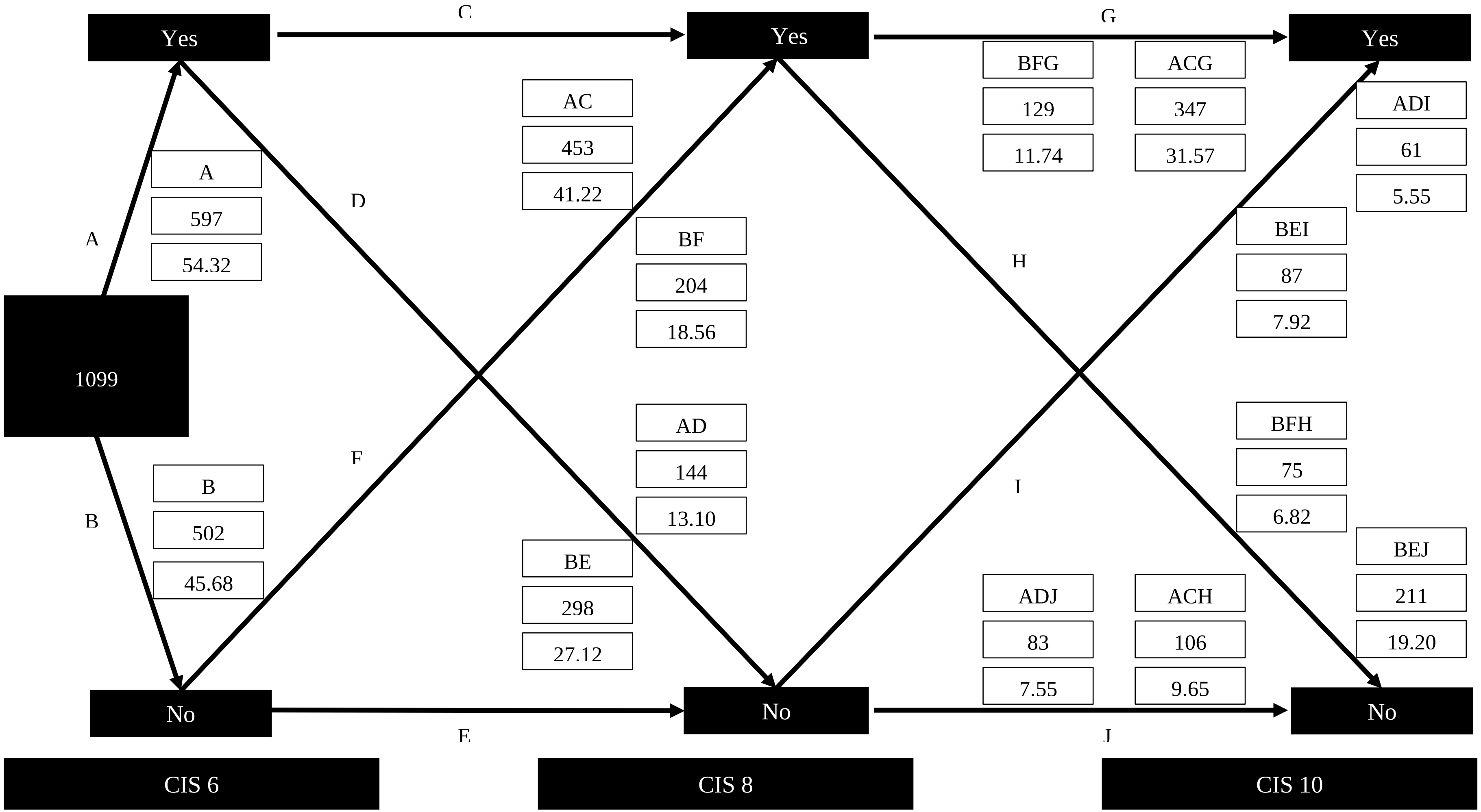
Source: Author's computation based on CIS data

Figure 3 - Transition frequencies – service innovation



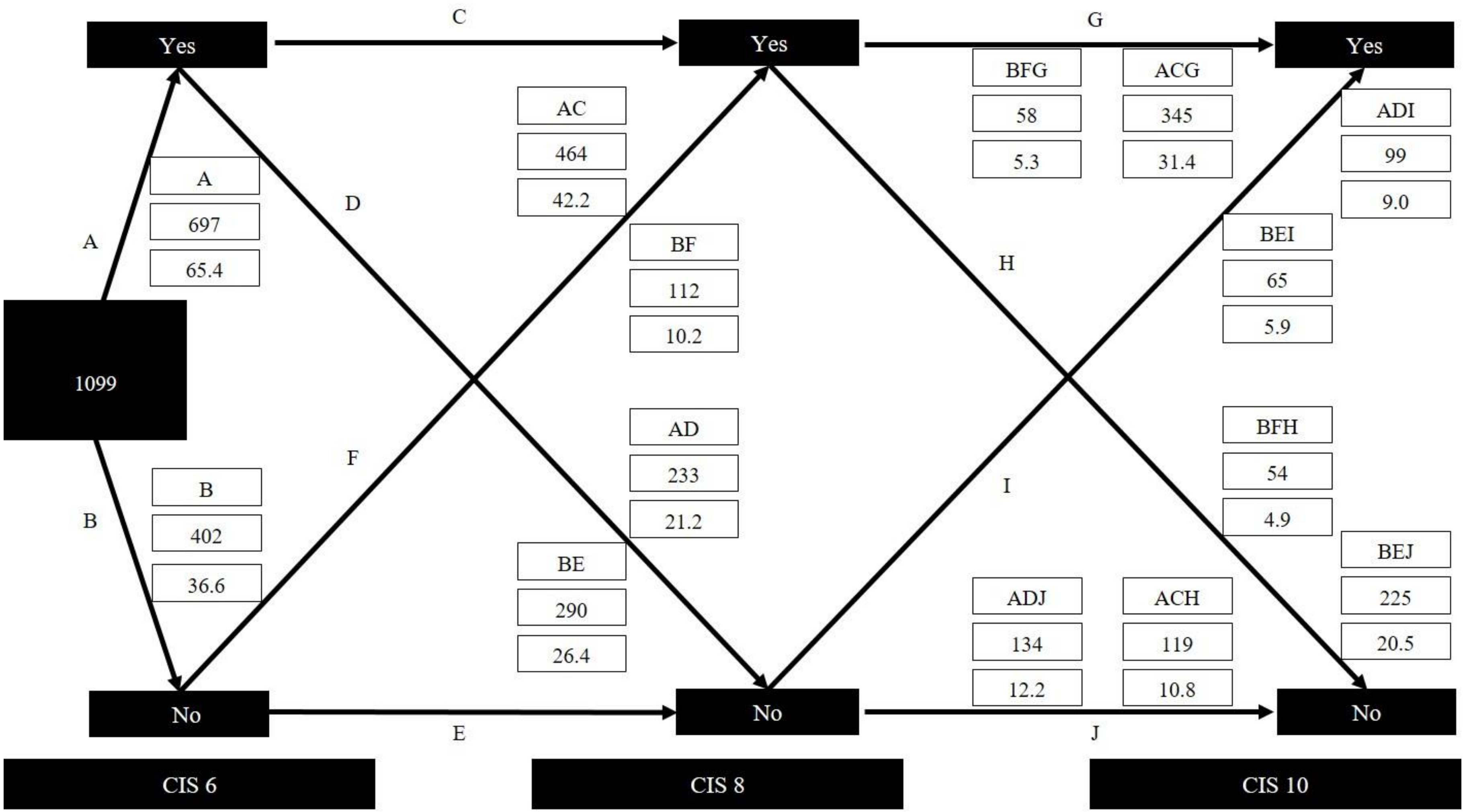
Source: Author's computation based on CIS data

Figure 4 - Transition frequencies – process innovation



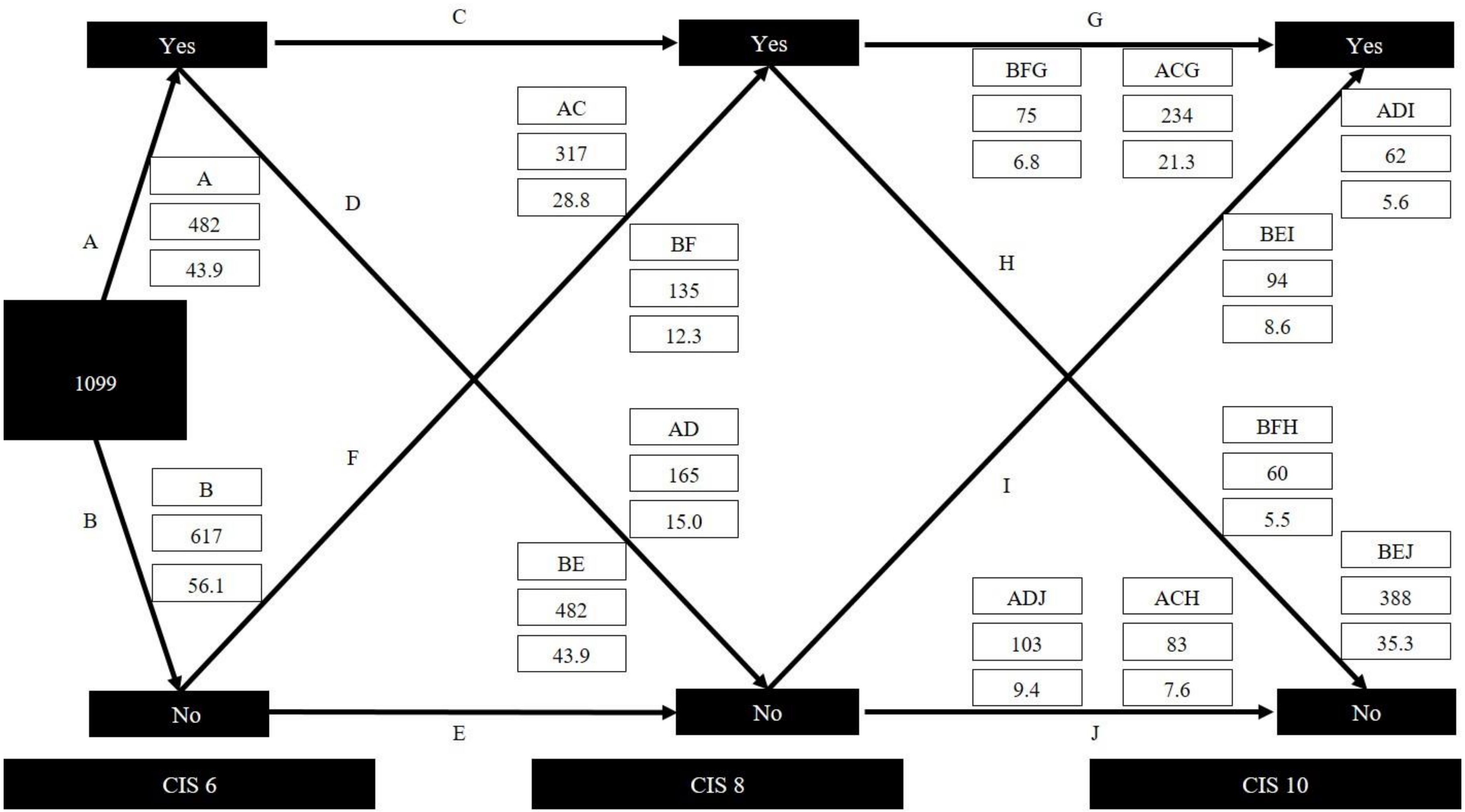
Source: Author's computation based on CIS data

Figure 5 - Transition frequencies – organisational innovation actions per CIS



Source: Author's computation based on CIS data

Figure 6 - Transition frequencies – marketing innovation actions per CIS



Source: Author's computation based on CIS data

Innovative strategies over time (summary)

Table 4 - Aggregation of the innovative strategies in the period of analysis

Innovative strategy		Type of innovation (nº of firms)					
		General	**Product**	**Service**	**Process**	**Organisational**	**Marketing**
ACG	Continuous	624	196	130	347	345	234
ACH	Continuous - Sporadic	101	54	69	106	119	83
ADI	Sporadic - New	77	33	29	61	99	62
ADJ	Sporadic - Non innovative	55	78	98	83	134	103
BFG	New - Continuous	74	92	75	129	58	75
BFH	New - Sporadic	26	97	102	75	54	60
BEI	Non - innovative - New	42	72	76	87	65	94
BEJ	Non - Innovative	100	477	520	211	225	388
	Total	**1099**	**1099**	**1099**	**1099**	**1099**	**1099**

Source: Author's computation based on the panel (CIS 6, CIS 8 and CIS 10)

The transition frequencies allow us to understand the innovation trajectories over time. The panel of firms is observed over three CIS waves, the CIS 6, the CIS 8 and the CIS 10. This diagram permits the understanding of the innovation strategies during the period of 2004-2010. Given the expected differences among innovation types, each one is made in separate: the first is for innovation in general (regardless the type), the second for product, the third for service, the fourth for process, and the fifth for organisational and the sixth for marketing.

When analysing the innovation in general, in the CIS6, 857 firms have reported having performed at least one type of innovation, which is 78% of the panel. When moving to the second period, the CIS8, one could report as persistent innovators 725 firms, meaning that 132 firms failed to continue their innovative path. Continuing to the CIS10, the number of persistent innovators felt to 624. On the contrary, 100 firms reported no innovation activities over the three consecutive periods.

No significant changes are found, from the first to the third period if we observe innovative firms at the aggregate level, 857 firms in the CIS6, and 817 in the CIS10. This preliminary analysis illustrates that when considering innovation in general, no significant changes were reported even though, the type of innovation may have changed from one moment to the other.

Concerning product innovation, the portion of firms reporting an affirmative answer is small, 361, which is one third of the firms contained in the panel. When observing innovation persistence in product innovation, 196 firms reported product innovation in all of the periods. Conversely, 477 firms did not innovate in any of the periods.

For the CIS6 738 firms mentioned not having performed product innovation; the number of non innovative firms in the CIS10 rose to 783. Discontinuous behaviours are also frequent, in the first threshold 189 were new to innovation, and 111 stopped innovating. The panel contains clear evidence that the firms punctually innovate when needed.

Service innovation is not pursued by most of the firms, 773 in the CIS6, 723 and 789 in the CIS10, this means that during the period of analysis no significant changes were found in terms of firm options; however we can observe intermittences, as only 130 firms were persistent service innovators in the three periods. Stopping and starting innovative actions may be a strategic option for these firms given the unnecessary expenditure in continuous actions.

Process innovation is pursued by an important number of firms in the panel, 597, which represents more than 54% of the total. This innovation strategy is expectable, considering the fact that Portugal is a moderate innovator. Continuous improvements to generate cost reductions are frequent under these circumstances.

Two thirds of the firms included in the panel, affirmatively responded to the development of organisational innovations in the CIS6. This number fell to 567 in the last period. Only one third remained as persistent organisational innovators in the three biennia.

Marketing innovation is not an option for almost a half of the firms in the panel; one third was continuously non-innovative in the three waves; on the contrary, one fifth of the panel were persistent innovators.

4.4. Main results

4.4.1. Descriptive statistics

The following table presents the descriptive statistics of the explanatory variables.

Table 5 - Descriptive statistics of the variables in analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
SIC_code	3297			7	74
tech_intensity	3297	2.298	0.778	1	3
sector	3297	2.329	0.517	1	3
size	3297	2.868	0.748	2	4
group	3297	0.485	0.500	0	1
product_innovation	3297	0.362	0.481	0	1
service_innovation	3297	0.307	0.461	0	1
process_innovation	3297	0.570	0.495	0	1
process_innov_production	3297	0.393	0.488	0	1
process_innov_logistic	3297	0.244	0.430	0	1
process_innov_support	3297	0.439	0.496	0	1
organisational_innov	3297	0.558	0.497	0	1
org_innov_procedure	3297	0.451	0.498	0	1
org_innov_responsibility	3297	0.442	0.497	0	1
org_innov_external_rel	3297	0.288	0.453	0	1
marketing_innovation	3297	0.424	0.494	0	1
mkting_innov_package	3297	0.258	0.438	0	1
mkting_innov_promotion	3297	0.290	0.454	0	1
mkting_innov_distribuition	3297	0.159	0.365	0	1
mkting_innov_price_pol	3297	0.205	0.404	0	1
innovation_in_general	3297	0.758	0.428	0	1
Funds_general	3297	0.189	0.392	0	1
Openess	3297	4.914	4.081	0	10
R&D_intensity	3297	4.533	115.682	0	6615.23
Education intensity	3297	2.521	1.557	0	6

Source: Author's own computation based on CIS 6, 8 and 10

4.4.2. Estimation results

The objective of analysis is to understand persistency in the innovative activities, which means, the relation between being an innovator in former time periods and being an innovator in the present. In order to capture the time effects of the endogenous variable (binary), we have opted for a dynamic probit random effects estimation.

Firm characteristics such as size, economic group, economic sector, use of funds, R&D intensity, technological intensity, intramural R&D activities, performing Innovation in general (independent on the type), among others were included to control for their effects.

There is no evidence concerning the different types of innovation in separate and the innovative behaviour of firms in these areas. Hence, previous exploratory analysis allowed for the understanding that the innovative strategy of firms importantly differs according to the type of innovation being performed.

Finding persistent innovators in terms of the product or the service component is far more difficult than in terms of processes or organisational. The complexity of these processes is very different in all dimensions but mostly in terms of financial requirements.

Innovation in general

The first attempt to measure persistence was done by means of running dynamic probit random effects and considering innovation in general (with no separation among the different innovation types). Concerning the traditional hypothesis of persistence (illustrated in model 1) being innovative in the past does not influence the probability of being innovative in the present. In other words, the hypothesis fails to be proved for innovation regardless the innovation type (innovation in general).

The controls for openness and initial innovation appear as being statistically significant; this fact highlights the importance of the sources of innovation to develop different innovative strategies and adapt to the changing environment. Relying on alternative sources of innovation, either internal or external to the firm, will require lower levels of finance and may be crucial to the maintenance of a persistence policy.

For innovation in general, the hypothesis formulated for volatile innovative strategies, appear as being significant only for new innovators. Therefore, being a new innovator in the previous period raises the probability of innovating in the present by 10.2 percentage points compared to the non-innovators. Continuity in sporadic innovation fail to be statistically significant.

Le Bas and Poussing, (2014) introduce the concept of complex innovators; these firms develop more than one type of innovation, normally product and process or organizational. They tend to be more persistence as there is a development of complementarities.

Table 6 – Estimation Results (alternative models of persistence)

	Innovation		Product		Service		Process		Organisational		Marketing	
	Model A1	Model A2	Model B1	Model B2	Model C1	Model C2	Model D1	Model D2	Model E1	Model E2	Model F1	Model F2
Innovation $_{t-1}$	0.025 -0.026		0.025 -0.034		**0.076*** -0.04		**0.057**** -0.026		0.03 -0.039		**0.125***** -0.041	
Persistent_gen_lag 1		0.001 -0.012		**-0.050***** -0.017		**-0.061***** -0.019		**-0.051***** -0.015		0.011 -0.018		**-0.037**** -0.017
Sporadic_gen_lag1		**-0.035*** -0.018		**-0.172***** -0.019		**-0.176***** -0.02		**-0.121***** -0.018		**-0.123***** -0.019		**-0.163***** -0.02
New_gen_lag1		**0.102***** -0.017		**0.112***** -0.018		**0.116***** -0.02		**0.090***** -0.017		**0.167***** -0.022		**0.161***** -0.019
R&D_intensity	**0.013**** -0.006	-6.94 x 10^{-5} (1.861 x 10^{-4})	0.002 -0.001	1.59 x 10^{-5} (3.9 x 10^{-5})	0.001 -0.001	-1.13 x 10^{-5} (2.19 x 10^{-5})	0.004 -0.003	0.001 -0.001	**0.004**** -0.002	0.001 -0.001	0.002 -0.002	0.001 -0.001
Mid_tech	0.014 -0.019	0.014 -0.013	**0.173***** -0.029	**0.108***** -0.017	0.038 -0.031	0.019 -0.019	-0.006 -0.021	-0.006 -0.015	**0.060*** -0.031	**0.037**** -0.018	-0.03 -0.03	-0.013 -0.019
High_tech	-0.025 -0.021	-0.006 -0.014	**0.070**** -0.029	**0.044**** -0.017	**0.064**** -0.03	**0.040**** -0.018	-0.002 -0.022	-0.002 -0.016	0.038 -0.03	**0.030*** -0.018	**-0.109***** -0.03	**-0.062***** -0.018
Balance	0.033 -0.059	0.049 -0.049	**0.065***** -0.024	**0.029*** -0.015	**0.121***** -0.022	**0.073***** -0.015	**0.083***** -0.028	**0.067***** -0.018	**0.142***** -0.031	**0.111***** -0.021	**0.130***** -0.027	**0.090***** -0.018
Education_intensity	0.012 -0.01	0.001 -0.008	-0.007 -0.016	-0.002 -0.011	**-0.031*** -0.016	-0.006 -0.011	0.007 -0.012	0.007 -0.009	0.003 -0.017	-0.009 -0.012	-0.007 -0.016	-0.007 -0.011
Openness	**0.056***** -0.004	**0.049***** -0.004	**0.043***** -0.003	**0.037***** -0.002	**0.046***** -0.004	**0.039***** -0.002	**0.054***** -0.003	**0.052***** -0.002	**0.039***** -0.004	**0.030***** -0.003	**0.034***** -0.004	**0.025***** -0.003
Funds	-0.036 -0.04	-0.019 -0.032	0.036 -0.023	**0.037**** -0.016	0.009 -0.023	0.006 -0.015	**0.061**** -0.024	**0.048**** -0.019	-0.002 -0.027	-0.019 -0.02	0.022 -0.026	0.019 -0.018
Medium_size	-0.013 -0.014	-0.009 -0.01	-0.004 -0.024	-0.007 -0.014	**-0.047**** -0.023	**-0.033**** -0.014	0.026 -0.017	0.016 -0.012	-0.014 -0.024	-0.012 -0.015	**-0.067***** -0.024	**-0.044***** -0.015
Large_size	0.035 -0.022	**0.031**** -0.014	0.012 -0.03	-0.001 -0.018	-0.028 -0.028	**-0.030*** -0.017	**0.066***** -0.022	**0.038**** -0.016	0.015 -0.031	0.007 -0.019	-0.045 -0.03	-0.028 -0.019
Group	0.003 -0.016	-0.008 -0.011	-0.008 -0.023	-0.007 -0.014	-0.008 -0.021	-0.001 -0.013	-0.002 -0.018	-0.003 -0.013	-0.002 -0.023	-0.011 -0.014	**-0.038*** -0.022	**-0.034**** -0.014
Industry	0.009 -0.036	-0.001 -0.026	**0.117**** -0.051	**0.061*** -0.032	0.06 -0.099	0.032 -0.057	0.034 -0.048	0.024 -0.035	0 -0.07	-0.01 -0.04	-0.043 -0.067	-0.035 -0.042
Services	0.025 -0.038	0.002 -0.027	-0.002 -0.055	-0.012 -0.034	**0.233**** -0.1	**0.140**** -0.058	0.001 -0.05	-0.001 -0.036	0.043 -0.072	0.008 -0.041	0.079 -0.069	0.037 -0.043
$Inno_0$	**0.066***** -0.021	**0.190***** -0.01	**0.191***** -0.031	**0.358***** -0.009	**0.115***** -0.035	**0.337***** -0.009	**0.054**** -0.022	**0.268***** -0.011	**0.153***** -0.034	**0.359***** -0.011	**0.157***** -0.038	**0.408***** -0.009
mean_rd_intensity	0.001 -0.001	2.446 x 10^{-4} -0.001	-2.73 x 10^{-4} 0.001	-8.47 x 10^{-5} 1.115 x 10^{-4}	**-1.788 x 10^{-4} **** 7.27 x 10^{-5}	**-1.016 x 10^{-4} *** 5.61 x 10^{-5}	**1.93 x 10^{-4} ***** 5.69 x 10^{-5}	**1.206 x 10^{-4} **** 5.38 x 10^{-5}	3.842 x 10^{-4} 2.829 x 10^{-4}	2.123 x 10^{-4} 1.362 x 10^{-4}	**-0.005*** -0.003	**-0.003*** -0.002
mean_educ_intensity	-0.008 -0.011	0.003 -0.009	-0.004 -0.017	-0.003 -0.012	**0.036**** -0.018	0.009 -0.012	-0.017 -0.013	-0.013 -0.01	0.012 -0.019	0.021 -0.013	0.025 -0.018	0.021 -0.013
mean_openness	4.432 x 10^{-4} -0.005	-0.003 -0.003	**0.011*** -0.006	-0.005 -0.003	-0.009 -0.006	**-0.014***** -0.003	**-0.011**** -0.005	**-0.020***** -0.003	0.008 -0.006	-0.002 -0.003	0.005 -0.006	-0.001 -0.003
No. observations	2198	3296	2198	3296	2198	3296	2198	3296	2198	3296	2198	3296
No. of groups	1099	1098	1099	1098	1099	1098	1099	1098	1099	1098	1099	1098
Wald test (p-value)	160.63 (<0.001)	750.14 (<0.001)	273.4 (<0.001)	1202.76 (<0.001)	301.12 (<0.001)	1071.1 (<0.001)	344.24 (<0.001)	1365.99 (<0.001)	349.43 (<0.001)	1187.57 (<0.001)	386.67 (<0.001)	1231.88 (<0.001)

Product innovation

When analysing product innovation as a separate innovation type, and considering stable environments, the hypothesis of persistence fails to be statistically significant. Therefore we reject the hypothesis of continuity.

Considering the model 2 in which we illustrate the hypotheses that approach the different scenarios under volatile innovative strategies we observe that persistence, either for new-innovative firms and sporadic innovators are significant. Being innovative in the past will decrease the probability of continuing the innovative path by 5 percentage points. Behaving as a sporadic innovator concerning product innovation (stopping innovative activities) will decrease the probability of innovation at present by 17.2 percentage points.

Those firms that were new to innovation in the former period have an increased probability of continuing innovation of 11.2 percentage points.

Service innovation

The classical hypothesis of persistence fails to be statistically significant for the service innovation. Some of the control variables, illustrating the firms' structural traits are presented as significant in Model 1 (High tech, Balance, Openness, among others).

For the unstable environment model, the results concerning service innovation are very similar from the product innovation. The Hypotheses of continuity, sporadic and new innovator are statistically significant.

Being a new innovator in the past raises the probability of innovating at present by 11.6 percentage points; being persistent or sporadic will generate a decrease in the probability to innovate.

Process innovation

Concerning process innovation, under stable environments, the hypothesis of persistence is statistically significant. Having performed innovation in the past raises the probability of continuing to innovate by 5.7 percentage points.

When considering dynamic innovative strategies, the three hypotheses are proved statistically significant. The persistence hypothesis is significant. Hence, being an innovative firm in the past will decrease the probability of continuity at present. Being a sporadic innovator in the past will also decrease the probability of innovating at present. New innovators in the former period have an increased probability to continue innovating of 9 percentage points.

Empirical evidence for Spain, classified as a moderate innovator likewise Portugal, complementarities between product and process innovation are found (Martínez-Ros and Labeaga, 2009); these results are similar from those found in our model. This may build some pattern among moderate innovators.

Organisational innovation

Organisational innovation has been scantily exploited in persistence literature apart from the recent work of Haned et al. (2014) and Le Bas, et al. (2015). In the context of a moderate innovator, this type of innovation bridges innovative opportunities from one period to the other. The financial requirements and the bureaucratic requirements of organizational innovation are far lower than other type of innovation, small firms with severe financial constraints may find in this procedure a smart way to perform innovation and operate cost reduction.

For organisational innovation the conventional hypothesis of persistence fails to be statistically significant. Moving to model 2, to illustrate innovative behaviour considering dynamic innovation strategies, only the sporadic and the new innovator hypothesis are presented as significant. Being a sporadic innovator in the past will decrease the probability of innovating at present by 12.3 percentage points. New innovators in the former period, have an increased probability to continue innovating of 16.7 percentage points.

Concerning the control variables, openness appears as having a positive effect in the probability to innovate, as well as belonging to a high tech sector.

Marketing innovation

The evaluation of persistence in terms of marketing innovation is somehow neglected in the existing literature. One of the few works devoted to this innovation type and its influence on persistence in Lhuillery, S. (2014).

For marketing innovation, the conventional hypothesis of innovation persistence is proved as being statistically significant. Having performed innovation in the past will increase the probability of innovating at present by 12.5 percentage points.

The hypotheses formulated for dynamic innovative strategies are proved as being significant. Persistent and sporadic innovators have a decreased probability to innovate compared to the default group; for new innovators the effect goes in the opposite direction. New innovators in the former period have an increased probability to innovate by 16 percentage points. Some of the control variables appear as significant for the usual levels reinforcing the importance of the structural traits.

5. Conclusions

The traditional hypothesis in terms of innovation persistence, in which it is considered pure serial correlation, fails to be significant when considering innovation in general. This result reinforces the need for a deeper understanding of the underlying reasons of the failure of this theoretical assumption.

Concerning innovation in general, without any distinction among its types, our results are similar from those found in Suaréz (2014), even though, when we run the same procedure for the different innovation types different results appear, concerning service and marketing innovation, persistence hypothesis in the conventional manner is proved being significant. When breaking down innovation into different types, past innovations seem to be useful to continue developing the present in the case of service, process and marketing innovations.

Moving to the analysis of discontinuous innovative strategies (models 2) we observe that the pure persistence hypothesis fails to be significant for innovation in general as well as organisational innovation, for the other innovation types it appears as statistically significant. It is of major worth to provide a deeper view to the estimations and its signs in order to detail the overall picture for the case of moderate innovators. This finding goes in the opposite direction than what is presented by Suaréz (2014), it is worth mentioning that only innovation in general was analysed on that paper, and in our case for general innovation persistence fails to be significant.

The negative sign may be due to the fact that past innovations are irrelevant in the new environment. Path dependence is limiting the range of possible responses of the firm; the former learning and accumulation id forcing the firm to postpone the present innovative activities. These firms may not yet be adapted to the new environment. Moreover they can be experiencing lock-in, being stuck in former innovation projects and being incapable to move forward.

One can expect that these firms may have delayed of interrupted their innovation projects in the present to adapt their behaviour to the new economic environment.

The hypothesis of sporadic innovation represents those firms that have stopped their innovative activities. It fails for general innovation. For all other innovation types this hypothesis appears statistically significant. To us, it has a negative sign, although, Suaréz (2014) has also presented a negative sign despite not being significant. This may be interpreted as isolated innovative actions, in other words, these firms perform their innovative activities with the simple purpose of solving a particular problem with no intent in terms of continuity. These firms may consider the innovative activities as punctual actions with very specific targets. Observing persistence among new innovative firms, this hypothesis is proved significant in all innovation types with a positive sign. These results match the findings of Suaréz (2014).

The positive sign may be explained by an increased ability of these firms in responding to the new economic environment. Quite surprising is that fact that these organisations did not perform innovative activities in the past. To them, the new economic environment is seen as one of emergent opportunities.

New innovators are completely free to decide in terms of their innovative projects, they are not sticky to lock-in or path dependence. The new economic environment has presented them new opportunities to innovate. In this case, the persistence hypothesis will once more be questioned.

These findings shed important light to the understanding of the huge difference among the empirical results of moderate innovators compared to the existing literature. The previous studies are mostly developed analysing innovation leaders, this points to the inadequacy of the perception of “one size fits all” in terms of persistence.

When we observe the different innovation types dissimilarities are also found, which points to evident asymmetries in terms of firms’ reality and their strategic options in terms of innovation. The empirical results depict intentional intermittence in terms of innovation options for the Portuguese firms, two major trends are highlighted: if the firm was as sporadic innovator in the past the probability of continuing to innovate is lower, which may be due to the perceived worthlessness of repeated innovative actions. On the contrary, new innovators have and increased probability to continue innovating, perhaps due to the fact that their projects are unfinished or need further investment. Persistent innovators will be stopping their actions, as the estimated sign is negative.

Portuguese firms are intentionally intermittent in their innovative activities, which mean that their actions target a problem solving strategy, are the pointlessness of continuity in their operative sectors.

Present public policy actions do not accommodate heterogeneity; they rely on the theoretical assumptions of pure persistence, the existing evidence based of the orthodox frameworks which are perhaps not suitable for weaker innovators. Strategically, our firms decide to interrupt their innovative actions may be due to the unprofitableness of pure persistence.

There is a need for a deeper understanding of the real causes of intermittence and its rationale; if intermittence is due to the existence of barriers or the excessive costs of innovation one must define the role of Governance and the Universities in overcoming this weakness.

It is generally accepted that innovation policy is a major issue to be dealt by the Triple Helix. The role of the Government and the Universities is considered as strategic to boost economic growth, sustainability and convergence among countries. Given the asymmetries found among leaders and moderate innovators smart policy needs to be implemented, otherwise the policy design will be unsuitable for those who need the most. Existing actions seem therefore to work as pick winners.

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APPLICATION OF TRIZ METHODOLOGY TO SUPPORT THE EMERGENCE OF COLLABORATIVE NETWORKS

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Abstract

Nowadays, companies operate in markets exposed to the effects of globalization, the opportunities for conducting business are becoming shorter in terms of time as well as the business environment is increasingly volatile. Thus, companies have to start learning to work together in certain areas or skills, to follow different paths other through the stimulation of inter-firm relationships giving rise to organizational models based on networks of collaboration between companies.

However, a major challenge with the knowledge that this area faces is related to the need to develop a general theory of collaborative networks. Thus, the establishment of collaborative processes in response to a business opportunity should not follow an ad-hoc process, but instead must be supported by appropriate methodologies to support the process of analysis of technological and organizational systems, identify contradictions and problematic situations and process indicate the likely solution to the found problems.

In this context, the Theory of Invention Problem Solving, better known by its acronym TRIZ, aims to aid in the detection of contradictions regarding systems and the generation of creative solutions which eliminate the contradictions found and get major improvements in technological and organizational systems.

Innovation is crucial to increasing the efficiency of organizations, to improve competitiveness and profitability, since life cycle of products is becoming shorter. The collaborative chains need to develop innovative solutions progressively with the aim of improving processes. The TRIZ methodology can indicate some guidelines for managers of companies and their network since it allows to generate solutions to radical or based on the application of the latest scientific discoveries and experienced little change. The aim of this paper is to contribute to greater agility and sustainability

of the processes of formation of collaborative chains to meet business opportunities, introducing the TRIZ methodology supporting the creation and development of collaborative chains.

Keywords: collaborative chains, cooperative processes, innovation, TRIZ.

1. Introduction

Nowadays, enterprises in global markets have to achieve high levels of performance and competitiveness to survive [1]. In order to be competitive, enterprises must develop capabilities that will enable them to respond quickly to market needs. According to several authors, one of the most relevant sources of competitive advantage is the innovation capacity [2]. However, the development of complex products or services requires access to several distinct types of knowledge that enterprises do not usually hold. As a result, the enterprises can improve their knowledge either from their own assets, making sometimes high investments, or from the knowledge that may be mobilized through other enterprises based on a collaborative process.

Nevertheless, despite the collaboration among enterprises has been considered unusual and indeed suspicious by many small and medium enterprises (SMEs) managers until a few years ago, nowadays it is commonly assumed that the participation in a collaborative process is a common trend for many enterprises. On the other hand, it is also easily recognizable that collaboration introduces high overheads due to the higher coordination costs, diversity of working methods and corporate culture, which induces higher transaction costs, loser control structures, etc.

Is the balance between the potential benefits and the increased overheads substantially positive? Literature in the field, as well as a growing number of practical case studies, seems to indicate that the answer is yes. On the basis of these expectations are, amongst others, the following factors: sharing of risks and resources, joining of complementary skills and capacities, access to new / wider markets and new knowledge, etc [3]. In fact, there is an intuitive assumption that, when an enterprise is a member of a long-term networked structure, the existence of a collaborative environment enables the increase of knowledge production as well as the transfer of knowledge, and thus the enterprises may operate more effectively in pursuit of their goals. Recent studies show that a growing number of innovations that are introduced in the market come from networks of enterprises that are created based on core competencies of each enterprise [4].

According to the HORIZON 2020 framework programme stresses the "Innovation Union" as the approach for Growth and Jobs and the aim of helping "to bring more good ideas to the market".

Collaboration with other enterprises and individuals, that means, sharing the needed knowledge and resources to co-work, co-develop, and co-innovate in an open-innovation environment, is nowadays a key approach for enterprises and specially SMEs, which otherwise cannot adequately respond to market demands. Therefore, through an open-innovation environment, enterprises can address emerging business opportunities and deal with a cost/time competitively with turbulent market conditions.

In this new business model, enterprises "split the innovation value chain" in various tasks where the process to assignment tasks to each partner is based on the identification of resources that hold lower costs, and better skills and/or access to specific knowledge, in order to make the outcome most competitive. Complementarily, the synergies created by “confrontation” of different perspectives and sharing of experiences in a “healthy” collaborative environment, lead to the reinforcement of innovation flows. The aim in such open-innovation ecosystems is to establish mutually beneficial relationships through which new products and services are created, often in close interaction with the customers.

However, in spite of this assumption, it has been difficult to prove its relevance due to the lack of models that support mechanisms that explain the emergence of collaborative networks.

Thus, the establishment of collaborative processes in response to a business opportunity should not follow an ad-hoc process, but instead must be supported by appropriate methodologies to support the process of analysis of technological and organizational systems, identify contradictions and problematic situations and process indicate the likely solution to the found problems.

In this context, the Theory of Invention Problem Solving, better known by its acronym TRIZ, aims to aid in the detection of contradictions in systems and the generation of creative solutions which eliminate the contradictions found and get major improvements in technological and organizational systems.

2. Systematic Innovation in Engineering - TRIZ

The Theory of Invention Problem Solving is a methodology especially suitable for solving problems in science and engineering. The TRIZ methodology seeks to solve the problem of solutions generation. This approach was developed by Genrich Altshuller in 1946 [5]. TRIZ is a systematic methodology oriented for humans, based on knowledge, for inventive problem solving [6].

Altshuller examined more than one and a half million patents and found that certain problems are often solved in different technical fields using only a small number of principles of invention. Altshuller systematized the solutions described in patent applications, dividing them into five levels [7]:

- Level 1: Routine solutions using well known methods in the respective area of specialty. This category represents around 30% of the total.
- Level 2: Minor corrections in existing systems, using methods well known in the industry. Around 45% of the total.
- Level 3: Major improvements that resolve contradictions in typical systems of a given branch of industry. Around 20% of the total. This is where creative design solutions appear.
- Level 4: Solutions based on the application of new scientific principles. About 4% of the total.
- Level 5: Innovative solutions based on scientific discoveries not previously exploited. Less than 1% of the total.

TRIZ aims to assist the development of projects and the solutions generate, especially in environments characterized by profound changes or based on the application of radical scientific discoveries, where the use of traditional engineering and management practices cannot produce remarkable results.

The practice of traditional engineering attempts to solve such problems finding acceptable compromises, while TRIZ aims to eliminate such a commitment. TRIZ seeks to overcome these conflicts through the application of creative solutions [6].

The TRIZ methodology is based on the following grounds:

- Ideality;

- Contradiction;

- Resources;

- Systematic Approach;

- Functionality.

Also, according to Altshuller, problems contain system conflicts or contradictions, that is, the improvement of an attribute of the system leads to degradation of other attributes.

The typical conflicts are: reliability/complexity; productivity/accuracy; strength/ductility, etc.

For example, in the case of the design of an automobile, there is a conflict between the need to ensure a good shock resistance, and at the same time, the requirement for reduced weight.

According to TRIZ methodology, the problems are divided into local and global problems [5]:

- The problem is considered local when it can be mitigated or eliminated by modifying a subsystem, keeping the rest unchanged.

- The problem is classified as a global when it can only be solved by developing a new system based on a different principle of operation.

At the beginning of the analysis process of a system, a project team faces a situation involving inconsistencies (contradictions) that need to be clarified [8]. Thus, the first step in the resolution of contradiction is elaboration of a statement of the problem in order to reveal the contradiction contained in the system. Then, identify the parameters that enhance and hinder system performance. Next, the contradictions are eliminated by modifying the system or one of its subsystems.

Altshuller found that, despite the great technological diversity, there are only 1250 typical system conflicts. Moreover, he identified 39 engineering parameters and product attributes that engineers usually try to improve [7]. All these 1250 conflicts can be resolved through the application of only 40 Principles of Invention [9], [7], often called Techniques for Overcoming System Conflict (TOSC).

The full development of TRIZ consists of several concepts [10], [11]:

- System for formulation of problems;
- Resolution of physical or technical contradictions;
- Concept of an Ideal State of a Project;
- "Substance - Field" Analysis,
- Algorithm for Inventive Problem Solving (ARIZ).

The TRIZ methodology can be seen and used at various levels [12]. At the highest level, TRIZ can be seen as a science, as a philosophy or a way of being in life - a creative way and a permanent quest for continuous improvement. On the practical level, TRIZ can be seen as a set of analytical tools that aid in the detection of contradictions in systems, in formulating and problem solving through the elimination or mitigation of found contradictions.

3. The Role of TRIZ in the Establishment of Collaborative Processes

As mentioned above, one of the main weaknesses in this area is the lack of appropriate formal methods to support the creation of collaborative networks taking into account the best technological solution and the assets that may be accessed through the network.

In an attempt to contribute to such need, as a first approach, the methodology proposed is illustrated in Figure 1.

The cooperation process begins when a company identifies a business opportunity and believes in its realization through a cooperative process as a way to optimize gains.

This situation occurs when:

- A company is unable to carry out the business opportunity and believes even having no clear evidence that there is a group of companies through a collaborative process can respond to business opportunity;
- A company has all the resources needed to conduct the business opportunity in isolation, but rather perform the work in collaboration with other companies. There are several reasons that can lead to this situation: the believe that working alone can compromise other business, or; believe that cooperation is the best solution since it can enable the realization of faster, more efficient, reliable work, etc.

After the company has recognized the need for cooperation, the next step is to identify the companies interested in cooperating with which the company believes accomplish their goals that is at this stage the company still does not have a guarantee that will successfully establish a coalition with which accomplishes the desired goals, what we can do is try to identify partners for a possible formation of a coalition.

So for a company to be successful at this stage have to ensure:

- The identification of a minimum number of undertakings in accordance with the identified needs and with which believes it can achieve the objectives set;
- For the companies contacted previously, there is a minimum number of companies with the ability to achieve the objectives and agree the proposals addressed to them.

The next stage is the formation of potential coalitions, that means, this stage companies are grouped to allow the resolution of the objective.

The process of forming coalitions thus corresponds to the formation of clusters of various companies from the information obtained in the previous phase, in terms of objectives, resources, knowledge and credibility for the realization of the proposed objective according to a set of processes previously identified and selected.

Figure 1 illustrates the proposed model for collaborative network creation.

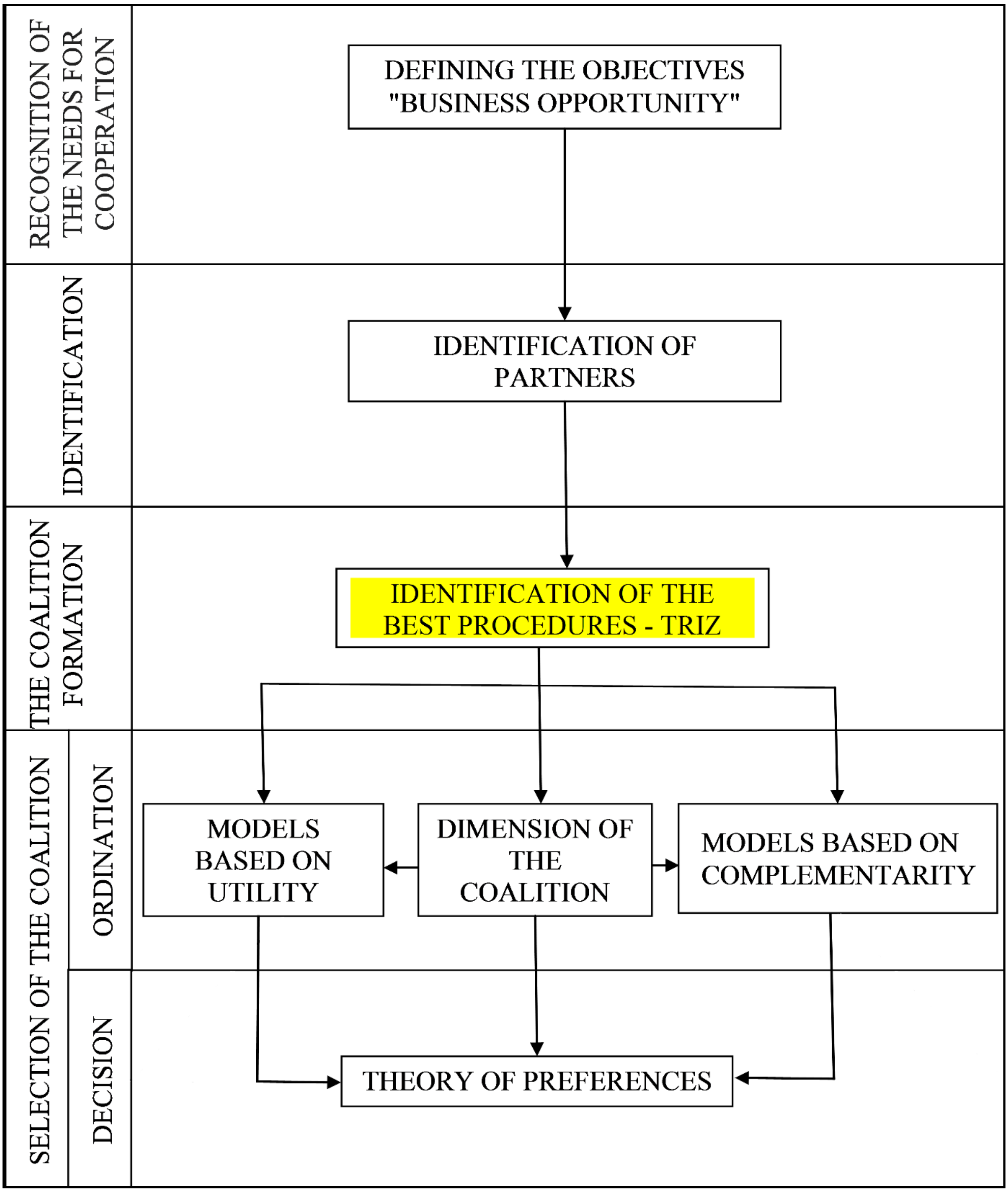

Figure 1. Methodology to support the creation of Collaborative Networks.

After identifying potential coalitions, construction of possible scenarios between the various companies, according to the criteria that guided its creation, the next steps are:

- To sort the different coalitions according to the evaluation criteria previously defined which are related to the criteria used in the creation of the coalition;

- To choose a rational way which maximizes the best coalition counterparts according to a set of preferences defined and weighted by the decision maker agent individually.

The selection criteria can be grouped into three major classes that are based on:

1. Maximization of usefulness;
2. The size of the coalition;
3. The complementarities of skills of the various companies.

The main characteristics of this model are:

- Ability to define criteria for the selection of coalitions in an integrated manner, taking into consideration different aspects (technical, strategic, economic) that are involved in its constitution;
- Greater consistency in the structure of the decision process, since the notion of feasible coalition includes parameters that are otherwise scattered;
- Greater facility in evaluating the criteria of coalition selection, especially in dynamic environments since it can easily adapt to various scenarios.

4. Conclusions

The establishment of collaborative processes in response to a business opportunity should not follow an ad-hoc process, but rather, must be backed by appropriate methodologies to support the process of analysis of technological and organizational systems, identifying contradictions and problematic situations and indicate the likely solution to the encountered problems.

Innovation is crucial to increasing of the efficiency of organizations, to the improvement of competitiveness and profitability. Collaborative chains need to develop innovative solutions with the aim of improve the traditional processes. In this field, the TRIZ methodology could indicate some guidelines for the managers of enterprises and the network itself since it allows to generate solutions for radical changes or based on the application of most recent and less experimented scientific discoveries.

Thus, acting as identifier of problems and potential generator for creative solutions, the TRIZ methodology could assist in creating and development of collaborative chains.

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Setting Up an Innovation Lab in a Manufacturing Company

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Abstract

The focus on 'manufacturing' is an important distinction as for many companies primarily involved with fabricating engineering products. The management doesn't see the company as engineering-centric; in fact the managers are really even more Marketing- or Sales- centric than manufacturing. The upshot of that is that for all of its talk about wanting to be (or at least saying the company is) innovative, the culture (as it is many similar companies) is focused on selling what it makes and making what it sells. The highest value is placed on execution and predictability, and the culture is not really comfortable with innovation, since it tends to upset established processes. So to invest in an innovation area (innovation lab) is really a counter-cultural move, and that affects what the engineers can do and how the engineers can innovate.

This paper looks at experiences a fairly large manufacturing company has had in setting up an innovation lab and then wondering why it is not utilized the way they expected. The conclusion is that the business staff (managers), need training in understanding innovation, specifically the difference between incremental innovation (engineers usual work practice) and break-through innovation (what the innovation lab is there to promote), and that this understanding requires fundamentally different responses/ behaviours to the two types of innovation. To further aid this culture change, the managers need different, specific, personal goals, alongside their usual goals (performance indicators). Finally, further research is needed to discover how best to support engineers' time-slice 15% of their time (as suggested by many companies) to innovation, alongside their normal minimally innovative work practice.

Keywords: company culture, innovation lab, managing innovation, TRIZ.

1. Introduction

Much has been written about setting up an innovation lab, its function, and its use (e.g., Puttick 2014), but what happens when you have an innovation lab and it is not being used for its purpose or it fails (Funk 2016, Berkun 2007)? This paper describes an in depth review of a company's innovation lab that is not being utilized for its envisaged innovation potential, by the majority of engineers. Talking with engineers, many companies have this issue and so this is far from an isolated case. The company reviewed says it allocates 15% of an individual's time to projects that they want to work on, but that rarely happens in practice. This paper thus explores the culture of the company and looks at practical steps that could revitalize real innovation in the company.

2. Company research

A relatively large manufacturing company was visited, which had commissioned and had a few years' experience in running an innovation laboratory. This provided what the author believes to be, a typical company innovation history profile. An account of company's experience follows.

The road to what ultimately became the company's Innovation Lab (referred to from now as the 'lab') began years before it was built. The company, like many, had begun its story with innovative products and built an enviable reputation for quality. As the company grew, however, the focus of management turned more and more toward reducing risk and ensuring a predictable outcome. To this end, all of the company's activities from top to bottom became very process oriented.

The managers and engineers kept telling themselves and others that they were innovative, but as time went on it became evident that they were not really as innovative as they wanted to think they were. Probably due in part to the company's process-oriented culture, engineers had become quite distanced and disconnected from the workshop where technicians built models of new designs, and the workshop itself had become very focused on making models that were very similar to the company's existing products i.e. incremental innovation, but not very good at things that were significantly different i.e., transformational innovation. As an engineer explained, the problem was that innovation by its very nature involves venturing into the unknown. It is hard when planning a journey to a destination for which no map is available to make a detailed plan for how to get there, how long it will take, and what it will cost. Unfortunately, those unknowns are the very things that were most highly valued by the management. Without a clear expectation of the time, steps, and cost, of an innovation project, the managers were reluctant to authorize funding. So the company had a culture in which it knew it should be innovating, but at the same time was uncomfortable with the process of innovation.

The company had a history of success in Continuous Improvement, and was very oriented toward the use of teams to solve problems. It seemed natural to many in the company, to utilize the team structure that had been valuable for continuous improvement, when it needed to do projects that were intentionally innovative. Unfortunately, the culture that had been very helpful for producing continuous improvement turned out to be a hindrance for (break-through) innovation, and most of the teams that worked on innovation projects ended up delivering incremental improvements instead of the transformational changes that were needed.

Several individuals who by their nature were oriented to prefer working on transformational changes over incremental changes had seen this problem growing. They began to propose a new paradigm for innovation, which was centred on individual and collaborative work, instead of team-oriented activity, and that also recognized the value of hands-on learning. They had begun describing a lab where motivated individuals could use a combination of analytical design tools and hands-on learning to produce examples of components and products that were truly new to the world (or at least to their particular industry). But it wasn't until the executive staff had received enough pressure from above them, to deliver innovation that the idea finally achieved critical mass, and the lab was built.

The lab that had been envisioned had several characteristics:-

- A wide array of general-purpose tools that facilitated construction of examples of most things that could be imagined. This included new tools and processes to be trialled, such as 3D printers etc.
- A space for storing a wide range raw materials and standard components.
- A space for hands-on building of newly conceived ideas.
- A space for meeting informally with other innovators to work out difficulties in projects and for getting a broader perspective.

It was hoped initially that the lab would be used by many engineers, working part-time on ideas about which they were passionate. This seemed reasonable as there had been quite a lot written about innovation following that model. It was expected that the lab would be the focal point of a large "innovation community" that included a significant number of the engineers and others in the organization. A little activity like this has been seen in the two years since the lab opened; but not nearly what was projected. The small amount of casual use of the lab seems to be mostly by people who have a small immediate need to quickly make an example of a small component; so they use the equipment in the lab to do that. In contrast, the majority use of the lab has been by a small handful of people, whose jobs naturally need a lab for a high percentage of their time. They work nearly full-time in the lab or in the adjacent office space, and they have a hard time remembering how they worked before the lab was built. For them, it has become an enabler to accomplish the work that needs to be done. These are the "power users", and without them, the lab would be vacant most of the time. Again, it is important to the "power users" to have the lab, and for them it is valuable. But still, even with those users, the company has not really reached its goal of the creation of a larger "innovation community" and a source of real innovation.

One puzzling question is, "where is everyone else"? There are many more engineers whose jobs would be made easier if they used the lab, but for unknown reasons, they stay away. Another puzzling question is, "where are the innovators"? The lab was built with the vision that it would enable those whose passions drove them to create new things, to work on those new ideas. It was expected that there would be a significant number of individuals who had ideas for new and improved products, who would use the facilities that the lab provided, to work part-time on those ideas. By 'part-time' it was envisaged that all engineers would be allowed and actively pursue 10% - 15% of their working week i.e., a morning or afternoon, to work on projects of their own envisaging, but this has never come to fruition.

Considering the disconnect between what was expected and the reality, one begins to wonder if part-time innovation, is even possible. In spite of what has been written about Microsoft and Google's staff spending some significant fraction of their time on projects of their own choosing, the experience in this company suggests it might not be workable. Can a person effectively solve hands-on problems when the work is limited to a few hours a week? The answer to this question for this company, is either "no", or "we haven't been able to figure out how to do it yet"!

Another possible explanation for why the majority of the engineers are staying away is that there aren't as many who have the passion for innovation as the company had hoped. When asked, many will say that they are innovators. But being an innovator requires vision to see opportunities for improvement, talent for creating the improvements, and energy to carry out the improvements. Is it possible that few of the engineers who were hired for their project management expertise possess all of those qualities?

Another problem that has yet to be solved (or is part of the same problem) is how to incentivize managers to not only permit, but to encourage, their people to work on innovation. The situation seems to be much as it has always been before the innovation lab arrived: the clear focus is on executing the projects on the project list, and any effort that doesn't support that goal is seen as wasted by those managers. So while at some levels (the very highest) and in some small areas in the company, there is acknowledgement that real product innovation is important to the future of the company, the culture that developed over many years, remains, and continues to guide, most of the day-to-day activity, in all areas of the company.

3. Analysis

For the company here, its focus on 'manufacturing' is an important distinction; as for many companies primarily involved with fabricating engineering products. In these companies the management doesn't see the company as engineering-centric; in fact the managers really consider the company as more Marketing- or Sales- centric than manufacturing. The highest value in operations is placed on execution and predictability. The upshot of this is that for all of its talk about wanting to be (or at least saying the company is) innovative, the culture (as it is in many similar companies) is not really comfortable with innovation. So to invest in an innovation area is really a counter-cultural move, and that affects what the engineers can do and how the engineers need to innovate. In support of this Stephen Denning (2015) said "Traditional management . . . is proving to be more like an ingeniously morphing virus that steadily adapts itself to, and ultimately defeats, intended fixes and returns to its original state, sometimes more virulent than before.'' So one needs to ask, is it the culture that needs to change and is this, the only area? James L. Heskett (2016) reports that 'Lou Gerstner, in reflecting on his stint as CEO of IBM, said, "Until I came to IBM, I probably would have told you that culture is just one among several important elements in any organization's makeup and success—along with vision, strategy, marketing, financials, and the like … I came to see, in my time at IBM, that culture isn't just one aspect of the game--it is the game." He set about personally to change it first before later transforming IBM's strategy.'

The question then one needs to ask is how to change the culture. Again Denning (2015) says on change 'Embracing a primary goal for the organization focused on adding value for customers, replacing shareholder value theory with customer-centricity. Making money becomes the result, not the goal.' And 'to do this one needs the 'Adoption of self-organizing teams, networks and eco-systems of employees, partners and customers building on change platforms, and agile approaches for coordinating work.' Would this work for the engrained culture of the company reported? I think as a primary driver the answer must be no, although what is suggested is very important. For the company in question and similar companies I think the approach of Dearlove (2006) has more promise. He reports Hamel as saying that the problem 'is that employees lower down the corporate hierarchy have not been trained in innovation and there are few processes or support mechanisms to nurture innovation. Hamel compares our current understanding of innovation with the business world's understanding of quality in 1970. At that time, people knew that quality was important but didn't know the processes or systems which could enable quality to happen.'

So for this and similar companies one can argue that the highest priority must be training in the understanding of innovation and its place within the company. The second priority must then be for the managers to be set personal goals that encourage their teams to undertake some real innovation.

4. Solution

What can aid the company's understanding of the innovation dichotomy? In the first place the company management needs to understand the difference between what is called incremental and break-through innovation. Also it needs to understand the danger of not undertaking break-through innovation, as, if your competitor does this first, you will not be able to catch up and so lose your market with appropriate consequences. The author has explained this before (Filmore 2014) but the key issues are understanding, the jump between s-curves as breakthrough-innovation, and the development of the product (incremental innovation) as staying but progressing up one s-curve. This is shown diagrammatically in Figure 1; the diagram is well known from technological forecasting (e.g., see Mann 2002). Note the jump shows the basis of the product being conceptually different in some way and this usually means patentable.

In terms of setting managers personal performance goals, senior managers must realise that different goals must be assigned for innovation alongside those for the majority of the organisations incremental functioning. Back in 1982 Galbrith said 'The basic components of the innovating organization are no different from those of an operating organization…… The innovating task is more uncertain and risky, takes place over longer time periods, assumes that failure in the early stages may be desirable, and so on.' So there must be goals that allow for failure and long development time. The key issue is that each engineer is given a license to follow up a hunch for an ideally uninterrupted morning or afternoon a week.

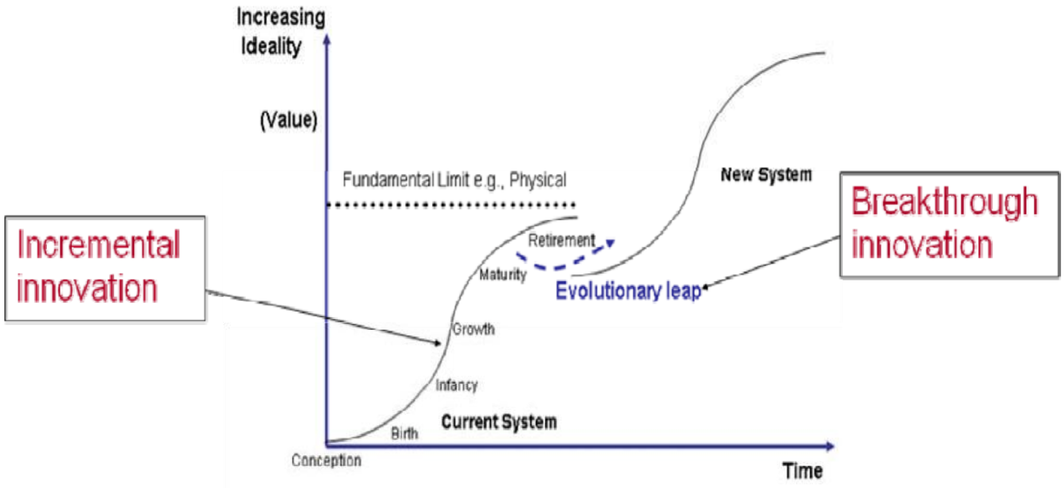

Figure 1: Showing the jump ('creativity leap') between s-curves which is characteristic of break-through innovation, and incremental innovation, which is progressing up the s-curve.

A further issue raised is whether some engineers are able to be highly innovative i.e., can perform break-through thinking. One assumes that all engineers can be innovative because of their training, but looking at staff personality profiles e.g., Myers-Briggs Type Indicator (MBTI), there will be a range of personality preferences i.e., areas in which people feel safest. This has been considered before (Filmore & Crust 2009) and it was found that there were two generic types of behaviour, firstly those happy with living with ambiguity, intuition, at the cutting edge/ quasi-academic, dramatic change (break-through innovation mind set), and those who prefer to live with certainty, improving, following procedures/ using techniques, doing 'what needs to be done' (incremental innovation mind set). So is it possible to encourage engineers who have been hired for talents other than innovation to begin to participate in innovation? Project management skill is given such high value in the interviewing process that from experience it can be seen that natural innovators are hardly ever hired. One solution to help engineers innovate has been found in the Living Labs development (see Schuurman et al 2012 for the development). It may be if incremental thinking engineers are involved directly with their customers in a 'real life' experimental environment (living lab), that they can change their mind-set from 'what needs to be done' to the more inspiring 'this is what our customers need'! Of course this will change the company culture even further by cutting out the marketing and sales people between the customer and the engineer!

The last issue raised in the company analysis, is whether staff can work ‘creatively’ in the innovation lab for only one morning or afternoon a week, or is this too disruptive for most people to undertake i.e., what the author calls time-slice innovation? Google (D’Onfro 2015), 3M (Goetz 2011 and Govindarajan & Srinivas 2013) and Microsoft (Knowledge@Wharton 2016) still promote the idea, but as D’Onfro reported ‘Only about 10% of Googlers are using it, last time the company checked, but it doesn't really matter, as long as *the idea* of it exists, according to Google HR boss Laszlo Bock’. Bock further says "In some ways, the idea of 20 percent time is more important than the reality of it," and "It operates somewhat outside the lines of formal management oversight, and always will, because the most talented and creative people can't be forced to work." Perhaps though the real issue may be that the more concentration that is required for a task, the more time it takes to switch tasks. This might give some credibility to the notion that a task like innovation, which is arguable requires a high level of concentration, could be expected to take a significant amount of time to switch to. Westbrook et al (2010) see this with doctors: ‘those completing complex tasks with a high frequency of interruptions had a significantly lower accuracy and significantly lower task completion times than those completing complex tasks with a low interruption frequency.’ A good summary of what researchers call ‘time switching’ is also given by the APA(2006), who say 'For all tasks, the participants lost time when they had to switch from one task to another. As tasks got more complex, participants lost more time. As a result, people took significantly longer to switch between more complex tasks. Time costs were also greater when the participants switched to tasks that were relatively unfamiliar.' This issue of whether time-slice innovation is possible or even practicable, thus in the author’s view, requires further research.

Goetz (2011) reports that author Scott Berkun writing about business innovation says ‘these policies only work when the outcomes are backed. "Many companies have tried to emulate the 20 percent time idea but failed because they remained conservative about supporting the new ideas”. Goetz continues that ‘experts agree that this kind of nudging probably works best at companies where there's a high level of creative competitiveness; that is, where impressing peers is just as important as the innovation itself.’ He further says how at 3M this can happen: ‘Once a year, about 200 employees from dozens of divisions make cardboard posters describing their 15 percent time project as if they were presenting volcano models at a middle school science fair. They stand up their poster, then hang out next to it, awaiting feedback, suggestions, and potential co-collaborators.’ What we have here is the ‘innovation community’ which is starkly missing in the company we have focused on. This does suggest that company management needs to celebrate the 15% innovation time by, for instance, having an annual ‘innovation fair’ and innovation award ceremony.

5. Conclusion

It is clear that unless the culture changes in the reported company and similar companies, most things will go on as they have for a long time, subject to the shocks of competitors overtaking them. It is not strategy that will change the company but getting the managers to understand innovation and so change the company culture by their behaviour. As Dearlove (2006) reported Hamel in 'comparing our current understanding of innovation with the business world's understanding of quality in 1970.' We must then educate the business world about the innovation process and in particular the difference between break-through and incremental innovation, and thus the consequences of very different behaviours that need to under pin each of these. Finally, whether time-slice innovation is possible, requires further research and understanding, to see if what is purported to be possible by large organisations, can actually take place in small to fairly large companies.

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Lean Banking: Application of lean concepts and tools to the banking industry

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Abstract

In recent years and especially in the wake of the worldwide economic recession banks have been subject to growing external pressures which combined to its internal constraints led to structural changes and aroused several challenges with a negative impact on their activity. To thrive in the new business environment and ensure sustainable profitability in medium and long term, these firms are focusing on the persecution of new management strategies that provide more efficient and cost effective services without jeopardizing quality from the customer perspective.

Cited as a holistic approach that aims to achieve operational excellence and create more value with fewer resources, lean management has been increasingly seen by banking services executives as a suitable solution to enhance competitive advantage and improve banking businesses performance. But in spite of its acclaimed success, especially when applied to manufacturing companies from where it stem from, the deployment of lean in a service enterprise still poses new challenges and obstacles that may even compromise its feasibility.

The purpose of this paper is to discuss the application of lean principles to banking services, including its challenges, potential benefits and critical success factors. The methodology used was a case study research, in which is described and analyzed a lean approach in a real banking environment. The findings of this study shows the great potential of lean management as a mean to maximize banking processes'. However, and as stated in previous studies, in order to achieve a sustainable and lasting success, lean practices must be adjusted and become intrinsic to the firms' culture.

Keywords: Banking Industry, Lean Banking, Lean Management, Performance

1. Introduction

In recent years the influence of external forces and internal constraints have fostered a paradigm shift in the banking industry. The global financial crisis affected the macroeconomic environment and as a consequence has impacted negatively companies' results and financial situations (Dimitras, et al., 2015), raised strict governmental regulations and spread a global climate of uncertainty and distrust towards banks. (Leyer & Moormann, 2014). At the same time there's a need to juggle the prospects of development of the customer relationship model, to enable the meeting of modern costumer's needs, and face increasing competitive pressures, especially with the emergence of new players and disruptive solutions in the financial market (Staikouras & Koutsomanoli-Fikipaki, 2006). This new environment has triggered a resurgence in the importance in uplifting banks core business performance to reduce operational costs but still retain a sustainable competitive advantage.

Most banks are endowed with slow and prone to error processes which contribute to the lack of flexibility, efficiency, effectiveness and responsiveness to cope with these challenges (Mathews & Muguntharajan, 2012). Accordingly they are led to pursue new strategies and alternative management models that enable value creation, risk mitigation and reduction of resources consumption, without jeopardizing quality from the customer perspective, in order to ensure a sustainable profitability and enhance their competitive position (Moyano-Fuentes & Macarena, 2012).

As a practice that focus on greater operational efficiency through waste elimination and continuous improvement lean management has increasingly been perceived as an effective methodology that contributes companies to improve their businesses performances and prosper in this challenging environment. This production ideology first became known during the 1950s after being developed and successfully implemented at Toyota Motor Company. While adopting this new system, at the time known as Toyota Production System (TPS), the company was able to object the seemingly western supremacy and became the largest and most successful automobile manufacturer. Ever since, it has been continuously developed, enhanced and has become one of the most prominent and acclaimed management practices across the world (Leyer & Moormann, 2014; Alsmadi, et al., 2012).

Lean is behold as a paradigm with potential to create more value for customers using less resources. By incorporating a collection of principles, concepts and tools into business processes it aims to minimize waste along value streams to provide products with greater quality and variety at lower costs and shorter lead times (Arfmann & Topolansky, 2014; Čiarnienė & Vienažindienė, 2012). Although there's not a unanimous universal definition of this paradigm there's a consensual perception of its value as a holistic and sustainable approach for management processes of an organization (Arfmann & Topolansky, 2014; Văduva, 2011). It aspires to optimize costs, boost products or services quality and improving productivity (Alsmadi, et al., 2012; Văduva, 2011), thus increasing companies' agility, flexibility and competitive advantage (Wang & Chen, 2010).

Although the origins of lean stem from manufacturing companies it has been widely adopted in non-manufacturing areas (Vlachos, 2015). However and in spite of its widely acclaimed success, its application in business environments that differ so substantially from manufacturing still arises multiple challenges that may even compromise its feasibility. Upon its application in banks, for example, huge enterprise wide benefits are expected. But, in order to achieve those goals, all efforts should be made to adjust lean principles in to the context of banking services working environment and address its major particularities (Leyer & Moormann, 2014).

Several researches and studies have been carried out to further understand, analyze and evaluate the deployment of lean principles to the service industry. But very few have addressed specifically the nature and distinctive characteristics of banking services. The aim of this paper is therefore to analyze the lean banking concept and its feasibility as a mean to maximize banking processes' performance. To achieve this main goal a case study was conducted to enable the exploration of a lean approach to a real banking environment.

The paper is structured as follows. Section 2 provides an overview of the dissemination of lean paradigm to the services sector. Section 3 focuses on lean banking and its key characteristics. Section 4 describes and justifies the selection of the research methodology. Section 5 gives a presentation of the case study conducted and reports its main findings. In section 6 there a draw of conclusions and presentation of the research limitations.

2. Lean Services

As stated by Alsmadi et al (2012), Lean has been primarily used to improve manufacturing processes but it is increasingly being applied to a wide range of service operations.

The outstanding importance of focusing on the service industry is reflected in the increase of its share in the gross domestic product (GDP) of countries across the whole world, with especial prominence in the world's largest economies (Portioli-Staudacher, 2010). Moreover, there's also a sense of greater opportunities for improvement in the tertiary sector (Alsmadi, et al., 2012; Laureani, 2012). In comparison to the manufacturing area the level of productivity in services has been underwhelming (Suárez-Barraza, et al., 2012). And while manufacturing industries are considered to be progressive and efficient, service industries are perceived as primitive and inefficient (Canel, et al., 200).

With growing external pressures, especially due to the current economic context, increasing, the increasing competitiveness on global markets and the evolving customer expectations, services companies are challenged to increase flexibility, improve quality and become as efficient and cost effective as possible (Suárez-Barraza, et al., 2012). Hence the increasing efforts to find profitable solutions that allow organizations to achieve long-term enterprise wide improvements.

Womack and Jones were among the first authors to propose the deployment of lean principles to the tertiary sector (Poksinska, 2010). Researchers Bowen and Youngdahl are also cited as pioneers in this scope, as they conducted the first set of lean services case studies and published their respective results. Ever since the paradigm has been evolving and has been spread to different types of services such as healthcare (Machado & Leitner, 2010; Kim, et al., 2006), financial services (Mathews & Muguntharajan, 2012; Văduva, 2011) and public services (Suárez-Barraza, et al., 2009), among others.

The service industry is endowed by its own particular characteristics, which differentiate it from manufacturing. Accordingly, the application of lean principles, which stem from a manufacturing background, to services companies encompasses new limitations and raises new challenges. The key distinguishing characteristics of services can be summarized in (Canel, et al., 200; Arfmann & Topolansky, 2014):

1. Inseparability. Since most services require simultaneous production and consumption and consequently the costumer participates actively in the production process.
2. Intangibility. An attribute that refers to the impossibility of apprehending a service in the same manner in which goods can be sensed.
3. Perishability. Defines the inability to store services which leads to greater caution to fluctuation in demand.
4. Variability. This defines the singularity underlying each event and resulting lack of consistency when providing a service. As mentioned by Canel et. al (2000) “the quality of a service can vary from provider to provider, from customer to customer, and from day to day”.

Therefore to achieve a successful lean transformation in a service environment these distinctive characteristics and potential theoretical inconsistencies raised must be taken into account. As expressed by authors Arfmann and Topolansky (2014), it is a fallacy to assume that a model fully developed for the manufacturing sector can be applied and work in services, an adjustment in required.

In manufacturing the lean paradigm is already a well-established and highly acclaimed management practice. But in regards to its expansion to new elusive areas such as services, researches and successful applications that provide specific, practicable and integrated frameworks that address properly its attributes are still scarce (Leite & Viera, 2015; Suárez-Barraza, et al., 2009). While some service companies' experience successful lean transformations others exhibit fragmented efforts and consequently fail to achieve the expected results. Which suggests that the key factors for success in this area reside in the strategic approach adopted within a specific scenario.

3. Lean Banking

In banking such as in other areas the main business focus is to achieve profitable operations and meet costumers' expectations while providing efficient, reliable and affordable services. These last few years, this industry have been notorious for the successive amendments driven by multiple forces of change. The main drivers to this change are interrelated and can be summarized as:

1. Globalization. Which refers to the increasing integration of international financial markets and consequent need of banks to expand their operations, physical branches and subsidiaries to foreign countries (Cetorelli & Goldberg, 2012).
2. Deregulation. The gradual process of reducing regulation that has effects in banking activity and economic performance.
3. Universalization. In respect of economic liberalization, globalization and financial deregulation, competitiveness in the financial sector has increased significantly (Zafar, 2012). As a consequence banks are increasingly expanding their range of financial services offered in order to sustain their competitive position and market share (Zafar, 2012).
4. Innovation. To meet evolving customer expectations, consolidate their competitive advantage and avail opportunities created by technological improvements and innovations, banks have been conducting constant efforts to innovate their products and services (Akhisar, et al., 2015).
5. Concentration. In many countries, during the last years, there's been an increase in concentration within the banking industry that has implications in its activities (Santillán-Salgado, 2011).

In addition, the economic recession experienced across the world since 2008 impacted this industry and raised new changes and challenges, such as the lack of customers' confidence and spawn of new regulatory actions

With regard to the changing environment banks increasingly devote to shaping their business and pursue new strategies to cope with the new challenges aroused. As a practice known to promote operational excellence and provide great benefits without incurring high investments the lean methodology has increasingly been perceived as a suitable solution to meet banks' needs. The deployment of lean tools and concepts to the banking environment gave place to the term lean banking.

As cited by Hatzakis et al. (2010) "s*ervices* represent a large category that encompasses firms as diverse as retail establishments, transportation firms, (…) real estate and healthcare". This wide variety compels a customized approach to meet the needs of each type of services firms. For example, banks such as others financial services companies primarily deal with originating and facilitating financial transactions (Hatzakis, et al., 2010), but even among them there are particularities that must be properly addressed. Banking services are broadly distinguished by its high volume and heterogeneity of customers, long-term contractual relationships between customers and firms (Hatzakis, et al., 2010), silo mentality, decentralization of activities in front and back office and high degree of employees' independence in decision making.

These distinctive banking characteristics along with the shared services nature mentioned in section 2, may impose new challenges in lean implementation.

The organization silos, for example, when combined with decentralized activities and the number of specialists required for certain banking operations contributes to an increasing complexity in coordinating processes activities and thus disrupts the achievement of the continuous flow a lean enterprise should have. Silo mentality also inhibits a perception of an organization as a whole. Each department or function focus exclusively in minimizing waste directly related with the outputs they produce, underrating the true dimension of waste in customers' perspective. In regards to their nature, banks are also known for their lack of standardisation (Alsmadi, et al., 2012), a key tool in lean management (Machado & Leitner, 2010).

Another pivotal goal of this methodology is eliminating waste, non-value added activities in Japanese also called *muda*. Possible *mudas* identified in these type of services can be caused by the lack of standardized procedures, providing customers more options than the valued, having multiple and unnecessary points of approval, information systems downtime and time spent waiting for an information or approval, among others. Services intangibility affects the perception, mensuration and thus the reduction of these inefficiencies.

Toyota developed a model, named House of TPS, depicting graphically the combination of lean concepts to achieve a truly lean system. The representation has intrinsic that as a house a lean system is only as strong as its weakest part (Liker & Morgan, 2006), which reinforces the importance of each element and attaining a synergetic effect between them for a successful lean implementation. Failing to acknowledge this fact and insisting in a limited vision or understanding of lean management is one of the main causes for unsuccessful efforts (Losonci, et al., 2011).

The dissimilarities when compared to manufacturing mean there's a significant complexity while trying to transpose these concepts and tools to a banking environment. Willing to replicate the success experienced in manufacturing multiple researchers have been trying to understand the value or purpose behind each lean concept or tool in services. According to a research conducted by Leite et al. (2015) the four most commonly used tools adapted and applied to lean service are: value stream mapping (VSM), production balancing (*heijunka*), just in time (JIT) and 5S standardization. VSM is a visual tool that supports waste identification by enhancing workflow understanding, *heijunka* enables the suppression of workload variation and thus promotes a greater stability, JIT is a philosophy that seeks to eliminate waste and finally 5S standardization is a workplace organization method.

Multiple international banks such as BNP Paribas and Bank of America have applied lean concepts and tools to their operations. A literature review highlighted the following benefits from these type of lean implementations (Văduva, 2011; Lasater Institute, 2008; Accenture, 2010):

- Lead time reductions;
- Increased quality of services;
- Increased productivity;
- Cost reduction;
- Gain of competitive advantage;
- Increased customer satisfaction.

The authors Womack and Jones (1996) described five lean principles: specifying value from customers' perspective, understanding the value stream, improving the flow, producing based on customers' pull and striving for perfection. Taking into account those principles, banks characteristics and reflections from multiple research studies (Losonci, et al., 2011; Leyer & Moormann, 2014; Christodoulou, 2008; Vyas, et al., 2015), the critical success factors for a holistic lean banking implementation can be summarized as the following:

- Customer segmentation and focus;
- Identification of value drivers;
- Diagnostic and analysis of the companies' current state;
- Definition of a shared vision and goals;
- Raise consciousness and awareness;

- Employees empowerment and training;
- Top management commitment;
- Gradual implementation;
- Measuring success and sharing the results;
- Creating a lean culture.

4. Methodology

In addition to the literature review the present paper was developed based on a case study, a research method with growing prominence in the education and social science field. As cited by Ying (2009), this methodology "allows an investigation to retain holistic and meaningful characteristics of real-life events" as it attempts to understand, explore or describe them. An explanatory study inquires a greater knowledge on a particular phenomenon to support a theory, an exploratory study aims to identify casual links between factors that contribute to the occurrence of certain events and finally a descriptive study provides an accurate representation of the phenomenon being studied (Meirinhos & Osório, 2010) .

The case study conducted within the development of this paper was both descriptive and exploratory. Considering the lack of practical examples and scarce knowledge of lean banking it's important to not only provide a description that can serve as basis for other lean banking implementations but also conduct a critical analysis to help develop and strengthen the theory.

5. Case Study

The case study in this research is a practical project to simplify and improve the operational performance of a front office banking process. The case company is one of the largest Portuguese banks, which has more than 2 million customers.

While offering a wide range of banking and financial products and services the bank has not only consolidated its position in Portugal but it's also a reference institution in other countries. For many years the bank remained profitable and revealed a positive growth trend in markets in which it operates. However the outbreak of the global financial crisis raised new adversities such as the loss of customers' confidence and the reduction of profit margins. As a result the bank had to be recapitalized and in counterpart was coerced in a strict restructuring plan. More than ever, the institution was pressed to revise its operating model in order to streamline its processes and achieve an effective cost reduction without compromising its competitive advantage. Against this scenario lean was perceived as one of the management strategies able to help the bank prosper.

The steps that the project team took prior the lean implementation were the following:

1. Processes prioritization;
2. Selection of agents of change (bank's employees);
3. Preliminary process analysis (through a *gemba walk* and documentary research).

After these steps there was an identification of improvement opportunities and the proposal of suitable solutions. Lastly there was a final selection of the solutions to implement, handled by the top management. Throughout the whole approach there was an active participation of the bank's employees from different departments and the support of the top management.

Targeting to improve a process that would provide a positive and significant impact on the bank, the processes prioritization was based on the results from a survey that inquired front office employees on the most critical processes. These employees had to choose up to three processes that in their perspective had greater opportunities for further enhancements. As shown in figure 1, two processes clearly stood out, the processes for account's opening and maintenance. Nonetheless, in the present study the focus will remain on the latter.

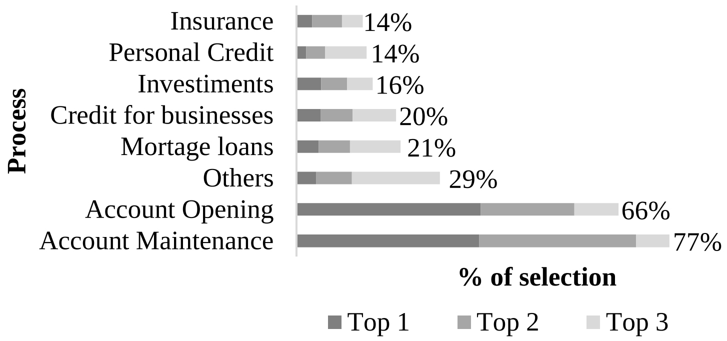

Figure 1 - Survey results

Customer's account maintenance is one of the banking operations that further fosters the establishment of a long term bank-customer relationship. It encompasses any changes that a customer may wish or is obliged to perform in order to manage their bank account to their will. The process requires coordination between employees from front and back office and it's usually performed through a software application. Its operations mainly include customer's documents collection, scan and indexation, printing of documents such as terms and conditions and forms' filling. To minimize operational risk and ensure the validity of operations there are multiple points of validation and approval throughout the process.

While analyzing the process the project team identified that it had a return rate of 28%. As presented in figure 2, a further investigation revealed that the main causes were the entry of incomplete or incorrect data and errors detected in document scanning or indexing.

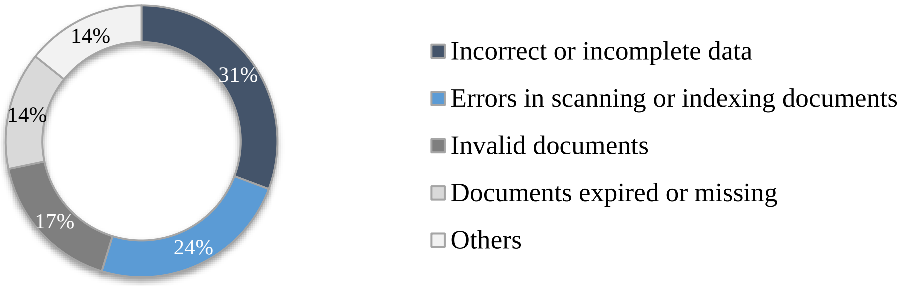

Figure 2 - Causes for account maintenance process return

For an accurate diagnosis of the current state of the process the project team also analyzed in more detail the survey conducted and performed a value stream mapping involving directly the employees.

Besides supporting the selection of process with greater room for improvement from employees' perspective, the survey conducted also enabled the identification of its main inefficiency factors, since each employee was also asked to justify their selection. The arguments raised were analyzed in detail and classified in five main categories. Figure 3 illustrates the percentage each factor was mentioned of all responses.

Figure 3- Inefficiency factors highlighted by employees

For the value stream mapping the process was divided in two sub processes, maintenance of customer's data and maintenance of customer's account details. In figure 4 and 5 the simplified value stream maps obtained for each sub process are presented.

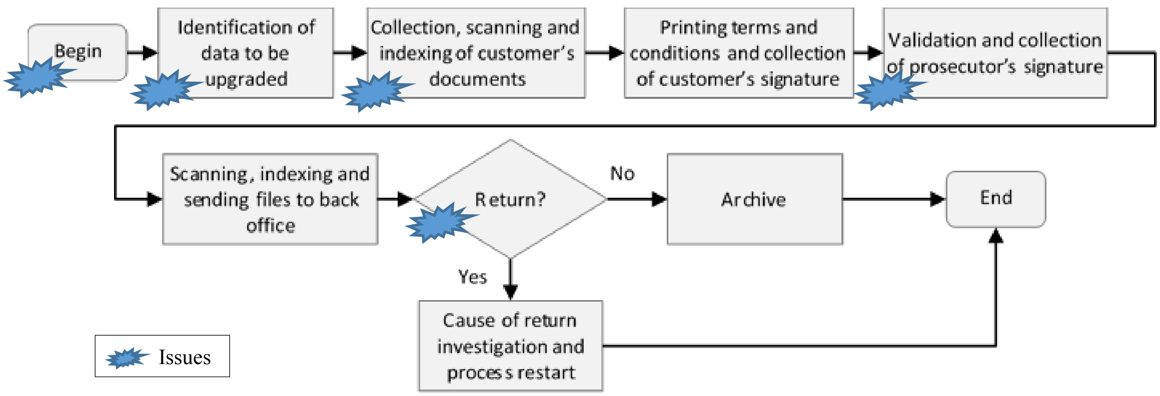

Figure 4 - Simplified value stream mapping of sub process "maintenance of customer's data"

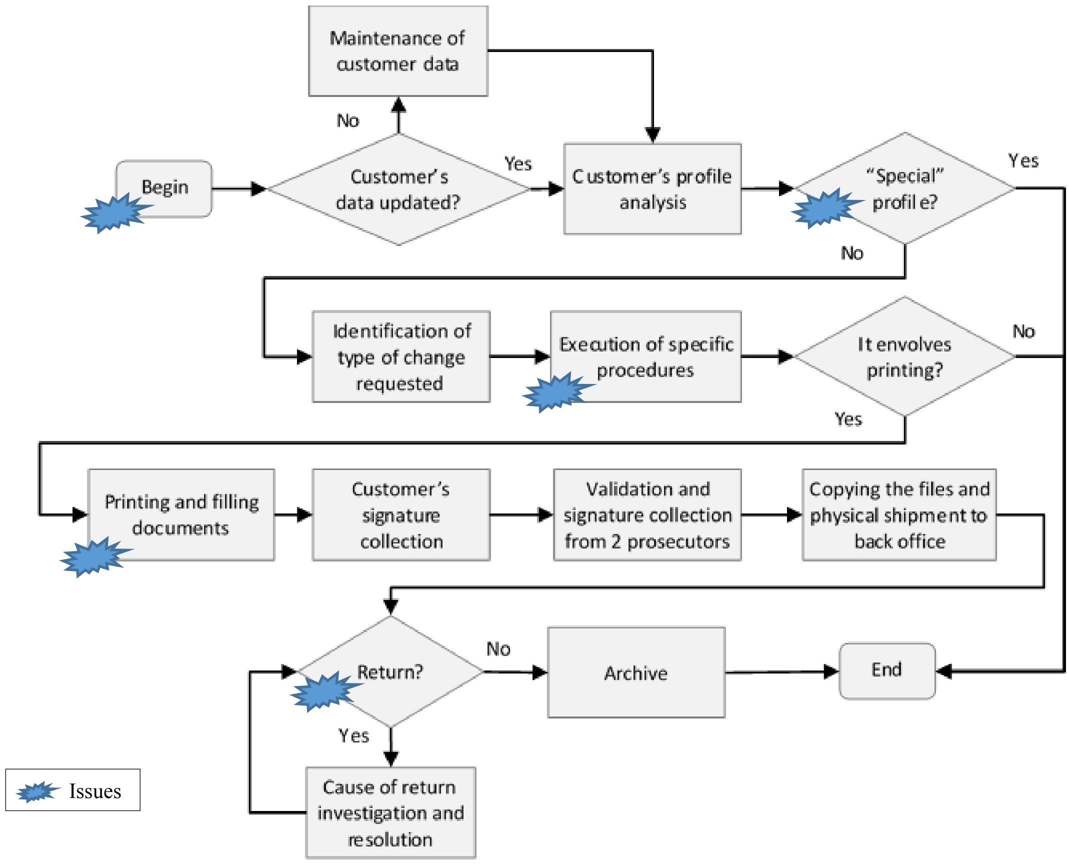

Figure 5 - Simplified value stream mapping of sub process "maintenance of customer's account details"

These detailed representations enabled the identification of several opportunities of improvement. Considering these and other opportunities identified throughout the different stages of diagnosis and analysis an Ishikawa diagram was created, as shown in figure 6.

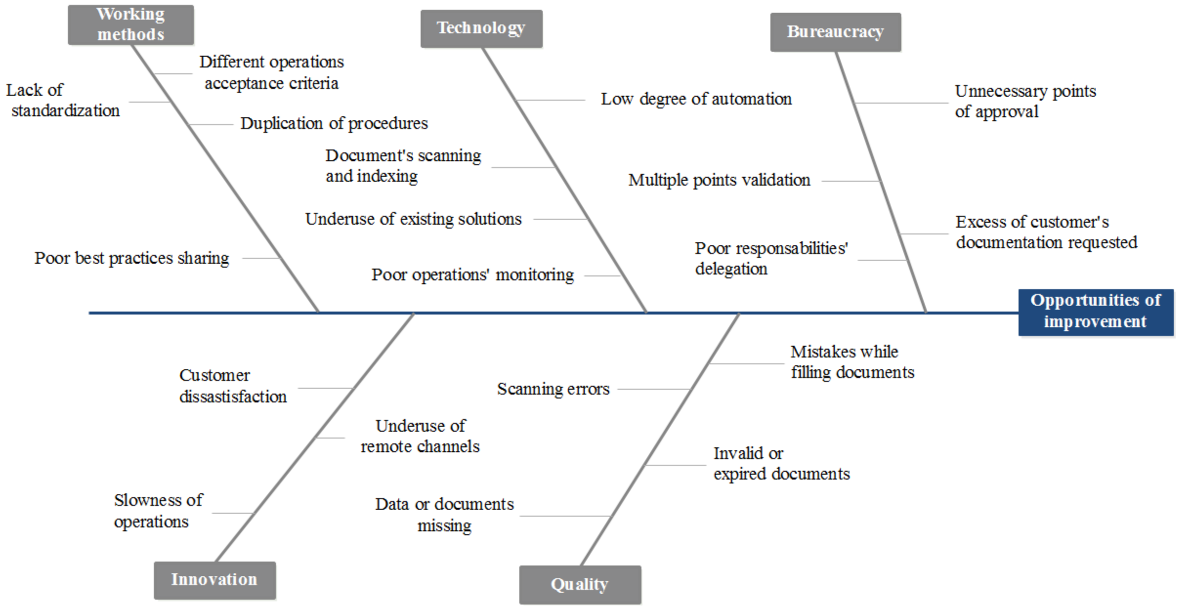

Figure 6 – Ishikawa diagram of the opportunities of improvement identified

The opportunities of improvement were systematized in five categories and for each there were defined multiple solutions summarized below:

1. Working methods. To face the lack of consistent and standardized working methods there were proposed multiple templates, checklists and establishment of the best practices to follow.
2. Technology. To carry out certain operation the process showed lack of adequate technological support. As a result it was much slower and prone to errors than it could potentially be. The proposed solutions in this regard was to adapt relevant technologies already used in other processes and develop the software application used, aiming to add new functionalities that enable a better process monitoring, automate certain form filling tasks and minimize errors.
3. Bureaucracy. In regard to the bureaucracy detected in this process it’s important to distinguish the formalities used in excess and the ones that are essential, in order to minimize operational risk for example. After a thorough analysis there was a proposal to eliminate all points of validation and approval seen as dispensable and keep to a minimum all administrative procedures.
4. Innovation. Considering the increasing market competitiveness and emergence of innovative solutions it’s critical to keep up with the new trends and find new ways to do business while continuing to meet the evolving customer’s needs and desires, in order to preserve competitive advantage. In this scenario the proposed solution was a greater use of online

channels to perform great part of the process. It was also proposed the incorporation of modern devices to capture images and thus enable the elimination of scanning tasks.

5. Quality. Regarding the promotion of greater quality in all operations and consequent reduction of the return rate several solutions previously mentioned can be applied, especially the establishment of the best working methods and the recurrence to technology to minimize errors.

With these implementation of the proposed solutions the process lead time and return rate are expected to decrease and the efficiency should increase significantly. In figure 7 the maximum potential estimated, in terms of FTE's (*full-time equivalent*) reduction, with this lean based approach in presented.

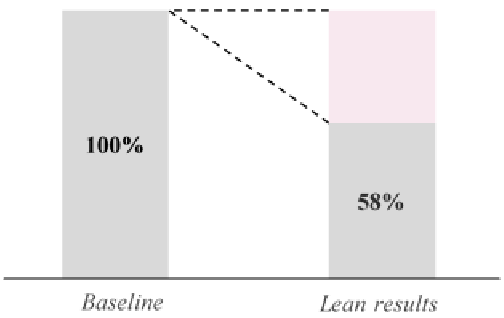

Figure 7 – Lean results estimated in reduction of FTE's allocated to the process

Currently after implementing exclusively quick wins, which represent 30% of all solutions proposed, the bank has already achieved a reduction of 25% of the lean results estimated.

6. Conclusions

The present paper has been developed to discuss the application of a lean concepts and tools to a real banking environment. The case study conducted included the design of a lean approach adjusted and suited to the reality of one of the largest Portuguese banks. The approach designed was based on multiple critical success factors identified in the literature review, such as the diagnosis of the current state, employees' empowerment, top management commitment and gradual implementation, but it didn't fully contemplate others.

The main lean concepts that guided the approach were the minimization of waste, work standardization, team work and continuous flow. As for the lean tools employed the value stream mapping, *gemba walk* and brainstorming should be highlighted.

The findings of the study conducted revealed that a lean based approach has potential to promote a greater operational efficiency of a banking process, however it's not enough to achieve a true lean enterprise. Currently, after a partial implementation of the solutions proposed within the lean project conducted, the bank has experienced several benefits in the process analysed and improved. However the approach used was not a holistic one, which means a lean culture was not created in the bank and other areas remained exactly the same. By continuing to disseminate lean practices throughout the bank the results experienced gain further impetus and more value can be created to customers.

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A Proposal to Systematic Innovation: Engineering and Financing Design

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Abstract

The worldwide market of nowadays is volatile and increasingly calls for tangible and nontangible customized products. This is a remarkable challenge to companies, which must implement processes for generating new ideas that could fulfil the consumer´s aspirations, as well as more efficient internal processes. The need of continuous production of new ideas implies a fast decision-making process to select the ideas that deserve to be explored. Such fast decision-making should take place in the conceptual design phase, and should consider both engineering and economic matters. TRIZ, "lateral thinking", "thinking out of the box" or "case-based reasoning" are useful to find design solutions, but they lack the tools that are required to evaluate the goodness of those new designs. However, the new designs should be technically and economically sound, so that the idea makes the innovation come true. This paper presents a decision-making framework based on Axiomatic Design (AD). Specifically, the AD's hierarchical decomposition and mapping between design domains will be used to systematically examine the engineering and the economic feasibility of innovative ideas.

Keywords: Axiomatic Design, Design Architecture, Engineering Design, Innovation.

1. Introduction

The market of nowadays is characterized by a continual willingness of new tangible and nontangible customized products and services. Innovative products or services are meant to exceed the perceived customer needs. The appropriate identification of those needs should answer, not only to the current, but also to the forecast needs. The success of organizations mostly depends on innovation.

The set of requirements for an innovative design is mostly originated through a careful interpretation of the current needs of people or organizations. A large number of researchers proposed several approaches to help on the identification of first-hand customer attributes that, once fulfilled, make an innovative design.

The elicitation of customer attributes emphasizes the transformation process that converts costumer verbatim constructs, which are often tacit and subjective, into an explicit and objective statement of customer needs (Jiao and Chen, 2006). Customer needs may originate from diverse customer groups in various markets, through different channels, such as interviews, questionnaires, feedback from sales agents and retailers, customer comments and complaints, as well as field maintenance reports. Jiao and Chen (2006) point out two different approaches: psychology-based approaches (perceptions, motivations, attitudes and personality) and AI-based approaches (fuzzy systems, regression analysis and neural network techniques).

In the management of product innovation, many researchers propose a combination of different analytical techniques to identify and assess the customer needs. Quality function deployment, analytical hierarchy process and fuzzy set theory are included in the hybrid system proposed by Fung *et al.* (1998). Other combined techniques are proposed by other authors, such as radial basis function (RBF) and neural networks (Chen *et al.*, 2003), axiomatic design (AD) and function-behaviour-structure (FBS) (Li *et al.*, 2010), and AD and Case-Based Reasoning (CBR) (Janthong *et al.*, 2010). The Kano's model is often used to understand the importance of customer attributes and their impact on the customer satisfaction, (Jin *et al*., 2016).

Matt (2011) suggests that the identification of the customer needs should be based on a hierarchical decomposition that can be depicted by a tree of customer attributes, which should take into account the costumer benefit. This decomposition should take place inside the costumer domain, as to keep the neutrality of the hypothetical solutions.

Systematic innovation is herein understood as the boldness of organizations to be permanently aware of new opportunities for the development of novel and useful ideas to cast innovative products. The success of the organizations largely depends on innovation. Together with the process of creativity, it is important the evaluation of new ideas. The scope of this paper is to provide a method that facilitates the evaluation and the further decision-making in the embodiment of new ideas, specifically in what concerns to discarding ideas that, for some reason, cannot be successful.

2. The Axiomatic Design framework

Axiomatic Design (AD) relies on the concepts of domains, mapping and two axioms: the independence axiom and the minimum information axiom (Suh, 1990). It provides a systematic and logic method to drive the design activity in such a way that avoids the traditional trial and error cycles in the search of good solutions, and can go from the early assessment of the solutions to the advanced control of the complete design process. As a sound theoretical foundation for engineering design that follows the pattern and the criteria of modern science, AD provides a systematic flow of procedures that encompasses evaluation criteria as to allow the elimination of the so-called "bad solutions" as soon as possible, empowering designers to focus on the most promising ideas.

In AD framework every "design object" can be represented in an interlinked set of design domains. Traditionally one considers four deign domains, costumer, functional, physical and process, but a different number of domains can be used, depending on the nature of the problem under analysis. For the case of this paper, we will consider just two domains: the functional domain and the physical domain, as depicted in Fig. 1.

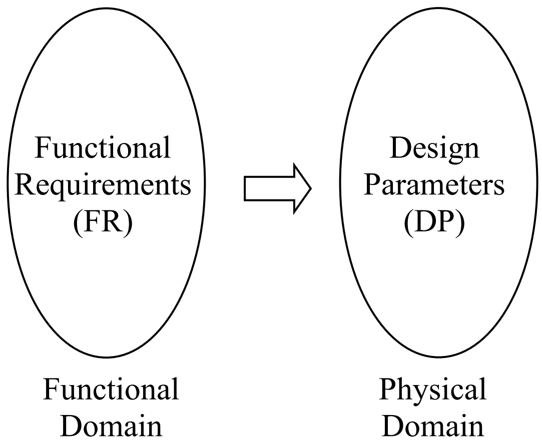

Figure 1. The functional and physical AD domains.

The mapping between those domains, from left to right and from top to bottom, following a zigzag path, is the basis of every AD assessment. This "zigzag" stops when an appropriate level of detail is attained in the description of the design object, as illustrated in Fig. 2. Notice that mapping between the costumer and the functional domains is not usually preformed as stressed by Matt (2011).

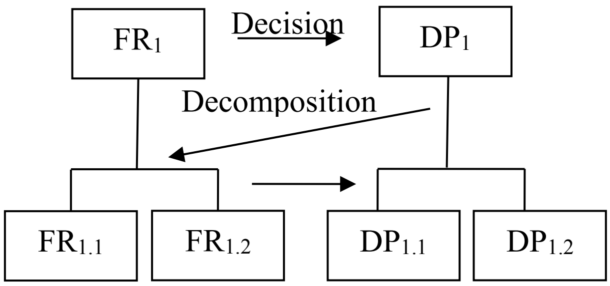

Figure 2. Mapping between the design domains.

The mapping between each pair of contiguous domains is represented by a design equation. For example, the mapping between the functional and the physical domains is represented by the equation

$$\{FR\} = [A]\{DP\}, \quad A_{ij} = \frac{\partial FR_i}{\partial DP_j}, \quad i = 1..,m, \ j = 1,..,n \tag{1}$$

where $\{FR\}$ is the vector of functional requirements, $[A]$ is the design matrix and $\{DP\}$ is the vector of design parameters. The total numbers of FRs and DPs are expressed by m and n, respectively.

During this process, a DP should be identified for each FR. The decomposition can then proceed to the next level of FR's and continue until the details of the design object are clearly understood. For the same pair of domains, the design equation of the two-level design of Fig. 2 is

$$\begin{Bmatrix} FR_0 \\ FR_{1.1} \\ FR_{1.2} \end{Bmatrix} = \begin{bmatrix} A_{00} & 0 & 0 \\ 0 & A_{111} & A_{112} \\ 0 & A_{121} & A_{122} \end{bmatrix} \begin{Bmatrix} DP_0 \\ DP_{1.1} \\ DP_{1.2} \end{Bmatrix} \tag{2}$$

The quality of the design process is evaluated trough the way the design matrix is populated. Ideal designs are uncoupled and have diagonal matrices, that is, each FR is fulfilled by setting one only design parameter (DP), which does not ultimately impact any other FR. Decoupled designs, with their triangular matrices, also fulfil the independence axiom. However, the values of the DP's should be set in a certain order, so that the value of each DP only impacts one FR. Designs with any other shape of the design matrix are coupled and the independence axiom does not hold. Therefore, coupled designs should be avoided. For all the suitable alternative solutions, the best is the one that has the minimum information content, as per the second axiom.

The zigzag decomposition that has been made in Fig. 2 describes a "design hierarchy" that represents the design object. Together with the design equation shown in Eq. 2, the design hierarchy reveals the existing interplay between all the design elements, even between the ones that belong to different design levels. In fact, the selection of DP_0 limits the selection of FR's and DP's in the next level (Lindholm *et al.*, 1999). As one can see, the zigzag decomposition turns the design process into a controllable procedure (Tate, 1998).

3. The assessment of innovative ideas

Organizations that work with systematic innovation have usually a large quantity of new ideas to deal with. Many of those ideas are not suitable for implementation because either they are technically unfeasible or economically inappropriate. Therefore, appropriate criteria are required to systematically evaluate the fittingness of those new ideas.

In this paper, we argue that Axiomatic Design is an appropriate framework to deal with innovative designs in what concerns to their feasibility, since the outset of their development. This allows to early get rid of the ideas that do not deserve to be explored. As a result, a method for the evaluation of the worthiness of new ideas is proposed.

Fig. 3 represents the design matrix of the equation that should rule the evaluation of a new idea, where "x" represents relationships between FRs and DPs. The DPs were selected as to satisfy the FRs and, at the same time, to create a triangular design matrix, so that the independence axiom is fulfilled. The selection of the DPs was repeated until the triangular condition was attained, so that each DP does not disturb the previous FRs.

		Process analysis	Marketing strategy	Technology	Internal resources / Development of partnerships	Management focused on value creation	Financing capacity	Information validation and confirmation of business model main assumptions
		DP_0	$DP_{1.1}$	$DP_{1.2}$	$DP_{1.3}$	$DP_{1.4}$	$DP_{1.5}$	$DP_{1.6}$
Evaluate a new idea	FR_0	x						
Ensure sales	$FR_{1.1}$		x					
Ensure technical feasibility	$FR_{1.2}$			x				
Utilize the maximum capability of the organization	$FR_{1.3}$		x	x	x			
Ensure a suitable economic return	$FR_{1.4}$		x	x		x		
Ensure financing	$FR_{1.5}$					x	x	
Anticipate business and context key risks	$FR_{1.6}$		x	x	x	x	x	x

Figure 3. The design equation of a new idea.

FR_0 represents the main goal of the evaluation and DP_0 is the adopted strategy. The functional requirements and the corresponding design parameters in the next level of the zigzag decomposition have the following explanation:

$FR_{1.1}$, “Ensure sales”, is easy to understand. New ideas must address the fulfilment of identified market needs. Each company may tend to focus on specific markets and segments, accordingly to its corporate development strategy. The corresponding $DP_{1.1}$, “Marketing strategy”, including market research and the setup of the marketing plan addressing product’s competitive advantages and price range, promotion and distribution channels (Burgleman *et al.*, 2009, 1073-1076), is the understandable way to fulfil FR_1.

$FR_{1.2}$, "Ensure technical feasibility", within prescribed cost parameters, is fulfilled trough $DP_{1.2}$, *i.e.*, the selected "Technology".

$FR_{1.3}$, "Utilize the maximum capability of the organization", means that the organization should have the ability to successfully implement and manage without waste the new idea. $DP_{1.3}$, "Internal resources / Development of partnerships", is the oriented strategy to set up the implementation team, optimizing the use of internal resources along with the development of the necessary partnerships with third parties. .

$FR_{1.4}$, "Ensure a suitable economic return", is self-explanatory. The corresponding $DP_{1.4}$, "Management focused on value creation" is the adopted strategy, described in a Business Plan that integrates the sales forecast, operational costs and total investment estimations (Burgleman *et al.*, 2009, 944-948).

$FR_{1.5}$, "Ensure financing", is guaranteed through $DP_{1.5}$, "Financing capacity". All companies have limitations to raise additional financing, either through shareholder's funds or bank debt. The financing needs for the implementation of the new idea, as previously determined, must be compatible with the financing capacity of the company.

$FR_{1.6}$, "Anticipate business and context key risks", represents the evaluation of the risks associated to the implementation of the new idea, as for example, the likely violation of regulations, patent infringement, and fair or unfair competition. $DP_{1.6}$, "Information validation and confirmation of business model main assumptions", is the strategy to anticipate the potential business and contextual risks.

It is worth noticing that the FRs of Fig. 3 describe a set of actions that are proposed for the evaluation of new ideas, while the DPs represent a possible solution for the aforesaid evaluation that complies with the independence axiom, which are inspired in the ones that are proposed in previous works (Santos, 2011a; Santos *et al.*, 2011b).

In a certain way, the criteria that were found are similar to the ones pointed by (Nasierowski, 2006), although this last author did not use an AD framework and did not take into account the relationships between FRs and DPs.

The triangular shape of the design matrix of Fig. 3 indicates that a certain order in the application of the assessment criteria should be followed. For example, it is worthless to evaluate the technical feasibility ($FR_{1.2}$) if sales ($FR_{1.1}$) are not ensured.

4. Conclusion

The goal of this paper was to create a method to systematically assess the feasibility of new ideas. This paper presents a decision-making framework based on Axiomatic Design (AD). It was shown that the problem of evaluating new ideas could be represented by a design equation with a triangular matrix. This means that the selected evaluation criteria should be used in a certain order as suggested by the AD's independence axiom. The proposed method allows the early exclusion of the new ideas that do not deserve to be explored.

When two or more new alternative ideas that serve the same set of technical functional requirements are found, then the information axiom should be used to select the best one, a matter that we are planning to study in the future.

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Multilevel Triz contradiction in biomimetic

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Abstract

Over the last years there has been an increment of papers regarding both TRIZ and biomimicry. The greatest efforts were produced to introduce TRIZ fundamentals, like technical contradictions or function modeling as tools for knowledge transfer of biological organisms, in order to solve technical problems. Until this days, there is still much work to do about the multilevel modeling of natural systems, which is a crucial task for better describing biologist's knowledge and also useful for a faster identification of physical and technical contradictions. This paper proposes a new conceptual design framework, in order to describe high complexity systems as the natural ones, taking into account multiple scale levels, the hierarchical organization of the elements, stimuli, physical effects and the topologies used for organizing the element's structure itself. An exemplary case study about orb web is provided to show a physical contradictions between macro level and micro level.

Keywords: Biomimetics, Design Model, Multilevel, Triz, Contradiction.

1. Introduction

In the past years, many researches have focused the attention on the biological systems: the reason of such interest is easily explained by the extraordinary performance of structures which may be found in nature. A vast literature has been produced about this topic, even if spread under different labels (biomimetics, bionics, biomimesis, biomimicry, bionics, biognosis, biologically inspired design).

The main part of these works are focused on new methods for searching biological literature for functional analogies to implement, while only few papers such as (Sartori et al., 2010) suggest how to make successful the transfer of a concept from living to non-living systems. As Vincent said in (Vincent et al. 2006) "a simple and direct replica of the biological prototype is rarely successful, even if it is possible with current technology".

There are many reasons for explaining these difficulties that we summarized in two main aspects: interdisciplinarity and function modelling.

In the first case there is a communication problem, in fact the most acknowledged database of biomimetics knowledge are run by biologists, which not necessarily describe a living organisms for technicians looking for functions and the most appropriate biological resources suitable for addressing an engineering problem. However, it is not only a language problem, that could be partially solved by Bridging cross-domain terminology for biomimetic design (Chiu and Shu, 2005), but what is intimately different is the way a biologist and an engineer look at the solution. For example, while an engineer describe a material in terms of performance or technical specifications and manufacturing requirements, biologist take into account how in natural systems a long term evolution allows a homogeneous material to change locally and temporally its structure variables, expanding the design space of homogeneous materials and allowing the creation of new materials with specific property profiles (Wegst and Ashby, 2004). From the nature perspective, instead of developing new materials each time we want new functionality, we should adapt and combine the materials we already have. Bogatyrev in (Bogatyreva et al., 2004, Vincent et al. 2006) contributed to prove this thesis demonstrating how technology solves problems largely by manipulating usage of energy, while biology uses information and structure, two factors largely ignored by technology.

The second bottleneck consists of creating efficient functional models for describing the complexity of natural system. Several attempts have been produced starting from implementing models from conceptual design as Energy Material Signal model (Nagel et al. 2008), cause effect (Chakrabarti et al. 2005), functional basis (Stroble et al. 2008) or Function Behaviour Structure model (Vattam et al. 2010). Also TRIZ community provided a big contribution on this topic.

TRIZ was developed as a systems approach for engineering; biology is, itself, a system. Starting from this assumption, the conflicting functions are similarly classified into the standard TRIZ (Altshuller, 1988) features, which now allow the conflicts to be treated in the standard TRIZ system. Many authors (Bogatyrev 2000, Vincent and Mann 2002, Bogatyreva et al. 2004, Vincent et al. 2005, Hill 2005) provided several works about conflicts identification in biomimicry, trying to interpret natural phenomena as technical contradiction and identifying resources and inventive principles adopted for overcoming the technical conflicts.

This paper presents in section 2 a synthesis of the main features characterizing a natural system in order to fix what entities has to be highlighted during biology transfer. Section 3 proposes a new representative model for describing natural systems. Thanks to this functional modeling is easier to identify physical contradictions (also multilevel) as shown extensively in the orb-web example at chapter 4.

2. What is a Natural system

Investigating extraordinary performance of structures which may be found in nature, it became evident that their origin stands in the interaction of several different factors, which are characteristic of the biological world. In order to exploit nature for technical scopes it is mandatory to identify the main features that distinguish it from other systems.

Multi-material - One of the first aspects which have been investigated since biomimetic was born, is that natural structures are hybrid, namely composed by different basic substances; under a technical point of view, hybrid materials and structures (Ashby and Brechet 2003), allow better performances compared to structures made of a single homogeneous element. Moreover, one of the crucial aspects provided by long term natural evolution is how the various components in hybrid materials are configured for determining a specific physical properties. Therefore it is not sufficient to list all components of a system but also its shape is a key factor that contribute to fulfill the required function.

Topology - Beside the specification of the constituent substances, another factor influences the global behavior: in fact, if the physical properties are directly influenced by the geometry of the disposition of the components the structures are made of (Vikentiev 1989), it means that the topology is as much important as the intrinsic mechanical properties of the basic constituents themselves.

An example of the relevance of this fact, is that different studies about auxetic materials have been developed: counting on the contribution of the particular morphologies, these structures are able to globally behave like materials with negative Poisson coefficient (Gatt et al. 2015); this is the classical example of how the distribution of the material in the space, allows the material itself to obtain a certain property, in opposition of its homogeneous form, so to fulfill a specific function actually.

Hierarchical multilevel - Anyway, even if there are many different examples of hybrid structures in the technical literature, we are far from replicate the way nature “design” biological systems: in fact, organisms present several levels of organization of their structure, at many different dimensional scales; plus, under a functional point of view, all this levels are strictly connected, and the macroscopic features of a level are dependent by the characteristics of the levels below: this is a result of the hierarchical organization of natural structures, and the influence of the topology over the (functional) passage from a level to another.

As it is well in (Vincent et al. 2006), there is a difference between technic and nature: the first have developed a multitude of materials in order to fulfill different tasks; on the other hand, organisms have less “basic components”, but in order to realize an increasing number of functions, they have multiplied the number of hierarchical levels in which these few basic elements are arranged.

So, the difference between simple mono-cellular organisms and higher vertebrates, is not in the nature of basic constituent, such as proteins, but in the level of complexity of the organization of their structure, so that, the higher is the level of evolution, the more organic matter is organized in cells, tissues, organs, apparatus, etc...

Physical effects at different levels – The scheme, in which all structures are organized, using many different topologies, with a hierarchic logic, at different dimensional levels, involves different physical models in order to pass from a level to another. The correlation between shape, physical phenomena and functions has been well investigated in (Vikentiev, 1989). His work represents one of the first attempts of explaining how the shape of an element trigs a physical phenomenon in order to realize a function. In natural system, (despite the case of a fractal structures, and metamaterials) depending on the different scale levels of representation, shape and morphology change, modifying consequently also physical interactions. Therefore it is very common to explain the physical effect of a natural system at macro level by mechanical effects and as you go down to the microscopic level by chemical or electromagnetic effects.

3. BFM - Biological Function Model

In order to model a natural system, it is necessary to provide a description of the elements at all the scale levels. The dimensional levels will be conventionally called macro, meso, micro and nano levels. For each level there must be a core functional decomposition into Structure, Behaviour, Function with a particular attention to Topology, External Stimuli and Physical Effect. Here some practical suggestion to collect information from Biological Databases suitable for building the Biological Function Model- BFM proposed in figure 1:

Structure: The list of different elements that constitute the system with a focus on the functional zone of that elements looking at their operative zone and times. Furthermore is crucial to identify all the geometrical links between elements that composing the system, in other terms the so called structure **Topology** at that level scale**.** For easier reading it is recommended to describe, even briefly, the role each element plays in the structure and differentiate it from the others by different function or behavior.

Behaviour: Every element of the system interacts with others for providing a function by creating a particular behaviour. It can be described looking at how structural Topology trigs a physical phenomenum under a specific load condition, called Stimuli**.**

Function: It is the list of the final goals, the system at each level has to fulfill.

Contradiction. The BFM model has been conceived for facilitate the physical contradictions. As shown in the map, following the concise map, it is possible to put in the map the parameters owning to the conflict, and indicating with arrows the levels the contradiction was generated.

4. Case study: BFM application on the orb-web

For the purpose of this paper, the orb-web represents a good case study to explain the possibility to organize, in a coherent framework, the information provided by the biomimetic studies. It will be reported a simplified description of the orb web, constituting of four hierarchical levels, a limited number of elements for each level. Only main functions has been considered.

4.1 Macro level.

Structure - The orb-web at a macroscopic level is composed by two kinds of threads (Denny, 1976): **the frame silk**, which is disposed in radial direction from the center of the structure to the edge of the structure itself, and constitute the main connection with the surrounding environment. Superimposed on this supporting framework is the **viscid spiral**, made up by the second type of elements. **Topology:** the orb-web is a tensile structure (elements carrying only tension), composed by elements of different nature which realize a net.

Behavior - The web changes is behaviour according to the external conditions, and the several functions that must be fulfilled in a certain moment: the first behavior is related to the "structural optimization" of the web, which is mostly realized by the complex of the frame silk threads. As it is well described in (Denny, 1976), such optimization is realized by the spider using a strategy similar to the application of the Clerk Maxwell's lemma: the said goal is achieved thanks to the behave of the frame silk: as illustrated in the figure 1, the maximum force is in correspondence of an elongation of 1.25 (ε_{max} =0.25), which, is the maximum deformation of the dragline silk, not far from the theoretical ideal.

The second behavior is typical of the part of the web composed by viscid silk: the main characteristic of such threads is that they are able to dissipate a huge amount of energy, realizing a huge deformation.

Function. - The frame silk must fulfill tasks such as realizing a web which is able to **<u>preserve structural integrity</u>**, using less material as possible, ideally using threads that may work as safety lines (which absorbs the force of the falling spider), and, obviously **<u>realize an efficient trap.</u>**

4.2 Meso level.

Structure - Threads are the structures at the meso-level, and their role is to provide elements (at the macro level) characterized by different yield stresses, strength, and maximum elongations. Mainly there are two kinds of threads, and their different behaviors are determined by the number and the physical properties of the elements they are made of, and the way these elements are disposed;frame silk is composed by an high number (4 or 5 for Araneus Sericatus) number of strands (Denny, 1976), which have high initial Young modulus, high strength, and relatedly low elongation; viscid silk is composed by 2 strands with a lower Young modulus, a lower strength, and higher elongation. **Topology**: both silks are a disposition in parallel of elements of a single kind.

Behavior - The described structures for the silk have their own behavior which, in both cases, correspond to the mechanical response of the thread: due to the parallel disposition of the strands, and for the said topology, the effect is just to influence the cross section of the thread, preserving the stress-strain diagram, and, on the other hand, influencing the maximum load, and the energy dissipated, that, in both structures, is more or less equal.

The viscid silk from Araneus Diadematus, thanks to its structure, is able to absorb a certain amount of energy realizing an high elongation, and frame silk is able to absorb the same amount of energy but being less deformed (Gosline et al. 1999) (and, such deformation, as already stated, correspond to the optimal of ε_{max}=0.2-0.3 in order to save material).

Function - At this level, the described structures have the function of fulfilling the requirement described at macro level: the mechanical responses of the frame and viscid threads, which are structures at the meso level, obviously correspond with the characteristics of the components at the macro level: for the viscid silk, **higher admissible force is in correspondence of a very high elongation**, meanwhile for frame silk, **higher admissible force is in correspondence of a an elongation compatible around 1,25**.

4.3 Micro level.

Structure - The strands composing frame and viscid silks are made of a semi crystalline material (De Tommasi, 2010), which is composed of amorphous flexible chains (α soft fraction), which are reinforced by stiff and strong crystals (β sheets). In literature, there are many models of frame and viscid silk; anyway, we accept the assumption (De Tommasi, 2010), that in the strand's structure (both of viscid and frame silk), the mechanical response is dependent by the characteristic of the α soft fraction and β sheets, and the amount of α soft fraction in the semi crystalline structure as well. In other words, the mechanical response depends from the parameters of the constituent elements (α and β), and the way they are arranged in the structure, which means the topology: for instance, strains of frame silk have a more coherent orientation of crystals compared to the viscid ones (Du et al. 2006). **Topology:** a disposition of many components of two kinds, along a principle direction, characterized by variable grades of order, and preferential orientation.

Behavior - Even if fibers at micro level have a complex behavior, for the purpose of the present work, we assume that the mechanical response is managed, simply modeling the thread using strands with an high percentage of α fraction (viscid silk), or an high number of β sheets (Du, 2006).

On the base of the theoretical scheme, and validate by many experimental studies, the mechanical responses of the strands for both viscid and frame silk are reported in the proposed scheme.

Function - As it happened in the previous level, the basic function of the strands is to fulfill the mechanical characterization required in order to obtain the behavior of the structure at the meso level: for the viscid strand, **higher admissible stress is in correspondence of a very high deformation**, meanwhile for frame silk, **higher admissible stress is in correspondence of a an deformation compatible around 0,25**.

4.4 Nano level.

Structure - At the nano-level, there are the very basic components of the model, so there is nothing more to do than simply do a list of the elements at this dimensional scale: α fraction and β sheets.

Behavior - Describing the behavior of the structures at micro level it had been stated that, in order to characterize the behavior of the structure of the strands, it is necessary to formalize the characteristic of their basic constituents. For instance α (soft) fraction is modeled such as an approximate stress-strain law may be written as:

(Eq. 1)
$$\sigma_s = E_s\left[\frac{1}{4}\left(1-\frac{\varepsilon}{\varepsilon_c}\right)^{-2} - \frac{1}{4} + \frac{\varepsilon}{\varepsilon_c}\right]$$

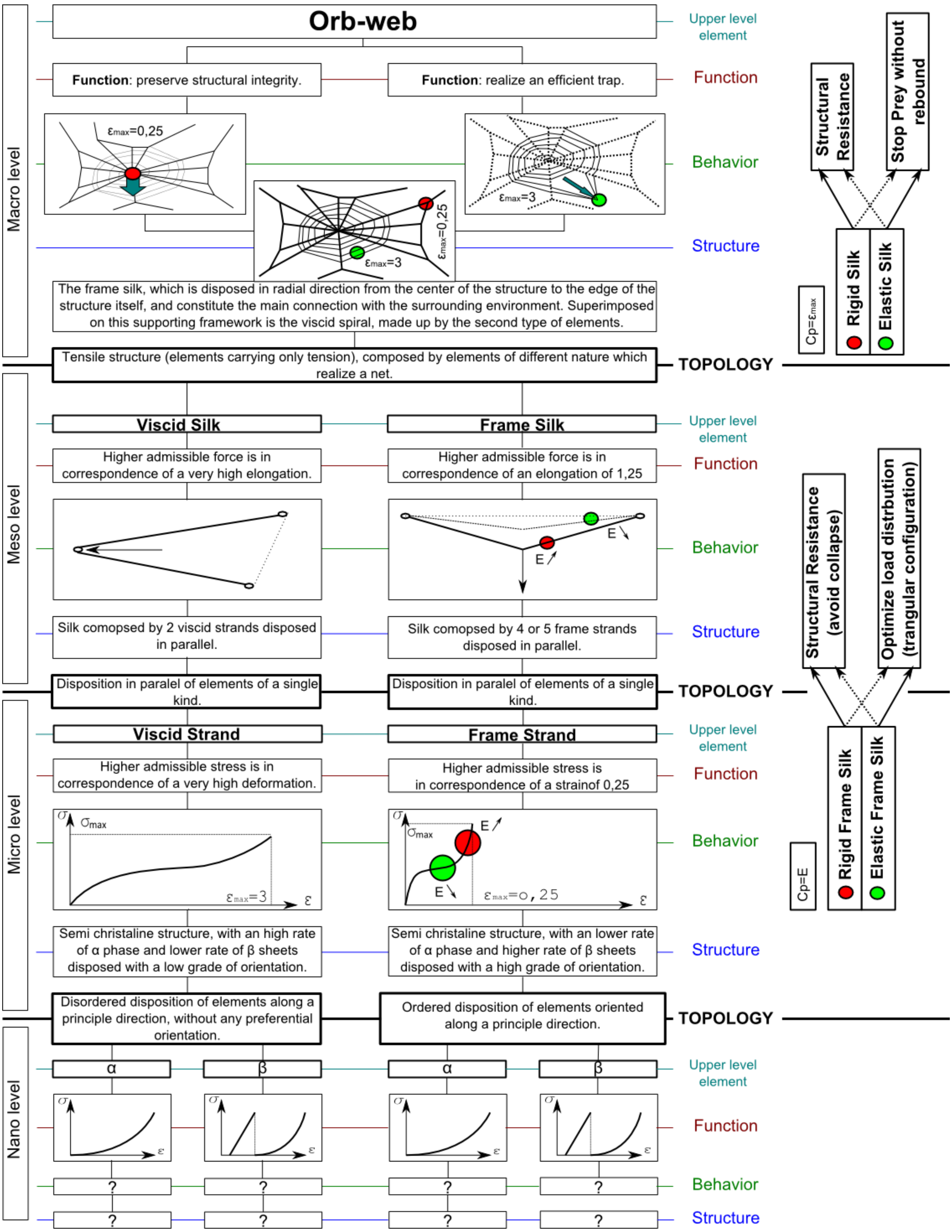
Where s_S, ε, and ε_C are the stress, the strain and a parameter that represent a contour length and assigns a limit strain.

Is it possible to characterize the second fraction, the harder one, provided by a superior percentage of crystalline state, the β sheets, as a linear elastic behavior:

(Eq. 2)
$$\sigma_h = \begin{cases} 0 & se\ \varepsilon \le \varepsilon_a \\ E_h(\varepsilon - \varepsilon_a) & se\ \varepsilon_a < \varepsilon < \varepsilon_t \\ \sigma_s & se\ \varepsilon > \varepsilon_t \end{cases}$$

Such equation system describes the phenomenon that had been described at meso level, in which the hard phase, reached a certain strain, operate a transition (De Tommasi et al. 2010).**Function** – Under a functional point of view, α fraction and β sheets must be characterized by eq. 1 and eq. 2 respectively, as it is reported in the proposed scheme, in order to fulfill the requirements of the elements at the meso level.

Figure 1. Scheme of BFM.



4.5 Contradiction.

Mono level contradiction can be formulated as follows:

PH-C1: I want the web has a **low deformation**, thanks to rigid silk (Ɛmax=0.2-0.3) in order to have a web with a high structural strength but in this way it is difficult to stop the prey can rebound.

PH-C2: I want the web with a **big deformation**/energy dissipation, thanks to elastic silk (Ɛmax=3) to stop the prey without rebound but in this way the web is not structurally resistant.

The solution to this contradiction at the macro level, is accomplished by the separation in space: a rigid frame (Frame silk) made of rigid silk contains the rest of the web made of elastic silk (called Viscid silk).

Multi level contradiction (is about the behaviour of the frame silk) can be formulated as follows:

PH-C1: I want the frame silk with an **elastic behaviour** *in order to* allow the web reaching a triangular configuration during first deformation (that allows to optimize the load distribution on the web as shown in Maxwell lemmas), *but in this way* the entire system cannot have enough structural strength and collapse.

PH-C2: I want the Frame silk with a **rigid behaviour** *in order to* have the desired structural strength avoiding the collapse of the structure, *but in this way* the web will not reach a triangular structural configuration during first deformation and will be not optimized.

The solution to this contradiction has been realized at multi-level by the separation in time: in fact, at **the meso level**, the fiber has to change his Young module on condition (after silk reaches Ɛmax> 0,2,5). In the diagram we can see a steep line on the left (before Ɛ=0,2,5) and a left portion that appears to be flat (low Young's module) up to a value of deflection close to that desired. To realize this behavior the solution works at **micro level:** silk frame is realized with a mix of low amount of amorphous chains α and β sheets high rate, organized in an ordered way. The different elastic response of α and β according to the growing of elongation allows to obtain the desired behavior at upper level.

5 Conclusion

In this paper a new functional modelling for biological system called BFM has been presented. It has been created exploding SBF at multilevel and focusing on physical effect, topology and stimuli. Thanks to this model is easier to identify physical contradiction both at the same level than multi level, allowing a better understanding of the biologic behaviour and contributing to creating a bridge between biology and technique. An example of contradiction formulated at meso level is resolved by the adoption of a specific structure (topology) in the micro level.

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The development of Technology Intelligence in the national innovation ecosystem; the case of Fuel Cell Technology

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Abstract

Policy makers at the national level and decision makers in firms generally needs to have appropriate and opportune information in various technological fields and innovation situations to make timely and effectively decisions. Lack of this information has irreparable consequences for organizations. The term "Technology Intelligence" is a generic solution for dealing with such a challenge. It is especially important in fields where technological development is rapid, and where changes are likely to occur more rapidly. The purpose of technology intelligence is to gain a technology based competitive advantage. This paper suggests a conceptual model for the development of technology intelligence in the national innovation ecosystem by using an empirical study in the fuel cell technology ecosystem. This model has six crucial items at its top level including performance and needed guidance, search and acquisition, processing, organizing and storing, analyzing, and documenting and disseminating. According to this model developing technology intelligence in the national innovation ecosystem can improve efficiency and increase wisdom in the ecosystem.

Keywords: Technology Intelligence System, Fuel Cell, Functional Architecture, Intelligence Needs**.**

1. Introduction:

Technology policy makers are always faced with the problem of decision-making and choices. Important factors in decision-making are accuracy, time and cost - which are often opposing dynamics. In other words, the decision maker must be able to establish an equilibrium between time, cost and accuracy to obtain the best result. Advances in information and communication science are some of the events that dramatically impact these three factors in decision making. These phenomena constitute a serious threat as they increase competitor intelligence which consequently increases science and technology growth rate which causes a shorter technology life cycle. This results in the time factor becoming more important in decision-making. On the other hand, this progress provides the decision maker access to a large volume of information. The inability of the decision maker to process and analyze this data can cause confusion and reduce accuracy. Therefore, rapid advances in science and technology can result in shorter life cycles for technology, increases uncertainly and risk in decision making, and gives access to a large volume of data which cannot be processed and analyzed by traditional methods. These kinds of factors show the necessity of a structured system for increasing the power of decision making.

Such a system has been introduced under various names in the literature in recent years, including technology intelligence (TI), Technical Intelligence (TI), competitive technical intelligence (CTI), a competitive technological intelligence[Vatcha,1993],[Safdari Ranjbar & Tavakoli,2015] or scientific competitive intelligence.[Bryant, 1993] Implementation and deployment of these systems increase the power of accurate and timely decisions in technological fields.[Porter, 2005] The importance and necessity of such systems can also be studied from the view point of the development platform of technology. Technology development is often dependent on the creativity of technology professionals and product designers. Since discovery of new opportunities and innovation in developing new technologies is necessary, innovative ideas are the basis for the successful development of technology. [Arai, 2006 & Yang, 2006]Creativity can be identified as the ability to detect new communications, testing subjects from a new aspect, and forming new concepts from current concept.[Couger, 1995 & Evans, 1990]Researchers have found that creativity is more dependent on a necessary infrastructure for growing ideas than the genius of the individual. [Gatignon, 2002] Therefore, it is necessary to increase innovative work by methods that facilitate the idea generation process and provide valuable information.[Yoon, 2008] This is one of the main goals of technology intelligence systems.

Today we know that there are three active ecosystems. First, business ecosystems focus on present customer value creation, and large companies are typical key players within them. Second, knowledge ecosystems focus on the generation of new knowledge, and research institutes and innovators, such as technology entrepreneurs, play a central role in these ecosystems. Third, innovation ecosystems occur as an integrating mechanism between the exploration of new knowledge and its exploitation for value co-creation in business ecosystems. The relationships and the dynamics between overlapping ecosystems is an important research theme, and we need to create tools to enable crossing borders between the ecosystems [Valkokari, 2015]. Technical Intelligence systems are one of the processes that focus on how actors can decision make in multi relationships and multi functions in their related ecosystems.

Based on these factors, the necessity of deploying and developing these kinds of systems are obviously understandable, particularly in countries like Iran where internal companies need to increase the level of professional expertise and science and knowledge in order to compete with foreign companies at the international level. Technology intelligence systems could provide valuable assistance at the national and regulatory levels. Therefore, this study aimed to concentrate on the conceptual design of technology intelligence systems in national level. But given that the design of this system is based on technology's innate characteristics the interests of beneficiaries associated with that technology and hence their variable needs should also be considered, intelligent system for advanced fuel cell technology was designed technology intelligence system is suggested for organizations or areas that have special circumstances such as the following:

1- Operate in technologically dynamic industry environments where the pace of change is rapid or new technologies are likely to surface.
2- Emphasize technology-intensive products where technology is a differentiating factor, product introduction rate is fast, market entry timing is important, regulatory approval of new products is complex.
3- Manage a significant R&D portfolio.

4- Expect a high share of near-term business revenue growth from new products.

For such companies, technology is a basic determinant of a company's competitive position and is the source of future growth.[Ashton, 1997] Accordingly, the establishment of a technology intelligence system for advanced fuel cell technology, which embodies all these of features [Karshenas, 2010],would be advantageous at a national level.

2. Literature Review

Because of The extensiveness and novelty of the literature we express this topic in three parts. In the First part we explain about the concept of intelligence and its position against other concepts such as data, information and knowledge.in the second part we will talk about kinds of intelligences and finally we will discuss about the provided models in this case.

2.1. Intelligence

When we want to talk about intelligence concept, it is unavoidable to face with other concepts such as data, information and knowledge which are strongly related to each other and we cannot analyze it without them. However some of editors believe that making differences between these concepts is useless. For example, we can mention to Mass which says:" data, words, records, or whatever it is called remains information and the term information encompasses all the others" [Mass, 1988]or the idea which denies the differences between data and information by reasoning that information is simply the physical representation of knowledge or its surrogate.[Farradane, 1979] However, the fact that there is a conceptual difference between Data, Information, Knowledge and Intelligence, has been confirmed by many authors that their comments are summarized in Table 1.

Table 1: Summarizing the literature of data, information, intelligence, knowledge

Concept	Definition
Data	Simple and naive Facts. [Courseault, 2004] A string of symbols, facts, measurements, statistics [Castillo, 2008] Scattered bits of knowledge. [Herring, 1998]
Information	The structured data [Adams, 2002] Given context and framework [Courseault, 2004] The data with relations [Arai, 2006] A piece of knowledge that can be encoded and stored. [Yang, 2006] Physical representation of knowledge [Couger, 1995] Composition of the particles [Herring, 1998]
Intelligence	Form of information [Castillo, 2008]

	Analyzed data [Adams, 2002] Inference analysis [Herring, 1998] Ability to understand and apply knowledge. [Yang, 2006]
Knowledge	Data / information, opinions [Evans, 1990] Information with high reliability and certainty. [Castillo, 2008] Information sharing [Castillo, 2008] Experienced data [Eysenck, 1995] structured internal data [Yang, 2006] Knowing mode [Yang, 2006]

In summary the above definitions can be stated that data is simple facts or a scattered bit which after restructure will change to information. This information, along with the meaning and concept is equal to intelligence. And finally, data, information or intelligence along with experience is equal to knowledge. These definitions are shown in Figure 1.

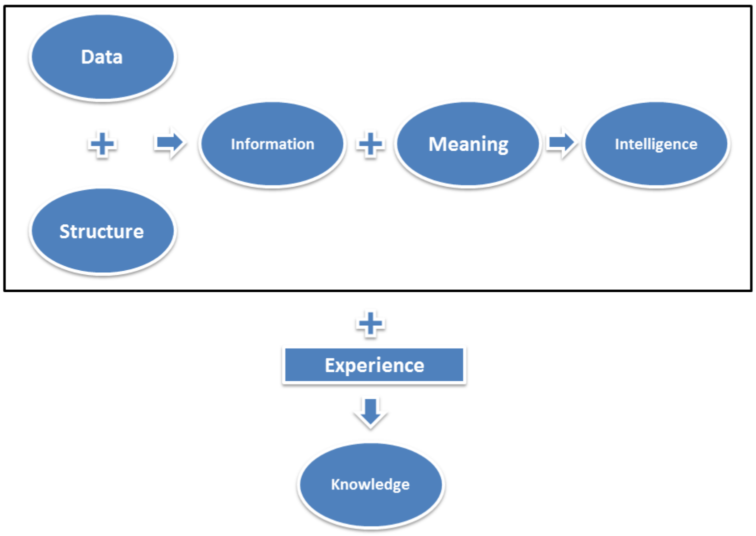


Figure 1.relation between Data, Information, Intelligence and Knowledge

2.2. Types of Intelligence

Intelligence based on an area that covers and the objectives which fulfills is divided into several types. Accordingly, intelligence that focused on the competitive environment of firm is known as Competitive Intelligence.[Kahaner, 1996] A CI system may track: a competitor's capabilities and strategies; the industry's structure and trends; the market and customer behavior; political, economic, and social forces; and technological developments.[Hohhoff, 1997] By the same token, when gaining insight about the environment is a part of the purpose of Intelligence systems, Business Intelligence, is introduced. [Savioz, 2004] Choo believes that: since competitive intelligence is a primary objective of activities within business intelligence, those two terms can be used more or less interchangeably.[Choo, 1998] Savioz presents the status of each of these concepts by using this idea which also has shown in Figure 2. Savioz believes that: Competitor intelligence is information-gathering about the actual and future activities of competitors, whereas competitive intelligence's focus is broader and embraces Porter's (1980) five competitive forces model. [Savioz, 2004] He also referred to the definition of business intelligence by "Gilad", believes that regarded to the relationship between study of the feasibility of future competitive environment of intelligent field and business intelligence approaches,operationally this kind of intelligence has the same kind of fireld with environmental scanning, which is defined as:"the acquisition and use of information about events, trends, and relationships in an organization's external environment, the knowledge of which would assist management in planning the organization's future course of action"[Auster, 1994] Social intelligence which is shown in figure 2, is concerned with the capability of society and institutions to identify problems, collect relevant information about those problems, and transmit, process, and evaluate, as well as ultimately put this information to use[Dedijer, 1987]

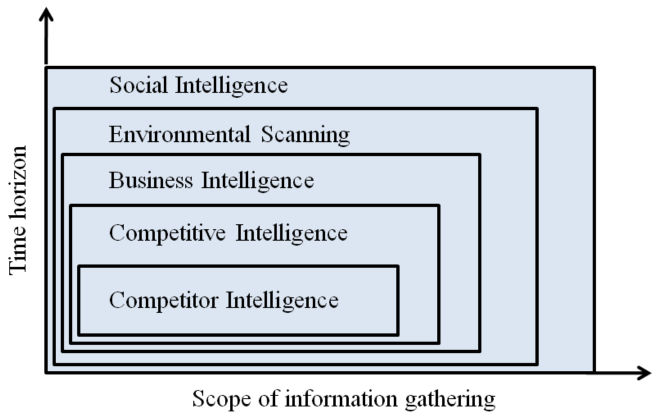


Figure 1: Types of Intelligence

However what will be investigetaed in this study, is the technology intelligence which is considered more as a subset of competitive intelligence. [Dugal, 1998] According to "Ashton", technology intelligence,is kind of intelligence which is conducted on technology and it's science infrastructure. that is component of the CI system that supports project and scientific funding decisions and helps decision-makers calculate the relative strength of other organizations.[Hohhoff, 1997] It emphasizes the R&D function of an organization, but can also encompass other technology-driven activities such as strategic planning, technology acquisition, and process equipment investments.

Technology Intelligence has been conceived as a capacity that allows identifying technology developments in time, and moreover, it comes up as a model that links the necessities of the market to technology innovation. In this way, it allows to differentiate among technology fields in use and those of interest that can be limited through future functions of the product and the weak signals in technology trends. [Castellanos, 2010]

Technology intelligence based on the concept and methodology is formed by several schools. From the perspective Savioz the definition of technology intelligence is in the heart of two schools of thought;
First, there are authors that present methods with the objective of predicting the technology development of the future. On the other hand, there is an attempt for the development of systems that allows observing the technology environment in which

the organization performs on a periodical basis with the purpose of evaluating its impact.[Savioz, 2004] The first school, in which the technology intelligence is conceived as a method to predict technology development in the future, belongs to Porter. He states that it is one of the many forms that overlap technology forecasting, including the road mapping and foresight, and this is why he classifies it as a family of the techniques of Technology Future Analysis –TFA. [Porter, 2004] in this school, "Porter" has seen the technology intelligence as a tool rather than considering it as a necessity for the future, and define it as wide current technical abilities. In this same school, Lang and Mueller with a strong approach technology- product- market (innovation), mention that the technology intelligence is a tool that allows to identify technology developments on time.[Lang, 1997] However, most of the authors belong to the second school that approaches the Technology Intelligence as a system that allows periodically observing the technology environment.López, expresses that technology intelligence is linked to knowledge related to the predominant directions in technology development, to the identification of the principal actors and to the actions that competitors in the different topics make.[Lopez-Ortega, 2006] Regarding Lichtenthaler, he conceives it as a group of activities related to the collection, analysis and communication of relevant information, taking into account the technology trends that support the technology decisions and the most general ones of the company.[Lichtenthaler, 2003] And this is why he states that it must be a systemic approach. This matches Rodríguez and Escorsa, when they state it includes an analytical work through time. [Rodriguez, 1998]

2.3. current intelligent Cycles and models

In this section we will review the intelligence cycles or models that provided by experts belonging to the second school. These models are developed for competitive intelligence models and business intelligence in the company’s level. The oldest and the most well-known of them is the model of The Central Intelligence Agency of the United States (CIA) which is shown in figure 3 (upper left side).[Kahaner, 1996] the other model belongs to the Savioz which is presented by utilizing Porter's value chain Figure 3 (bottom left). Savioz work has differences regarded to other cases. He introduced two sets of activities. The first group is TI process activities include determining the need for technology intelligence process, data collection, analysis, dissemination and use of information about the activities which is defined as original or direct activities for value creation, and the second group is indirect activities or supported activities that make the main activities possible. In Savioz chain the value in improving decision-making (through improved data quality (in terms of content and timing) and thus reduce uncertainty) is found. [Savioz, 2004] Third model is presented by Kerr to create technology intelligent system in company level from summarization of models available until 2006. The model as shown in Figure 3 (top right) includes 6 steps of coordination, search, filtering, analysis, documentation and dissemination. [Kerr, 2006]

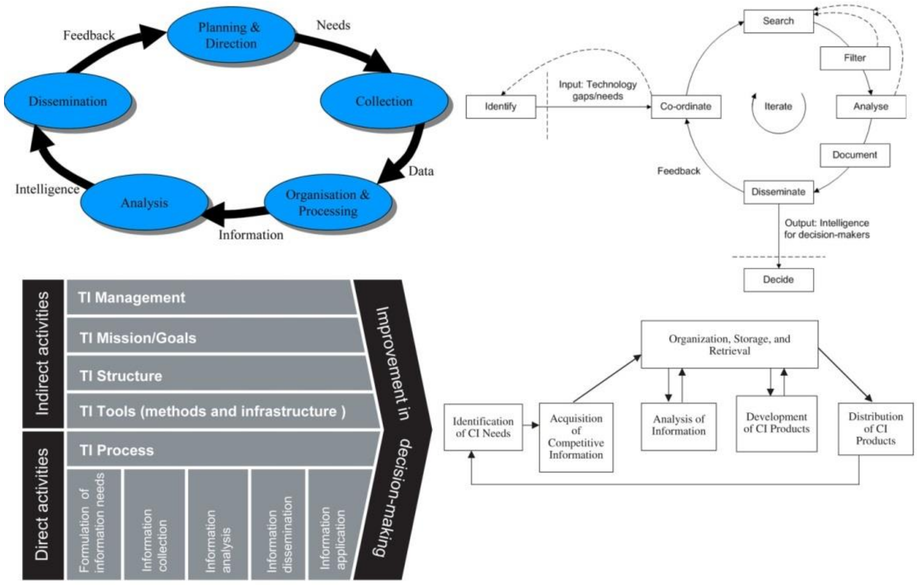


Figure 3.CIA, Kerr, Savioz, bouthillier models

Also Kerr believes that any intelligence system in an organization has four distinctive modes. Accordin to figure 4 the first mode (down left) is related to the time which the required intelligence in a system existes inside the organization, and the orgainization is aware of it's information weaknesses. In this condition the system will search them and explore the needed parts. The second mode (up left) is equal to the time when the required intelligenece is exist in the organization but the organization is not aware of it. in this condition the system should specify that who knows about information and where are documents.[Kerr, 2006] Unlike these two modes of system which concentrate on inside of the organization,two other modes have external focus.the third mode (down left) equals to the time when the organization knows what it is looking for and where should it concentrate, but in the fourth mode of organization even does not know about what it wants.

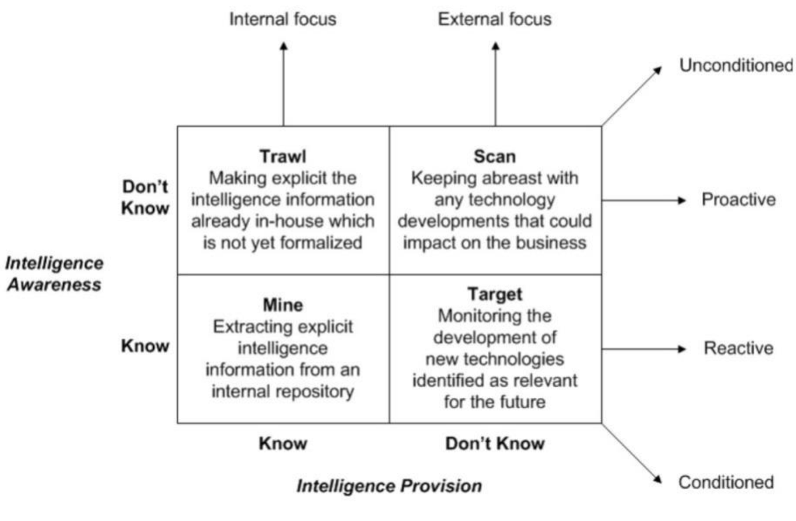


Figure 4. four modes of intelligence system in evry organization from Kerr view

3. Research Method

this research based on its porpuse, is applied research because that is trying to answer a difficult problem in reality .also this research based on methode, is qualitative research. Community of Experts and Interviewees are limited and descriptive data and results are wide and open. This research extracts the functional architecture of the system for designing of a technology intelligence system at the national level. However, due to the reasons which explained in prefrence, the structure of fuel cell advanced technology is presented.
Systems are integrated set of interoperable elements, each with explicitly specified and bounded capabilities, working synergistically to perform value-added processing to enable a User to satisfy mission-oriented operational needs in a prescribed operating environment with a specified outcome and probability of success. [Wasson, 2006]

Each of these elements is known as the physics that are responsible for one or more functions. Functions are processes of changes inside the system which have series of inputs and outputs. In other words, functions are saying a system as a whole (which is responsible for the main functions) and subsystems (which are responsible for sub functions) what will be doing, and physics are responsible for performing these functions. Set of functions and their relationships form the functional architecture, and set of physics and their relationships form the physical architecture, and finally connection between the two structures together with the appropriate interfaces, creates the whole system.[Wasson, 2006& Buede, 2009] Thus the functional architecture of the system is a map of what the system must do to meet the needs of its stakeholders. Therefore to design the functional architecture of a system first we should determine stakeholders and their needs.[Wasson, 2006& Buede, 2009] In this research the result is conducted through explored semi-structured interviews. The population is divided to two grope on this point. One group is customers, investors and capital funders who decide on technology choosing and second is the professionals, developers, and researchers who will decide on the acquisition and application of fuel cell technology. The firs group is defined for people who ordered one project for fuel cell technology or invested on it and the second group is people who have presented at least one scientific paper about this subject. Data for this section were analyzed using content analysis and based on that, the framework of technology intelligence needs of fuel cell is presented.

After identifying stakeholders and their needs, based on that the functional architecture of the system is designed. To derive the functional architecture, due to the novelty of the subject, limited resources, and even the experts it is used from two steps processes. In the first stage the functions of the system is derived by using of a comparative study of current models and cycles, analysis and interpretation of data which are obtained from library research ,and finally researchers experience in the system analysis and design .in the second stage the functions derived from the first stage is completed and the relations between them are explored by a 10 people expert panel (including experts in intelligence, data mining, and information technology) and by using storm thinking and What If Scenario.

4. Research results

4.1. Stakeholders of Fuel Cell Technology Intelligence System

A fuel cell is an electrochemical cell that converts chemical energy produced from the reaction directly into electrical energy. This technology is in the first step of its life cycle and does not enter to the marketing step seriously; therefore presently a considerable part of the technology portfolio includes research and development. It is hoped that this technology is replaced with alternative available products in the market in the near future.[Karshenas, 2010]fuel cell applications will consist of a wide range of applications. Mainly places in three groups: power plants, portable and transportation, for this reason many stakeholders are concerned for this technology. Based on the results of the content analysis of the results semi-structured interviews with population introduced, stakeholders of fuel cell technology are placed in ten groups as follows:

1. Specialists and manufacturers of fuel cell 2.Investors and financial supporters 3.consulting firms and inspectors.4.Research and academic organizations 5.Maintainers 6. Organization of Standardization 7.The owners of the exclusive rights 8.customers: private or governmental companies which require this technology based on their needs. The difference between fuel cells and other energy supply resources is that some of its advantages and applications are unknown till now and therefore has a great potential of customers which need this technology as soon as they inform of its applications. Therefore we can divide this group in to two groups of potential customers and actual costumers 9.policy makers 10.Compatitors.

The mentioned stakeholders based on the similarity of the decision field are divided into five groups in accordance with Figure 5. Both customers and investors based on their needs (profitability of investment, energy supply, energy security, etc.) choose an appropriate product technology and then order the specifications and indices of the selected product to the professionals and vendors. The other three groups are making decision about acquisition and utilization of technology. These groups should decide about which method be used to meet the costumers’ needs and profit more. Also these people should be able to use the achieved technology in various applications to attract potential customers.

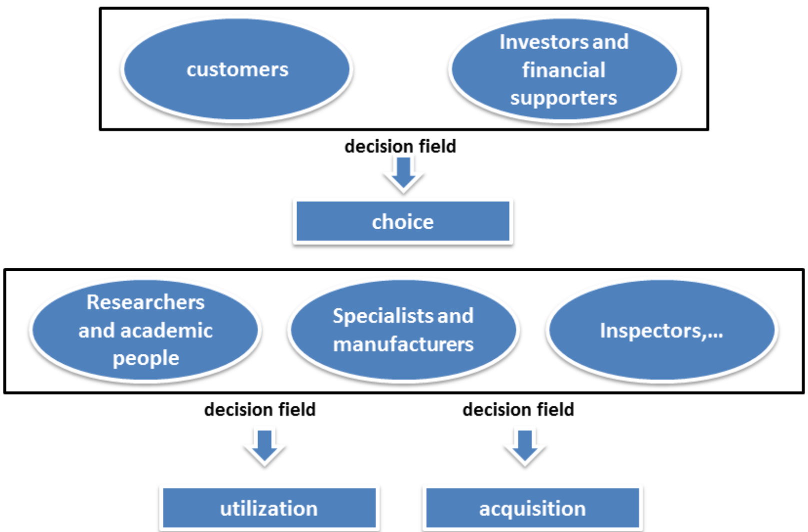


Figure 5. decision field of system stakeholders

4.2. Framework of needs of fuel cell technology intelligent system

The first group of stakeholders' is policy makers often include a government, unions (national and international) or even Parliament. These decisions because of great importance in the development of technology must manage and be guided by the system. System has the task of intelligence management of this group and how to deal with this system is not demand-driven. The next group is potential customers who do not have any demand of fuel cell because of lack of knowledge about the technology, lack of recognition or presentations related to their applications in the field of fuel and etc. these people needs to be informed about this technology to become actual customers which needs a kind of neutral and universal intelligence from the system. While the potential costumer does not apply any request to the system, actual customers, professionals, researchers, etc apply their demand to the system. This demand can be a simple demand which is merely a request for information on a specific topic (information demand). The system should meet their demand as soon as possible and analyzing information and data is no longer needed. In that case, the user gives an intelligence demand to the system, it means, his request is not raw data, the system must answer it the user according to its needs. However according to person interviewed the whole needs of all stakeholders are not what they say. Part of stakeholder needs, are the needs that decision makers are not aware of it now and it does not demanded, therefore it is not easy to estimate it accurately. We call these kinds of needs as unconscious needs. And in case of previous needs which decision maker are aware of it and ask for it from the system are conscious needs. Intelligence demands are output of conscious needs.

So what the system should meet them is classified to four major groups according to Figure 6: the first are intelligence needs which are asked from the system by the decision-makers and we call it Intelligence Demands and the system provides them according to receiving the request. The second one is constant needs that should be met by the system generally and continuously and are not request-based (such as potential customers need). Third are unconscious needs which decision maker is not aware of them and the system must alarm to the decision maker about it. These needs are also not request-based and the system should meet that by use of scanning environment continuously, and finally the information demand that is requested from the system.

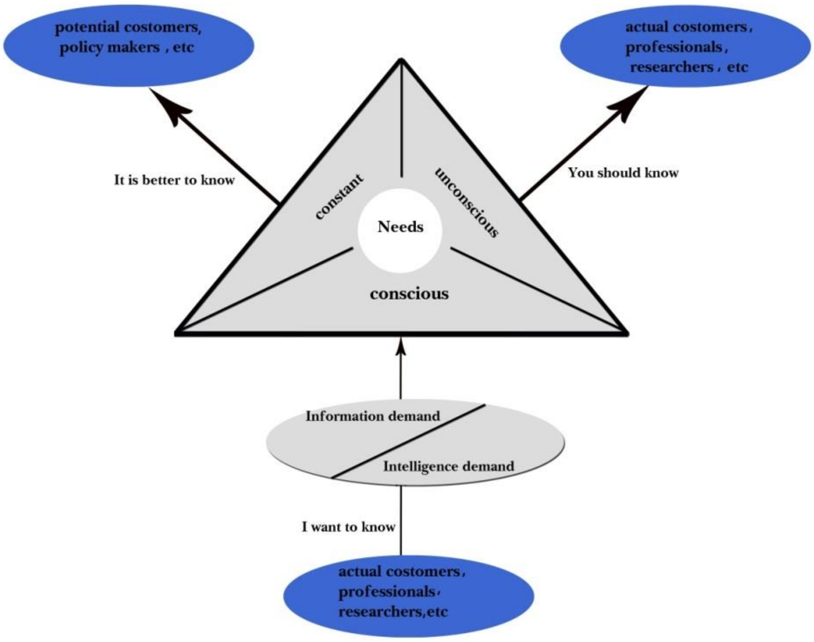


Figure 6. Framework needed forof needs of fuel cell technology intelligent system

4.3. Functional Architecture

After stakeholders of the fuel cell technology intelligence system and their needs framework are specified, we explored the functional Architecture of system based on that and by analyzing and studding of current intelligence models, analyzing and explaining the data gathered from library studies, researchers experience in system design ,and also forming a 10 person panel from expertise which results will discuss in next step.

Based on what has been discussed so far, the main function of each technology intelligence system is to enhance decision-making power in the field of technology. Based on the results of this study, the top level function will divided to six parts in second level which are: Identifying & Direction; search & acquisition; processing, organization & storing; analyzing; documenting; disseminating. Figure 7 shows the second surface (layer) of the system. Using IDEF0 tools in this figure, we show that each of these six are working in cooperation with other functions and have inputs and outputs to each other. In addition as the function of the first surface divided to these six functions, each of these functions is divided to sub functions in lower levels which will be discussed.

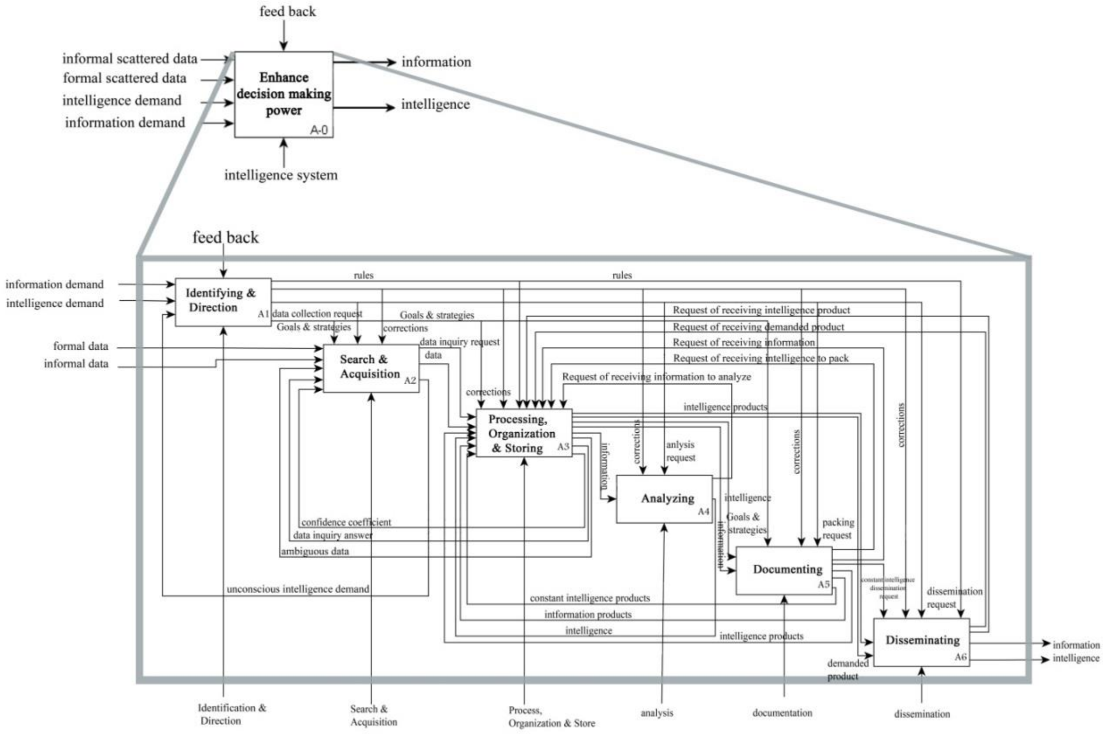


Figure 7. IDEO chart of system second level

Identifying & Direction: Based on needs and requirements which are obtained by Part 2-4, the system must receive two demands of intelligence and information from customers and answer to them. But before answering the demands should be analyzed regarding to the law of system and if they match it should be responded (the system has no obligation to respond to any demands). This is done by the function called input transducer. This function with output transducer function are parts of the basic functions system which monitor whatever enter to the system and whatever the logged out of the system .because of there are lot of users work with this system and in some cases there are strategic and vital information of companies inside this system, it must have a regulatory rule to avoid any probable abuse.

In most cases, the demand is logged does not indicate the work should be done. All system users do not have enough knowledge about the analysis tools to define which sources or data will provide their needs. The Task is presented here as a function of the converter is responsible for overcoming these challenges. This function will translate needs of users for data gathering, analysis, documentation, and finally, publish according to Figure 8.

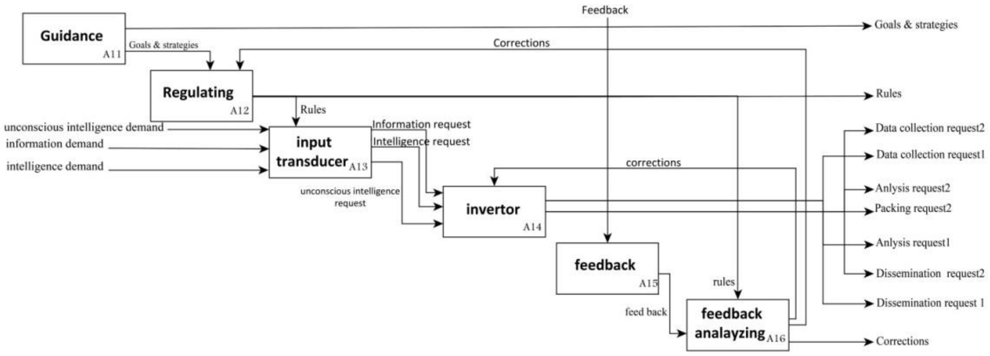


Figure 8: The third level requires the following system functions and navigation

Search & Acquisition(R&A): Intelligence matrix "Kerr" which was shown in Figure 4provides a good idea to specify the search and acquisition functions within the intelligent national system of fuel cell technology. But to bring up the idea at the national level there are fundamental differences between the organizational level and national level which should be considered. One of these differences is that an organization usually is aware of internal activities and changes in projects and does not need to scan and monitor its internal environment; however it is not true for national level. in the interview which is done with stakeholders of fuel cell technology, 80 percent of the stakeholders of fuel cell filed point to the weaknesses in having access to the internal data of the country and lack of proper information about facilities, projects, activities and developments of internal technologies and they believe these kinds of problems are more important than others. Therefore R&A on internal environment is one of the functions which should be considered. The R&A can be done in 2 modes: continuous and demand-base. To explain the continuous R&A (internal and external), we describe it to a radar which gives alarm about the unknown and disruptive technologies. This case is used to learn about new technology which is able to affect the agency business. Continuous R&A (internal and external) is used to define intelligence for unconscious needs. In this case there is no cognitive about needed intelligence than and therefore it would be no demand for it. Therefor this function should be monitored and scanned continuously the fuel cell technology domains which are relevant to data and develop the intelligence of demands to Identifying & Direction function.

Another discussion that defines in following function is the data sources used by the system. The system must have both formal and informal resources for collecting and evaluating its data and in the case utilization trend without identifying and evaluating data cannot respond to these needs and is a high risk project. Another function in this direction is providing identification for the resources. This certificate should be concluded with reliability of the sources, the level of availability, quality and up to date information and....

Processing, Organization & Storing: Based on the results of the study, in order to avoid errors in the output layer of the system three defense layers is defined here. The first layer of defense is a sieve performance data collected will be evaluated in order to eliminate waste and duplication. The second function is related to the collected data and clarification of ambiguous data and the third one is analyzing functionality accuracy of the information. There are two possibilities for the misinformation, one is that information are wrong inadvertently wrong and second one is that the information is presented wrongly by competitors in order to deceive the system. These two cases should be considered to determine the identity of sources of information. Three functions of sieve (excluding waste and duplication), refine (Excluding unrelated and obscure) and validation (delete the wrong data), according to experts opinions, is shown in Figure 9.

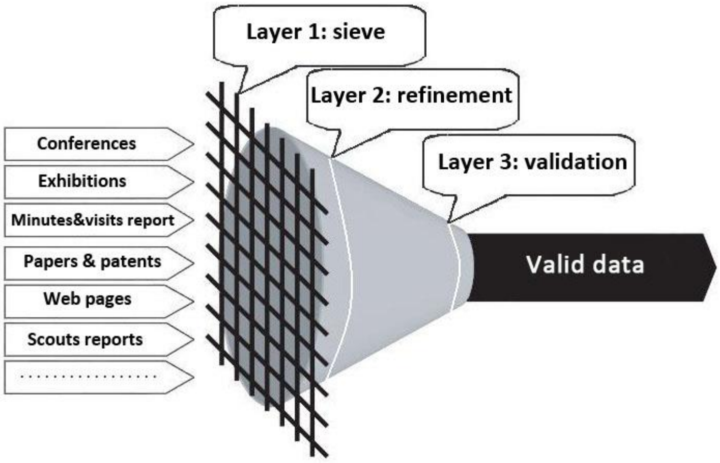


Figure 9: defense layers

The next function after these three layers is determination of level of access to the data acquisition system. When a system is identified in national, it needs to fulfill the needs of all to use their cooperation. So before anything else level of access to information should be defined. This function works in four categories, general, confidential, highly confidential and secret.
Collected and processed data should be stored at the local place and because of we need to find them easily when we are searching, they must be organized and encoded before storage. Data organizations should be rated based on the need for intelligence and information retrieval and encoding must be able to demonstrate hierarchical relations (e.g. company X -> Roadmap -> Vision -> Mission). Two cases encoding and organization are very similar and so we define them as encoding functions.

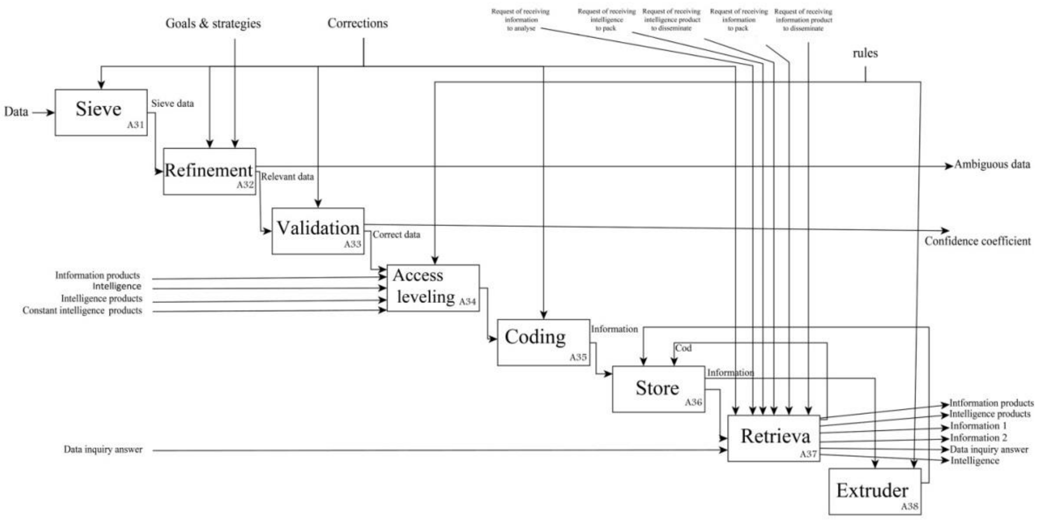


Figure 10. The third level of system; Processing, Organization & Storing subfunctions

The next function is data storage in the data station system and subsequently retrieval of its adherents. Since the data are growing at an exponential rate, and also the system is not able to store any volume of data, an existence of a function for the disposal of expired data is necessary. We call this function the extruder.

Analyzing: This function can be considered as an intelligence brain for business. Data collection without analysis has no value, and if analyzes in not done whole the intelligence unit will change to a service unit of the Library. Depending on the circumstances, form of the organization and users need different types of analysis can be performed on the data. But analysis has the highest value, for example, one or more proposals to be presented to the decision maker. Different methods of analysis are considered as a tool in the service of an intelligent system and are not considered as functions. Two sub functions which are placed under this function are analysis and the analysis performing.

Current literature provides an extensive literature range of tools and methods which are useful in technology intelligent. The important question is which method should be used where? Technology strategy, environmental complexity and uncertainty of the industry, can be influencing tools choice of analyzing tools. Another important factor is the time of concentration. Available analysis tools do not have same power in analyzing of the present and future.

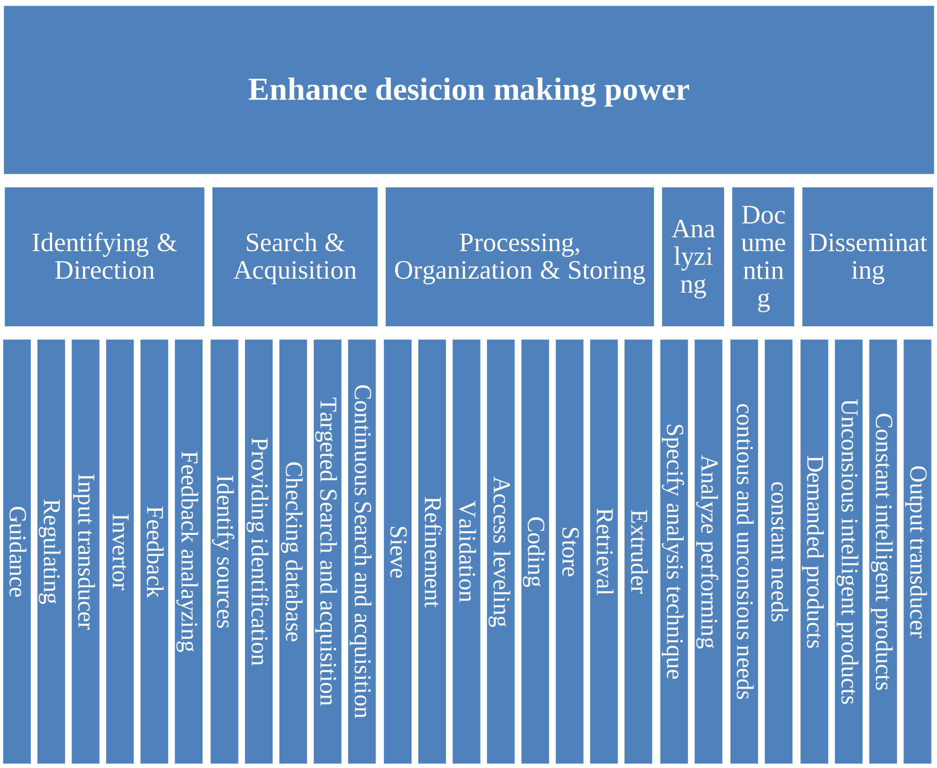
Documenting & Disseminating: The task of this step is to organize the outputs of analysis for different groups of users and stakeholders. The analysis depends on the audience that will receive it. For example, analytical analysis for delivery to the professionals must be different with senior managements. As it was brought in competent stakeholders' part , stakeholders of fuel cell qualified into five groups of customers - Investors and financial supporters - Specialists and manufacturers - inspectors, laboratories and centers - Researchers and academic people. To provide intelligence, each of these groups has a specific format to be followed. Reports that are provided for researchers, scholars, and instructors should be along with the technical details; however such a report is not acceptable for investors.

There are two sub-functions, corresponding to the three types of fuel cell stakeholders needing. First sub-function based on the request of Identifying & Direction function provides the information for responding to the received request from customers (conscious need) and also from continuous R&A function (unconscious need). And the second sub-function has the task of providing constant needs, and therefore prepare information as magazines, newspapers ... regarded to the kind of information and situation of organization.

Disseminating: On time delivery of intelligence products to the people who need to receive it, is the output of this function. Here there are three types of emissions. The first one is to provide fixed needs which are in the frame of bulletins, periodicals, and magazine and.... The second one is publishing in order to respond to the request for information dissemination and application of intelligent system and the last one is concerned for beneficiary who they should be aware of this information. The method of intelligence publishing is an important method for effectiveness and success of the method which can be done in different ways such as talking face to face, telephoning, emailing, mail, magazines, bulletins, posters, and etc. Selecting any one of these methods largely depends on the characteristics and parameters of the recipients and the nature of intelligence.

5. Conclusions

In this research a technology intelligence system is introduced as a modern method to increase the power of decisions made by managers, investors, experts, professionals and all people who work in this field. We then discuss the design of a system for a sample high technology (fuel cell) field at the national level. To design a Fuel Cell Technology intelligence system at the national level, we first identified the fuel cell stakeholders and their needs through semi-structured interviews. Next, ten groups were identified based on the relevant interests, and these ten groups were further divided into five groups based on their needs and then their frame needs were extracted. Based on the results of this research, we identified three categories of stakeholder needs: conscious, unconscious, and constant. After extracting the needs framework of fuel cell stakeholders, the functional architecture of the system was driven by a library study, a comparative study, the researcher, and an expert panel. The architecture included 34 collected functions and is shown in the following diagram.



Evaluation by the researcher of all the above data showed that the lack of the 34 specified functions identified in this research and the lack of communication and connection between these functions provided by the IDEFO model cause instability in the system at the national level. In addition, this structure could also be used as the basis for the implementation of an intelligent system for other technologies.

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Applying TRIZ and Multi-Attribute Utility Theory to Develop Innovative Designs: A Case Study of Carbohydrate Detecting Device

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Abstract

People with diabetes usually have metabolic problems because their own insulin is unable to operate effectively. Consequently, diabetics are required to control their blood glucose under diet management. The diabetics take proper dose of insulin to convert the carbohydrate levels according to their experience. However, most of the diabetics are not able to calculate the levels of carbohydrate correctly. Moreover, the currently measuring blood glucose apparatus is glucometer which might cause the risk of infection. Therefore, this research developed a new noninvasive carbohydrate detecting device which combines hyperspectral imaging and light field technique to identify the food ingredients along with their quantity. Theory of Inventive Problem Solving (TRIZ) is applied to generate the possible concepts and Multi-Attribute Utility Theory (MAUT) is utilized to select the best one. This research demonstrates a noninvasive detecting device to help diabetic control their blood glucose. In the future, this device can apply in weight control and food safety.

Keywords: Diabetic, Hyperpsectral Imaging, MAUT, TRIZ

1. Introduction

According to the International Diabetes Federation, there are currently around 380 million diabetes all over the world in 2013 (Aguiree et al. 2013). The origin of diabetes is human pancreas cannot produce enough insulin or use insulin effectively. Hence, diabetes is shortage of insulin to enter the cell of body where it provides energy. There are three main types of diabetes: (1) Type 1 diabetes, (2) Type 2 diabetes, and (3) Gestational diabetes. People with diabetes have to carefully handle their health status because diabetes can damage the nerves and blood vessels. These would be accompanied by other chronic complications such as cardiovascular disease, kidney disease, eye disease, and nerve damage. Periodically monitoring the blood glucose levels can delay or prevent diabetes complications. Thus, diabetics have to regularly monitoring the blood glucose levels. In order to control blood glucose, diabetics are obligated to audit daily dietary management, especially the levels of carbohydrate. Currently diabetics use electronic balance to compute the weight of food and take proper dose of insulin to convert the carbohydrate levels according to their experience.

Hyperspectral imaging is a technology that combines the spatial and spectral information, this technology collects hundred wavebands and obtains abundant spectrum for each pixel of an image. It reflects the internal or external characteristics of an object. Hyperspectral imaging is applied in many fields such as food quality assessment, medicine, remote sensing, etc. The advantage of this technology is to provide a rapid and nondestructive technique.

Since most of diabetics cannot accurately calculate the carbohydrate and the existing glucometer might have the problem of infection. The aim of this research is to propose a noninvasive device that can detect the levels of carbohydrate. This device integrates the hyperspectral imaging and light field technique for food recognition and volume calculation. This paper employed TRIZ to develop the feasible concepts and applied the MAUT to select the best design concept. The research finding shows that the optimal product prototype is accord with the demands of diabetics and a process model which conducts an interactive relationship between patient and device. This study is divided into four sections. Section 2 reviews the related literatures and Section 3 proposes methodology for service and product design. Section 4 presents a carbohydrate detecting device as a case study and Section 5 discusses the result and draws conclusion.

2. Literature Review

▪2.1 New Product Development

A new product is developed from an intangible concept to a physical product. The evolution of new product development has some differences based on different industries. The product development process can assist company in increasing competitiveness. There is a large volume of published studies that describe the process of new product development. Krishnan and Ulrich (2001) reviewed the decisions of product development according to 200 studies and identified 30 indicators for product development strategies. Cooper (1988) presented a guideline for systematic new product development based on State-Gate Process which consists of six stages and gates. The function of a gate is to control the whole process and ensure the task is completed with good quality. Booz-Allen (1982) provided a framework of new product develop process with an aim to minimize risk and achieve successful launch. Schilling and Hill (1998) indicated the goal of a new product development is to minimize time to market and maximize meet for customer requirement. This study indicated four strategic issues which can aid company to achieve successful new product development. There are many studies focused on product development, it does not involve the service process and customer satisfaction.

▪2.2 TRIZ

Theory of Inventive Problem Solving (TRIZ) was developed by Altshuller in 1946. This method is a systematic problem solving method. Altshuller analyzed 2.5 million patents to conclude a systematic problem solving method and develop a series of tools. In particular, the 40 inventive principles are widely used tool in numerous studies. The typical problem solving process of TRIZ has three stages: problem definition, problem resolution, and solution evaluation. Imoh et al. (2013) carried out a survey which investigated the application of TRIZ in practice from different fields. The result showed that the benefit of TRIZ which provided a structured approach to solving problem and breakthrough innovation. There have been several studies in the literature reporting the application of TRIZ to develop product design. Cho and Kim (2010) showed that design the deburring tools for intersecting holes based on TRIZ. Kremer et al. (2012) presented TRIZ method was applied in combining axiomatic design and mixed integer programming to design a locomotive ballast arrangement. Mansor et al. (2014) proposed an integration of TRIZ, morphological chart and AHP method to design an automotive parking brake lever. In addition, much research in recent years has focused on service design by TRIZ. Zhang et al. (2005) developed a new service design of the operations at a university canteen. Chai et al. (2005) proposed a TRIZ-based approach to redesign a sightseeing scheme and restaurant operation service.

Although there were many researches about applying TRIZ in product design and service design. Therefore it is necessary to do deep research in integrating product and service.

▪2.3 Multi-Attribute Utility Theory (MAUT)

Multi-Attribute Utility Theory (MAUT) is one of the methodologies multi-criteria decision making. Unlike the AHP method which defines all criteria are mutually independent. MAUT can deal with the problem of interdependence and uncertainty issues. Velasquz and Hester (2013) reviewed the available literature on multi-criteria decision making methods, this study pointed out the advantage of MAUT is that it considers uncertainty and incorporates preferences. Okudan et al. (2013) used MAUT to decide the product family functions based on customer preference. There have been several studies in literature reporting how to select candidate such as suppliers and stakeholders. Min (1994) extended this work to evaluate the international suppliers, and the study developed an efficient way to take uncertainty environment into account to assist company evaluate suppliers. Chiu and Okudan (2008) developed promoting the capability of QFD approach with MAUT to choose the quality of stakeholder. There are relatively few historical studies in the area of emergency department. Claudio and Okudan (2010) presented a hypothetical scenario that the nurse decided the priority of patients when several patients come to emergency department. The prioritization was determined by utility function with multi-criteria. In brief, these studies provide important insights into the MAUT can assist decision maker to easier evaluate criteria and make decision.

Since TRIZ can assist designer in creating idea for concept design and MAUT takes uncertainty in account. The aim of this paper is to integrate TRIZ and MAUT for an innovative product design.

3. Methodology

This research proposes a framework about solving problem of service and product design by Theory of Inventive Problem Solving (TRIZ). The framework is shown in Figure 1. The first step is to identify the opportunities of problem. After opportunities identification, the next is to identify the service problems from existing services. The next step is to find the ideal service concepts as solutions which require to bundle with product to meet the service satisfaction. For the conflicts between desired product functions and service requirements, feasible solutions are developed by TRIZ. Finally, the optimal product concept is selected by MAUT and the develop product prototype.

▪3.1 Opportunities Exploration and Identification

The opportunities exploration and identification can quickly catch the direction of problem. This study adopts the Problem Hierarchy of TRIZ to develop initial ideas, which is an explorer tool to define broader and narrower problem levels. Problem Hierarchy is a breakdown structure from top to bottom which expands the problem to each subsection and helps designer to recognize the critical problem.

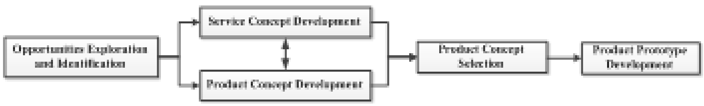


Figure 1: The framework of service and product design.

▪3.2 Service Concept Development

▪3.2.1 Service Problem Identification

To develop service concepts, the problem should be identified at first. This research adopts function analysis to identify the service problem. Chai et al. (2005) presented the function analysis explores the relationships between different functions. The functions are divided into two types: useful functions (UF) and harmful functions (HF). The illustrated example is shown in Figure 2. Functions A and B are UF, and function C is HF. Function B is required for achieving function A. At the same time, function B will produce harmful function C which is also influence function A. Finally the structure of service process is created by function analysis. Through this approach provides the UF and HF, the designer would be able to identify the currently difficult problem.

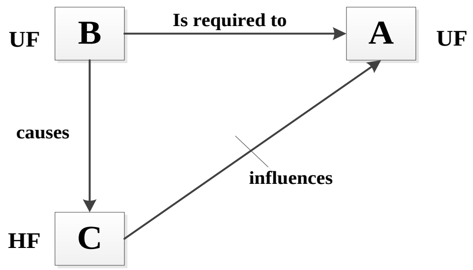


Figure 2: The illustrated function analysis example.

▪3.2.2 Service Problem Resolution

After identifying the UF and HF function by the function analysis depicts the service process. The Substance Field Analysis (Su-Field Analysis) is able to build a relationship between problem and existing technique. The Su-Field model presents a system which consists of two substances and one field. The substance 1 (S1) is activated by field (F), which is applied in substance 2 (S2). The interaction of these three elements generates output which means function. The Su-Field Analysis has four basic models: (1) Effective complete system, (2) Incomplete system, (3) Harmful complete system, and (4) Ineffective complete system. The Su-Field Analysis is shown in Figure 3.

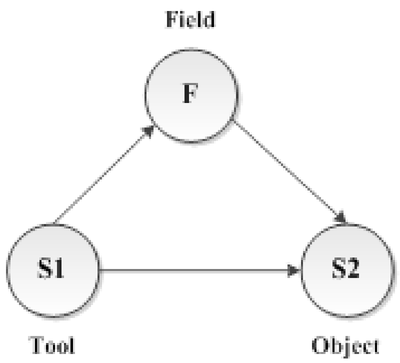


Figure 3: The Su-Field Analysis

▪3.2.3 Service Concept Generation

After constructing the substance field analysis modeling, the service concept is generated by 76 standard solutions which proposed by Altshuller (Domb, 1999).

▪3.3 Product Concept Development

▪3.3.1 Product Problem Identification

First of this stage is to identify the product problem by a contradiction matrix of TRIZ. The contradiction matrix means there are existing conflict between 39 improving and 39 worsening engineering parameter. Also, the matrix provides 40 inventive principles based on different contradiction.

▪3.3.2 Product Concept Generation

After identifying the product problem, this research generates product concept based on the 40 inventive principles. Besides, this research applies the morphological analysis by Mansor (2014), which can assist designer in creating more design ideas based on these 40 inventive principles.

▪3.4 Product Concept Selection

In the concept selection, this study presents a multi-attribute utility theory (MAUT) to select the ideal concept. The advantage of MAUT is to deal with the interdependence and uncertainty issue. The first step is to construct each utility which is represented by exponential function. The utility formula is as follow:

$$\boldsymbol{U_i(x_{ij}) = A_i - B_i * e^{\frac{-x_{ij}}{RT_i}}} \tag{1}$$

$$\boldsymbol{A_i = \frac{e^{\frac{-Min(x_{ij})}{RT_i}}}{e^{\frac{-Min(x_{ij})}{RT_i}} - e^{\frac{-Max(x_{ij})}{RT_i}}}} \tag{2}$$

$$\boldsymbol{B_i = \frac{1}{e^{\frac{-Min(x_{ij})}{RT_i}} - e^{\frac{-Max(x_{ij})}{RT_i}}}} \tag{3}$$

where:

x_{ij}: The *j*th value of attribute *i*

RT_i = Risk tolerance for the attribute *i*

Min (x_{ij}) = Minimum value of the attribute *i* across all alternatives

Max (x_{ij}) = Maximum value of the attribute *i* across all alternatives

The second step is to takes the utility independence in account. The utility function aggregation is presented by multiplicative form. The multiplicative form of the product utility attribute as given by Keeney and Raiffa (1993):

$$U_{all}(x) = \frac{1}{k}\left[\prod_{i-1}^{n}\left(Kk_iU_i(x_{ij}) + 1\right) - 1\right] \tag{4}$$

$$1 + \mathrm{K} = \prod_{i-1}^{n}(1 + Kk_i) \tag{5}$$

where,

$U_{all}(x)$: The total utility

x_{ij}: The *j*th value of attribute *i*

$U_i(x_{ij})$: The single attribute utility for attribute *i*

k_i: Attribute-scaling parameter for attribute *i*

K: Normalizing constant

▪3.5 Product Prototype Development

After selecting best concept design, the final ideal product prototype could be developed. In addition, this research conducts a process model which shows the interactive relationship of the user and product.

4. Case Study

▪4.1 Opportunities Exploration and Identification

This research utilizes the problem hierarchy to explore the opportunities of diabetic therapies. These are mainly divided into four parts: general therapy, medicine therapy, exercise therapy, and diet therapy. These therapies could prevent the disease worsen. The problem hierarchy of diabetic is shown in Figure 4. According to above description, the diabetics are required to measure blood glucose in pre-prandial and post-prandial. Thus, we choose self-monitoring blood glucose and carbohydrate counting as discussed issues.

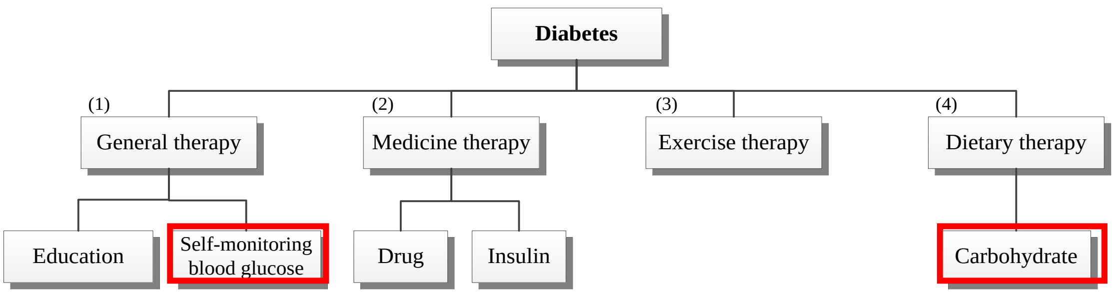


Figure 4: The problem hierarchy of diabetic.

▪4.2 Service Concept Development

▪4.2.1 Service Problem Identification

To exploit the problem of diabetic's self-care service process by function analysis which is shown in Figure 5. If diabetics attempt to control their disease, they should be managed by diet management. Hence, diabetics are required to measure their pre-prandial blood glucose level by glucometer. If the blood glucose does not achieve the standard level, the diabetics need to inject insulin or take medicine. Most of diabetics evaluate the carbohydrate content of foods according to their experience, electronic scale, and dietitian. In the post-prandial, diabetics measure the blood glucose level again. Also, if the value shows abnormal, the diabetics are required to reduce the blood glucose by insulin injection. In addition, this study analyzes the service process of diabetics dine out. Many diabetics would not choose to eat unfamiliar food, because they are worried about the strange food would influence blood glucose. Furthermore, they are not sure how to inject the proper dose of insulin or take medicine.

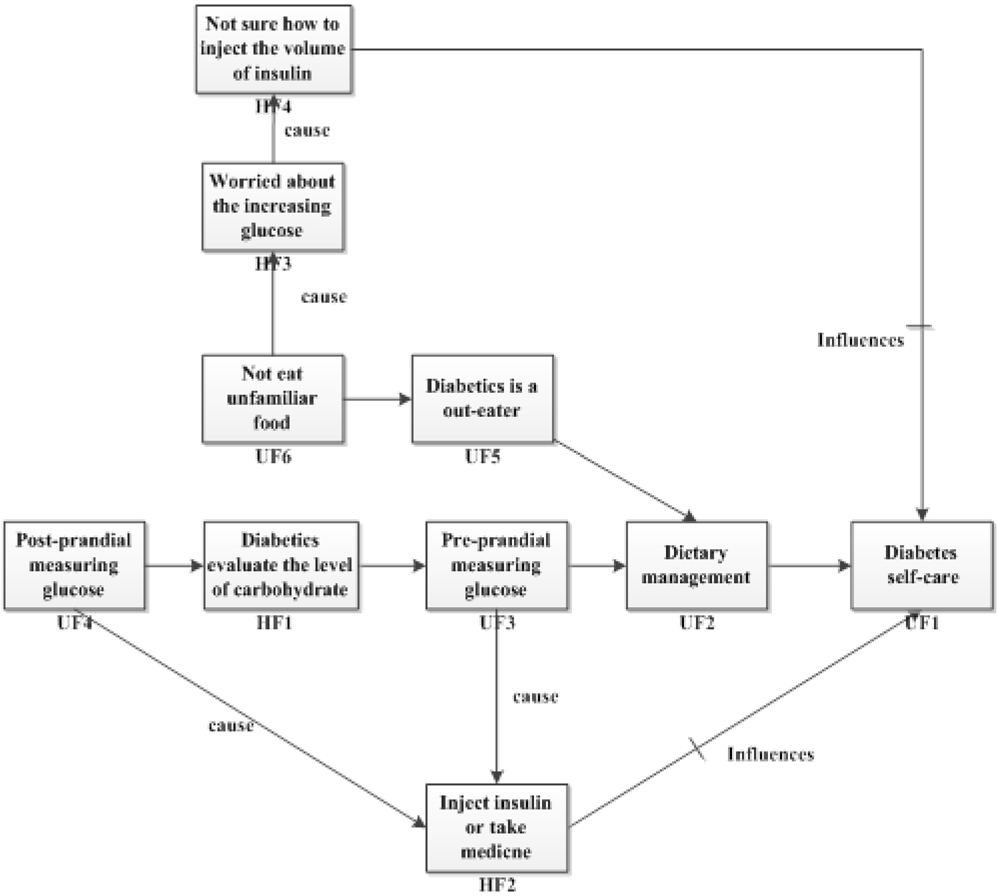


Figure 5: The function analysis of diabetic self-care process

▪4.2.2 Service Problem Resolution

Through the previous function analysis, it seems that the diet management has a great impact on blood glucose. Nevertheless if the glucose value does not achieve the standard level, the diabetics are required to inject insulin or take medicine. After exploring the service problem, this study conducts the substance field analysis to build the relationship between service problem and existing technique. This modeling is divided into three parts: (1) the substance 1 is insulin injector, (2) the substance 2 is blood glucose control, and (3) the field is mechanical. The insulin injector would have the risk of infection. Hence, this system is ineffective complete system which means the components of system has existing, but the effect is insufficient. The Su-Field modeling is shown in Figure 6 (a).

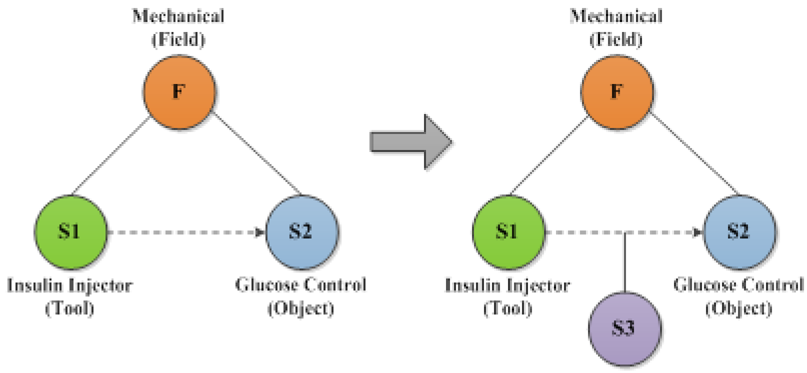


Figure 6: The Su-Field modeling.

▪4.2.3 Service Concept Generation

After constructing the Su-Field Analysis, this study adopts the 76 standard solutions to solve the problem. Due to the ineffective complete system, the solution indicates that add a new substance (S3) to the new system. The function of S3 could improve the ineffective system. The new system is shown in Figure 6 (b). Therefore, this research develops a noninvasive device which can aid diabetics to calculate the level of carbohydrate.

▪4.3 Product Concept Development

▪4.3.1 Product Problem Identification

After service concept developing, this study designs a carbohydrate detecting device for diabetics. Therefore, this device needs a high accuracy sampling method for extracting, and designs a calculating volume function which is able to convert food content to carbohydrate levels. The TRIZ is introduced to find the contradiction, the improving parameter is regarded as accuracy of measurement (#28) and the corresponding worsening parameter is regarded as reliability (#27). The related inventive principles are merging or combining (#5), previously placed pillow (#11), segmentation (#1), and feedback (#23).

▪4.3.2 Product Concept Generation

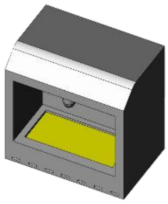
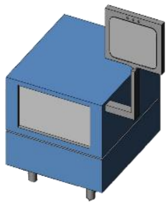
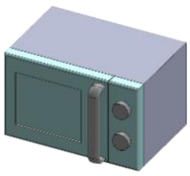
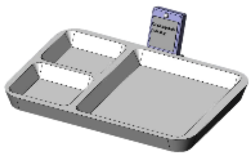
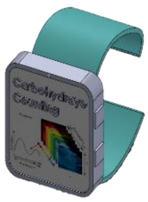
The concept is designed by different solutions based on inventive principles and morphological chart. For the sampling method, this research designs spectral recognition and image recognition to extract sample. The feature of calculating food volume is designed the light field camera, electronic scale or patient's experience, database comparison, and backend medical personal assist to computing. The design solutions are shown in Table 1. Therefore, this study designs a spectral camera which can input different product types. According to this camera, this research generates three product types based on their function for different application. The product concept generation is shown in Table 2.

Table 1: The TRIZ and morphological solutions.

TRIZ solution	Design	Morphological Chart Solutions

principles	feature	1	2	3	4
#5 Merging or combining	Sampling method	Spectral recognition	Image recognition		
#11 Previously placed pillow	Calculating volume	Light field camera	Electronic scale or patient's experience	Database comparison	Backend medical personal assist to computing
#1 Segmentation	Body type	Big	Medium	Small	
#23 Feedback	Function	Industrial-use type	Domestic-use type	Personal-use type	

Table 2: The product concept generation.

Product Concept Generation				
	Concept A	*Concept B*	*Concept C*	
Industrial-Use Type	 Industrial Machine	 Industrial Machine 2	 Industrial Machine 3	
	Concept A	*Concept B*	*Concept C*	
Domestic-Use Type	 Mircrowave	 Dinner Plate	 Brush	
	Concept A	*Concept B*	*Concept C*	*Concept D*
Personal-Use Type	 Cellphone Case	 Watch	 Necklace	 Glasses

▪4.4 Product Concept Selection

The final product concepts are selected by multi-attribute utility theory (MAUT). This method considers a variety of attributes and uncertainty, and aggregates overall utility in order to rank each concept. The Likert scale is applied in this research. This research assumes the value scale is from 1 to 5, where 5 represents the best value. The Table 3 shows the attributes of product concept which is evaluated by expert from the research institute in Taiwan.

Table 3: The value of product concept

Industrial-Use Type				
	Speed	Lifespan	Cost	Function
Concept A	3	3	5	2
Concept B	4	4	3	4
Concept C	5	4	3	5
Domestic-Use Type				
	Easy to use	Efficiency	Cost	Function
Concept A	5	5	3	5
Concept B	4	4	4	4
Concept C	3	2	4	2
Personal-Use Type				
	Portable	Aesthetic	Cost	Function
Concept A	4	3	5	3
Concept B	5	5	3	5
Concept C	5	4	4	4
Concept D	3	2	3	3

▪4.4.1 Overall Utility

Followed by the equation 4 and 5, all of the attributes are calculated to aggregated utility. The aggregation of utility is shown in Table 4.

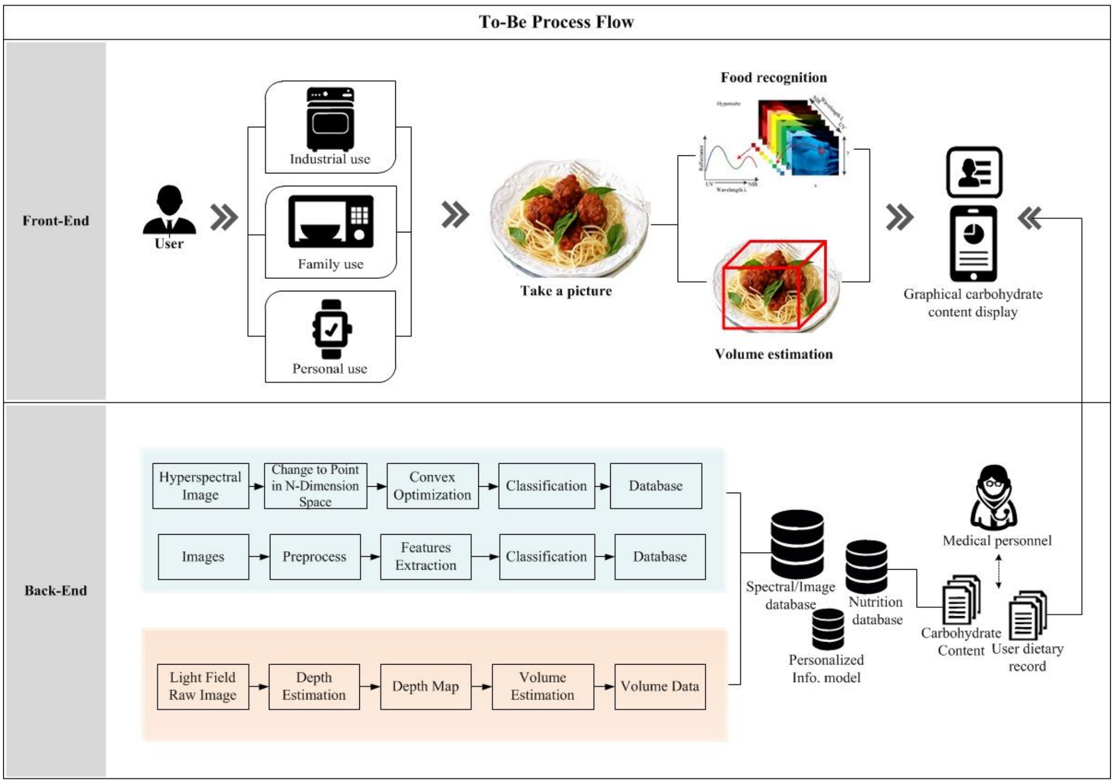
▪4.5 Product Prototype Development

Based on the analysis of the MAUT, the result demonstrates that the concept C with industrial-use type; concept B with domestic-use type; and concept B with personal-use type are the ideal concepts. This research presents a process model between diabetics and product. The model is shown in Figure 7. First, the device is used to detect the food. Then, the hyperspectral imaging would automatically recognize the food type and the light field technique calculate the food volume. After the preprocessing, the food data is connected to the database and converts the carbohydrate level to user.

Table 4: The utility aggregation table.

Industrial-Use Type										
	Speed	Lifespan	Cost	Function	$U_1(x_1)$	$U_2(x_2)$	$U_3(x_3)$	$U_4(x_4)$	$U(x)$	Rank
Concept A	3	3	5	2	0	0	1	0	0.5094	3
Concept B	4	4	3	4	0.5592	1	0	0.7457	0.7975	2
Concept C	5	4	3	5	1	1	0	1	0.9345	1
Domestic-Use Type										
	Easy to use	Efficiency	Cost	Function	$U_1(x_1)$	$U_2(x_2)$	$U_3(x_3)$	$U_4(x_4)$	$U(x)$	Rank
Concept A	5	5	3	5	1	1	0	1	0.3668	3
Concept B	4	4	4	4	0.5519	0.7457	1	0.7562	0.8901	1
Concept C	3	2	4	4	0	0	1	0	0.6800	2
Personal-Use Type										
	Portable	Aesthetic	Cost	Function	$U_1(x_1)$	$U_2(x_2)$	$U_3(x_3)$	$U_4(x_4)$	$U(x)$	Rank
Concept A	4	3	5	3	0.5775	0.4047	1	0	0.7072	3
Concept B	5	5	3	5	1	1	0	1	0.8894	1
Concept C	5	4	4	4	1	0.7332	0.5622	0.5541	0.8320	2
Concept D	3	2	3	3	0	0	0	0	0	4

Figure 7: The process model



5. Conclusion

This research proposed an integrated TRIZ and MAUT method to design an innovative carbohydrate detecting device. TRIZ is applied to identify the service problem by function analysis and establish the problem with existing technique by Su-Field Analysis. This research developed the innovative 10 product development concepts with three types (industrial, domestic, and personal) based on the 40 inventive principles. MAUT is used to explore and evaluate the suitable design after generating concept design. The result shows the device not only records user's nutrition intake condition but also converts the food to carbohydrate level. This device is able to assist diabetics in monitoring their blood glucose intake with a noninvasive way. The integration of TRIZ and MAUT assists designer in easily executing service and product development. The limitation of this study is that there is not a physical carbohydrate detecting device. Future work might explore the food safety issue and weight loss management by this device.

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Applied Innovation by SMEs for RDI Certification Purposes

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Abstract:

This paper aims at bringing an inside country analysis of innovation (macro environment) down to the level of SMEs activities (micro environment) and their outputs to the economy.

For that purpose, a study was been conducted based on the full population of certified SMEs accordingly to a RDI (research, development and innovation) standard in one EU country, using statistical data from Eurostat and other sources, complemented with an opinion study set on criteria established upon practical and theoretical models.

The criteria were established upon current worldwide-accepted concepts (Oslo Manual) and new theoretical developments in the understanding of innovation on the creation and generation of value and technological and cultural innovation. A panel of experts from the fields of value management, innovation, economics, quality assurance and management systems auditing, performed an opinion study using the focus group methodology.

The results show that most SMEs develop their innovation activities in the lowest level of difficulty in innovation and value creation and generation, applying the basic technological innovation processes and missing cultural innovation changes in society. Due to sample dimension and to the dispersion of activities performed by the enterprises in the sample, it was not possible to establish a correlation between economical activities and types of innovation.

A closer analysis of innovation at the micro level (SMEs) gives insight to potential innovation and innovation management outputs and to new innovation strategies and policymaking.

A better understanding of how innovation impacts value creation and generation, how the technological innovation process affects outputs, and how SMEs may take advantage of cultural innovation (behaviour changes in society and markets), may be drawn from the conclusions of the study.

Keywords: innovation, value, technological innovation, cultural innovation.

1. Introduction

The existing studies on the Portuguese reality (i.e.: COTEC, 2014; Innovation Union Scoreboard, 2014; Community Inquiry on Innovation, 2012) mostly provide macro and "meso" focused results, not specifying the type of innovation that companies produce at their micro level.

Despite the studies try to correlate their findings to data that reflects the implementation of innovation and innovation management concepts, there still remains a gap at the macro results characterization level as to the impact of innovation at the micro level.

This study tries to highlight the importance of focusing the "object", understood as a product/service, and the "subject", understood as an organization (i.e. strategy and executed activities), as recipients of actions developed in innovation processes. We argue that there is a need to characterize the object and subject of innovation actions so that the macro results obtained may be enlarged and implemented more usefully. Our empirical results are directed at the innovation agents, aiming at supplying a structured result frame in terms of incidence, type and innovation process used by the analyzed companies, focusing on their tangible and intangible outputs. This study contributes to translate information from the macro and "meso" level to the micro reality of companies, based on qualification criteria by areas of innovation. In that sense, it'll also contribute to help companies drawing up strategies and action plans that will increment the results of the efforts undertaken in innovating.

This study is structured in the following way: first, the theoretical framework is presented, making reference to the main macro studies available. The criteria used for qualifying the different types of innovation developed by companies, as well as the generic results obtained by each one, is also included. Next, the study's methodology is described, focusing on the micro aspects of innovation. This allows for a deeper reflection on the potential influences that each type of innovation may have on the economy. Finally, the results are presented, being possible to identify potential strategy or action errors that can be explored in future studies. This provides room for new decisions to be made, leading to a type of innovation that'll create or generate more value for all the economic agents involved and also for the respective country.

2. Statistical, normative and theoretical framework

2.1. Statistical studies

The Innovation Barometer (COTEC, 2014) analyses Portugal's and a total of another 51 countries' competitiveness in macro form, basing the process on four dimensions that can be divided into analysis pillars; (i) conditions – institutional environment, information and communication technologies, infrastructure and utilization; (ii) resources – human capital, financing and investment; (iii) processes

– networking and entrepreneurship, knowledge application and technology incorporation; and, (iv) results – economic and innovation impacts.

Globally, Portugal comes in at 29th on the ranking of the 52 countries that make up the analyzed sample. For the “conditions” and “processes” dimensions, Portugal is placed above average by comparison to the rest of the countries in the sample, but, in the “resources”, it’s a little below average. For the “results” dimension, Portugal is quite below average and even below the average taken of the Southern European countries (Spain, Greece, Italy and Portugal). This last dimension is the one that has the poorest classifications out of all four. In comparison to countries with similar dimension (Austria, Belgium, Finland, Netherlands and Ireland), Portugal has a poorer performance in all dimensions, being that the largest gap in reference to the other countries is in the “results” dimension. By observing the indicators, it is evident that the “results” dimension is Portugal’s biggest weakness in the macro framework in which the study was undertaken.

The “Innovation Union Scoreboard” (European Union, 2014) analyses innovation competitiveness in European Union (EU) countries in a macro framework composed of 3 type of indicators that are made up of eight innovation dimensions as follows: (i) enablers – human capital, investigation system and financing and support; (ii) firm activities – company investments, entrepreneurship and connections, and intellectual patrimony; and, (iii) outputs – innovative and economic effects. This study provides a macro vision of the state of every country in the EU based on the information supplied by the different economic agents via Eurostat and other sources. In general terms, Portugal presents itself as a “moderate innovator”, ranking below the EU average and with a poor position in the “results” dimension, more specifically in the “economical effects” indicator.

The “Community Inquiry on Innovation” (CIS 2012) presents key indicators that describe innovation activities and standards in the business sector. It includes the resources and investments realized with innovation activities in the companies, the different types of innovation activities undertaken (product, process, organizational, marketing), the degree of novelty of the innovation (only for the company, market, country and for the European and international markets), the effectiveness of the methods used to maintain or increase the competitiveness of the product and process innovations, the degree of importance attributed to strategy and, finally, the obstacles that may infer on the company reaching its goals. It’s a meso analysis of innovation segmented by sectors and types of activity.

The CIS results (2012) indicate that 54,5% of Portuguese companies developed innovation activities (product, process, organizational, marketing), with 41,2% indicating having developed product and/or process innovation, 33% introduced organizational innovations and 32,6% introduced marketing innovations (including innovation activities which were abandoned or incomplete). An “innovative company” is one that introduces an innovation, even if only internally. It’s not necessary to be considered as such by the market. From the same study, and out of the national total, 19,3% of companies innovated in terms of goods and 16,6% in services whilst 20,1% innovated their production processes, 12,4% their logistic, delivery or distribution methods and 24,4% innovated their process support activities.

The study goes further and presents results about the way in which the product/process innovation was gained: 14,5% based their innovation on R&D activities realized internally, 9,2% on external acquisition of R&D, 25,2% on new machinery, equipment, software and infrastructure acquisitions, 7,1% on the acquisition of knowledge from other companies or institutions and 30,9% in all other possible areas of innovation. In total, 41,2% of the companies developed at least one of the five activities mentioned. In relation to organizational innovation, 24,0% innovated their business practices by better organizing procedures, 25,8% in new methods for organizing responsibility and decision making processes and 15,1% in new methods applied to organizing external relations with other companies or public institutions. In total, 33,0% applied at least one of the three mentioned methods. In relation to marketing innovation, 17,9% innovated through significant changes to their product packaging or aesthetics/appearance, 18,4% through new techniques or means of communication for the promotion of their goods or services, 10,5% through product distribution/allocation methods in new sales channels and 17,7% through new pricing policies for their products. In total, 32,6% applied at least one of the four mentioned methods.

The criteria and scope of these studies do not provide a detailed micro view of the innovation reality in Portugal. Therefore, some more detailed and conspicuous study needs to be developed in order to understand the reality of the innovation created by Portuguese enterprises.

2.2 Norms applied to Innovation

Despite the importance for businesses of innovation and innovation management, the movement to produce standards on the issue has taken a little too long in reacting to such a necessity. Nonetheless, the last decade has brought with it a set of normative documents that support innovation management best practices.

One of the more recent normalization documents in the innovation field is the European Norm “Innovation Management – Part 1: Innovation Management System” (CEN/TS 16555-1:2013), published with a “Technical Specification” that aims at guiding organizations to introduce, develop and maintain a systematic management framework for innovation practices based on an Innovation Management System. This management system should allow organizations to become more innovative so that they may have more success with the innovations applied to products, services, processes, organizational design and business models. To do so, the management system should include all the activities necessary to generating innovation on a continuous basis, whatever the size of the company, in the areas of organizational context, leadership and strategy, planning, innovation facilitation factors, management processes, performance evaluation and system improvements.

Published prior to CEN/TS 16555-1:2013, the Portuguese Norm “Research, Development and Innovation Management (RDI): System Requisites for RDI management” (NP4457:2007) establishes the certification requirements for an RDI management system. The conceptual structure of the Norm follows three principles: (i) the need to generalize the use of the chain-linked model (Kline and Rosenberg, 1986) in the knowledge economy; (ii) accommodate the concepts of the Oslo Manual from the OECD (2005); and, (iii) consider innovation in industry (goods), services (supplying of intangibles), traditional sectors (low-tech) and the more sophisticated ones (high-tech). The management principle inherent to the norm is based on the organization's interaction with various external agents via three different interfaces that can assume different forms according to internal and external factors that influence the organization's needs.

According to IPAC records (March, 2015), there are 164 organizations in Portugal certified by the Portuguese norm. The published records present the name of the entity, the area of certification and activity code, in accordance with an IPAC reference document – "Process for the accreditation of certification entities". This information was used for the purpose of this study.

2.3 Concepts and criteria for innovation classification

In the 1930's, Shumpeter presented one of the first definitions of innovation, as referred to by the Oslo Manual (OECD, 1997), in which he identifies five types of innovation: (i) introduction of a new product or qualitative change in existing product; (ii) new industrial process; (iii) opening of a new market; (iv) development of a new raw-material source or of another kind of input, and (v) changes in industrial organizations.

Deriving from the principles, the Oslo Manual (OECD, 2005), defines four types of innovation: (i) product innovation: introduction of a new good or service or a significantly improved good or service, in relation to its use or characteristics, (technical specifications, material components, incorporated software, ease of use); (ii) process innovation: implementation of a new or significantly improved production or distribution method (technical changes, equipments, software); (iii) marketing innovation: implementation of new marketing methods with significant changes in product conception, packaging, positioning, promotion or pricing; and, (iv) organizational innovation: implementation of new organizational methods in terms of business practices, functional organization or in relation to company's external relationships.

In collecting data, innovation focuses on two areas: "object" – the product (good or service) to which the specific innovation refers to; and "subject" – an organization (activities and strategies that lead to innovation). Innovation can be seen as the introduction of a new product or improved product that is accepted by the market (consumers).

Kim and Mauborgne (1999) defend that innovation creates value through product attribute performance, even if they aren't originated in technological innovation. This can be represented by a value curve, translating the various product attributes or, in other words, the value proposal for the consumer. By altering the attributes' performance, individually or in group, the product's value is also altered and this, depending on the different types of results obtained, can lead to different types of innovation: breakthrough, adding-value, turning-around and up-grading.

Technological and cultural innovations, which generate aggregated value to product or to organizational procedures being properly accepted by the market, are created by technological and cultural processes, respectively. Technological innovation is the result of an organization’s actions towards developing technology-based innovation. Cultural innovation is a consequence of a market’s behavioral changes, being these external to the organization (Fernandes, 2014).

The innovation types qualification in the sample is based on five areas of evaluation and their criteria, as presented in table 1. The evaluation areas 1 and 2 derive from Oslo Manual (2005) principles, the evaluation area 3 derives from Kim and Mauborgne theory (1999), and the evaluation areas 4 and 5 derive from Fernandes theory (2014). The criteria definitions derive from interpreting the mentioned theories in face of feedback obtained from the panel of experts. The qualification attributed to each criterion derived from the discussion held with the panel of experts and the evaluation carried out was based on a binary criteria (yes or no) in terms of its verification.

Table 1: Qualification criteria by areas of innovation evaluation

Criteria	Qualification
Evaluation Area 1: Final results of innovation	
Goods for consumption	The effects of any innovation that reflects directly on the end consumer (medication, electric appliances)
Goods for Professional use	Benefits that are indirectly reflected on the end consumer (professional tools, application tools).
Goods for incorporation	They reach end consumers or professionals who apply or use them (mechanical pieces, packaging).
Consumer Services	Provided directly to the final consumer (customer service, treatment of physical or motor conditions or capacity).
Consumer services with the incorporation of goods	Consumer owned product for continued use and operation (electric room temperature control system installation, surveillance system installation)
Organizational Services	Services provided directly to organizations (technical consultancy, information and data supply services)
Organizational Services with the incorporation of goods	Organization owned product for posterior and continued use and operation (software installation, software, technology bases quality control mechanical systems
Internal technological processes	New technology development applied to operational and production processes (creation of new machinery, development of new manufacturing processes)
Internal management processes	Management, control and decision making (ICT, internal communication organization)
Internal marketing and networking processes	Cooperation with external agents to the company (distribution chains, sales and client assistance processes).
Evaluation Area 2: Innovation Scope	
Product functions	What the product supplies users/consumers as a result of the application of new technologies to products (wireless communications, control automatisms)
Product design	Shown through the adoption of new cultural and aesthetic preferences (format, colour, style)
Product inputs	Materials and ingredients used to manufacture a product as a result of investigation processes (disease treatment by medical equipments based on new technologies, usage of new prime materials).
Manufacturing processes in the organization	New technology development level (creation of new machines/machinery, development of new manufacturing processes)
Management processes in the organization	Management, control and decision making (ICT, internal communication)
Marketing processes in the organization	Marketing and networking processes with external agents to the organization (distribution chains, sales and client assistance processes).
Evaluation Area 3: Value created at the product or organizational level	
Breakthrough	Incomparable in many or all of its attributes to competing products (the first microwave oven, the first cell phone)

Adding-value	Superior performance in many or all of it's attributes when compared to competing products or processes (luxury watches and cars).
Turning-around	Alternative performances, despite being inferior to competitor products or processes, but still within consumers' parameters for acceptability, functioning as an economic alternative to the existent supply (second generation cell phones, low-cost furniture).
Up-grading	Similar to competitor products and organizations, differentiating themselves through the attributes most valued by consumers or clients (Zara, tourist packs)
Evaluation Area 4: Type of processes used to create technological innovation	
Planned	R&D focused on fundamental and applied investigation, developing new knowledge – know the why (drones, medicine).
Targeted	Satisfaction of very specific client needs with basis on design innovation so as to create meaning, desire and aesthetic qualities appreciated by the market – know for who (iPhone, Cirque du Soleil)
Adopted/Adapted	Imitation of existent products and processes using knowledge that exists in different ways – know how (compacts for offices – photocopy, print, fax and scan machine; multifunction packaging systems).
Serendipitous	Fundamental and applied investigation that creates new knowledge but that results from serendipitous situations, being that the result is unexpected (discovery of penicillin, creation of velcro)
Evaluation area 5: Cultural change	
Newel	New technology induced behavioural changes in vast factions of the population (videoconference, mobile chatting)
Moral	New codes of conduct, rules and laws that lead to behavioural changes in vast factions of the population (seatbelt usage in cars, helmets).
Gnosil	Diffusion of knowledge on a certain subject or discipline that may affect consumers' lives, leading to changes in individual behaviour for small fractions of the population (jogging, civic duty participation).
Beautel	Adoption of new aesthetic styles applied to products and processes that alter consumer's individual behaviours for small fractions of the population (fashion and clothing, music).

3. Methodology

3.1. Method

The article reflects the result of a study based on the contribution of a panel of ten experts in the areas of value management (two), innovation (three), economy (one), quality assurance (three) and auditing of management systems subject to third party certification (one), using the same methodology as that is used by studies done by focus groups. The evaluation method used by the focus group followed what is generally presented a standard procedure by Kitzinger (1995), Gibbs (1997) and

Grudens-Schuck et al. (2004). The goal was to carry out a qualitative evaluation of the available information.

The study underwent two distinct phases: the first in which the investigators determined the qualitative criteria that would serve as a basis for the later experts' opinions, as identified in point 2.2; and a second in which the panel of experts met up to carry out individual evaluations of all the companies in the sample, based on the decided evaluation criteria and on the previously identified and gathered information. These results are in chapter 4.

3.2. Population and sample

The study's population is composed of the 164 companies certified by the Portuguese Norm "Research, Development and Innovation Management (RDI): RDI management system requirements" (NP4457:2007) and that population appear publically listed on the "National Data Base for Certified management Systems" by IPAC (2015). The sample corresponds to 100% of the identified population.

3.3. Data collection

The data collected refers to: (i) description and code for certification scope, in accordance with the "National Data Base for Certified management Systems" by IPAC (2015); (ii) description of the activity and products (goods and services) supplied, as referred by company's websites; and, (iii) management reports made available online by the companies (when existing).

3.4. Data treatment

An individual analysis of each company was carried out for each defined evaluation criteria. The evaluation was carried out in accordance with binary criteria (yes or no) in terms of verification.

So as to simplify this study, only the main evidence of RDI developed by each company was considered, despite many of them would develop innovations in more than one area - products and processes, for example. This decision was made based on the impossibility of determining, using only the available information, all the RDI activities that the companies developed in a clear and unequivocal way.

In 92,1% of the sample, the panel of experts reached a consensus. In 7,9% of the evaluations, equivalent to 13 cases, the result was reached by vote, all referring to the "final results of innovation" criteria.

4. Study results and discussion

4.1. Results of the innovation and scope of the innovation

The results show that 94,5% of the companies is developing innovation activities around the product (good and service) and only 5,5% focus their innovation on the organization, as we will see later.

In more detail, out of those 94,5% of companies that focus their innovation mainly on the product, 26,6% innovates in their goods and 68,3% in their services, as shown in table 2.

Table 2: Final results of the innovation

<table>
<tr><th colspan="3">Good (Tangible)</th><th colspan="4">Service (Intangible)</th></tr>
<tr><td rowspan="2">Consumer</td><td rowspan="2">Professional</td><td rowspan="2">Integration</td><td colspan="2">For consumers</td><td colspan="2">For organizations</td></tr>
<tr><td>Service</td><td>Service with product</td><td>Service</td><td>Service with product</td></tr>
<tr><td>GC</td><td>GP</td><td>GI</td><td>SC</td><td>SCP</td><td>SO</td><td>SOP</td></tr>
<tr><td>14</td><td>15</td><td>14</td><td>5</td><td>1</td><td>46</td><td>60</td></tr>
<tr><td>8,5%</td><td>9,1%</td><td>8,5%</td><td>3,0%</td><td>0,6%</td><td>28,0%</td><td>36,6%</td></tr>
<tr><td colspan="3">TOTAL: 26,6%</td><td colspan="4">TOTAL: 68,3%</td></tr>
</table>

The largest fraction of the sample (36,6%) develops innovation in the services they supply to other organizations, incorporating some kind of product in the service. The second largest fraction of the sample (28%) only innovates in services supplied to other organizations. The sum of these two fractions (64,6%), plus the sum of the fractions that represent goods for professionals and for incorporation on other goods (17,1%), indicates that an overwhelming majority of the companies that make up the sample (82,2%), works in the business-to-business market (B2B). In the opinion of the panel of experts, this reality represents a fragility in that very same relationship due to the lack of direct contact with those that determine the acceptance of the innovation (consumer).

In terms of the scope of innovation, divided by specific areas in which it's carried out, the results are as shown in Table 3.

From the results, 90,2% of innovations focus on products functions (goods and services), while the innovation at new inputs and in organizational processes level out at 3,7% each. The other indicators are practically irrelevant for the discussion. The panel of experts is of the opinion that these results represent a failure in focusing on the creation of something "new", being the existing verified focus set on changing something that already exists at product characteristic and attribute levels.

Table 3: Scope of the innovation

Product (Object)			**Organization (Subject)**		
Function	Design	Input	Process	Management	Marketing
PF	PD	PI	OP	OMn	OMk
148	1	6	6	1	2
90,2%	0,6%	3,7%	3,7%	0,6%	1,2%
TOTAL: 94,5%			TOTAL: 5,5%		

From these two evaluations results, providing us a "meso" vision of RDI in Portugal, it's very difficult to establish a direct relation between these results and those of the Community Inquiry on Innovation – CIS (2012), as identified in point 2. The specificity of the sample under study, RDI certified companies, in comparison to the generality and amplitude of the sample used by CIS (companies of all dimensions) may be one of the causes of not being possible to compare both studies to one another. Another cause is related to the singular focus used in this study on the most evident RDI activity practiced by the companies against the plurality of activities of RDI expressed in the CIS study results.

4.2. Value innovation

The overwhelming majority of innovation by value produced by the companies in the sample is situated in "Up-grading innovation", as in table 4.

Table 4: Types of value innovation

Breakthrough	**Added-value**	**Turning-around**	**Up-grading**
4	1	0	159
2,4%	0,6%	0,0%	97,0%
TOTAL: 100,0%			

This type of innovation, in accordance with the panel of experts, is translated in less value generated for the products, and derives itself from new combinations of productive factors that are based on operative efficiency and design (at the functionality level). The consequence of such fact is the reduced effects that this type on innovation has on the value curve of products, and consequently, on the economy.

4.3. Technological Innovation Processes

A large majority of companies develops technological innovation through processes that limit themselves to being adoption/adaption of already existing technological innovations (96,3%), as illustrated in table 5. This is generally translated by the acquisition of existing technology. Only 1,8%, corresponding to three companies in the sample, were able to unequivocally demonstrate that they mainly produce innovation through fundamental science-based R&D, developing new products for the world. Corresponding to one company, 0,6% recognizably produce innovation based on new product design, to satisfy specific consumer needs.

Table 5: Technological innovation processes

Planned	Targeted	Adopted	Serendipitous
3	1	158	0
1,8%	0,6%	96,3%	0,0%
TOTAL: 98,8%			

It's worthy of mentioning that 1,2% of the sample represents two companies, both of which have not any activities related to technological innovation in their IDI certification.

4.4. Cultural innovation processes

This type of innovation is the one that, with the exception of one company, appears to be not developed by companies, as seen in the results in table 6.

Table 6: Cultural innovation processes

Newel	Moral	Gnosil	Beautel
0	0	0	1
0,0%	0,0%	0,0%	0,6%
TOTAL: 0,6%			

The company that appears to have a clear involvement in a behavioral change process (cultural innovation) did this through the new design of its product based on an identified aesthetic preference held by a niche of the market.

4.5. Correlations between areas of activity and results

The reduced dimension of the sample and its enormous dispersion in various industries that lead to very different outputs in terms of RDI, do not allow for establishing correlations between the types of innovation and who is making them happen, as in table 7.

Table 7: RDI system main outputs

Industrial activities – goods producing	**Quantity**	**Service activities**	**Quantity**
Food products	2	Product trading	3
Footwear	1	Contracting/Construction	10
Electric meters	1	Consultancy to companies	22
Equipments for electrical networks	2	Graphic and industrial design	2
Electronic equipments	1	3D scanning and modelling	2
Foam	1	Energy distribution	1
Machinery and tools	5	Property management	2
Building materials	3	Logistic services	1
Medicines	3	Machining parts	3
Professional furniture/furnishings	2	Media	1
Moulds	6	Mobility system	2
Photovoltaic panels	1	Residue management	1
Toilet paper	1	Health services	3
Plastics	2	Road safety	1
School boards	2	Heating systems	1
Industrial Chemicals	2	Communication systems	5
Textiles	7	Information and data systems	6
Protective clothing	1	Management software	51
		Geographic location software	1
		Multimedia software	3
Total	43	Total	121

We should refer that out of the 22 companies that provide “consultancy to companies”, 81,8% of these offer “services to other organizations” (SO) and their focus of innovation is on the functions of those services (PF). Out of these 22 companies, 82% develop RDI in the services they offer to other organizations (SO), 9% in their own internal technological processes (ITP), 4,5% on goods for professionals (GP), and 4,5% in services with goods for professionals (SOP). Much in the same way, 82% innovate in product functions (PF), 9% on product inputs (PI), and 9% in production processes (OP). All, without exception, carry out value improvement innovation (M) and adopt/adapt technological innovations developed by others.

Out of the 51 companies that work in the management software area, 84,3% develop RDI in the services they render other organizations with the incorporation of goods (SOP) and the remaining 15,7% offer services to organizations (SO). All, without exception, practice innovation focused on the functions of their services (PF), on the improvement (I) their value curve and via technological processes of adoption/adaption (A) of third party technology.

5. Conclusion

According to theory, “Breakthrough” and “Added-value” innovations are the types that are able to create the most economic value as a direct effect of RDI activities in a company. Nonetheless, only 3% of the sample fits into these two types of value innovation. This may mean that RDI efforts made by RDI certified companies aren’t inducing high value creation (economic) for society.

In theory, the “Planned” and “Targeted” types of technological process innovation have more potential to create or generate value. Only 2,4% of the sample fit in this type of innovation, thus confirming the last conclusion. Finally, cultural innovation, deriving from behavioral changes in markets, is the type of innovation that, in theory, may induce the highest growth of market share and product sales volumes. The two sub-types of cultural innovation that most contribute to this are “Newel” and “Moral”. Only 0,6% of the sample is clearly positioned as participating in a cultural innovation process, but not in any of the two sub-types of cultural innovation that generate most value to the economy.

6. Study limitations and future investigation

The study suffers from various limitations, namely: (i) it only reflects the opinion of a reduced number of individuals, even if they are experts in the disciplines directly tied to innovation and RDI certification; (ii) limitations of available information via IPAC data base and the annual management reports published online by the companies, shortening the vision of RDI activities and their outputs; (iii) the sole focus of the study on the company’s main innovation activity, the one that seemed more evident to the panel of experts, leaving out other RDI activities that may also have strong impacts on the economy; and, (iv) non-existent quantitative data referring to RDI activities at a micro level that could be used to establish, with the same scope of the used criteria, correlations for the validation of the opinions expressed in the study with the reality of the market.

Despite that, the results from this opinion study may serve as a starting point for a deeper understanding of some issues that should be brought up, as following.

The study is based on the classification given by a panel of experts, set on criteria with a large theoretical base. The aim was to obtain a more micro perspective of what innovation is and what it achieves in Portugal. However, the study leaves even more questions at the knowledge and best strategic management of innovation practices levels. These issues should be subject to future studies so as to contribute to the development of micro, meso and macro innovation policies that may create and generate higher value for the economy. The results also bring to the table the need to involve other agents in future studies at the sample level, the methodology applied to the study or the quantitative data presenting the results of the RDI activities developed by companies.

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Efficiency analysis of innovation: an application to European Regions

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Abstract

European policy makers have widely recognized the importance of science, technology and innovation, and Member States are asked to make a major effort to invest more in R&D and other innovation related activities and to improve the efficiency of their innovative efforts. But the European Union is composed of countries which vary considerably in terms of innovative capacity and technological expertise. Indeed, the existence of significant gaps within Europe at innovation level is widely recognized. Enlargement further hastened heterogeneity within EU in terms of innovation capabilities and technological development. There is a wide variety of studies revealing the asymmetries in innovation performance across Europe. These studies use a variety of indicators, either individual measures or composite synthetic indicators. In this paper we use data envelopment analysis method (DEA) to estimate regions' positioning in terms of innovation efficiency according to an efficient frontier. From a methodological point of view, this innovative perspective allows considering simultaneously several indicators to evaluate performance, avoiding biased perspectives that may result from only looking at a single indicator of input or output. By using this nonparametric method we contribute to expand the analysis and knowledge about European regions innovative performance. This paper reports preliminary results from a wider study undergoing at the University of Aveiro. The work and results herein reported should be considered as work in progress.

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1. Introduction

European policy makers have widely recognized the importance of science, technology and innovation, and Member States are asked to make a major effort to invest more in R&D and other innovation related activities and to improve the efficiency of their innovative efforts. But the European Union is composed of countries which vary considerably in terms of innovative capacity and technological expertise. Indeed, the existence of significant gaps within Europe at innovation level is widely recognized. Enlargement further hastened heterogeneity within EU in terms of innovation capabilities and technological development.

There is a wide variety of studies revealing the asymmetries in innovation performance across Europe. These studies use a variety of indicators, either individual measures or composite synthetic indicators (e.g. Barbosa and Faria, 2011; European Commission, 2015).

In this paper we use data envelopment analysis method (DEA) to estimate regions' positioning in terms of innovation efficiency according to an efficient frontier. From a methodological point of view, this innovative perspective allows considering simultaneously several indicators to evaluate performance, avoiding biased perspectives that may result from only looking at a single indicator of input or output. By using this nonparametric method we contribute to expand the analysis and knowledge about European regions innovative performance (Dzemydaitė and Galinienė, 2013). This paper reports preliminary results from a wider study undergoing at the University of Aveiro. The work and results herein reported should be considered as work in progress.

2. Theoretical background

To evaluate the efficiency level of regional innovation systems, it is important to detect how far their regional production technology is from the efficient frontier. This position is found comparing different regions' performance involved in the analysis. In the first step, the most efficient regions of the group are detected. Then performance of other regions is compared to the most efficient regions. A number of studies have been developed on this line, either at national or subnational level.

Cai and Hanley (2014) made a rating of world countries by evaluating technical efficiency of creating innovations. The research reflected that developed countries, which had a number of potential resources for creating innovation, such as the USA, Great Britain, and Austria, used the resources not efficiently enough. Developing countries such as China and India and a developed country Switzerland were more efficient. Some researchers try to evaluate the efficiency of region innovation systems by analysing the production function of knowledge creation, which relates the inputs and outputs in one model (D'Agostino et al., 2013). At subnational level, Lafarga and Balderrama (2015), for example, measured the relative technical efficiency of Mexico's regional innovation systems, as defined by its 32 states. The results led to the conclusion of the non-existence of a positive relation between the number of resources of an innovation system and its productivity efficiency. Zhong et al. (2011) examined the efficiency of regional investment for research and technology spillovers in China. The research results reflected that a more diversified regional policy should be formed in order to achieve effective creation process of innovation in different country regions.

In the empirical section we follow this line of approach, using DEA to estimate a composite indicator of efficiency for 29 European countries. This innovative perspective allows considering simultaneously several indicators to evaluate performance, avoiding biased perspectives that may result from only looking at a single indicator of input or output.

When analyzing country data, several studies suggest that within the wide diversity, countries show some communalities and groupings do tend to emerge. Filippetti & Archibugi (2011) identified group groups of countries considering the way they reacted to the 2007 crises:

"The Catching-up countries: although they do not show a high strength of their national innovation system, they have been increasing their investments more than the average relative to the considered period. This group includes five New Member States.

The Frontrunners: this group consists of those countries which show both a consolidated structural leadership of their innovation performance, and at the same time, they keep increasing their investments in innovation.

The Declining: these countries which, despite having a strong national innovation system, have been relatively increasing their innovation expenditureslessoverthe2006–2008.

The Lagging-behind: is that group of countries characterized both by a low innovation performance at national level and a low performance in firms' innovation spending."

As the authors clearly highlight, countries in these groupings have reacted differently to the crises. A number of factors, primarily the strength of the national innovation system, contributed to explain how firms reacted. Are these factors also likely to affect the innovation efficiency of these economies? How do these groupings stand when we consider the innovation efficiency of these economies? Hence, beyond analyzing country level differences in terms of efficiency, these questions are also addressed in the empirical section of the study.

3. Methodology and data

3.1. Method and variables

The methodology used in this study included two stages. In the first stage, the methodology adopted involved the estimation of efficiency levels using data envelopment analysis (DEA). The relative performance of European countries is evaluated using a composite indicator, estimated using DEA technique. In a second stage it is explored weather there are differences between groupings of countries.

The composite indicator was then decomposed in two components to investigate in detail the efficiency levels of countries from the four groups.

The rationale for using a DEA model to construct a composite indicator is to aggregate a set of key performance indicators into a single overall measure of performance. A composite indicator is a mathematical aggregation of a set of sub-indicators for measuring multidimensional concepts that cannot be captured by a single indicator. The use of DEA to estimate composite indicators has gained popularity in recent years. A DEA-based composite indicator is obtained through linear programming, and shows each Decision Making Unit (DMU) in its most favorable setting.

Data envelopment analysis, introduced by Charnes et al. (1978), is a linear programming technique used for comparing the efficiency of organizational decision making units (DMUs) in their use of multiple inputs to produce multiple outputs. DEA derives a single summary measure of efficiency for each DMU, which is based on the comparison with the other DMUs in the sample. DEA identifies a subset of efficient DMUs, located in the production possibility frontier, and others located inside the PPF - the magnitude of the inefficiency is derived by the distance of each to the frontier.

Consider *n* DMUs (j=1, …, n), each consuming *m* inputs X_{ij} (i=1, …, m) to produce *s* outputs y_{rj} r=1,…,s). For an input minimization perspective and assuming constant returns to scale (CRS), the relative efficiency of a DMU can be evaluated using a linear programming model. The efficient countries have an efficiency score of one (or of 100%) whereas the inefficient countries have a score lower than one (or lower than 100%).

In this paper we estimate the relative efficiency of a country compared to the best practices observed in a given year. To measure the performance of the countries, a DEA model was run with a pooled sample of all countries whose frontier represents the European best practices. The performance score obtained is called pooled performance.

The pooled performance score was decomposed into two components. One component reflects the spread in performance within the group. This component is called within group performance hereafter, and measures the distance of the country to its own group frontier. The within group performance is obtained by running model (1) only with the countries belonging to a particular innovation group (i.e. catching-up, lagging-behind, declining, frontrunner).

The other component reflects the gap between the group best practices and the European benchmarks obtained with the pooled frontier. This component is called group gap hereafter, and measures the distance between the group frontier and the pooled frontier. The group gap corresponds to the ratio between the pooled score and the within group score.

The decomposition of the pooled performance is shown in (2). This decomposition follows the rationale of the “program efficiency" method, first proposed by Charnes et al. (1981), and popularized by Battese et al. (2004), and followed by other authors in other contexts, such as Horta et al. (2016).

Pooled performance= within group performance*group gap

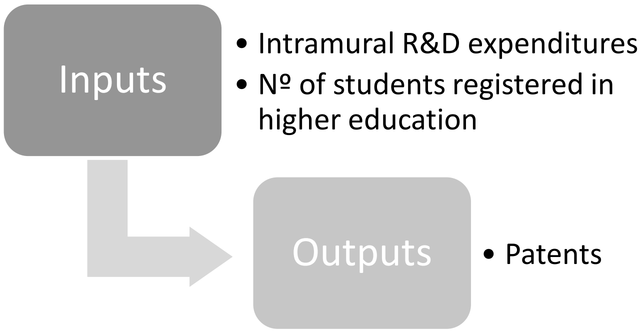
The main indicators for the evaluation of innovation efficiency were selected according to the available datasets and according to the latest research of regional innovation systems.

One output was selected and evaluated in the first stage of the research: y1 – number of patents. Two input indicators were selected that were mostly related to human capital characteristics and investments in R&D x1 – the expenditures of research and development (intramural R&D) and x2 – number of persons registered in tertiary education as proxy for the scale of the scientific community (see Cai & Hanley, 2012). The data is for 2012, the latest year for which we had data for all countries and for the input and output variables considered.

The study is conducted for 29 European countries.

Figure 1 represents the variables.

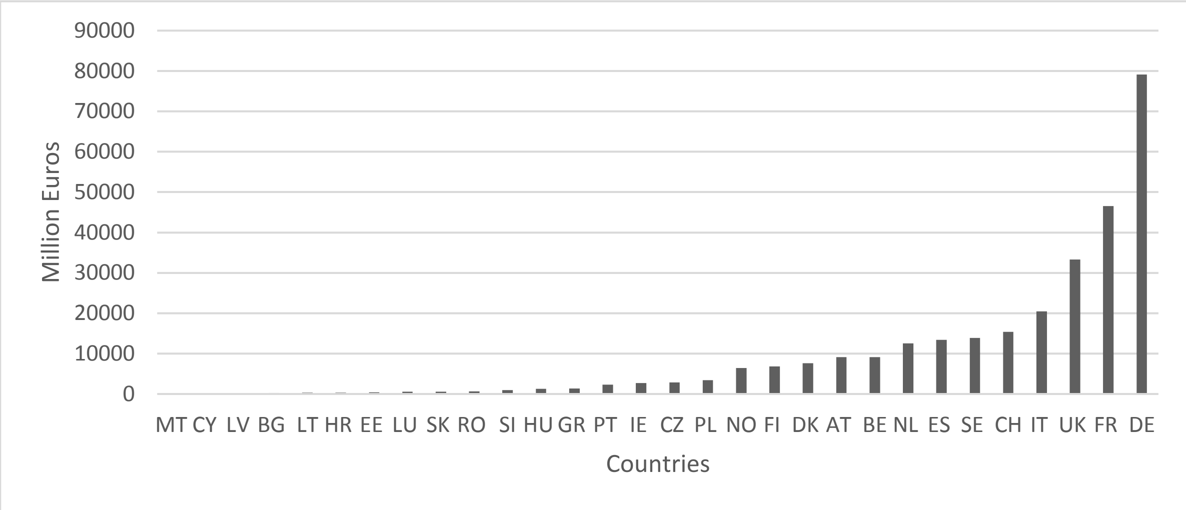
Figure 1- Inputs and outputs



Source: Own elaboration

3.2. Descriptive statistics

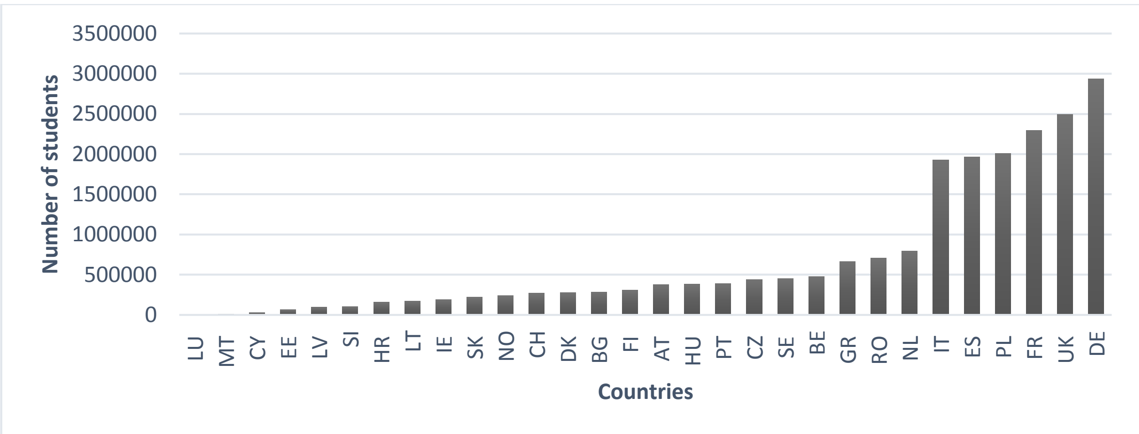
Graph 1: R&D expenditures (Million Euros)



Source: Own elaboration, Eurostat

Graph 1 plots the data for 2012 for 30 European countries revealing high heterogeneity, being at the high end , France and UK and at the low end Malta, Cyprus, Lethonia, Bulgaria.

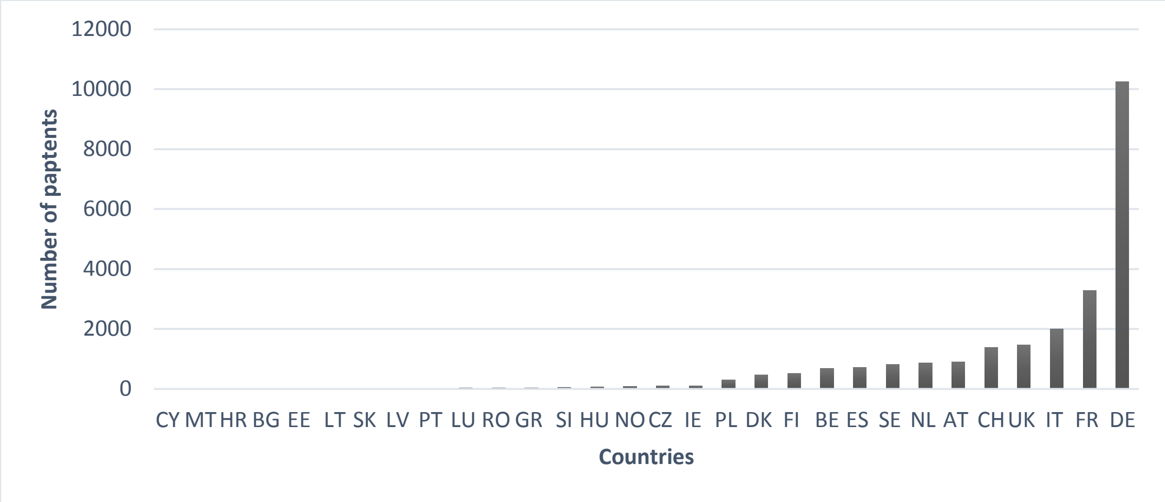
Graph 1: Number of students in higher education (HE)



Source: Own elaboration

Graph 2 reports the number of students registered in higher education. , UK, France, but also Poland, Spain and Italy appear with the highest values.

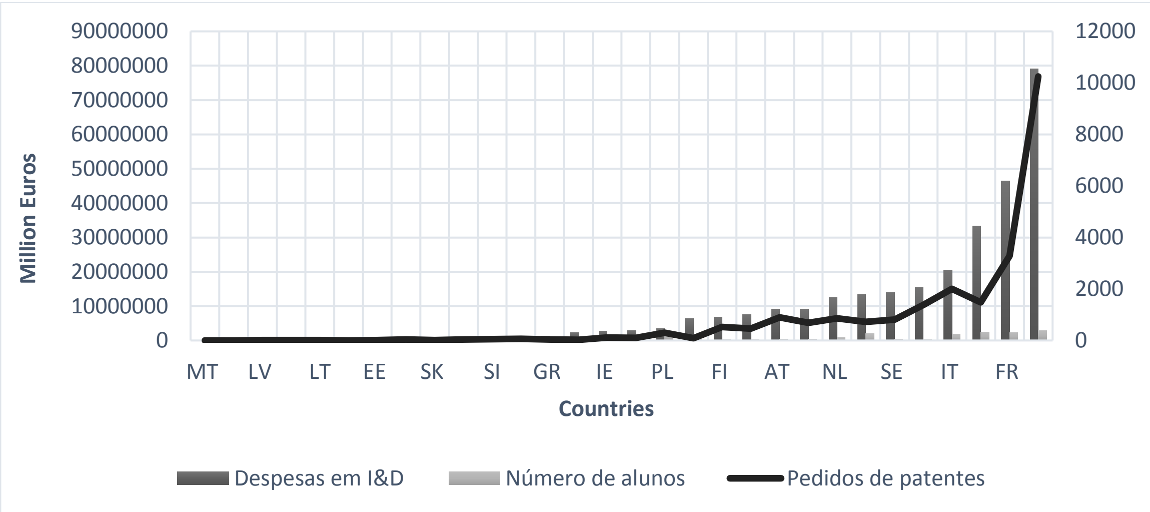
Graph 2: Patents



Source: Own elaboration, Eurostat

Graph 3 pictures the number of patents across European countries, our output measure. , France and Italy show the highest values, contrasting with Malta, Cyprus and Croatia.

Graph 3: Input and output variables



Source: Own elaboration, Eurostat

The Graph indicates that a correlation between the variables do exist, which is also expressed in the correlation results obtained.

Table 1- Descriptive statistics

	R&D expenditures	Nº students in higher education	Patents
Average	9732296,667	691789,73	810,89
Median	2805600	342711	98,47
Standard Dev	16842950,89	842234,32	1930,50
Variance	2,83685E+14	7,09359E+11	3726841,73
Kurtosis	10,07	1,06	21,02
Asymmetry	2,99	1,55	4,36
Min.	61700	6085	1
Max.	79110400	2939463	10247,41
N.	30	30	30

Source: Own elaboration

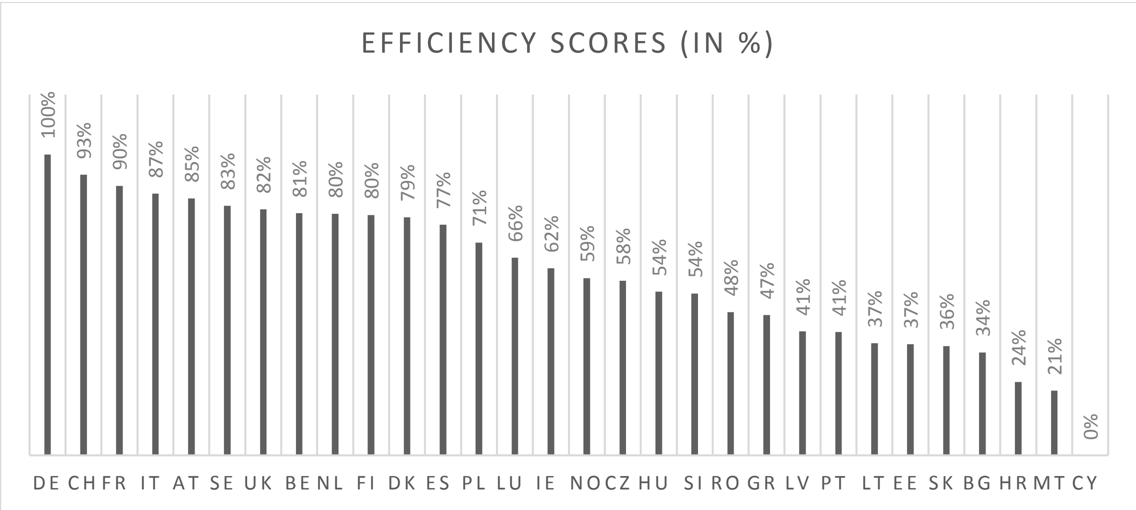
4. Results

4.1. DEA results

The model exposed above was applied to the data, using constant returns to scale and an input oriented approach. It was used the Software ….

The DEA scores are plotted in graph 5.

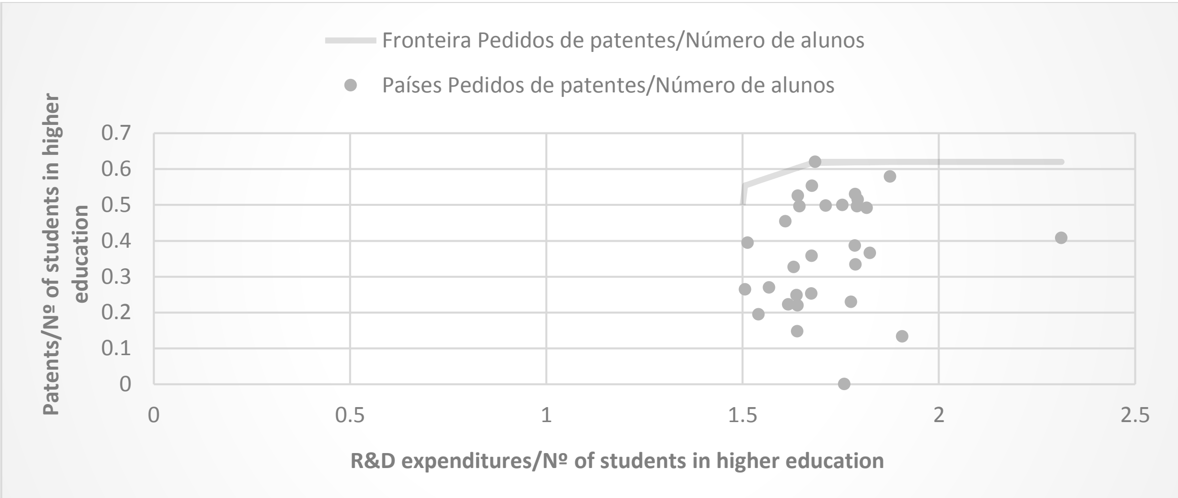
Graph 4: DEA Efficiency scores



Source: Own elaboration

France and Italy appear with highest efficiency scores. The least efficient are eastern European countries.

Graph 5: Frontier patents/ students in higher education and R&D expenditures / students in higher education

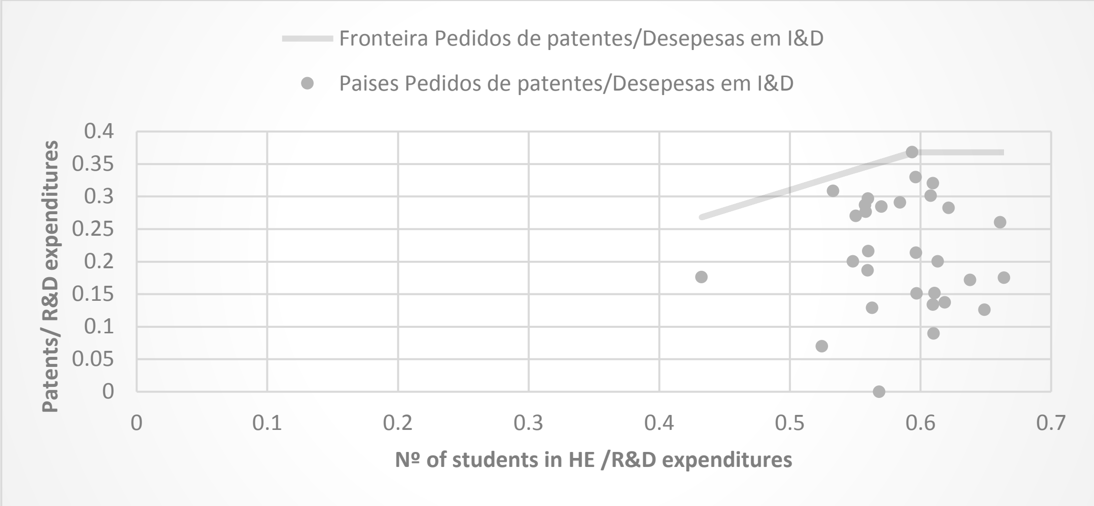


Source : Own elaboration

Graph 6 represents the frontier (X,Y) relating R&D expenditures on number of students and patents on number of students. The efficiency frontier represents the maximum output that can be achieved with minimum inputs.

Countries located on the frontier are the most efficient, and below are inefficient. is located over the frontier, followed by France and Switzerland. Cyprus being the least efficient.

Graph 6: Frontier patents/ R&D expenditures and number of students/ R&D expenditures

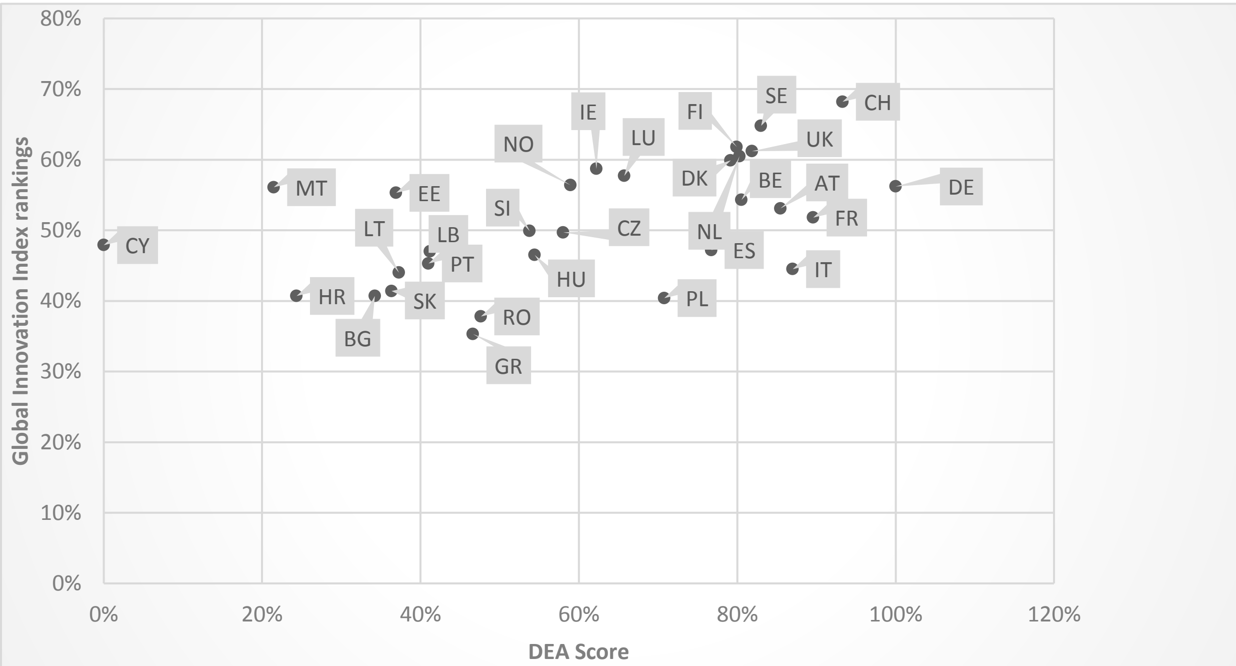


Source: Own elaboration

Graph 7 represents the efficiency frontier when X is given by the number of students on R&D expenditures and Y for patents on R&D expenditures. The location of the countries does not vary from Graph 6.

Our ranking of efficiency to a certain extant resembles that from the Global Innovation Index (GII) (Dutta, 2012). The GII Ranks countries according to their ability and success in innovation, aiming to capture the multidimensional aspects of innovation.

Graph 7- GII and DEA Scores



Source: Own elaboration

On graph 9, X accounts for the DEA score, and Y is the Global Innovation Index. It is possible to identify a good adjustment between the two indicators.

4.1. Comparing efficiency across groupings

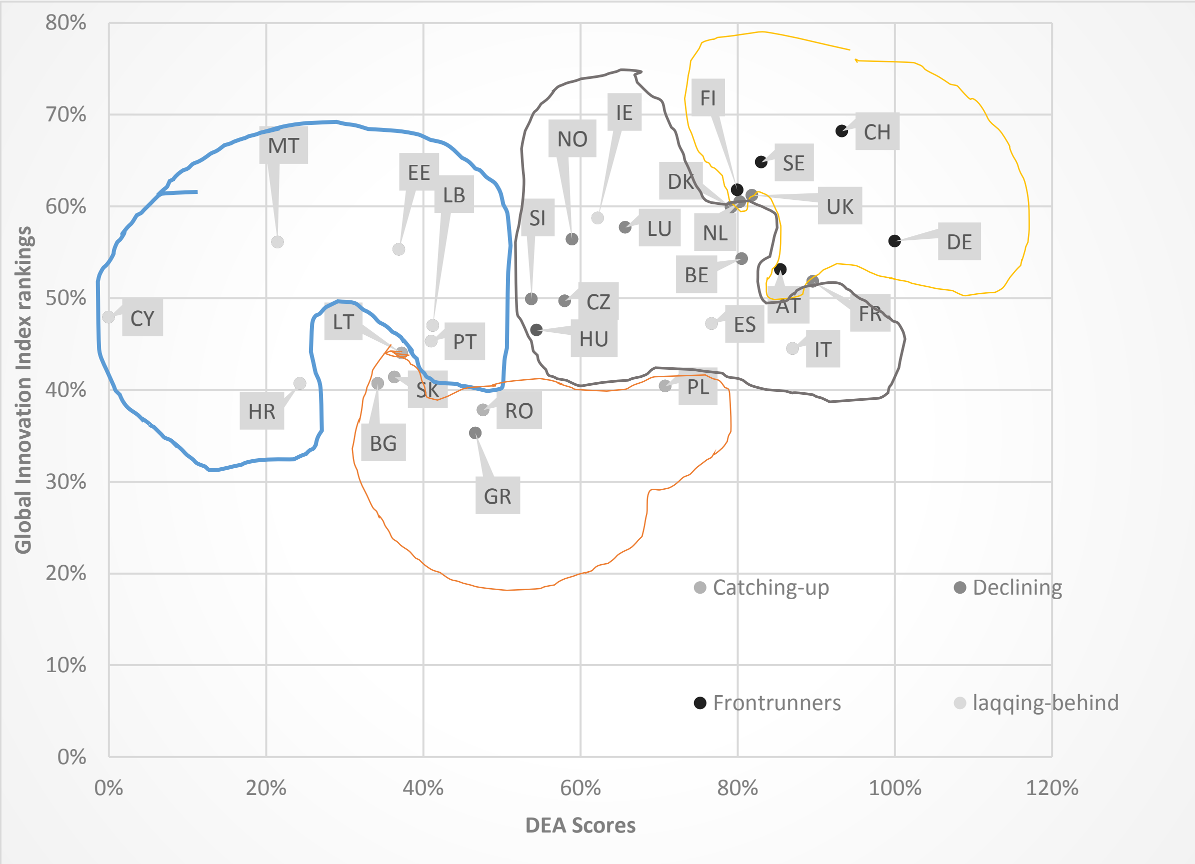
In this section we explore the differences in efficiency between the country groupings suggested by Filippetti and Archibugi (2011). In a first stage we explore the differences in average performance between countries from the different groups (pooled performance). The sources of performance differences are further explored by looking at the spread of performance levels within each group (within group performance), or gaps in performance between the best practices of each group and Europe best practices (group gap). Considering the groupings suggested by Filipetti and Archibugy, it is possible to verify that the groupings do differ in terms of innovation efficiency - hence another aspect along which the groupings differ. The front runners show the highest level of efficiency, followed by the declining countries' group. The catching-up and lagging-behind show the lowest levels on average, but there are not significant differences in efficiency between them.

Table 2 reports the mean of the performance scores of each grouping. Graph 11 plot the results matching with the groupings.

Table 2- DEA and GII average scores by groupings

	DEA pooled score average	DEA within group Average	GII score (mean)
Frontrunners	0,883	0,883	0,608
Declining	0,695	0,777	0,537
Catching-up	0,453	0,657	0,408
Lagging-behind	0,434	0,504	0,492
N.	29	29	29

Graph 8- DEA Scores, GII and Filipetti and Archibugy classification



Source: Own elaboration

In addition, the decomposition of the pooled performance shows that the countries in each group have different performance (Table 3). In particular, catching-up and lagging-behind operate more distant to their own group frontier, which means that they are more heterogeneous in terms of their performance. The high values of the group gap show that the best performing companies in the pooled sample are mainly from frontrunners and declining.

Table 3- DEA and GII average scores by groupings

	DEA pooled results	Within group score	Group GAP
Frontrunners			
DE – Germany	1,000	1,000	1
FI – Finland	0,799	0,799	1
AT – Austria	0,855	0,855	1
SE – Sweden	0,830	0,830	1
CH - Switzerland	0,933	0,933	1
Declining			
DK - Denmark	0,792	0,888	0,892
UK - United Kingdom	0,819	0,914	0,896
LU – Luxembourg	0,657	0,737	0,892
BE – Belgium	0,805	0,903	0,892
GR – Greece	0,466	0,521	0,896

NO – Norway	0,589	0,661	0,892
CZ - Check Republic	0,580	0,648	0,896
FR – France	0,896	1,000	0,896
NL – Netherlands	0,803	0,900	0,892
SI – Slovenia	0,538	0,603	0,892
Catching-up			
PL – Poland	0,708	1,000	0,708
LT – Lithuania	0,373	0,563	0,663
RO - Romenia	0,476	0,673	0,708
BG – Bulgaria	0,342	0,493	0,695
SK - Slovakia	0,363	0,557	0,653
Laqqing-behind			
IE – Ireland	0,622	0,734	0,847
EE – Estonia	0,369	0,436	0,847
ES – Spain	0,767	0,882	0,870
PT - Portugal	0,410	0,481	0,852
IT – Italy	0,870	1,000	0,870
LV - Latvia	0,412	0,474	0,870
MT - Malta	0,215	0,253	0,847
HR - Croatia	0,244	0,280	0,870
CY - Cyprus	0,000	0,000	n.a

5. Conclusion and discussion

This study reports preliminary results from a wider study undergoing at the University of Aveiro, aiming at study the efficiency of national and regional innovation systems in Europe. The work and results herein reported should be considered as work in progress.

From a methodological point of view, a composite indicator model was used to evaluate the innovation performance of a number of European Economies. It involved the use of DEA to estimate a composite indicator of efficiency. This innovative perspective allows considering simultaneously several indicators to evaluate performance, avoiding biased perspectives that may result from only looking at a single indicator of input or output.

Our results reveal high differences in the innovation efficiency of European countries. The group analysis draws on the groupings suggested by Filipetti and Archibugi (2011). We show an additional aspect along which the groups differ- efficiency.

According to Archibugi and Coco (2005), among others, the reduction of national disparities in scientific and technological competences is a priority not only for the continent's economic growth and well-being but also in allowing the EU to close the gap with their direct counterparts, USA and Japan. Our results reveal high differences in the innovation efficiency of European countries, supporting the view that the innovation policy in Europe should not only tackle the low innovation activity of several economies as also the factors likely to affect the efficiency of the national systems of innovation

As mentioned above, being a work in progress, and several directions can be followed. First, different alternatives in terms of DEA model can be explored upon a deeper analysis of relevant literature. It should be explored the possibility for output maximization as well as variable returns to scale. The second step will be to identify the determinants for explaining differences in innovation efficiency.

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Innovation Convergence in the performance of the European Regions – Was the 2008 crisis a structural break?

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Abstract

Since the signature of the peace treaties after the II World War the economic and political relations among the countries were intensified, European countries became allies targeting convergence and a common objective of sustainable growth. Innovation has become of increasing importance among members and the Governance is focused in boosting innovative practices as well as the establishment of relevant innovation networks to exploit the innovative spillovers. Consecutive enlargements of the European Union have grown the area of influence, which shapes the role model of the European firms and their productive chain. Globalization is both the cause and the consequence of technological improvements that took place over the last decades. Technological progress boosted economic growth and development, markets are no longer able to be closed as progress is not an option, and firms can only decide rather being active or passive towards modernity. Goods and services are distributed worldwide, there is free movement of capital venture, and productive processes are diffused worldwide. Innovation is a capital tool to meet the requests of the modern world economic, political and social challenges. The cohesion of the European space will become unsustainable if policy actions do not promote the reduction of Regional asymmetries; European policy makers must pursuit all efforts to promote the approach among regions. It is therefore of major relevance to evaluate the policy measures implemented and their efficiency in terms of cohesion, to endeavour what is theoretically defined as catching-up. Using the accurate conceptual framework and methodology results will highlight the success of the existing policy actions. In the first section we will discuss the existing literature and revisit the conceptual issues in terms of convergence. The existing views will be critically compared and the connection between convergence, innovation, growth, convergence and cohesion. In the following section the empirical analysis will be implemented, using the beta-convergence model, allowing for the convergence estimations. The estimation results will allow a further discussion of the indicators, and shed some light to the policy failures, presenting some further recommendations.

Keywords: regions, beta convergence, GERD, trade marks, catching-up

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Introduction

Since its creation, and with the consecutive enlargements, the European Union increased not only in scale but also in diversity, which brought additional challenges to the EU policy. European economies became more attentive towards convergence while pursuing a common objective of sustainable growth. Disparities between European regions at several levels are considerable, and it is recognised that the future of Europe implies policy actions to reduce regional asymmetries. Hence, strengthening economic, social, and territorial cohesion is a central objective of the European Union.

Innovation has become of increasing importance for that objective. Pinho, Varum and Antunes (2015), Alexiadis et al. (2010) and others, argue that the European policy should focus on innovation activities in order to promote regional growth. These arguments go along the European 2020 growth strategy where a policy target of an investment share in R&D of 3.0 percent of GDP has been defined.

However, disparities between European regions in innovation performance are considerable, and there are doubts as to whether they can to be attenuated. In recent years, there has been a growing body of literature examining regional asymmetries in innovation, highlighting the great diversity in development and patterns of innovation across European regions. There are also doubts about the effectiveness of the European Union’s funds for promoting growth and reducing asymmetries among members (….). We contribute to this literature by examining the evolution of the asymmetries in the innovation performance of several European regions. The analysis is conducted for four indicators, two inputs and two outputs of innovation. In this paper we analyze the results from our work in progress, reporting preliminary results covering NUT II regions from 8 European countries.

In the following section we discuss background literature that supports our research questions.

Theoretical Background

The European Union has devoted major attention to the importance of innovation, and it is recognized that this may contribute to the reduction of the asymmetries among the European regions. This approach is supported on the fact that economic studies came to highlight the importance of innovation to sustainable growth, cohesion and convergence among European regions (Filippetti and Archibugi, 2011a and 2011b; Pinho et al., 2015).

Two alternative scenarios can occur as a consequence of the economic integration process: the first argues in favour of technological homogenization, with full diffusion of knowledge and technology - this means that the European regions, different at first, will have access to the knowledge heritage, absorbing and replicating the existing expertise; leading to higher proximity across regions over time. Conversely, the other view suggests the prevalence of the asymmetries with the more capable regions attracting the knowledge intensive activities and the less capable the low-tech activities, therefore maintaining or enhancing the technological gap and the differences among them (Filippetti and Archibugi , 2011a and 2011b). If this is the case, increasing differences in innovative performance are likely to raise the regional gaps.

In spite the generalized effort to promote innovation across Europe, existing comparative studies reveal that regions show different innovation patterns and different innovative capacity (see RIS, 2014 in European Commission, 2014). This evidence can be easily understood from the Regional Innovation Scoreboard (RIS). Recall that the RIS provides a comparative assessment of innovation performance across 190 regions of the European Union, Norway and Switzerland. It follows the same methodology used at national level to measure performance. The RIS is also based upon data about enablers, firm activities and outputs. Notwithstanding, regional innovation analysis are less frequent and less detailed than the IUS due to a generalized "lack of innovation data at the regional level" (see RIS, 2014 in European Comission, 2014).

European regions are indeed very distinct in several innovation aspects, from enablers, to inputs and outputs, in terms of ability to innovate, in terms of infrastructures and financial resources devoted to innovation, and so on (Sharp, 1998). It remains to be further investigated whether the inter-regional gap is widening or getting narrower. In a study conducted by Markowska and Strahl (2012) for a 10 year period (10 years, 1999-2008) it was registered a reduction in differences between regions in terms of Input and Output European regional innovation indicators. However, they also reveal that this was accompanied by a sharp increase between the extreme values of indicators. Other studies reveal that the economic crisis of 2008 came to highlight the diversity between regions in terms of capacity and vulnerability to external factors (Archibuchi and Filippetti, 2011a and 211b). The empirical evidence on these matters is still scant and inconclusive.

In this study we aim to contribute to knowledge about this issue. We report preliminary results from an on-going study about convergence in innovation performance across European regions.

Empirical analysis

Database[1]

For this study we used data from the *Eurostat*. We gathered data on selected variables to evaluate regional innovative performance. The area of analysis is the European Union, and the unit of study is the NUT II. The European Innovation Scoreboards provide a comparative assessment of research and innovation performance in Europe, and accordingly to their performance they are classified into Leading innovators; strong innovators; moderate innovators; and modest innovators see Innovation Union Scoreboard at European Commission, 2015). In this paper, and to start our analysis, we have chosen two countries from each grouping: Romania, Bulgarian (Modest), Portugal, Czech Republic (Moderate), Netherlands, Luxembourg (Followers), Denmark and Finland (Leaders).

Concerning inputs, we use GERD in euro per inhabitant and Human Resources measured by the number of people with third level of education employed in Science and Technology (measured in thousands). As outputs we explore number of registered patents by the firms operating in each region presented by the European Patent Office as well as trade marks measured by the number of European Trade Marks.

Que central research question is: Are there signs of convergence among European Regions in terms of innovation? Was the financial crisis a structural break?

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[1] Data Base - Eurostat, online http://ec.europa.eu/eurostat/web/regions/data/database?p_p_id=NavTreeportletprod_WAR_NavTreeportletprod_INSTANCE_BQqmHeCfV1BE&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2&p_p_col_count=1

Descriptive analysis

The annual growth rate over the period reveals that innovation inputs have increased for most regions. The data also signal a break in 2008-9. In that year, the growth in innovation inputs declined or was even negative in some cases.

In table 1, modest innovators present the higher rates of growth in terms of R&D expenditures (GERD) from 2003-2013. The rate of growth was higher for this group, reinforcing the convergence hypothesis. It is noteworthy the break registered with the 2008-2009 crisis. Despite the recovery, the growth has not been so evident as before.

Table 1 – Rate of change of input indicators, 2003-2013

	GERD			RH			
	Modest	Moderate	Leaders	Modest	Moderate	Follower	Leaders
	% growth			% growth			
2003	27%	-10%	n.a	20%	3%	6%	9%
2004	14%	8%	n.a	1%	7%	5%	3%
2005	27%	12%	n.a	1%	5%	1%	8%
2006	31%	23%	n.a	2%	1%	-2%	2%
2007	37%	20%	n.a	1%	3%	5%	-2%
2008	24%	17%	n.a	3%	4%	1%	3%
2009	-23%	-1%	n.a	3%	4%	4%	0%
2010	6%	1%	-4%	0%	2%	2%	1%
2011	10%	9%	3%	5%	2%	-1%	1%
2012	4%	6%	1%	2%	5%	1%	3%
2013	-6%	1%	5%	1%	3%	0%	1%

Source: author's own elaboration

Concerning *trade marks* modest innovators present the highest growth. In 2004, 2006 and 2007 the rate of growth was higher than 100%. Moderate innovators also rose in terms of trade marks, and leaders have presented the poorer rate of growth.

Table 2 – Rate of change of output indicators, 2003-2013

	TM				PATENTS			
	Modest	Moderate	Follower	Leader	Modest	Moderate	Follower	Leader
	% growth				% growth			
2003	10%	46%	80%	0%	440%	36%	4%	-4%
2004	135%	14%	-5%	-10%	-63%	2%	13%	4%
2005	47%	6%	3%	11%	152%	37%	-3%	0%
2006	113%	89%	23%	17%	12%	3%	9%	-2%
2007	119%	22%	18%	14%	-75%	12%	-2%	3%
2008	10%	-12%	1%	0%	257%	10%	0%	-1%
2009	8%	-5%	22%	0%	-7%	-18%	-4%	-2%
2010	24%	3%	-2%	20%	136%	17%	-7%	6%
2011	31%	15%	6%	4%	-70%	8%	2%	5%
2012	-1%	17%	1%	5%	135%	-13%	-20%	-16%
2013	-15%	-5%	0%	2%	-	-	-	-

Source: author's own elaboration

The results may illustrate some volatility in terms of the innovation policy for modest innovators. The policy support may be inappropriate.   Even though there are sign of catching-up between worst performers and better performers.

In the next Figure we analyse the evolution of the different regions over time, in terms of their classification with the regional innovation scoreboard. We observe that there are very few changes in the classification of regions, meaning that the relative performance between them has been relatively stable over time.

Regions	2004*	2007	2009	2011	Contry	Country classification
Nord-Vest	Modest	Modest-low	Modest -low	Modest - low	Romenia	Modest
Centru	Modest	Modest-low	Modest -low	Modest - low		
Nord-Est	Modest	Modest-low	Modest - Medium	Modest - low		
Sud-Est	Modest	Modest-low	Modest - low	Modest - low		
Sud - Muntenia	Modest	Modest-low	Modest - low	Modest - low		
Bucuresti - Ilfov	Modetare	Moderate-medium	Moderate-medium	Moderate-medium		
Sud-Vest Oltenia	Modest	Modeste-low	Modest - low	Modest - low		
Vest	Modest	Modeste-low	Modest - low	Modest - low		
Severozapaden	n.a.	n.a.	n.a.	n.a.	Bulgary	
Severen tsentralen	n.a.	n.a.	n.a.	n.a.		
Severoiztochen	n.a.	n.a.	n.a.	n.a.		
Yugoiztochen	n.a.	n.a.	n.a.	n.a.		
Yugozapaden	n.a.	n.a.	n.a.	n.a.		
Yuzhen tsentralen	n.a.	n.a.	n.a.	n.a.		
Praha	Follower	Leader-low	Leader -medium	Leader - medium	Check Republick	Moderate
Stredni Cechy	Moderate	Follower-low	Follower -low	Follower -high		
Jihozápad	Moderate	Moderate-medium	Moderate - medium	Moderate - high		
Severozápad	Moderate	Modest-high	Modest - medium	Moderate - low		
Severovýchod	Moderate	Moderate-high	Moderate - high	Follower -medium		
Jihovýchod	Moderate	Follower-low	Follower -low	Follower - medium		
Stredni Morava	Moderate	Moderate-high	Follower -low	Follower - medium		
Moravskoslezsko	Moderate	Moderate-low	Modest -high	Moderate - low		
Norte	Moderate	Modest-high	Moderate - low	Moderate - high	Portugal	
Algarve	Modest	Modest-medium	Moderate - low	Moderate - high		
Centro (PT)	Moderate	Moderate-low	Moderate - medium	Follower - low		
Área Metropolitana de Lisboa	Moderate	Follower-medium	Follower-high	Leader-low		
Alentejo	Moderate	Moderate-low	Moderate - medium	Moderate -medium		
Região Autónoma dos Açores (PT)	Moderate	Modest-medium	Modest - medium	Modest- high		
Região Autónoma da Madeira (PT)	Moderate	Modest-low	Modest - low	Modest -medium		
Luxembourg	Follower	Follower	Follower	Follower	Luxembourg	Follower
Groningen	Follower	Follower-high	Follower -medium	Follower - high	Netherlands	
Friesland (NL)	Moderate	Moderate-low	Moderate -low	Moderate - low		
Drenthe	Follower	Moderate-medium	Moderate - medium	Moderate -medium		
Overijssel	Follower	Follower-low	Follower -medium	Follower - low		
Gelderland	Follower	Follower-high	Follower -high	Follower - high		
Flevoland	Follower	Follower-high	Follower - high	Follower - high		
Utrecht	Leader	Leader-medium	Leader - medium	Leader - medium		
Noord-Holland	Follower	Leader-low	Leader - low	Leader - medium		
Zuid-Holland	Follower	Leader-low	Leader -low	Leader- low		
Zeeland	Moderate	Moderate-high	Moderate -high	Moderate-high		
Noord-Brabant	Leader	Leader-low	Leader - medium	Leader - medium		
Limburg (NL)	Follower	Follower-high	Follower - high	Follower -high		
Hovedstaden	Leader	Leader-high	Leader - high	Leader - high	Denmark	Leader
Sjælland	Leader	Follower-high	Follower - medium	Follower - high		
Syddanmark	Leader	Follower-high	Follower - medium	Follower -high		
Midtjylland	Leader	Leader-low	Leader -low	Leader -low		
Nordjylland	Follower	Follower-high	Follower - medium	Follower - high		
Länsi-Suomi	Follower	Leader-low	Leader - medium	Leader - medium	Finland	
Etelä-Suomi	Leader	Leader-high	Leader - high	Leader - high		
Helsinki-Uusimaa	Leader	Leader-medium	Follower - high	Follower - medium		
Pohjois- ja Itä-Suomi	Follower	Leader-low	Leader - medium	Leader - medium		
Åland	Follower	Moderate-medium	Moderate - low	Moderate-low		

Figure 1. Classification of regions in the regional innovation scoreboard

Source: author's own elaboration, based upon European Commission 2014

Convergence analysis

Methodology

To study the convergence hypothesis we use four different variables proxying innovation performance at the regional level. We apply a beta-convergence model, applied to the regions of the 8 countries expressed above.

The analysis was based on the following equation:

$$\ln\left[\frac{y_{T,i} - y_{0,i}}{y_{0,i}}\right] = \alpha + \beta \ln y_{0,i} + \varepsilon_i$$

In which the dependent variable represents the rate of change for the convergence, α is a constant, $Y_{0,i}$ initial value, $Y_{t,i}$ final value for a certain region of the country i and ε is the random error.

Results: *Beta- Convergence Test*

In order to test in a more robust way the convergence hypothesis, we have performed the Beta-convergence test for the four innovation indicators for the longer available period. Table (3) presents the estimation results. All coefficients are negative and statistically significant; this means the convergence hypothesis is fully confirmed as expected from the theoretical assumptions.

These findings go in the same direction than the exploratory analysis of the previous tables, and the existing results from Filippetti & Archibugi (2011). In the same vein, these authors found evidence of convergence for the EU regions. The higher rate of convergence is found for *Finance and Support which includes Public R&D*, *capital venture* and private equity and in *outputs* which includes indicators such as patents and *trade marks*. Our results go in the same direction.

Table 3 - Beta-Convergence results (model 1)

Dependent Variable	Patents	GERD	RH 3rd level	*Trade marks*
Β	*-0.345****	-0.106**	-0.975***	-0.873***
Observations	110	120	156	217

*Note: p-value not rejection H0: *** p <0.01, ** p <0.05, * p <0.1*

Source: author's own elaboration

The results are statistically significant, confirming the convergence hypothesis among the European regions over the all period of analysis.

These results do not highlight the crisis effect, as the timespan hides eventual structural breaks (given that the time period in analysis includes before, during and after the crisis).

To achieve a full understanding of the possible effect of the crisis we will build different sub-samples to separate the period before (2004-2006) and after (2008-2011) the structural break. The results are shown in table (4).

The results for this estimation, considering GERD and *Trade marks* suggest a reduction in the propensity to innovate in the lower performers after the economic crisis of 2008. These regions are more vulnerable in terms of the innovative system, in consequence, the effects of the crisis are more noteworthy. The innovation indicator GERD achieved a convergence rate higher the result achieved for model 1, despite becoming statistically insignificant. Concerning *trade mark* no substantial decrease is found compared to the previous model, although the convergence is smaller after than before the crisis.

Table 4 - Beta-Convergence results, before and after the crisis (model 2)

Variable	GERD		Trade marks	
	Before	After	Before	After
Β	-0.281***	-0.124	-0.447***	-0.368***
N.	99	104	102	124
Variable	Patents		Human Resources	
	Before	After	Before	After
β	*-0.26445****	-0.1974***	-0.75649***	-0.23966**
N.	114	152	129	160

*Note: p-value not rejection H0: *** p <0.01, ** p <0.05, * p <0.1*

Source: author's own elaboration

The results reinforce the convergence process occurring in the EU being similar to the *catching-up* theory. Less developed regions are achieving better innovation results than in the past, approaching their performance to the innovation leaders'. This result reinforces the convergence hypothesis, and allow us to affirm that the crisis slowed down bit did not stop the convergence process among the regions here considered.

Despite the validation of the convergence hypothesis, the European regions are growing at a slower pace, which is perhaps explained by the low availability of finance to devote to R&D activities. The reduction is the expenditure in R&D naturally contracts the results in terms of innovation, in general, the innovative performance is poorer in all regions but the catching-up is still verified.

Conclusion

Convergence and cohesion are determinants in the future of the European Union, and the innovation policy will play a major role in creating the conditions to create and diffuse the technological progress to feed the process and boost economic growth. Convergence will re-unite the EU and approach the members, devastated more or less intensively by the crisis of 2008.

The empirical findings illustrate that technological progress is enhancing convergence and allowing less developed EU members to approach the leaders. Less developed members are growing faster. During the period of analysis,a dn fore the regions considered, convergence is empirically supported.

In the last decades, the European enlargements included less developed countries with poor technological conditions; this panorama would let us think about the impossible approach among members, even though the European policy makers have set ambitious targets in terms of cohesion, helping the new members to approach the leaders. The fact is, less developed countries which were included in the latest enlargements are improving their technological conditions validating the convergence hypothesis.

During the period of analysis it was verified an approximation among the European regions, although, after the economic crisis, convergence was maintained, despite de slow down in the rate of convergence. Public policy must get full awareness of this difference as, if properly supported these regions may approach others, still, the "one size fits all" policy making seems to be inadequate.

Leaders and followers do not need the same type of help, and policy makers have to reinforce their actions when facing adverse shocks as followers are more vulnerable.

The 2008 crisis has deaccelerated the convergence process; followers and moderate innovators, due to the financial constraints, were forced to reduce their expenditures in R&D, which damages the speed of adjustment. In consequence, the achievements in terms of economic development were poorer than in the past. The creation of specific policy actions and the understanding of the differences among members allowed overcoming the negative aspects of the 2008 financial crisis.

Smart policies are required as the needs of the leaders and the followers are different. The simple attribution of funds do not produce the same result among members and may even increase the asymmetries among regions. Supporting the construction of infrastructures and the qualification of the labour force will play a major role in the results for the less developed countries. The criteria in terms of the attribution of funds is also determinant, as the simple choice of different innovation measures will bias the results.

Policy makers must have a deeper understanding of the NSI, the RSI and the Triple Helix operating in each region as the generation and exploitation of the knowledge externalities will depend on the interaction of all agents. The institutions will play a determinant role in terms of knowledge creation and diffusion, it is of worth mentioning the role of the Universities in terms of what is called its “third mission”.

Strengthening institutions, understanding the weaknesses and the strengths of its region will allow a cohesive development respecting the everlasting differences among regions. Convergence means approach, does not mean cloning, the policy actions must reinforce the respect for heterogeneity and the benefit from being dissimilar.

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Proposal of the Instrument for Measuring Innovation level in the Industrial Energy Efficiency

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Abstract

The intelligent and efficient use of electricity, and its treatment and control made responsibly and rationally, generate repercussions for business, the economy and society. In this sense, the energy management system constantly seeks innovations that aims to better use of electrical installations and equipment, reduce energy consumption and, consequently, increased productivity without affecting the safety and reduction of costs of electricity. Thus, this paper presents an instrument proposed to measure the level of innovation in industries that have an energy efficiency plan in their production processes. The instrument features 30 performance indicators grouped into 10 critical success factors fragmented into four points fundamentas view. The construction of the instrument was based on a survey on organizational innovation and industrial energy efficiency. With the implementation of this instrument is intended to generate a current diagnosis of the situation of the evaluated organizations, and support decisions of innovation managers in energy efficiency to get the best performance in the production of a service with the least expenditure of energy.

Keywords: Energy Efficiency, Organizational Innovation, Performance Indicators.

1. Introduction

The increasing demand for electricity has a world stage to search for new sources of energy to meet the rapid increase in consumption and minimize the impact of the energy crisis. optimization of energy management measures emerged in the eighties, in many countries where the programs management stood out. This decade also emerged the Integrated Resource Planning (IRP), which considered new energy efficiency programs competing with the alternatives available to expand supply, which occurred mainly in the United States, Canada and Denmark. And finally, completing the eighties, it was the United States the emergence of methods of tariff regulation by incentives, which sought to share between monopolistic utilities and their consumers, any benefits associated with the improvement in the economic performance of these utilities. Given this context, dedicated to legislation establishing minimum levels required for efficient equipment, vehicles and buildings, by means of tagging programs (Ipea, 2015).

In the Brazilian industrial scenario, the negative impact on the profitability of export business from the appreciation of the real against the US currency, high interest rates practiced in the country, and especially the lack of a widespread culture of investment in energy efficiency projects by industries it has been reflected in the poor performance of government programs to encourage increased energy efficiency (MME, 2012). specifically assessing the situation of the industrial sector, Barbieri (2007) states that the electricity tariffs for industries rose 108.9% during the last decade. In December 2002, the industry paid around R $ 95.77 per MWh; in June 2006, these rates rose to R $ 200.03 per MWh.

In this case, from a strategic point of view, the search for a potentially competitive performance are targeting industries the use of innovations that contribute to a more responsible way of acting (Silva and Corrêa and Gomez, 2012). The cost of energy and international competitiveness has exercised over the Brazilian industry is growing pressure in that adopt innovative technologies capable of producing energy-saving in consumption. Therefore, this article aims to draft a research tool to measure the level of innovation in industries that have an energy efficiency plan.

2. Innovation Management in Energy Efficiency

Organizations have experienced periods of intense competition in the global economy, characterized by processes and increasingly effective and qualified technology, so that the adoption of innovative strategies becomes crucial in the management process (Porter, 2009 and Hitt, 2012). The search for a potentially competitive performance is driving organizations to the use of innovations that contribute to a form of more responsible behavior on the market (Silva and Corrêa and Gomez, 2012). According to Barbieri (2007), "innovations represent changes, disruptions and uncertainties that will be the greater the better the news and the scope of their impact on the elements of the dimensions of sustainability associated with development." This idea transcribes the concern of the industry to invest in energy efficiency management and technological innovation of renewable resources.

Innovation is an asset consists of several elements that help develop and support the company's relationship with its customers. The quality of this link and its potential to generate satisfactory results depend on the process of management of the innovative actions in organizations. Therefore, investments in innovation can generate many benefits for a company; however, its continuation will depend on a set of assets, such as research and development, introduction of new technologies and training of your work team (Walls and Santana and Fell, 2014). Thus, the management of innovation is a dynamic concept, which implies the latent need for organizations renew themselves constantly through innovations and updates that, on the one hand, to add value to processes or products, and other install barriers that limit access competition to new technologies. (Porter, 2009 and Tidd, 2008).

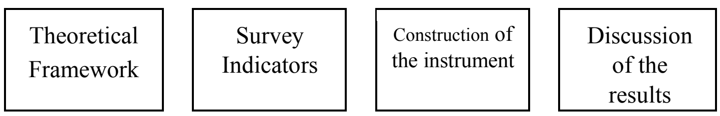
Given the growing importance of innovation management in the development of organizations, the diagnosis has become an important tool in that it allows you to view an overview of the strategic actions of the company under study (Marques and Siluk and Neulenfeudt, 2014.). To Terra (2007), it is essential for organizations that want to keep themselves active in the market, maintain a strategic vision of innovation, taking into account the processes, people, technologies, the approach to the market, energy efficiency and building partnerships. Thus, the author states that any evolutionary change that aims to extend the life of organizations should be understood as innovation.

In this case, the implementation of an energy efficiency plan in the production process can be considered a strategic vision of innovation with a view to the future scenarios of the company and the country's energy sector. As a result, this study aims to analyze the innovative profile of organizations that invest in technology and procedures to reduce energy costs.

3. Methodology

To understand the main points raised and achieve the proposed objective, the methodological procedure was conducted in four stages, as shown in Figure 1.

Figure 1. Schematic representation of the methodology.



For the fulfillment of the first stage was used the Journals Portal of Higher Education Personnel Improvement Coordination (CAPES / MEC) and consultation in books, articles published in conference proceedings and technical notes on innovation and industrial energy efficiency with purpose of seeking theoretical basis for construction of the measuring instrument proposed.

The step includes the survey of indicators was based on the tool developed by the Innovation Center and Competitiveness / NIC-UFSM to measure innovation from the central objective unfolding Fundamental Viewpoints (PVFS) and Critical Success Factors (FCS). In addition to this tool, PVFS and FCS for assessing the level of innovation in industries that use an energy efficiency plan, were drawn from recurrences identified through bibliographic and documentary research, sticking thus the objective of identifying the most factors relevant to the assessment of the level of innovation. The structuring of the indicators was given to the construction of the decision tree in which the Fundamental Viewpoints (PVFS) are part of the main structure of the tree and are relevant indicators to identify the extent of this innovation in organizations that will be evaluated.

From the survey indicators and the construction of the decision tree has prepared the construction of the innovation measuring instrument. Therefore, two electronic forms were constructed, a reference to the collection of data that will feed the instrument and will serve to identify the level of innovation in the company evaluated at the time of research, and other referring to the importance attached to each indicator by the managers of the participating companies. At the end of this phase, the third phase is fully completed, which included the construction of the instrument.

The final phase of this research includes the drafting of conclusions. In this, the goal is resumed, and checks whether the results meet the research problem set in the introductory section, and present limitations, expectations and suggestions for future work.

4. Results and Discussions

The survey of indicators, followed by the construction of the decision tree, began by conducting exploratory research on the current context of innovation in industrial energy efficiency, from the making of bibliographic and documentary research. During the reading of materials, we sought to identify the elements that shape innovation in the search for energy efficiency and renewable energy technologies.

Fundamentally, the readings of scientific and documentary materials showed some points as the main obstacles to the consolidation of industrial energy efficiency were used to determine the four fundamental points of view (PVF's).

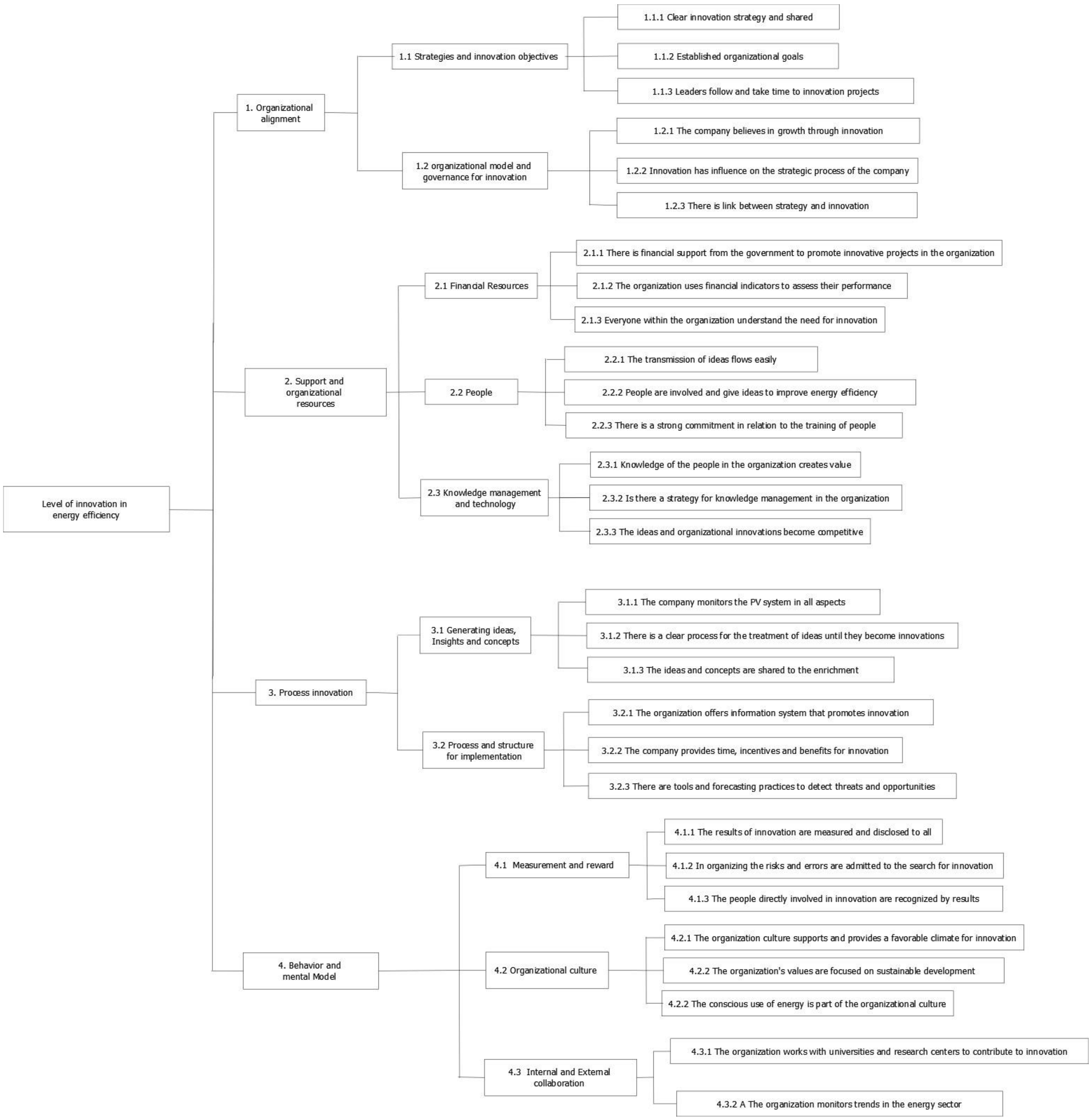
Based on these four PVFS, as well as other information gathered through the research conducted, it was proposed to build an instrument that covers the critical success factors (CSFs) listed in Figure 2.

Figure 2. Placement of PVFs and CSFs.

Fundamental Point of View (PVF)	Critical Success Factor (CSF)
Organizational Alignment (PVF1)	Strategy and Innovation Objectives (FCS 1)
	Organizational Model and Governance Innovation (FCS 2)
Organizational Support and Resources (PVF2)	Financial Resources (FCS 3)
	People (FCS 4)
	Knowledge Management and Technological (FCS5)
Process innovation (PFV3)	Idea Generation, Insights and Concepts (FCS 6)
	Process and Framework for Implementation (FCS 7)
Behavior and Mental Model (PFV4)	Measurement and reward (FCS 8)
	Organizational culture (FCS 9)
	Collaboration Internal and External (FCS 10)

Each critical success factor has a group of performance indicators which have a purpose of measurement, according to the schematic illustration of the decision tree in Figure 3.

Figure 3. Schematic illustration of the decision tree.



For the construction of the proposed instrument they were raised 30 performance indicators, grouped into 10 critical success factors and key 4 views. From the definition of indicators, early gave up the development of the survey instrument, which presents each indicator broken down into five possible levels of response. Level 5 (N5) corresponds to the situation of a fully innovative organization in the assessed indicator, N3 corresponds to the midpoint, and N1 the worst possible situation. That is, when an organization reaches the N5 of an indicator, it will be at a high level of innovation. At the other end, to reach N1, innovation in the organization will be committed from the perspective of that performance indicator.

In this case, in order to assess the overall level of innovation in organizations have been proposed for all indicators linear functions with a score between 0 and 10, the end of the instrument application can frame the organization in one of the four levels of organizational innovation, as shown in Figure 4.

Figure 4. Scales rating.

Organizational Innovation level	Description
0% |--------------- 25%	No Innovative
25% |------------- 50%	Little Innovative
50% |------------- 75%	Potentially Innovative
75% |------------- 100%	Full Innovative

Additionally, the instrument asks respondents about the level of importance that they attach to each of the indicators raised, this information will be used later to calculate replacement rates and distribution of the weights of each PVF and FCS, which lets you create a ranking of importance among the indicators. For this, it built the relevance of scale, where respondents should indicate an alternative from 1 to 9, where 1 is the alternative "of No Importance," 5 to "Average Importance" and 9 to "Very High Importance".

The research instrument proposed to assess the organizational level of innovation of the participating organizations as follows the structure of Figure 5.

Figure 5. Proposed instrument.

PVF 1	**FCS 1.1 - STRATEGIES AND INNOVATION GOALS**	
Nível	**1.1.1 Innovation strategy in the organization is clear and organized?**	**Weight**
N1	All organizational innovation strategies are clear and organized.	100%
N2	More than 65% of innovation strategies are clear and organized.	75%
N3	Half of innovation strategies are clear and organized.	50%
N4	Less than 15% of innovation strategies are clear and organized.	25%
N5	There is no clarity and organization in innovation strategies.	0
Relevance	1.( ) 2.( ) 3.( ) 4.( ) 5.( ) 6.( ) 7.( ) 8.( ) 9.( )	

The return of the answered research tool will provide quantitative data that will feed the proposed model to assess organizational innovation, and allows a diagnosis of the situation at the time of data collection. The focus in this case is to promote improvements in indicators that have greater relevance in order to contribute more significantly to boost the overall level of innovation in the assessed company. In addition to these results, it is intended with this proposed instrument to verify the relationship of the innovative profile of organizations with advances in energy efficiency, or check whether there is an association between organizations with innovative features and concern for energy efficiency and search for alternatives renewables for power generation. With all these expected results, we seek to develop increasingly the Brazilian energy sector positively influencing the industrial energy consumption.

Additionally, this article highlights as points for future research one modeling to measure the level of innovation based on the results of the proposed instrument and the possibility of an investigation into the systemic factors that shape organizational innovation in energy efficiency investments.

5. Conclusions

The present study had as its starting point the analysis of bibliographical and documentary information collected on energy efficiency and organizational innovation. Based on the methodological approach and the results, it is considered that objective was achieved, since the proposed survey instrument was developed through the performance indicator survey that indicate the level of innovation in organizations that have an efficiency plan energy in their processes. The instrument was built by identifying four key views, 10 critical success factors and 30 performance indicators, presented in the shape of closed questions multiple choice. The main limitation of this article appears in the absence of presentation of the data collected in organizations, which prevented him from presenting the relevance, elencada the instrument of respondents, fundamental views, critical success factors and indicators. Thus, research has continued to be worked out in future research.

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Joint Deployment of Lean and TRIZ Methodologies in Industrial Environment

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Abstract

TRIZ (Theory of Inventive Problem Solving) and Lean methodologies can alone be used to analyze and provide solutions to any system. Implementation of their techniques and methods can allow companies and industries to improve their processes and eliminate waste and find new solutions. Lean is a methodology which has spread around the world and is part of many companies strategy. The core principles of Lean are to maximize customer value and is a method of managing an organization with the objective of improving key indicators like productivity, efficiency and product quality. On the other hand, TRIZ as an inventing methodology and scientifically driven, is a powerful tool during the analytical stage. By proposing a combined use of Lean and TRIZ methodologies in industrial environment, a new approach can be adopted by companies in order to address issues detected in their processes.

Keywords: DMAIC, Ideality Matrix, Ishikawa Diagram, Lean, SIPOC,TRIZ.

1. Introduction

We live nowadays in a highly competitive and demanding world, where evolution, constant innovation and creativity define the survival or disappearance of certain industries and services and the emergence of new products and solutions. The urgency to meet the market's specific needs requires more agile procedures and the use of methodologies and heuristics exploring the systematization on creativity and innovation. Decision making must be supported with strong arguments, either in terms of implementation of new policies, or in terms of new product development. Thus, the use of tools and methodologies which may allow the decision making to be sustained in strong bases and previous experience becomes vital. Similarly, innovation is today one of the main objectives of many organizations, being a necessary condition for any kind of activity. (Mareis, 2012).

2. TRIZ

TRIZ is an especially appropriate methodology to solve new problems in science and engineering and aims to help the development of projects where the simple application of "best practice" management or engineering does not produce remarkable results (Navas, 2013). As science, TRIZ methodology addresses the problem of determining and categorizing all the features and technical aspects of the technology systems and processes that need to be invented or improved as well as its inventive process.

3. Lean

Lean Manufacturing, also called the Toyota Production System, is a management philosophy focused on reduction of seven types of waste (transportation, defects, motion, waiting time, over-processing, over- production, and inventory). Lean Production System focuses its analysis on the value stream that gives rise to the product in terms of maximal value together with the elimination of Muda (waste in Japanese), optimizing all process activities and stages (Machado and Navas, 2015). Traditional Lean tools are Value Stream Mapping, Quick Changeover/Setup Reduction, Single Minute Exchange of Dies (SMED), Kaizen, Flow Manufacturing, Visual Workplace/Five S Good Housekeeping, Total Productive maintenance (TPM) and Pull (Kanban System), Poka-Yoke (error-proofing), etc. (Bradley and Ikovenko, 2004).

4. TRIZ-Lean approach

The Lean approach is to find the best compromise between contradictions, whereas the TRIZ approach is to eliminate contradictions avoiding the compromise or trade off. TRIZ can be seen as a Lean tool. There are many Lean techniques and concepts where TRIZ might be applied (Campbell, 2004). TRIZ, as a problem solving technique, can be used within lean to find methods of accomplishing tasks that may not have otherwise been found. TRIZ lends itself well to finding solutions that utilize currently available resources that may otherwise be seen as waste (‘muda’ in lean). In addition, TRIZ’s ideal final result could help in developing future state maps, by looking at a particular process and its role in the entire system and determining how ideality for both can be balanced (Bligh, 2006).

Due to recognized benefits of Lean Production in the world, companies of all kinds and sizes are trying to implement the techniques to this production system. Nowadays it can also be applied to TRIZ by proposing a new approach to the Japanese Method of Lean Production. Traditionally, the effectiveness of new process is unpredictable as process relies largely on inspiration and the past experiences of the producing system. Therefore, by integrating TRIZ problem-solving and Lean tools, it’s proposed a new TRIZ-based approach to address this weaknesses in the processes (Silva, 2013).

4.1 Combined use of TRIZ and Lean model

There has been some debate on how to best use TRIZ with the set of Lean tools, and how to combine Lean and TRIZ or how to integrate each other. The purpose of this model is to create a solution to problems detected through the analysis of a system in a step-by-step process. At the end of the application of the model, the solution of the problem is identified and ready to be implemented. (Lopes, 2015)

According to Lopes (2015), aspects that are identified as waste according to the Lean, simultaneously represent a contradiction in TRIZ. With this parallelism created, those of TRIZ tools can be applied to complement Lean tools to identify waste, and to support them. All of TRIZ tools can be used in this process, since its goal is the identification and resolution of contradictions - waste in Lean language. The model proposed by Lopes, allows an analysis of the existence of waste/contradictions in the system, ie, the existence of a problem. This analysis is divided into four main phases: analysis of a technical/organizational system, classification and formulation of the problem, generation of the problem solutions and finally the phase of the solution ideality level (Lopes, 2015).

4.2 Step-by-step system analysis

In this model is suggested that when the analysis of a system starts, figure 1, three activities are defined. Two of them, the mapping value stream and construction a Ishikawa diagram, are preceded by a brainstorming. This, in turn, will examine the results obtained in these two activities, and thus is decided final result of the whole analysis. The genesis of this flowchart branch is Lean.
The third activity begins with the analysis of a system using a brainstorm. This will serve as a basis for the construction of Ideality Matrix and the ideal solution, as well as for the construction of the Matrix of Contradictions. Ideality matrix is constructed with the aim of analyzing the parameters entering in a negative iteration, which in turn constitute a contradiction (Lopes, 2015).

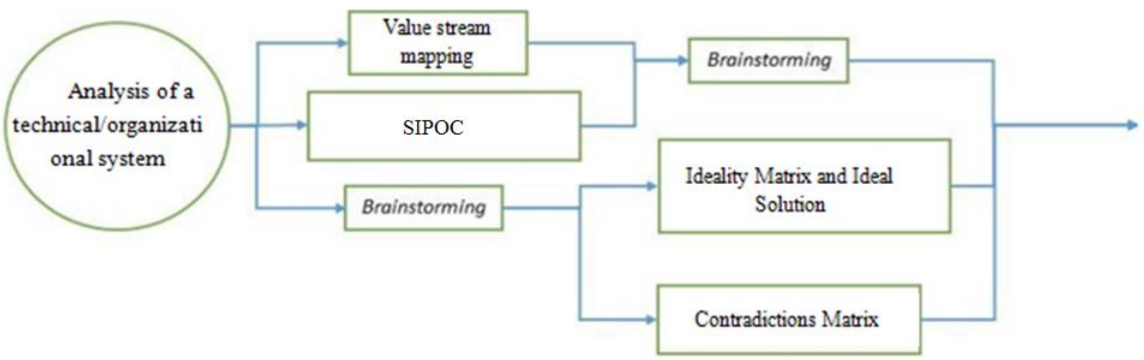

Figure 1. First part of the model – Analysis of a technical/organizational system, adapted (Lopes, 2015).

The model suggests that in case if any waste or contradiction has been found, it should continue to move through the flow chart for the phase of Classification and Problem Formulation. This model suggests the drawing up of two activities for this phase, figure 2 (Lopes, 2015).

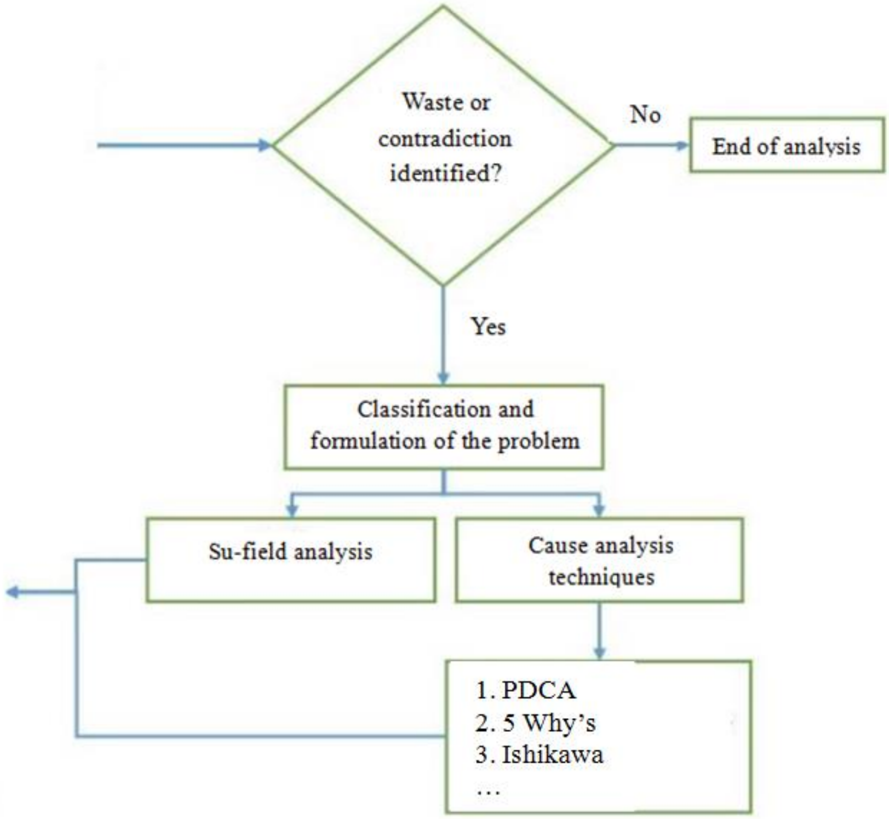

Figure 2. Second part of the model – Waste or contradictions analysis, adapted (Lopes, 2015).

Following the second part of the model, and in case of considering that it is a complex problem, it starts to generate the solutions to the problem by using TRIZ tools. It suggests using various tools so that the obtained solutions are confirmed. If it isn't considers a complex problem, figure 3, more direct solutions can be used, both from TRIZ and Lean (Lopes, 2015).

5. Case study

This case study was developed in the washing and maintenance line of recycling containers of a certain company. This department was responsible for collecting the container from the street, washing, cleaning and performing maintenance in it, restoring it to the condition "as new". This line was having trouble in being able to attain the required level of a performance indicator, which was the number of washed and repaired containers. The objective of the study was to analyze the department technical capabilities, procedures, human tasks and all the surrounding conditions, identifying the cause or causes, leading to the lack of process capacity or bottleneck. In the end, it was intended that this study lead to an increase in the number of containers that were subject to washing and maintenance during a day shift. TRIZ and Lean tools were used in this study, following the model which integrates TRIZ and Lean, described as above. Only some branches of the suggested model were followed, adapting it to the needs of the analysis.

5.1 Define, Measure, Analyze, Improve, Control (DMAIC)

Being DMAIC an iterative process, it gives structure and guidance to improving processes and productivity in the workplace. Applying the DMAIC steps and appropriate analysis tools under each step, it allows the analysis and improvement of the key metrics of a business. Metrics are established and processes are improved and optimized. The result is improved performance, fewer errors and increased efficiency and productivity (Rever, 2015). The DMAIC which was developed is identified in figure 4, and was used, as said above, as guidance in order to analyze all the process.

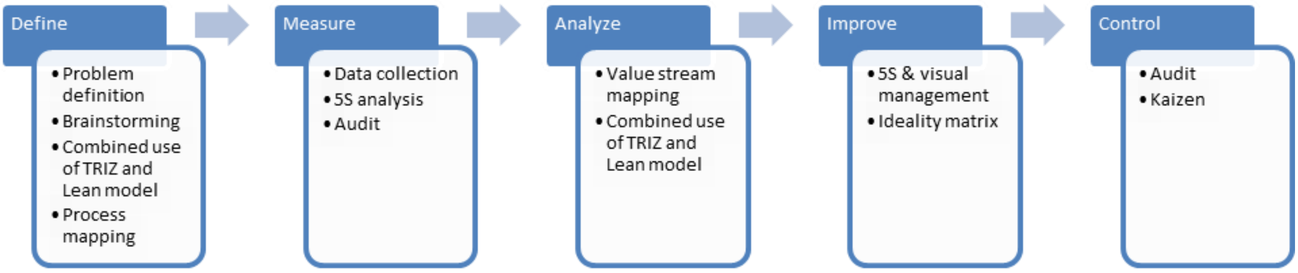

Figure 3. DMAIC steps and tools.

5.2 Applying the combined model of TRIZ and Lean

As identified in the DMAIC, in the steps Define and Analyze was used the combined model in order to conduct the study. This model may allow in a first phase to define metrics and in the Analyze phase, offers a way to describe, identify causes and find solutions.

5.3 Suppliers, Inputs, Process, Output, Customers (SIPOC)

SIPOC diagram is a tool used to identify all relevant elements of a process improvement project before work begins. Mapping the process of the SIPOC into various levels allows better understanding on how it is performed. Below, in figure 5, it is shown in detail the process mapping of the process.

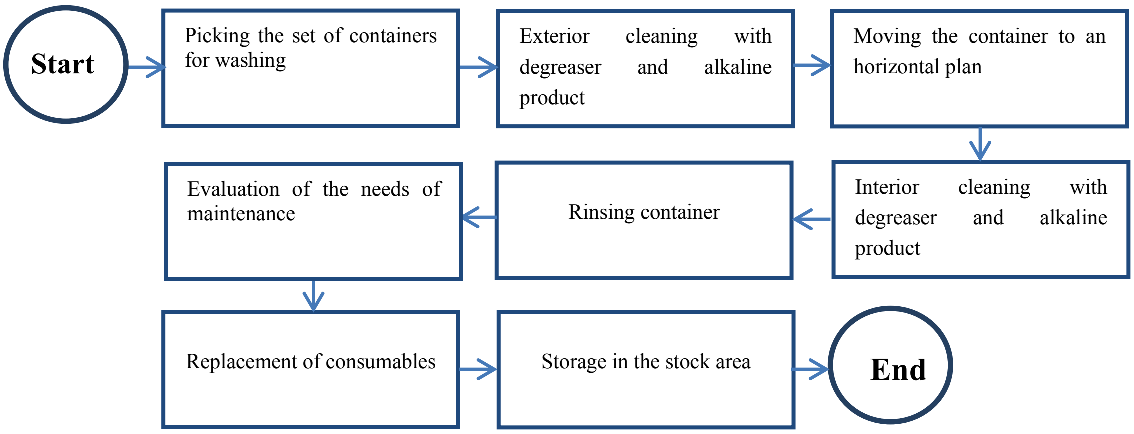

Figure 4. SIPOC, process in detail.

Having the steps of the process clearly defined and identified, it allows the capability of identifying the most critical activities, effects and causes.

5.4 Ideality matrix

The ideality matrix was used to find which the beneficial functions were and which ones were the harmful, Table 1.

Table 1. Ideality matrix.

Parameter	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Need to wash the container exterior with degreaser									-	+	-	+
2. Need to wash the container exterior with alcaline product									-	+	-	+
3. Need to wash the container interior with degreaser					+	+			-	+	-	+
4. Need to wash the container interior with alcaline product					+	+			-	+	-	-
5. Need to scrape the interior base			+	+		+			-	+		-
6. Need to move the container to an horizontal plan			+	+	+				-		-	-
7. Picking time from the stock area								-	-			-
8. Operators movements							-		-			-
9.Washing operation time	-	-	-	-	-	-	-	-		-		-
10.Hygienization quality levels of containers	+	+	+	+	+				-			
11.Physical effort needed	-	-	-	-		-						
12.Value added operation	+	+	+	-	-	-	-	-	-			

Several parameters were defined according to the main tasks performed by the operators. The effects each one has on the others, are reflected in the figure above, and are a good indicator on the effect they produce. The ideality is measured according to the Equation (1):

$$Ideality = \frac{\sum Beneficial\ functions}{\sum Harmfull\ functions} \quad (1)$$

$Ideality = \frac{26}{42} \approx 0.62$ The result obtained was 0.62, Equation (2). Acting on the harmful functions would increase the ideality.

(2)

It was noted that several activities existed and provided no value added. Reformulating procedures and acting on those activities could prove useful and allow an increase of the Ideality.

5.5 Ishikawa diagram

The Ishikawa diagram was used to list possible causes for the main problems that were identified. The problems leading to the effect, insufficient number of washed and repaired containers were listed: material, machines, processes, operator's movements, people, work environment and stock.

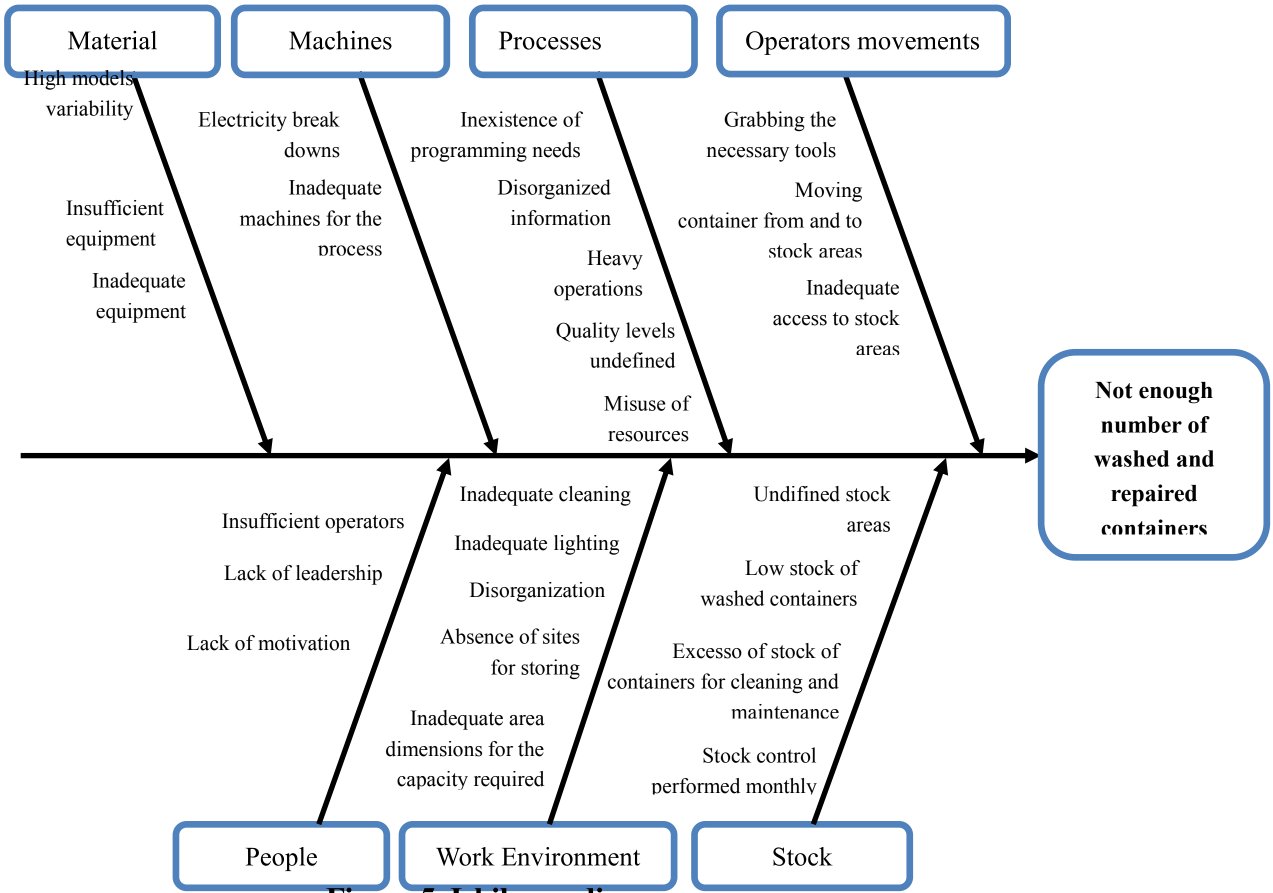

Figure 5. Ishikawa diagram.

The Ishikawa diagram allowed to have a better understanding of the causes of the problem. It was followed by a brainstorming session where the main causes of problems were discussed, leading to decisions in which causes to act.

6. Conclusions

The combination of TRIZ and Lean tools proves to be very useful in the analysis of problems like the one presented in the case study. The importance in integrating TRIZ and Lean is of great relevance. The tools used allowed a better understanding of the problems and its causes, and leaded to better decisions in order to solve the problems identified. The related case study is still ongoing, and having established the action plan and having identified problems and its causes, it is believed that the implementation of new measures will improve the process and increase the ideality of the system.

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