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FULL PAPERS

Applied Innovation by SMEs for RDI Certification Purposes

Manuel Teles Fernandes
CAAM, Corporate Academy for Advanced Management (by Gestão Total).
mtf@gestaototal.com
(Received 22 August 2016; final version received 26 March 2017)

R&D Director and researcher

Abstract

This paper aims at bringing the analysis of innovation from a macro perspective down to the level of SMEs (small and medium enterprises) activities (a micro perspective), pointing out their contributive inputs to the economy. For that purpose, a study has been conducted based on the full population of certified SMEs, according to a RDI (research, development and innovation) standard in one specific 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 currently worldwide-accepted concepts (the Oslo Manual) and new theoretical developments in the understanding of innovation in 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 a focus group methodology.

A closer analysis of innovation at the micro level (for SMEs) gives insight into potential innovation and innovative management inputs and to new innovation strategies and policymaking. A better understanding of how innovation impacts the creation and generation of value, how the technological innovation process affects ultimate productive output, and how SMEs may take advantage of cultural innovation, may be drawn from the conclusions of the study.

Keywords: innovation, value, technological innovation, cultural innovation.

1. Introduction

The study of innovation in the private sector is a constant need, because its productive effects have a tremendous influence on the growth of the economy, as demonstrated by some empirical studies (Mowen and Rosenberg, 1979). However, quantifying, evaluating, and comparing innovation, at the level of needed competencies and of the used practices, is a complex issue, difficult to solve, for those organization that have the mission and the intention of doing that (Frenkel, Maital and Grupp, 2000).

Sometimes, these realities make it difficult to reach a vast, precise and detailed understanding of the different dimensions of innovation, mainly at the final output and outcome levels. One of the hardest challenges is measuring the complex processes that influence the capacity of an organization to innovate, in order to improve its managerial capability (Cordero, 1990). Measuring innovation is highly important for political and economical agents, but also for academic researchers. Unless the constructs related to the phenomenon of innovation are measurable, using methods commonly accepted, there is the possibility of different evaluations of the same effect producing conflicting results, wasting technological advances in the different terminologies (Adams, Bessant and Phelps, 2006). The constant new proposals to measure different aspects of innovation, to provide answers to companies and academia, in order to understand the efficacy of the taken actions (Kim and Oh, 2002), makes the full exercise very much fragmented, as well as the results. A potential consequence of such fragmentation is that most empirical studies identify the exclusive focus of many organizations, when evaluating inputs and outputs of innovation, at the levels of costs, time-to-market and number of new products, ignoring the processes involved (Cordero, 1990).

The existing studies about the Portuguese reality (i.e.: COTEC, 2014; Innovation Union Scoreboard, 2014; Community Inquiry on Innovation, 2012) mostly provide macro and "meso-level" (intermediate) results, not specifying the type of innovation that companies produce at their micro level.

Despite those studies trying 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 on the "object", understood as a product (good or service), and on the "subject", understood as an organization (i.e. strategy and executed activities), as recipients of actions developed in innovation processes. I 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 level of companies, based on qualification criteria by areas of innovation. In that sense, it should also contribute to help companies to draw 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, we will present the theoretical framework, making reference to the main macro studies available to the market, reproducing their main outputs in relation to the innovation status quo, and identifying potential missing conclusions. Second, we include the criteria used for qualifying the different types of innovation developed by companies, as well as the generic results obtained by each one. Next, we describe the study's methodology, 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, we present the results, it then 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 country.

2. Statistical, Normative and Theoretical Framework

2.1 Existing Statistical Studies

a) 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 pillars for analysis: (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 innovative 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 a lot 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. This says nothing at the micro levels, and the results are of very little use to companies, in order to develop innovation strategies, as the study does not point out the specific areas of companies' weaknesses, in particular.

b) The "Innovation Union Scoreboard" (European Union, 2014) analyses the innovation competitiveness in European Union (EU) countries in a macro framework composed of 3 types 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 property; and, (iii) Outputs – innovative and economic effects.

This study provides a macro vision of the status quo 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. Like the Cotec study, the information does not provide clear clues to companies, in order to develop new innovation actions at the micro level.

c) 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-level 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. This leaves expectations for innovation very low, and leads to miss-representing results that may induce deviated perceptions of the status quo of innovation in companies.

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.

Despite the finer and more detailed picture in this study of the innovation status, it still presents results only at the meso-level, which are of little use to companies seeking detailed information that can be specifically used to develop innovation actions, at the product, processes, organization and market levels. Therefore, there is a need to go further in detail of the innovations produced by companies, if one desires to induce and help companies to innovate, mainly at the product (good or service) level.

2.2 Norms Applied to Innovation

Despite the importance of innovation and innovation management, for businesses in general, the world movement for standardization has taken a little too long in reacting to such necessity in this issue. Nonetheless, the last decade has brought with it a set of normative documents that support innovation management best practices, first at the level of some countries (Spain, Portugal, Brazil, Mexico, Germany and United Kingdom), and later at the level of international standardization organizations (CEN and ISO).

Despite all existing difficulties to overcome cultural and methodological barriers (Clausen and Elvestad, 2015), as a result of the EU diversity, 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".

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 those principles, the Oslo Manual (OECD, 2005), defines four types of innovation, for evaluation purposes: (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 (Fernandes and Martins, 2011): 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, induced by a new product (good or service), being those 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 adapted by Fernandes and Martins (2011), 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 criterion (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/Structured	R&D focused on fundamental and applied investigation, developing new knowledge – know the why (drones, medicine).
Targeted/Objective driven	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 the market – know how (compacts for offices – photocopy, print, fax and scan machine; multifunction packaging systems).
Serendipitous/Stochastic	Fundamental and applied investigation that creates new knowledge but that results from serendipitous and stochastic situations, being that the result is unexpected (discovery of penicillin, creation of velcro)
Evaluation area 5: Cultural change	
Newoel	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).
Beutel	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 use of experts in the evaluation exercise follows the practice in empirical opinion studies, even if using other methods like Delphy Technique (Adams et al., 2006)

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' evaluation, 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). The coding method used by the certification body is very definitive and specific in scope, providing a clear understanding of the innovation scope in which firms have achieve their certification and, therefore, the type of innovation that they produce at the product o processes level; (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 criterion. The evaluation was carried out in accordance with binary criterion (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 determination was validated by the certification code, and consequent description, provided by the certification body (IPAC). 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. An individualized and more contextual evidence of the produced innovation by each company was undertaken, in accordance to the theoretical line that signs that innovation is evolving into a more contextual approach (Ortt and van der Duin, 2008).

In 92.1% of the sample, the panel of experts reached a consensus. In 7.9% of all evaluations, equivalent to 13 cases, the result was reached by vote, all referring to the "final results of innovation" criterion.

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 are developing innovation activities around the products (goods and services) and only 5.5% focus their main innovation activity on their own 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% innovate in their goods and 68.3% in their services, as shown in table 2.

Table 2 Final result of the innovation

Good (Tangible)			**Service (Intangible)**			
			For consumers		For organizations	
Consumer	Professional	Integration	Service	Service with product	Service	Service with product
GC	GP	GI	SC	SCP	SO	SOP
14	15	14	5	1	46	60
8.5%	9.1%	8.5%	3.0%	0.6%	28.0%	36.6%
TOTAL: 26.6%			TOTAL: 68.3%			

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 (the consumers).

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.

Table 3 Final result 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 the results, 90.2% of the main innovations produced by companies 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. This preference for product innovation is confirmed by other empirical studies that point out in the same direction (Parisi, *Schiantarelli and Sembenelli*, 2006). The focalization on innovations of products is in accordance with what Gunday, *et al.* (2011) named as critical driver to the performance on innovating companies, in other words, the product innovation functions as the fulcrum to the development of other innovations at the process, organization activities and marketing levels.

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

Innovations have always a recipient as target (who accepts it), and this is always a direct beneficiary of value creation and value generation. The final value, resulting from innovation, is normally designated as "customer value". This value is the result of the preference and perceptional evaluation made by the customer, in relation to the attributes, attributes' performance, and other outcomes resulting from use situations (Woodruff, 1997, p.142). Many customer value concepts include the idea of *trade-off* between quality and price (benefits versus sacrifice). Business customers (B2B) are more concerned with the *trade-off* between functionalities, services and benefits of business relationships and the monetary and non-monetary sacrifices related to specific objectives (Lapierre, 2000; Ulaga, 2003). The experts in the panel kept all that in mind when evaluation this part of the study.

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.

The 2.4% of companies that seem to develop “breakthrough innovation” are, theoretically, those which generate more added value to products. According to Verspagen (1995), the “high-tech” companies, in the particular case of this study those in the biology and pharmaceutical industries, are those that benefit more from R&D activities and, consequently, generate more value.

One company, 0.6% of the sample, develops “adding-value innovation”. This belongs to an industrial activity considered as “low-tech”, still focusing on market niches with specific needs and wants that value its products. The fact that no company focus on “turning-around innovation” indicates that all of them try to bet on RDI strategies that generate more added value. Still according to Verspagem (*op. cit.*), higher ratios resulting from obtained results (return on investment, sales volume) versus the cost of R&D are part of high-tech companies, what seems not to be the case in all extension of this study.

4.3 Technological innovation process

The importance of measuring the technological innovation comes from the need to distinguish between technical innovation and administration innovation, referring the first to technology and the last to social structure (Evans, 1966). Technical innovation includes products, processes and technology used to produce products (goods or services), while administrative innovation is concerned with organizational structure, administrative processes and human resources (Gopalakrishnan and Damanpour, 1997). 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 and delivering new products to the world. Only one company, or 0,6% of the sample, recognizably produces innovation based on new product design, to satisfy specific consumer needs. The first conclusion denotes an incremental innovation style and the other two, mainly the second, targets a radical innovation style (Ettlie, Bridges and O’Keefe, 1984). The last two conclusions refer to companies developing products targeting specific needs and wants of consumers.

Table 5 Technological innovation process

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% out of this sample represents two companies, both of which have not any activities related to technological innovation in their IDI certification, excluding themselves of the real force (technology) behind the perpetual increment of the quality of life (Grossman and Helpman, 1994, p.24).

4.4 Cultural innovation process

The existing literature is very scarce on the subject of cultural innovation implying the use of products (goods or services), which will lead to a change in behavior of some specific consumer groups. Yet, we may find some authors who try to find the factors that may explain the variations in the adoption of innovation, more at the organizational level, known as *varience sociologists* (Gopalakrishnan and Damanpour, *op. cit*). In the same field, some authors try to identify the innovation processes in some cultural industries, acting in some market niches, where they produce a product with a cultural dimension (Islam, Toraldo and Mercúrio, 2015). Nevertheless, one of the two dimensions of novelty (newness) in innovative products, related to the effect in their market orientation, is the consumer perspective (the second is the company perspective), which is related to the extension of the innovation and how this is compatible with the experiences and patterns of consumption in consumers. This novelty dimension reflects the extension of the change of behavior required by consumers to adopt a new product (Lawton and Parasuraman, 1980).

The study that served as the based for this article set on a model that characterizes the causes and effects that will lead to the adoption of behavior changes by consumers, implying the usage of products, in which a product, even not being the main cause of that behavior change, is part of that process of cultural innovation (Fernandes, 2014).

This type of innovation is the one that, with the exception of one company, appears to be not mainly targeted by the companies of the sample, as seen in the results in table 6.

Table 6 Cultural innovation process

Neowel	Moral	Gnosil	Beutel
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. Normally, this type of cultural innovation (Beutel) is the result of a *market-driven* strategy, that is set on the modification of products (Bennet and Cooper, 1981), in order to satisfy consumers and reduce the risk associated with the innovation process, leading the creation of products less radical in the long term, according to some authors (Hayes and Abernathy, 1980), or of products, less compatible with consumers' needs, that facilitate the adoption and acceptance of the innovation in a much faster manner, according to other authors (Cooper, 1979, Cooper and Kleinschmidt, 1987, Zeithmal, 1981). In relation to the prior value innovation analysis, this is the same company that develops "added-value innovation", which can explain its positioning in the cultural innovation realm.

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 us to establish any correlation between the types of innovation and what is forcing them to happen, as we can observe 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 modeling	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 to other organizations with the incorporation of goods (SOP) and the remaining 15.7% offer services to organizations (SO) not leaving any technology for their use. Even this study has not any connection with an international benchmarking RDI study for the information technologies sector (R&D+I International Benchmarking, 2013), this distribution is much in line with the last, where the percentage of firms that provide only services é below the percentage of those that leave some kind of good with the client, in this case software.

All, without exception, practice innovation focused on the functions of their services (PF), on the improvement (I) of their value curve, and via technological processes of adoption/adaption (A) of third party technology.

5. Conclusion

This study aimed at introducing a new understanding of innovation at the micro level, in companies, pointing out the outputs of their main innovation activities, and qualifying those results.

The results of innovation produced by firms, as a result of their own capability and capacity to innovate, are determined by many factors related with the internal organization and the market contexts (Rothwell, *et al.*, 1974), but the development and evolution stage of firms is a critical aspect for innovation (Albernathy and Utterback, 1978). The same seems to be true when the analysis covers one or more regions, where the more developed regions are more capable of generating innovations (Bilbao-Osorio and Rodriguez-Pose, 2004). Those concepts could not be validated by the study, as the information gathered was irrelevant in that sense. Nevertheless, the study seems to show that the capability and capacity of innovation is not related to some specific industries or outputs, as companies come from 38 different specific fields.

In order to reach higher stages of organizational development in the field of innovation, the adoption of standards and other norms for innovation management purposes can become fundamental tools (Pellicer, *et al.*, 2008). This could not be proved by the study, since it is not done any comparison between firms following standards and norms' prescriptions and others not doing so. However, even considering that the observation is only focusing on companies following some kind of standard prescription, the results don't indicate any special or specific benefits for such choice.

Despite indications that R&D creates more innovation in the private sector (firms) than in others (public or educational) (Bilbao-Osorio and Rodriguez-Pose, *op. cit.*), the study could not indicate that the result of developed RDI in certified firms is connected to the holding activity sector.

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. Only 3% of the sample fits into these two types of value innovation, which indicates that all other companies may ignore this factor. It seems to indicate that RDI efforts made by RDI certified companies aren't inducing high value creation (economic) in the market, not delivering the may be expected high economical impact to 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 fits in this type of innovation, thus confirming the last conclusion. In fact, some may draw the conclusion that most firms in the sample are not taking economical advantage of their efforts to obtain RDI certification.

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 of product sales. The two sub-types of cultural innovation that most contribute to this are "Newel" and "Moral". One can verify that 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. It seems that all companied, except one, have not assimilated the concept of cultural innovation, and, consequently, are missing one of the major sources of revenue linked to innovation.

These findings seem to be not in accordance or supporting the findings of the three studies that provided the initial statistical data analyzed in this study. In fact, the Innovation Barometer (Cotec, 2014), the Innovation Union Scoreboard (European Union, 2014) and the Community Inquiry on Innovation (CIS, 2012) seem all to have a very much more optimistic view of the level of innovation produced by companies in Portugal that what the focus group could come up in this study. Despite the fact that the methodologies used by the three surveys and by the focus group were completely apart, the former seem to point out that the innovation activities in Portuguese firms are still of some positive or relevant contribution to the economy, while the findings of this study seem to point out how weak the innovation of Portuguese firms seems to be and the low value that is created and induced into the economy.

It seems we should also deserve some consideration to the meaning of all this information to firms. The three official surveys have a wide scope in the used criteria, while this study focused on particular aspects (inputs, outputs, innovation processes) of individual companies. Theoretically, this last kind of information is of higher value to companies than a more holistic view of the economy in general. While an holistic type of information may b helpful to understand the context where firms are positioned and how that can influence their future innovation strategies, a more singular or individual information can be used to determine how well firms innovate and what needs to be done in order to improve the value of their innovation. This is of particular importance if firms want to determine the value created or generated by their innovation, either at a quantitative or qualitative dimension, in order to make choices regarding market and organizational strategies.

To conclude, this study seems to bring a new need in surveying the innovation and its effects: a further segmentation of the criteria to the very specific level of the value of the innovation outputs and outcomes.

6. Study limitations and future research

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 in the future.

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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AUTHOR BIOGRAPHIES

Manuel Teles Fernandes is a professional consultant at Gestão Total (Portugal), since 1994. He has a long experience, since he was twenty years old, in entrepreneurship and management. Manuel received his MBA degree and a BM degree from EU (Lisbon). He is a qualified Trainer in Value Management (TVM) and Professional in value Management (PVM). He has dedicated the last twenty years to research, in the fields of value management and innovation. He has design and developed an application to assess the level of value and innovation creation in firms. He has and is still participating in different technical commissions for standardization, national and international.

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TRIZ and MACBETH in Chemical Process Engineering

Isabel Maria João[1,2]* and João Miguel Silva[1,3]

[1] Chemical Engineering Department, ISEL – Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Portugal
[2] CEG-IST, Instituto Superior Técnico, Universidade de Lisboa, Portugal
[3] CATHPRO-CQE, Instituto Superior Técnico, Universidade de Lisboa, Portugal

*Corresponding author, E-mail: ijoao@deq.isel.ipl.pt
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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, is the 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 combined 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: Chemical process engineering, Creativity, Innovative process, M-MACBETH, Theory of inventive problem-solving (TRIZ).

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 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 the 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 lacks the capability to 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 products 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 meaning that almost each anthropogenic system has its predecessor, also created by people. However, TRIZ is so powerful that can be applied at studying both anthropogenic, and not anthropogenic systems as well as social systems as the laws of overcoming of contradictions at their development are identical. Behind TRIZ philosophy some real world regularity stands functioning in anthropogenic as well as in non-anthropogenic world.

TRIZ has been used in industrial practice since its development in the 50s of the last century. There are several books that introduce the basics of TRIZ tools from a practitioners perspective (e.g. Terninko et al., 1998, Savransky, 2000, Hipple, 2012).

It is well known that processing industries commonly use TRIZ to solve their design and operational problems. However, the chemical and process engineering journals have seldom published papers dealing with the methods supporting engineering creativity (Kraslawsky et al., 2015). 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 a framework for combining TRIZ and MACBETH in systematic innovation. Section 5 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, section 6 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 analyzing the vast number of patents Altshuller detected that the best engineering solutions were obtained by removal of trade-offs between the objectives. According to TRIZ, a problem is solved if a technical contradiction is recognized and eliminated. The simplified TRIZ approach for creative problem solving is described in Fig. 1.

The application of the basic principles is made as shown in Fig. 1. This diagram is widely used in TRIZ literature and represents a simplified schema of a generic problem solving reflecting the idea that inventiveness can be easily understood and developed in a systematic way. The skill to solve problems is essential in any innovation process but the standard procedure to deal with them is mainly to use a trial and

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error procedure despite the existence of other approaches, namely TRIZ that support the idea that inventiveness can be easily understood and systematically developed. Many problem solvers try going directly from problem to solution through trial and error. Looking at an analogous general problem and its associated general solution is a more efficient approach.

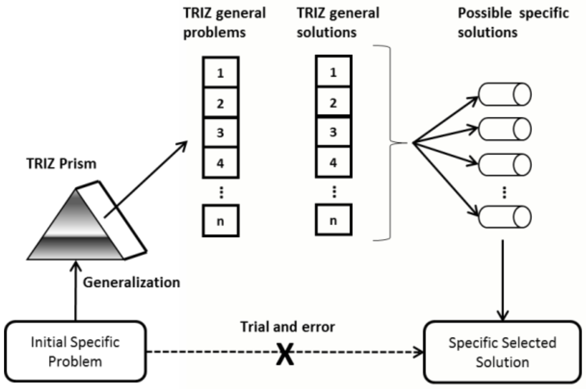

Fig. 1 TRIZ approach to problem solving.

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 analysis is a powerful method of looking at the problem with new eyes. Once the reader understood this perspective the contradiction table becomes an important tool for generating several solution concepts. The contradiction matrix and the 40 inventive principles offer clues to the solution of the problems (Terninko et al., 1998). 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 these 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 Fig. 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	

Fig. 2 Section of a classic contradiction matrix (adapted from Terninko et al., 1998).

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. Spreafico and Russo (2016) analysed more than two hundred papers about TRIZ applications covering a large spectrum of industrial sectors with a high number of applications in mechanical engineering, automotive, electronics, energy and electrical, home appliances, and with less expression sectors like biomedical, chemical or textile just to name a few. 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. Despite significant achievements and several success stories and technological developments occurred in quite a lot of industries a lot of work needs to be done to generalize the use of TRIZ in chemical engineering (Ferrer et al., 2009, Rahim et al., 2015). However, the applications in chemical engineering are growing as displayed by the statistics of application of TRIZ presented by Abramov et al. (2015) concerning the chemical and chemical engineering industries. 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). 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).

A systematic and reliable methodology is needed for chemical engineers to bring innovation for their products and processes and TRIZ will be very helpful allowing people to remove the psychological inertia and expand their thinking (Bechermann, 2014).

The research work regarding the application of TRIZ to chemical and process engineering problems is recently proliferating in the literature (e.g. Pokhrel et al., 2015, Rahim et al., 2015).

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/solutions and to weight the criteria used to evaluate the options/solutions. The approach, based on the additive value model, aims to support interactive learning about evaluation problems and the elaboration of recommendations to prioritize and select options/solutions in individual or group decision-making processes. Several applications of MACBETH approach cover areas like energy with project prioritization and selection (Bana e Costa *et al.* 2008), or Technology choice (Burton and Hubacek 2007, Montignac *et al.* 2009), areas like environment with landscape management (Soguel *et al*., 2008), risk management (Bana e Costa *et al.* 2008, Dall'Osso *et al.* 2009, Joerin *et al.* 2010) or water resource management (Bana e Costa *et al* 2004). Also in the public sector, there are many applications of MACBETH like in project prioritization and resource allocation (Mateus *et al.* 2008, Oliveira and Lourenço, 2002) or in engineering education for sustainability (João and

Quadrado, 2014) just to mention some of the many examples of the literature. MACBETH is a good approach to use in systematic innovation mainly to select a specific solution among different specific concepts because the approach is useful in any problem related with prioritization and selection of options.

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

$$v(A) = \sum_{i=1}^{n} w_i v_i(A)$$

$$\text{with} \quad \sum_{i=1}^{n} w_i = 1, \; w_i > 0 \quad \begin{cases} v_i(good) = 100 \\ v_i(neutral) = 0 \end{cases} \qquad (1)$$

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. Eq. (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 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 Fig. 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.

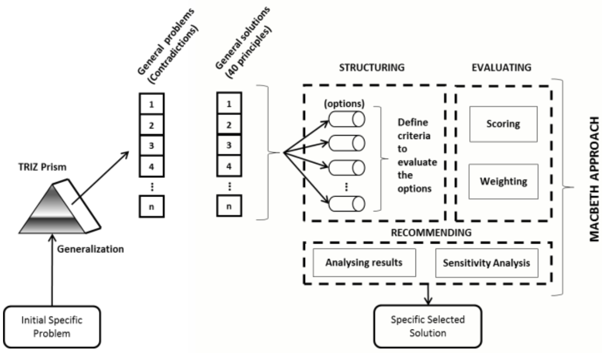

Fig. 3 Framework for combining TRIZ and MACBETH in systematic innovation.

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.

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.

Understanding how to structure the problem as a contradiction is an essential step in the analysis.

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). In this work, we used the table of conflicts between the 39 design parameters and the 40 generic principles used in contradiction analysis as described in Terninko *et al*. (1998).

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, extracted 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.

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 Fig. 4.

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 analysis of the inventive principles of Fig. 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.

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.

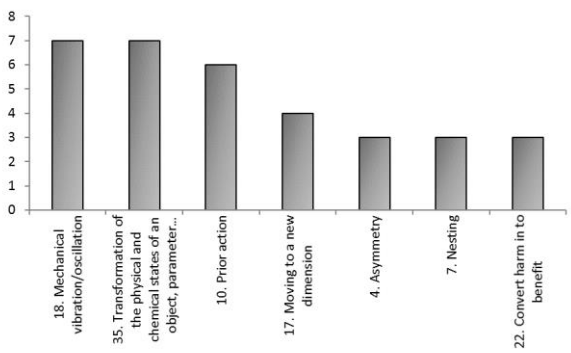

Fig. 4 The frequency of inventive principles recommendations.

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 coefficient, 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 Fig. 5.

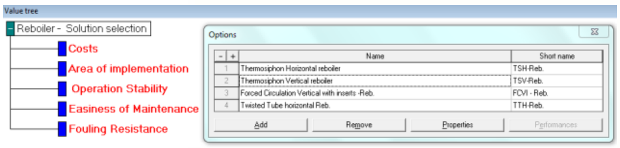

Fig. 5 Value tree and reboiler options.

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. From the completed consistent matrix of judgements MACBETH created a numerical scale (see the matrix of judgements in Fig. 6)

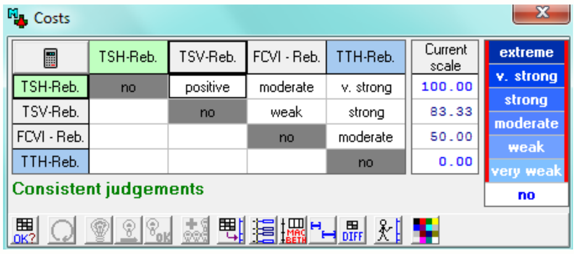

Fig. 6 Matrix of judgements and MACBETH value scale for costs.

The process was then repeated to create value scales for the remaining criteria (all of the scores can be found in Fig. 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 Fig. 7. A table with the partial and global scores was then created allowing to see the final results of the model (see Fig. 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.

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 Fig. 8.

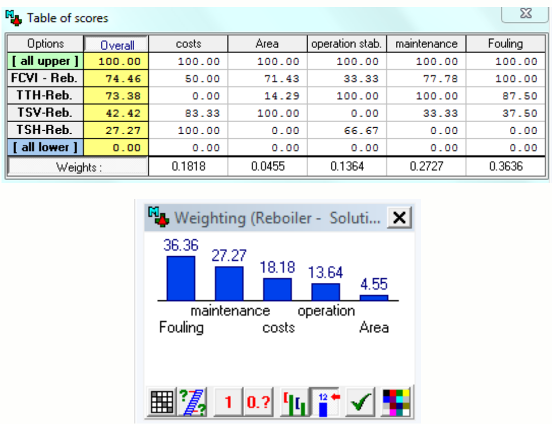
Table of scores

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

Fig. 7 Table of scores and histogram of criteria weights.

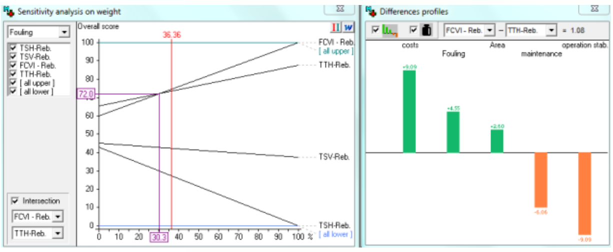

Fig. 8 Sensitivity analysis on weight of criterion fouling and difference profiles of TTH-Reb and FCVI-Reb.

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 favor 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 successfully assist chemical engineers in solving problems 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 is related with distillation which is very important process unit in chemical process industry because most chemical processes require separation of chemical mixtures, and distillation is widely used. Distillation is also a major user of energy in the process industry, reason why it is very important to reduce the operational problems that can reduce the energy efficiency of a distillation process. The focus of the case study was on the type of reboiler because one of the things that is crucial for a good operation is the selection of the type of reboiler due to problems of fouling that can occur and are responsible for the reduction of heat transfer rates increasing steam demands.

The case study illustrates the effectiveness of MACBETH approach in order to support TRIZ methodology. TRIZ was essential to achieve the specific solutions with simplicity but displaying the distinctive way of thinking in TRIZ methodology making people think beyond their own experience reaching across disciplines to solve problems.

The MACBETH approach can be very helpful in the subsequent steps in order to select the specific solution. To make the selection it is necessary to identify the evaluation criteria used to appraise the specific solutions and determine the criteria weights and aggregation procedures in order to score the solutions. The use of MACBETH to perform the selection can be seen as an advantage due to the simplicity of the pairwise comparison questioning mode to compare the solutions. The multicriteria decision support software M-MACBETH also allows sensitivity and robustness analysis to be easily performed. 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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AUTHOR BIOGRAPHIES

Isabel Maria João is a Professor at the Polytechnic Institute of Lisbon, School of Engineering (ISEL), at the Chemical Engineering Department since 2000. She has 9 years of Industrial experience in a Plastic industry where she was the chief of the laboratory of I&D and quality control and improvement. Isabel received her PhD degree in Industrial Engineering and Management from IST/UTL and a Master degree in Management and Quality of Materials from FCT/UNL and she also holds a graduation in Chemical Engineering from IST/UTL. She is a researcher at the Centre for Management Studies of IST (CEG-IST) and her areas of interest include Innovative Product and Process Design, Quality Management and Decision Analysis and Information Systems.

João Miguel Silva is a Coordinator Professor at the Polytechnic Institute of Lisbon, School of Engineering (ISEL) and the Head of the Chemical Engineering Department since 2010. He is member of the research center CQE – Centro de Química Estrutural in the Heterogeneous Catalysis and Catalytic Processes (CATHPRO) group at IST. João received his PhD degree in Chemical Engineering in 1994 from IST/UTL and is co-author of over 50 articles in peer-review journals. His areas of interest include Innovative Product and Process Design, Process Simulation and Heterogeneous Catalysis, specifically with zeolites.

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From Value to Technological and Cultural Innovations

Manuel Teles Fernandes
CAAM, Corporate Academy for Advanced Management (by Gestão Total).
mtf@gestaototal.com
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Abstract

The aim of this theoretical paper is to introduce a holistic view of innovation and its interconnections with other phenomena, such as value, value creation, and processes needed to create new value. Consumers use the concept of value, as a function of benefits versus sacrifices, when making their buying decisions. Product value creation and product value changes are consequences of some type of applied innovation. Innovations might have a technical dimension, when resulting from some type of technological advancement, or a cultural dimension, when it results as a behavior change of consumers, induced by the product. To understand the phenomenon, for scholars' benefit or firms' applications, this paper proposes a theoretical path to understand how value is created or modified, always through some innovation process, and how innovation tools can be applied, and when are of most applicability, in order to develop a culture of systematic innovation in firms. Some empirical observations using the presented concepts and some experimental applications in firms have, so far, provided indications for the validity and robustness of the argument.

Keywords: Value creation, technological innovation process, cultural innovation process, systematic innovation.

1. Introduction

The concept of "value" has intrigued many and has created research in many disciplines, from economy to psychology, passing through philosophy, anthropology, sociology, and many other disciplines. Value is always related to something that can take a tangible or intangible form, normally meaning that it is connected to human utilization. This paper is particularly concerned with to these phenomena.

It is commonly accepted that product value equals customer value, and that the individual needs of the customer define the value of the product and, therefore, the value creation of a product is dependent on the product's participation in the customer's own value creation. According to Cook (1997) product value can be placed at the relatively objective "use value" or "design value" or at a more subjective "customer value". "Design value" is expressed under market conditions by the "exchange value", while "customer value" is decisive on how the demand for potential customers is divided on competing products. According to Ford, et al. (2002) a customer can gain value in two ways: The value of the offering and the value of the relationship. These aspects of value and other related phenomena will be explored further in this paper.

There is also an incessant urge for the creation, adoption, and diffusion of innovation in our society, as referred by Pol and Ville (2009). Innovation can be classified in different sorts, like business, social and artistic for example (ibid.). The business innovation itself can be classified in other sub-levels, like "technological innovations (new or improved products or processes) or organizational innovation (changes to the firm's strategies, structures and routines)" (ibid., p.881), and it can have direct or indirect impact in other areas of our structured society, namely in the cultural and economical arenas.

The direct importance of innovation for firms, but indirect for the economy, has been widely studied by scholars, namely Cainelli, Evangelista, and Savona (2004), Chaney and Devinney (1992), Ferguson and Hlavinka (2006), Geroski and Machin (1992), King and Tucci (2002), Marvel and Lumpkin (2007), Matthyssens, Vandenbempt, and Berghman (2006), Mishra and Bhabra (2001), and Nayyar (1995), most concluding it reflects on greater profit margins and larger market shares as a direct result of increased customer loyalty and limited competitive entry into markets. Innovation positively affects customer choice and preference for new products and competitive market dynamics, as identified by King and Tucci (*op. cit.*), and Marvel and Lumpkin (*op. cit.*), as it also aids existing products through updates that prolong product's lifecycles and retard their decline, as concluded by Berenson and Mohr-Jackson (1994). These issues will be addressed later in this paper, in connection to product and consumer value and to innovation processes.

2. Value

2.1 Literature review

In his journey in demand for the definition of "good", in a vast philosophical sense, Hartman (1967) came to the deduction that a thing is good if it has all the properties it is supposed to have, or in other words, a thing is good if it fulfills its definition. The goodness in a thing is the value of that same thing, and therefore the measure of value of a thing is the set of properties that defines the thing. That has led him to the development of his value theory, or Axiology, as the German philosopher Edmund Husserl coined it, in 1903. Accordingly to Hartman (*op.cit*), when we value the properties of a thing, as part of what the thing needs to have to be good, or have value, we are dealing with the "intrinsic value" of a thing. When what is valued is not the thing itself but its belonging to a certain class is called "extrinsic value". A thing can also have "systemic value", but it relates only to the perfection or non-existence of a thing, as there are no degrees of valuation. I will come back to the intrinsic value and the extrinsic value concepts later, when discussing the final view of what defines the value of a product.

Since primordial times in the human race, Man started to see "value" in things, even if they were taken from nature in its natural form, transformed or not and used by Man. We may consider that it was the understanding of value in things that drove Man to innovate by creating objects for his own utilization, such the stone hammer and the arrow. These primary innovations created the basis for the (human) culture expansion about 50,000 years ago, that we may find proof in archeological terms (Shenan 2001). Basically, objects used as tools had a use value, therefore objective and tangible. However, primitive men had also the understanding of subjective and intangible value, namely religious and cultural, like primitive singing and decorative items such as collars of shelves.

The intrinsic value, and even the extrinsic value of things generated the opportunity for exchange, among humans. Aristotle (384-322 B.C.) was the first to differentiate between a use value and an exchange value of goods. (Politics, Book I.). Based on the utility concept of Hobbes (1588-1679) and using the water and diamonds example, Smith (1776) formulated the "paradox of value" concept, stating that the element that has higher value in use has low or no value in exchange and, on the contrary, the element with higher value in exchange has low or no value in use. Departing from the premise that value was related to labor, Smith (*op.cit.*) named "labor commanded value" or, in other words, how much labor-time is needed to produce any good, and to whom value had two different meanings, one expressing the utility of some particular object, "value in use" and the other, the power that the possession of an object conveys to purchase other goods, "value in exchange". For Ricardo (1821) value or "innate worth" was the amount of labor needed to produce the commodity and its exchangeable value comes from two different sources: scarcity and quantity of labor required to obtain it. In fact, exchange was at the heart of the value concept in classical economy.

In this line of thought, Keen (2001) claimed that value referred to the innate worth of a commodity, which determines the normal (equilibrium) ratio at which two commodities exchange. Marx (1887) made a clear distinction between "value in use", use-value or what a product or service provides to the user, "value", the socially-necessary labor time embodied in it, and "exchange value", how much labor-time the sale of the commodity can claim. In classical (and marxist) economics, value of an object or condition is considered as the amount of discomfort or "labor" saved through their consumption or use.

George (1908) mentioned that value of a thing in any time and place is the largest amount of exertion that anyone will render in exchange for it; or to make the estimate from the other side, that it is the smallest amount of exertion for which anyone will part with it in exchange. He also claims that many things having value do not originate in labor. Mises (1934) added to this that value, meaning exchange-value, is always the result of subjective value judgments, or still, according to Burke (2005) value is intrinsically related to the worth derived by the consumer. The last leads us to the concept of "real value" or "actual value", which is the measure of worth based purely on the utility derived from the consumption or utilization of a product or service, allowing these to be measured on outcomes instead of demand or supply theories.

Most of the classical and neoclassical economy concepts consider that "only economic goods have value to us, while goods subject to the quantitative relation- ship responsible for non-economic character cannot attain value at all" as Menger (1950) has claimed. In neoclassical economics, the value of a product or service is mostly seen as the "utility" that it has for the user or purchaser. This utility, or value in use, can be: (i) "intrinsic utility", or objective value in use, defined by the characteristic inherent to the object and (ii) "extrinsic utility", or subjective value in use, defined by the importance given to an object by someone, aiming at some benefit by its possession and utilization. It is the extrinsic utility that determines the price or monetary value of exchange.

Both classical and neoclassical economists admit that the value of exchange of a product (good) equals its total economical utility, or, the power to purchase other products (goods). In economic terms, value is defined by the monetary sacrifice that people are willing to make to acquire a product or service (Butz & Goodstein, 1996; Gale, 1994; Zeithaml, 1988). The emphasis is placed on the point of exchange, with money being the fundamental index of value (Boztepe, 2007).

It is normally understood in existing literature that "user" is someone who utilizes some equipment or product, "consumer" is someone who consumes some product (good or service), "client" is someone who has a commercial or economic relation with a supplier of a product or service and "customer" is someone who, being also a client, has some kind of utilization or consumption relation with the product (good or service). A client of one can be, at the same time, a supplier of other. A supplier, as an element in the beginning or middle of the value chain, is normally understood as creating or adding value and a consumer, as the last element of the value chain, as ceasing or destroying value. A client or customer can be a user. Consumers are also users, but they cease the value creation chain, potentially destroying the existing value. A customer, being also a consumer, can be seen as destroying value as well (Lay, 1995; Christopher, 1996; Ramírez, 1999). From the understanding that user, consumers, clients, and customers are all, beyond others, market agents, we may try to uncover how value is seen and felt differently by them.

There is still no agreement among most theories that value is something assigned by the user, being independent of the product's physical qualities, or embedded in the object and recognized by the user (Boztepe, *op. cit.*). This leads to the view of the philosophical branch concerned with the theory of value, known as axiology, which posits a bipolar distinction between objectivism and subjectivism (Frondizi, 1971). Positioning value as inherent in an object, prior to any subject interaction or evaluation, is an objectivist view. On other hand, if it is the user understanding that prevails, including many factors under consideration, it can be seen as a subjectivist view. This dichotomy between objectivism and subjectivism views leads to a discussion between tangible or intangible, use or emotion, and utility or esteem, which I will address later.

The meaning of value in marketing literature has not yet achieved consensus between marketing strategy and consumer behavior, and what marketing strategists mean by "customer value" does not match the meaning of "consumer values" in consumer behavior research (Peter and Olson, 1990; Sheth, Newman and Gross, 1991; Vinson, Scott and Lamont, 1977; Wilkie, 1990). In general terms, customer value refers to buyer's evaluation of product purchase and consumer values refer to people's valuation on the consumption or possession of products.

One view is that customers buy based on value and they determine the value of any product or service by the relation "quality/price" (Gale, *op.cit.*). Ranging the two variables from low to high, Gale identifies four types of value: (i) commodity (low price and low quality) – products with no differentiation and buying decision based on price; (ii) the worst value for the customer (high price and low quality) – products that will be disregard as soon as a better alternative is available; (iii) unique value (high price and high quality) – top of the scale products with no substitutes or opposition; and (iv) Best value for the customer (low price and high quality) – value leaders when aligned with customer preferences.

In this search for value for customers, Christopher (*op. cit.*), defines that customer value is created when the "perception of benefits" received from the transaction exceed the "cost of ownership". This line of thought follows a similar one from Day (1990). For Christopher (*op. cit.*) the cost of ownership represents all costs including price of acquisition and all others like inventory, maintenance, and transportation. This equation presupposes that value is positive when the nominator (perception of benefits) is greater than the denominator (cost of ownership) and should be measured against competitive offers. This concept includes subjectivism in itself, as perceptions of benefits can be related to intangibilities.

As value becomes more understood as a perception function, starting from an equation that defines "customer perceived value" as "perceived benefits/ perceived sacrifice" (Ravald and Gronroos, 1996), Gronoos, (1997) proposes two more equations: (i) customer perceived value = episode benefits + relationship benefits / episode sacrifices + relationships sacrifices; which derived to (ii) customer perceived value = core solution + additional services / price + relationship cost.

Another way to view the issue, supported by Anderson, Narus and Kumar (2007), is that "*customer perceived value = customer benefits – customer sacrifices*", arguing that this is easier to be understood by individuals and businesses. We should note that perceived value differs from "desired value", where the last represents what the customer wants to happen and the first represents what the customer has obtained or that it has happened. Desired value has two sides: value in use and possession value (Flint, Woodruff and Gardial, 1997).

The customer value can also be affected by other factors, like: the view of relationship; the view of customer; customer needs; and customer benefits (Khalifa, 2004). The first two and last two factors are closely related to each other. The relationship develops from a simple transaction towards an interaction between parties. The customer view ranges between being a consumer and a person with individual interests. Customer needs range from utilitarian to psychic needs while benefits vary from tangible to intangible (*ibid.*) The accumulation of value can take distinctive forms, ranging from low to high: "functionality", meaning a product or service providing basic features; "solution", adding to the basic offer some supporting functions that customers use to attend for themselves; "experience", adding intangible features to the tangible offering; and "meaning", providing the experience that supports the customer's self actualization needs. Boyd and Levy (1963) clarify that in terms of the use behavior of consumers, "Whatever reasons people have for buying a particular product are rooted in how they use that product, and how well it serves the use to which they put it" (p. 130), while when relating to the interrelations between the products that comprise a consumption system "The use behavior for a particular product is bound to be affected not only by ... the task to be performed with the use of that product but also by the related products and their use behaviors that make up the total consumption system" (*ibid.*)

According to Clawson and Vinson (1978) in order to investigate consumer's product valuation it is necessary to integrate cultural values, personal values, consumption values, and product benefits. Cultural values are related to how cultural, social and familial environments affect the formation and development of individual beliefs, also called "society core values" (Engel, Blackwell and Miniard, 1990), which are implanted into individuals naturally through socialization and education. Personal values are the individuals' beliefs about what are desirable for themselves, therefore self-centered, and deriving from, and modified through, personal, social, and cultural learning (Clawson and Vinson, *op.cit.*). Rokeach (1973) divides "human values" into two types: terminal (or end-state), beliefs about goals that people strive for, like self-fulfillment and enjoyment in life, and instrumental (or means), beliefs about desirable ways to attain those terminal values, like owning a luxury car or going to an entertainment. Personal values correspond to terminal values, while instrumental values are comparable to values of desirable "activities". According to Sheth, Newman and Gross (*op.cit.*), people achieve personal values, or goals, through actions or activities, such as social interaction, economic exchange, possession, and consumption. Consumption values refer to subjective beliefs about desirable manners to attain personal values, therefore being instrumental in nature. Product benefits refer to what customers benefit from buying, using or consuming a product (Hooley and Saunders, 1993). In the customers' perspective, product benefits are not the same as product attributes (Day, *op. cit.*; Peter and Olson, *op. cit.*). In a competitive market, products have many other attributes, such as features, durability, quality, style, symbolism, and related services, in addition to the basic provided benefits.

One of the many ways to understand users' needs, as consumers, is studying their specific functional and emotional needs and, consequently, transforming those into product attributes or functions (Fernandes, 2011, 2015). Value Analysis (VA) contributes to that understanding through a process of functional analysis (FA) and function costing (Miles, 1972), determining the relation between the satisfaction of needs and resources utilized, being this relation called "value" (European Norm EN 12973:2000). This concept of value was initially mostly based on the satisfaction of the user's needs and wants, but it has been developing into the concept that value also counts to all other stakeholders in the same manner (Value Management Handbook 1995). Considering all stakeholders with some kind of interest in a product and its life cycle opens an opportunity to determine some of those stakeholders that will be affected positively (positive value) and others that may be impacted negatively (negative value) by the value subject. In the same fashion, different stakeholders may take advantages and benefits, from some attributes or functions of the product and its life cycle, in use (tangible/utility value) or emotional terms (intangible/esteem value).

In nature, the main elements, in their natural form of energy or matter, are not concerned at all with the value of things, and nature is not affected by any transformations of energy into matter and vice versa, as the sum of the total existing energy and mater remains constant. However, living organisms and living beings, when faced with making a decision related to their survival condition, seem to have some kind of value consideration, as they appear to know when attack their objective or run away from danger. We may find proof that some forms of life in a higher rational stage are able to understand the value of things, as they use them for different kinds of activities and even exchange them for some kind of favor or benefit (Biro, 2003).

Therefore, value can be seen as the absolute criteria used in any decision making process. This applies to any "objective output" of any action taken by individuals or collective groups of people. Therefore, any human activity is potentially producing, positively or negatively, some kind of value. This leads to the definition of different value outputs, like: (i) value creation – first time process transformation of an input into a certain output, which is accepted by people for use or consumption (i.e.: first microwave oven, first television set, first x-ray machine); (ii) value generation – repetition of the value creation process, achieving the same output (i.e.: industrial production of any product); (iii) added value – augmented value resulting from the aggregation of some additional value to existing value (i.e.: aggregation of cultural value to existing use value, like applying a brand name to an existing product); (iv) value improvement – increment of existing ratio between use value and economic value of a product; (v) value accumulation – retention of produced value for future utilization, in any form of product, idea or contract, (i.e.: stock of products, patents or obligations); (vi) value consumption – utilization of existing accumulated value through consumption to maintain a certain status quo (i.e.: consumption of combustion material to generate electricity for any purpose); and, (vii) value destruction – elimination of existing accumulated value through purposed or un-purposed action or event, by people or by nature.

2.2 Value model concept

Coming as well from existing literature, Jensen (2005) identified four types of value (in the singular) related to products: (i) economic value – value as exchange; (ii) use value – value as utility; (iii) cultural value – value as meaning and sign; and (iv) perception value – value as experience. To illustrate these four types of value, we may use the example of a pencil, as in the Figure 1.

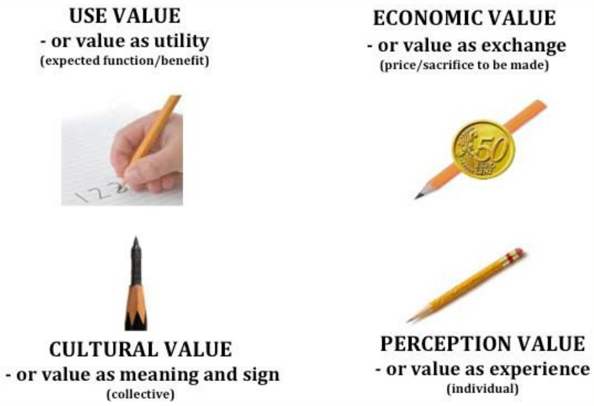

Fig. 1 Value in a pencil.

Any simple pencil has, as its main function, the purpose of "leaving a marc on a surface" (that is what we call writing). This function is of use or utility to any user, therefore we might say that a pencil has "use value", or value as utility.

To take benefit from that function, "leaving a marc on a surface", users are prepared to give some sacrifice away in order to acquire any pencil, normally expressing that sacrifice in monetary terms, therefore, that pencil has "economic value" or value as exchange.

Some brand names, limited editions or artistic versions might add extra value to some pencils, at an emotional dimension. This esteem value exists in the collective cultural realm, being understood as "cultural value", or value as meaning and sign, intangible by nature.

An old or special pencil or some special add-on, given to us by someone close or acquired at a special moment, may have a tremendous emotional significance to one as an individual. This esteem value only exists at the individual level, and it is understood as "perception value", or value as experience, also intangible by nature. Due to the difficulty of making one's "perception value" significant to others, due to its individual nature, the potential economic value of a thing, related to the perception value that it may have to someone, may be inexistent to others, except at the eyes of the beholder.

It is very clear that use value, cultural value, and perception value, either individually or combined, are what constitutes the benefits that a user or consumer expects or needs to obtain from a product. The economic value works to consumers, when purchasers as well, as the sacrifice that has to be given away in other to obtain the benefit, or the other three values.

This indicates that, at a buying situation, consumers, when buyers, will make their decision about buying or not a product based upon the benefits that they may obtain from the product, expressed as use value, cultural value and perception value, against the sacrifices that they need to make, expressed as economic value.

Despite the fact that there is a high difficulty of expressing the economic value for the part of the product that might contain cultural value or perception value, some how buyers take seem to take all those factor in consideration, in a very individual fashion. At that point, the value of any product becomes "relative" to each individual buyer, and the willingness for making the needed sacrifice to acquire the product varies very much among individuals, due to many reasons, which are related to the economic capacity of the buyer and to the weight of the necessity of the product, the meaning and sign that it may represent, and the relation to previous experience with same or similar products in the past to the same buyer. The benefits are in the numerator and the sacrifice in the denominator of an equation that buyers calculate mentally, even without realizing it. Any time that the denominator seems to be greater, or even equal, than the numerator, the purchasing decision is aborted, except in special situations, such us compulsive buying, exaggerated or deficient information, and manipulation of the buyer's emotions.

The benefits of a product are reflected through their attributes. These are of use, of meaning and sign, and of relation to past experience. These attributes of a product are, in fact, function of the product, or what is does. Products must have use functions, related to the utility that the user needs or expects from the product, and esteem functions, related to the meaning and sign that the product may contain and also connected to the buyers past experience with the same product or similar ones. The price, or cost, is an attribute as well but works against the others and is not considered as a function.

This set of considerations might be visually represented in a 2x2 matrix, as in Figure 2, where: (i) on the vertical axis we have the benefits, in which the bottom half reflects the level of use functions that the product offers, or utility (intrinsic value), and the top half represents the level of the esteem functions that are aggregated to the product, or emotions (extrinsic value) and, (ii) on the horizontal axis we have the sacrifice, in which the left half contains de level of the price imposed by the market (buyers or competitors) and the right half reflects the level of the price imposed my the seller (based on production cost plus desired margin). The subsequent four quadrants of the matrix represent four types of product value, in the consumers' point of view.

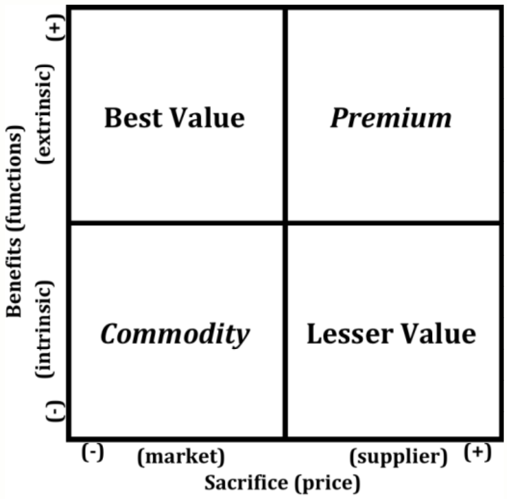

Fig. 2 Value Matrix.

The "commodity" type covers most of the products that consumers can find in the market. They perform the use needed functions, intrinsic to the product, and their price is either determined by the demand (consumers) or by the supply (competitors). The consumer understands very well what expects from the product and is only willing to pay a certain amount of money for it, rejecting to buy it if the price is above the level that is considered acceptable. Products within this type of value are normally in an advanced stage of maturity.

The "premium" type relates to very specific products, either resulting from very new and sophisticated technology, as a result of innovation, or from the targeting of a very specific market niche needs, as a consequence of an extrinsic valuation of the product by that niche. They offer the expected intrinsic use functions, plus the extrinsic esteem functions related to cultural value and perception value, at a price that is determined and imposed by the producer or seller. The consumer is mainly looking for the emotions that the product can provide, related to prestige, luxury, beauty, and enjoyment.

The "best value" type of product value corresponds to a temporary market context in the life cycle of a product. It corresponds to the phase that follows the market acceptance, by innovators and early adopters, of a new technological product that has been considered as of "premium value", somewhere in time when the large majority gets in and many competitors launch new substituting variations of the product, competing with the initial one. It may also might correspond to a new variation of an existing "premium value" product, which has been dominating a specific market niche, that is targeting a new market segment. This positioning is due to the fact that a "best value" product is seen by consumers as still integrating the emotional component of the original one, with esteem functions in complement of the use functions, but made available to the market at a very affordable cost to the new buyers. Invariably, this type of value corresponds to an intermediary phase during the commoditization cycle, between the "premium value" stage and the "commodity value" stage of a product.

The "lesser value" type applies to new launched products that have not been accepted by consumers, corresponding to real market failures, or to products that are of obligatory purchase, due to legislation or regulations. Products considered as "lesser value" are seen as too expensive for the intrinsic use value that they offer, and with no extrinsic value at all. Products considered as "lesser value" only survive while the purchasing obligation lasts or until a substitute makes its way to the market.

Value can still be visually represented as a graph, as we will see ahead. This graphical representation expresses the "value curve" of the product, where all attributes are represented, evolving along the measurement of the performance of each one (Kim and Mauborgne, 1999).

3. Innovation

3.1 Literature review

According to Cummings (1998), innovation refers to a successful first time application in the market of a firm's product or process. Abernathy and Clark (1985) agree with the concept and even connect the meaning of innovation to the creation of value added. Innovation is also "… a firm's tendency to engage in and support new ideas, experimentation, and creativity for the development of new processes" as referred by Lumpkin and Dess (1996, p.142). According to Piana (2003) "innovation is the complex development of discoveries (eg. new physical laws) and inventions (eg. a new machinery) brought in the business and social environment (eg. introduced on the market), hopefully leading to diffusion (adoption by new users)". Schumpeter (1934) even considered innovation as "creative destruction" when new technologies substitute the old. Today, the most well accepted definition is in the Oslo Manual: "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" (OECD, 2005, p. 46).

Innovation has been studied at various levels such as industries, firms, and individuals. It can address the needs of existing customers or be designed for new or evolving markets as pointed by Christensen and Bower (1996). Or it can focus mainly on the organization's side. The dual-core model of innovation, as referred by Daft (1978), Grover, Fiedler & Teng (1997), and Knight (1967), divides organizational innovations into two levels: technical innovation and administrative innovation. Technical innovation, not technological innovation, relates to the technical nature of an organization or a primary work activity in which an organization converts raw materials into finished products. Technical innovations are not merely innovations resulting from advanced technology, but they are linked to the primary activities and the value adding process of firms, and adopted as a means of changing and improving those activities which in themselves may or may not exploit technology, as mentioned by Damanpour & Evan (1084). Administrative innovation refers to the behavioral or managerial side of the organization, the social system of rules, roles, procedures, and structures (e.g. a new way to organize internal communication). Sometimes, according to Mouzas and Araujo (2000), administrative innovation is used synonymously for organizational innovations.

However, when we come to the scope for the application of innovation, that being in what innovation is applied or used, and despite some slightly different opinions, such as from Schumpeter (*op. cit*), Piana (*op. cit*) and, Kingsland (2007), it is widely accepted that there are four major types of innovation: "product innovation" – introduction of a new product (good or service) or major improvement of its characteristics; "process innovation" – implementation of new or significantly improved methods in production or distribution; "marketing innovation" – implementation of a new marketing method, evolving changes in design, packaging, placement, promotion or pricing; and, "organizational innovation" – implementation of a new organizational method in the firm's business practices, organization of workplace or external relations (OECD, 2005).

To simplify our understanding of the scope for the application of innovation, Pol and Ville's (2009) understanding of innovation will be adopted, covering two levels: "technological innovations (new or improved products or processes) or organizational innovation (changes to the firm's strategies, structures and routines)" (p. 881). This is in line with other similar views that set the product and the organization as the arenas where firms' innovation is developed, like those of Fernandes (2012 a), and, Fernandes and Martins (2011). Innovation at the product (good and service) level refers to the introduction of new functions or changes in existing products' functions (related to product attributes/functionalities demanded by consumers – thus, demand driven), the creation of new designs or adjustments in existing products' designs (related to the aesthetic side of the product supplied by the inducer – thus, supply driven), and the usage of new or substitute input (related to resources' offer – thus, context driven). Innovation at the processes level refers to the creation of new methods or adjustments in existing methods (related to applied technology – hardware and software – thus, process driven). Innovation at the product level will be the core of this paper. Innovation at the organizational level refers to the introduction of new or changes in existing management systems (related to the organizational structure, the ICT, and institutional relations with stakeholders – thus, organization driven). Innovation at the marketing level refers to new or changes in existing marketing strategies (related to promotional processes, image creation and development, and distribution network – thus, marketing driven) (ibid.). These last views of innovation match extensively with the former definition in the Oslo Manual (OECD, 2005).

Innovation can also be seen in relation to its novelty or how it diffuses among firms and consumers. In relation to innovation adoption by firms, the Oslo Manual classifies it at three levels: "new to the firm" – first time a firm adopts a given innovation; "new to the market" – first time a given innovation is introduced in a market (or industry); and, "new to the world" – first time that an innovation is introduced to all markets and industries, national and international. Regarding adoption by consumers, Rogers (1995) considers five levels of innovation diffusion: "innovators" – brave people, first to try; "early adopters" – opinion leader, try out new ideas; "early majority" – thoughtful people, accept changes more quickly; "late majority" – skeptic people, use only when majority is using; and "laggards" – traditional people, only accept new idea when it becomes mainstream. Those types of innovation adoption are directly connected to the different types of value based innovation, as we will see next.

3.2 Value based innovation concept

The act of innovating coincides with that of value change. Value changes are creations or modifications (additions or subtractions) of the value of a thing or solution (potentially a product – good or service), achieved by actions or events. The concept of "value based innovation" (VBI) implies that any act of innovation creates a new or changes an existing value curve of a thing or solution, normally presented as a product (good or service). The value curve of a product is defined by the performance of all its attributes, as in Figure 3, and it defines the product and how it stands in comparison with competing products.

These changes in the value curve are triggered by the customers demand for innovation, either expressed or not by the them and related to new needed functions, operational easiness, and new aesthetics in the product, or imposed by external context forces related to economic, production, environmental, political, and technological factors. Depending of the intensity of those factors, firms have more or less difficulty to create innovative solutions to satisfy the demand. This called difficulty to satisfy the demand for innovation is one major vector for the type of value based innovation more suitable for each innovation-demanding situation. But, the value curve also reflects the capacity that the firm has to develop the needed innovation effort to create product solutions with the desired and expected value by the market. This is the other vector that contributes to the type of innovation that is developed around a product.

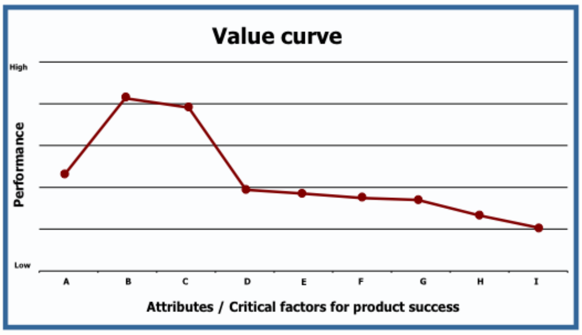

Fig. 3 Value Curve.

The combination of those two vectors in a 2x2 matrix can determine the type of value-based innovation resulting from it, as in figure 4, and the respective value curves. This leads us to four types of innovation based on the resulting value: (i) breakthrough innovation – creation of a new value curve, corresponding to a new product, defined by a stand alone value curve, not comparable to any existing product; (ii) adding value innovation – addition of some type of value (in the tangible or intangible realm) to an existing product, via a strong increment in the attributes' performance, placing its value curve much above competing products' value curves; (iii) turning around innovation – lowering the performance of the attributes of a product, but turning it into a much cheaper solution comparing to other competing ones, placing the value curve of the product below the ones of competitors; and, (iv) up-grading innovation – changing the performance of some attributes of the product, with small improvements, mainly the preferred ones by consumers, playing with the value curve of the product in order to differentiate it when in comparison with competitors.

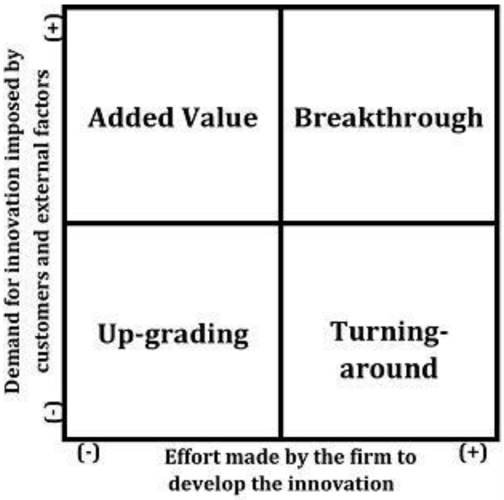

Fig. 4 Value Based Innovation (VBI) and corresponding value curves.

All value phenomena (creation, generation, addition, improvement, consumption, destruction, and accumulation) happen in a context of human activities (processes) defined by the resulting value form (tangible or intangible) and the process applied to materialize the same value (simple or complex). The form and materialization of value is related to the environment where action is happening (Allee, 2000). The resulting four levels of human activities are, as in Figure 5: (i) ideation level – conceptualization and creation of ideas; (ii) technological level – transformation of any existing resource (material or non material) into a new thing or solution, by applying technology (human transformation); (iii) cultural level – change of human behaviors, induced by or using a thing or solution, through the creation of some meaning to the usage; and, (iv) distribution and consumption level – making a thing or solution available to consumers, for purchase and consumption or usage.

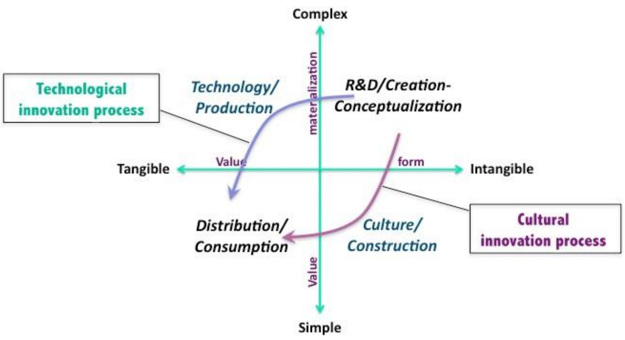

Fig. 5 Innovation processes.

The journey from the ideation level to the distribution level can take one at a time or two simultaneously paths: through the technological level, through the cultural level, or through both. The first corresponds to a process of technological innovation, and the second to a process of cultural innovation. The type of creativity methods and ideation tools used for each process differ from one another, and will be further discussed next.

3.3 Technological Innovation process concept

In order to understand the variables that contribute to technological innovation, we must first understand what technology is. One of the most general definitions of technology is the application of science or knowledge to commerce and industry. According to businessdiccionary.com technology is "The purposeful application of information in the design, production, and utilization of goods and services, and in the organization of human activities". Despite the potential disagreement about the accuracy of any definition, we may define technology as "the applied knowledge to a (physical and non-physical) tangible value form utilizing physical (hardware) and non-physical (software) means in a systematic way". Tangible value form relates to an output of any action or event that is accepted by Man as adequate for use and for exchange (transaction that implies a defined compensation) and, therefore, measurable, and quantifiable in close boundaries for most people.

Another term that needs a clear understanding is technological innovation. According to Tornatzky and Fleitcher (1990), technological innovation is the process of introducing new tools in a specific social environment and the tools by themselves. The technological innovation process is often related to the dynamic desire of innovating and there are two variables that can influence that dynamic: the technology derived from systemic knowledge, normally of scientific nature, and the technology normally involving a mixture of physical artifact and social context and content. Despite the fact that the word "technological" has been removed from the definitions in the Oslo Manual (2005), it is still understood, as before, that innovation itself is an iterative process initiated by the perception of a new market and/or new service opportunity for a technology-based invention which can lead to development, production, and marketing tasks striving for the commercial success of the invention, as defended by Garcia and Calantone (2002). We may conclude that technology is "a Man created process based on knowledge". This means that a technological outcome may have a physical or tangible form (product), or a non-physical and intangible form (service), independently of using physical or non-physical tools in the creation, development. and production processes.

Thus, one may say that technological innovation can be "the application of technology in the production of physical (hardware) and non-physical (software) outcomes that artificially substitute human labor and reduce the utilization of resources (production costs), being the outcomes accepted by market materialized in some object or equipment and presented as a tangible good, or in some software or convenience form as a tangible service". New or modified organizations' internal processes, management systems and other non-physical outcomes, most expressed in the form of labor activities, resulting from human intelligent actions, can be considered as services, and, consequently, resulting from technological innovation.

Following a mechanism-type approach, we can characterize technological innovation by two variables: (1) "what" one wants to achieve (goals and objective) and, (2) "how" one may achieve it. The "what" is represented by the product (good or service) value curve outcome and the "how" by the process applied to the innovation process.

All these views lead to a more focused approach on the processes. Therefore, the technological innovation process might be defined by the resulting value curve coming out of the innovation process (new vs. modified), and the applied creation process (procedural vs. loose), resulting into four types of technological innovation processes, as in Figure 6: (i) planned/structured process – this process is analytical, systematic, science based (fundamental and applied R&D), and develops new knowledge about natural systems by applying scientific laws (know why), based upon scientific knowledge and models, deductive by nature, and supported by collaboration within and between research units or entities, producing strong codified knowledge contents, highly abstract, but universal; (ii) targeted/objective driven process – answers specific needs of users, consumers or of the organization. This kind of innovation mostly fits in the non R&D based innovation class, focusing mainly on design innovation. The process of this type of innovation is symbolic (art-based), creating meaning, desire, aesthetic qualities, affect, symbols and images (know who), based on creative processes and supported by high interaction between teams and projects, requiring creativity, importance of interpretation, cultural knowledge, creating sign value and implying strong context specificity; (iii) adapted/ adopted process – relates to strategies of adoption and adaptation of innovations initiated and developed by others, based on the "imitation" of products (goods and services) attributes and of organizational processes. This kind of innovation mostly fits in the non R&D based innovation class, focusing mainly on equipment and input-embodied innovation. This type of innovation process is synthetic, engineering-based, applying or combining existing knowledge in new ways (know how), based upon problem solving capabilities and custom production, therefore being inductive, and supported by interactive learning with customers and suppliers, producing partially codified knowledge and strong tacit components which are very context-specific; and, (iv) serendipitous/stochastic process – defined by stochastic results of focused or trial and error experiments, it is mostly based upon fundamental and applied R&D. This also fits in the R&D investment based innovation profile. The process of this type of innovation, like the planned/structured type, is analytical, science based, and developing new knowledge about natural systems by applying scientific laws, supported by collaboration within and between research units or entities, producing a strong codified knowledge content, highly abstract, but universal.

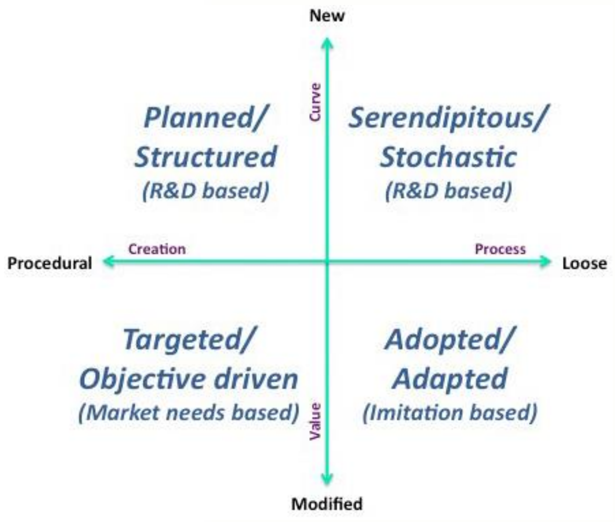

Fig. 6 Technological innovation process.

The applicability of innovation tools differs among those four types of technological innovation process. While the types "planned/structured" and "serendipitous/stochastic" are more appropriate for the use of value engineering (VE), functional performance specification (FPE) and TRIZ, the "targeted/objective driven" is more suitable for the application of "design thinking", VE, value proposition design (VPD) and open innovation (OI), and the "adopted/adapted" is the perfect for the application of TRIZ, VE/Lean, VPD and OI. These are typical recommendations from practical applications in firms. Other innovation tools are not so clearly related to a specific type or innovation process.

3.4 Cultural Innovation process concept

To later understand which variables contribute to cultural innovation, firstly we need to understand what culture is and what it can mean to the business world. According to Hofstede (1994) culture is "the collective programming of the mind which distinguishes the members of one category of people from another". Culture in this sense is a system of collectively held values. According to Schein (2004), culture is "the deeper level of basic assumptions and beliefs that are shared by members of an organization, that operate unconsciously and define in a basic 'taken for granted' fashion an organization's view of its self and its environment". This looks more like an organization's inside view of culture. Aguilar-Millan (2005) argues that we must even consider that, in accordance with the "spiral dynamics" concept:- in dealing with others, people reflect their own life conditions, which are bundled into "memes" – aggregation elements of cultural influence, attitudes, ways of doing things, etc.. Culture is, therefore, the human-made part of the environment, as long defended by Herskovits (1995), and it can be divided into objective culture (eg. roads, buildings, and tools) and subjective culture (eg. beliefs, attitudes, norms, values, role definitions), as defined by Triandis (1996).

It is widely agreed that culture consists of "shared" elements, as defended by Shweder and LeVine (1984), that provide the standards for perceiving, believing, evaluating, communicating, and acting(I see the last two as behavioral forms) among those who share a language, a historic period, and a geographic location (Triandis, 1996). The shared elements are transmitted from one generation to the next with modifications, encompassing unexamined assumptions and standard operation procedures that reflect "what was worked" at one point in history of a culture group (Schein, 2004).

Postmodernism has had a major influence on culture and the way it manifests in our society. Baudrillard (1998) defines culture as: "(i) An inherited legacy of works, thought and tradition; and, (ii) A continuous dimension of theoretical and critical reflection – critical transcendence and symbolic function" (p.101). The author distinguishes between the High Culture and the Mass Media Culture or, as he calls it, the Lowest Common Culture. For him, the High Culture is available only to the elites of the society, as it has been for centuries. In this, and bringing the issue down to the level of culture products, which is of interest to this paper, he encompasses the true works of art that have passed the test of time, those unique and invaluable products that are irreplaceable and hold intrinsic value that grows as years, or even centuries, go by. The Lower Common Culture is the popular culture, the culture of the masses, as mass production, and mass communication has made it available to all social categories. The author argues that the mass production of that which is unique is the one reason for the downfall in culture and the apparition of the Lower Common Culture together with the mass media movement. The High Culture becomes subjected to the same competitive demand for signs as any other category of objects, forcing production to meet the demand. As culture becomes a commodity, the new objects are no longer seen as works of art but just as finite objects into themselves. The value has decreased to the point where they became mundane, "part of the package, the constellation of accessories by which the socio-cultural standing of the average citizen is determined" (ibid., 107).

Thus, we come to a point where one may understand culture as "a set of attitude patterns of a population towards a certain subject, expressed in an intangible or tangible (value) form, reflected in general and consistent/systematic behavior that can be transferred to or make use of objects". We must remember that intangible value form relates to everything, output or not of an event or action, which cannot be exchanged (transacted against a compensation) as such and, therefore, it is not measurable and quantifiable inside close boundaries for most people, while tangible value form relates to every thing or object, output of an action or event, such as products (goods or services) that can be exchanged, therefore measurable and quantifiable inside close boundaries for most people.

Some communal work has been developed on the concept of cultural innovation. According to wiki.answers.com discussion panel, "cultural innovations are internal changes that depend (and are limited) upon the recombination of already existing elements in culture. They can occur independently in different times and places, however not all lead to change in culture. They occur more frequently in technologically complex societies than in less developed ones." This is more of a general society view that is also of interest to this paper.

Cultural innovation may be seen under two different perspectives: (i) as the creation of a collective common adopted behavior based on an idea with no materialization in any physical product (good or service) [e.g. part of the population start using long-hair, speaking a new dialect, start following specific custom or start grouping around some spiritual beliefs); and, (ii) as the creation of a collective common adopted behavior through the utilization of a product (good or service) that contributes to creating a preference, a meaning and a way of being and acting in a large portion of a population or of a region (e.g. people creating new rules to regulate peoples' behaviors supported by a judging system, creating Internet social networks that allow users to create social/cultural ties, creating new music styles supported on the utilization of specific new musical instruments (eg. Jazz, Hip Hop), developing new fashion styles through the creation of specific cloths (eg. T-shirts and miniskirt), inducing certain life styles through the utilization of certain new products (eg. walkman, toaster, microwave, tattooing equipments), or still, creating a certain painting style or technique which has originated a different painting style). Thus, we may define cultural innovation as an "effectively adopted or changed collective behavior in a group of people".

Culture is intangible. Cultural innovation creates intangible value that cannot be measured in a quantitative form, but can be felt and lived in a qualitative form.

It is accepted that consumption determines many consumers' values and experiences regarding life and being. As McCracken (1986) states, "Usually, cultural meaning is drawn from a culturally constituted world and transferred to a consumer good. Then the meaning is drawn from the object and transferred to an individual consumer. In other words, cultural meaning is located in three places: the culturally constituted world, the consumer good, and the individual consumer, and moves in a trajectory at two points of transfer: world to good and good to individual" (p. 71).

The consumption comes to be seen as a language, a "system of exchange", and as "a process of classification and social differentiation" (Baudrillard, 1998, p. 7). This takes us to a stage that living in a commodity driven society is that all the objects need to be acknowledged and exchanged for their value, producing them is not enough. The market is definitely such a place for that purpose. To Debord (1995), the commodity has turned "the whole planet into a single world market" (p. 27). The postmodern market is beyond monetary. It takes its fuel from satisfying the needs of the consumer, which, as previously said, go beyond utility but are undoubtedly present. It is true that most of them are fabricated by advertisers and marketers, but they are still very much real to the consumer and they need to be fully satisfied. It is in this cultural framework that the proposed cultural innovation process construct model presented next was thought and conceived.

In order to understand how culture influences the innovation creation process, we need to define which variables contribute to such phenomena. Departing from Schwartz's (1996) values system, which affects attitudes and behaviors, we find two basic dimensions, based on value conflicts. One dimension opposes Openness to Change (combining the self-direction and stimulation value types) to Conservation (combining security, conformity, and tradition). This basic dimension reflects a conflict between emphases on own independent thought and action and favoring change (open to change) versus submissive self-restriction, preservation of traditional practices, and protection of stability (conservation). The second dimension opposes Self-Transcendence (combining benevolence and universalism) to Self-Enhancement (combining power and achievement). This dimension reflects a conflict between acceptance of others as equals and concern for their welfare (self-transcendence) versus pursuit of one's own relative success and dominance over others (self-enhancement). Hedonism shares elements of both Openness and Self- Enhancement (p.124)

Therefore, the cultural innovation process is characterized by context in which behavior changes happen. This context is defined by the cultural individual orientation (materialistic view of life / self-enhancement vs. idealistic view of life / self transcendence), and by the cultural collective orientation (view towards the unknown / openness to change vs. view towards the known / conservation), resulting into four types of cultural innovation processes, as in Figure 7: (i) neowel – generalized human behavior changes in large portions of the society induced by or using a new thing or solution based on new technology. New technological things and solutions induce new "created" behaviors/habits in relevant portions of the population, developing new meanings and signs. The impact of this type of innovation has a collective dimension as it creates standard behaviors at people's group level, reflecting a high capability for collective creation and adoption. (ii) moral – generalized human behavior changes in large portions of the society induced by or using a thing or solution imposed by codes, rules and laws, or advocated by some preeminent opinion maker. New morals force new "adapted" behaviors in the large majority of a population. This type of innovation has a strong impact at the societal sphere, forcing behaviors at community level, but reflected in a moderate and slow capability for full collective adoption; (iii) beutel – restricted human behavior changes in a fringe or niche of the society induced by or using a thing or solution with some strong artistic or fashionable characteristics or attributes. New aesthetic trends reflected on products (goods and services) induce new "created" behaviors/habits in some small pockets of the population, developing new meanings and signs. This type of innovation mainly impacts the individual level, reflecting a very high capability for individual creation and adoption; and, (iv) gnosil – restricted human behavior changes in a fringe or niche of the society induced by or using a thing or solution caused by the acquisition of knowledge and information. New knowledge, resulting in new attitudes, forces new "adapted" behaviors in some small pockets of the population. The new knowledge refers to scientific findings that have impact on human life. The impact of this type of innovation is manifested at the personal (individual) level, reflected in a moderate and slow capability for vast individual adoption. The cultural changes in this archetype appear to be mostly induced by opinion makers and others in closed individual cycles.

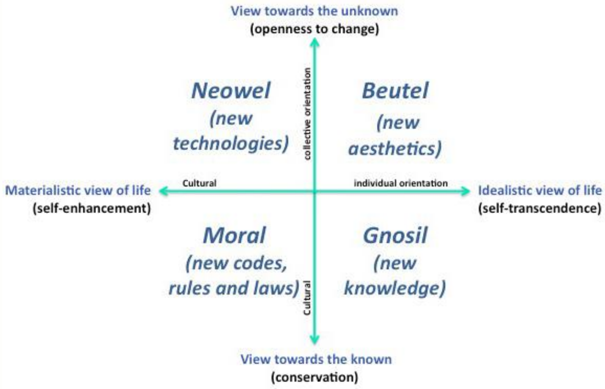

Fig. 7 Cultural innovation process.

Some innovation tools seem to be more suitable to be applied in the cultural innovation processes, such as Neuro-Linguistic Programming (NLP), Mind Mapping, Heuristic Ideation, Scamper and Delphi or Focus groups methods. At least there is some indications of past experience that these tools have produced some outputs more prone to create cultural innovation than others.

4. A Case Study to illustrate the concepts: The Blue Jeans

The search for products that have been subjected to value change and innovation is endless. However, not many are so evident on the resulting outcomes and so well known to most world population as the blue jeans, when it comes to the creation of use and cultural value and, consequently, to the development of technological and cultural innovation processes.

Despite some different told stories about the genesis of the blue jeans, it seems that the famous garment is the result of the combination of two events: (i) the introduction of a known technology at the time, the riveting, and (ii) the change of a fabric used for other purposes, canvas for tents and wagon covers, but applied to make pants, to a more resistant fabric for the same purpose, the denim, both to reinforce the strength of the mention clothing item, in order to improve the utilization of it.

To understand the phenomenon we need to go back to USA, during the second half of the XIX century. The work in America's far west at that time, either farming in the countryside or mining for gold, was to hard on workers pants. The heavy work of the days used to rip apart the workers pants in most points of stain, reducing the resistance and the life of the product, certainly two items among the most important functions of the pants for the users. This condition would reduce tremendously the use value of the product, and, consequently, its economic value to the purchaser. The user's dissatisfaction regarding the low resistance of the available pants at the time, for the purpose of working in mines and farms, was the trigger for some to look for new innovative solutions, in order to overcome the resilient problem.

According to several sources (newint.org; ideafinder.com), Jacob Davis, a tailor living in Reno, Nevada, immigrant from Latvia, decided to apply the riveting he normally used on horse blankets to the pants of one particular customer, who used to complain about the resistance of the garments made by Davis. The riveted pants were an immediate success with many other customers, which led Davis to think about a patent, before anyone else could do it. For that purpose, and due to his lack of money to support the original costs involved in the patenting, Davis offers partnership to Levi Straws, an immigrant from Austria who run a warehouse in California selling dry goods to prospectors during the gold rush, and also his usual suppliers.

Originally, according to Solomon (1986), Straws intended to sell rolls of canvas for tents and wagon covers, but quickly realized that the material could serve another purpose: making pants for workers in the mining industry. Later, he decided to switch to a tough cotton fabric made in France, the "serge de Nimes", which became pronounced as "denim".

When, in 1873, the patent was awarded to Jacob Davis and one half assigned to Levi Straws & Co., the jeans were officially borne. The riveted pants production at the S. Francisco plant was started, and in 1890 the lot number "501®" was first used to designate the denim waist overalls that would later spread the concept worldwide. The word "jeans" came from "genes", the term used by the French to identify the heavy cotton pants used by the sailors from Geneo (Solomon, op. cit.).

The original application of rivets to the pocket corners and to the base of the button fly on pants by Jacob Davis corresponds to an act of innovation that solved the recurrent problem of pants resistance. This innovation was a result of a new application of an existing technology from other industry, the riveting, into a different product and industry, which corresponds to the process of adoption and adaptation of existing technology. The utilization of canvas, and later denim, by Levi Straws to make more resistant pants is the result of a process of adoption of existing materials in the same industry. Both cases illustrate the "adopted/adapted" technological innovation process.

When the patent ended and the rivet pants went into public domain, some other producers created new brands and aesthetic variations of Levi Straws garments, but the product remained as mostly preferred by a single segment of the consumer market for some time, the working class, mainly operating in the agricultural countryside and in the industrial urban settings, satisfying its main use or utility purposes: durability and resistance. This lasted until the arisen of the great depression, when the new economical e social context brought new life and behavior perspectives to people.

During the depression, a series of contingent events and circumstances encouraged the industry and the consumers to use blue jeans as a symbolic and stylish versatile, class and gender blurring national icon. The blue jeans served as a bridge between the working class and the middle class, and between male and female consumers, destroying existing moral paradigms and promoting equalitarianism and freedom. We can find two distinct approaches to explain the increase and diverse use of jeans from the 1930's: the "consumption-side factors" and the "production-side factors". On the consumption side, as argued by Rabine and Kiser (2006), the changes in middle class Americans' everyday activities (such as increased leisure time, women's entry into paid work, greater emphasis on women's sport) led to a need for casual clothing. On the production side, Fine and Leopold (1993) argue that the changes in technologies, labor management processes of mass-production, and new mass-distribution capabilities created the competition in the women's ready-made garment industry, pushing manufacturers and retailers to market dungarees and other standardized garments in new ways, in order to expand their markets and compete with one another. The fact is that during the great depression two categories of events (regulatory and aesthetic) helped to spur the phenomenon. The first type of events was related to the reorganization of the clothing consumption and production in a more equitable fashion. The second was connected to the social aim of using aesthetics to make sense of the Depression-era calamities and reinterpret the meaning of the American way of life (Comstock, 2016).

This is also coincident with the use of jeans by Hollywood films actors in their normal social and street appearances, which were playing in western films reproducing the life of the far west cowboys. The blue jeans were not anymore a garment only for workers during their duties, but it was also a casual and equalitarian dressing code.

In 1935 Levi's jeans for women were first featured in Vogue magazine, as a consequence of the adoption of the garment by workingwomen and by housewives dressing as some Hollywood feminine stars were doing at the time.

This liberation of set formal dressing codes for men and women advanced further during the fifties and sixties, with the growing youth culture of juvenile delinquency during the first of the two mentioned decades (Gordon, 1991), and with the hippies movement of the second. Blue jeans were the right tool to symbolize and to support such changes in both genders dressing codes, reflecting other important changes in culture and social behavior. Jeans were then satisfying more expectations such as comfort, informality, and versatility than the initial expectations of durability and resistance to the far west workers and miners.

The word jeans became popular worldwide when the baby-boom generation adopted the term for the pants, the American jeans producers went further in their internationalization process and other western countries opened their frontiers to new ideas in the realm of politics, social behavior, and economics. The democratic countries in Europe were the first to make the blue jeans one of their own most common garments, for both genders.

In Argentina, jeans were the first dress item to be used mainly by young men and women, who increasingly dressed, thought, and behaved differently from the older generation, serving to signal, and reinforce class distinction and gender differences among young people (Manzano, 2009). During the dictatorship regime in Portugal, the production and commercialization of jeans were not allowed as it symbolized the American way of life, meaning freedom and democracy, being only made available to the consumers after the democratic revolution of 1975. South Korea only allowed the imports of blue jeans in the 1980's (DeLong et. al., 1998).

Dress acts as a visual metaphor for identity and for noting the culturally anchored ambivalences that resonate among and within entities (Davis, 1993). Users associate products such as jeans, based on their particular set of experiences and values that are shared within a cultural context, which certainly leads to certain expectations regarding the use of the product (Kaiser, 1997). Jeans, as a cultural object, are comprised of both form and content, components that are often separated during the communication process (Hillestad, 1994).

Fiske (1990) presents a number of models to understand the communication process based on the premise that the communication is influenced by culture, and that cultures have different underlying codes. The author defines a code as a system of meaning that is common to the members of a culture. Therefore, all codes depend upon common bonds among members. A sign is defined as a unit, component, or object that refers to, represents, or stands for something other than itself; a sign relies on an underlying code to establish its meaning (Berger, 1992). Objects of culture, such as jeans, can function as a sign of three types: an icon, an index and a symbol (DeLong et. al., op. cit.). Wilson (1991) describes jeans as "the symbolic vessel into which any and every aspiration about one's identity can be poured, the ultimate conveyer of that greatest fashion paradox: how to be just the same as, yet entirely different from, everyone else" (p. 122). This paradox of individuality and conformity that jeans can represent has led to a large number of meanings, associated with that ambiguity for the individual and society at large. At the individual level, favorite items of clothing might be perceived by users as meaningful, often contextualized by emotional or aesthetics properties or capabilities for them (Kaiser, Freeman and Chandler, 1993).

All this reflects a process of change in the product value, at the intangible dimension level, or "cultural value" (value as meaning and sign), resulting in a process of cultural innovation, achieved by the changes in behavior in a group of users or consumers and caused or induced by the use of the product. In the particular case of the blue jeans, one can identify a "beutel" cultural innovation process all along the history of the product, and also a "moral" cultural innovation process in some particular situations when a new behavior reaches large numbers of the population and is led by a certain behavioral code defined as appropriate by someone or by the group.

The blue jeans are, in fact, an almost perfect case to illustrate how the change in use value (or value as utility) and cultural value (or value as meaning and sign) were the result of some technological and cultural innovation processes.

5. Conclusions

We have learned, from existing literature, empirical observation and experimentation, and professional application, that products have value, other wise they are discarded by consumers. Consumers buy products to accomplish different objectives, of utility or emotional. Consequently, products might have value of different kinds, tangible or intangible in its form. The value of a product can be measured as a function of the benefits that it provides to the user or consumer versus de sacrifice that the same user or consumer has to provide to acquire and use or consume the product. The total value of a product can be visually represented by a value curve, which helps in the decision making process when some action is needed to be taken, mainly in the strategic realm.

We have also learned that the induced change in the value curve of a product is the result of some kind of innovative action. That value creation or modification can lead to different end results in the positioning of the product in the market, in relation to the customer standpoint. The innovation is inevitably the result of a transformation of some conceptual ideation into a final product (good or service) accepted by the market, that can go either through a process of technological transformation or of cultural construction.

Those two well differentiated processes are individually characterized by different factors, in the first case related to the human activity applied in the making of the innovation, and in the second related to the change that the product may induce in the human behavior of consumers. In both innovation processes tools are used to facilitate the desired end result, varying in accordance to the specificity of each one.

We may conclude that the innovation phenomenon is directly and inevitable connected to the value phenomenon, which makes them inseparable. The acceptance of this paradigm may contribute to the development of more systematic innovation in firms, but also to a better comprehension of the entire phenomenon by scholars and professional. Further empirical studies and experimental applications are still needed to fully validate all concepts and provide insight to the development of new managerial tool.

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AUTHOR'S BIOGRAPHY

Manuel Teles Fernandes is a professional consultant at Gestão Total (Portugal), since 1994. He has a long experience, since he was twenty years old, in entrepreneurship and management. Manuel received his MBA degree and a BM degree from EU (Lisbon). He is a qualified Trainer in Value Management (TVM) and Professional in value Management (PVM). He has dedicated the last twenty years to research, in the fields of value management and innovation. He has design and developed an application to assess the level of value and innovation creation in firms. He has and is still participating in different technical commissions for standardization, national and international.

ISO 9001:2015 and Its New Requirement to Address Risk: A Demonstration Case-Study

Filipe Perdigão[1], Celeste Jacinto[1], Sandra Lopes[2] and Ana Sofia Matos[1*]

[1] UNIDEMI – Mechanical and Industrial Engineering, Faculty of Science and Technology, Universidade Nova de Lisboa, Portugal

[2] Lusosider-aços Planos SA, Seixal, 2840-075 Aldeia de Paio Pires, Portugal

*Corresponding author, e-mail: asvm@fct.unl.pt

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Abstract

The recent 2015 edition of ISO 9001 introduces a risk-thinking approach in its new section 6.1. Comparing with previous editions of the standard, the main innovation is the need to address risk and identify improvement 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 current work is restricted to the study of main process (management function) "Sales", for which the analysis of a particular sub-process, "Sales plan development", is herein presented and discussed step-by-step, to give insight of details. Within "Sales plan development", the results revealed 10 failure modes that, in turn, can originate from 17 potential causes that were organized into 4 "sets of causes" because certain failure modes share the same causes and require similar improvement actions; these are also pinpointed in this paper. With regard to the main process "Sales", this analysis disclosed 38 sets of causes that were categorized by risk level, i.e., by their risk priority number (NPR), using a Pareto Diagram, to establish intervention / improvement priorities. It was also found that, apparently, either FMEA/FMECA or the adapted QF-HAZOP produce similar results. Both constitute useful approaches to fulfil the new requirements of ISO 9001:2015 Quality Standard.

Keywords: Quality, Risk analysis, Risk-based thinking, Quality management, ISO 9001:2015, FMEA / FMECA, HAZOP.

1. Introduction

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

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 centerpiece 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).
	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.

last version published and replaces the 2008 version. The changes associated with this new edition require companies to adopt a novel *risk thinking approach* towards quality management (*c.f.* ISO 9001:2015). The evolution of ISO 9001 underlying philosophy is summarized in Table 1.

The requirements comprised 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 improvements that will reflect on their 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. An important change in this new edition is the requirement to address risk and identify opportunities, compelling managers to identify 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.

The concept of risk has always been implicit in ISO 9001, but this revision makes it more explicit and builds it into the whole management system. Within this Standard (ISO 9001, 2015), two fundamental objectives are, 1) to give confidence in the organization's ability to consistently provide customers with conforming products and services, and 2) to enhance customer satisfaction. In the context of the Standard, "risk" relates to the uncertainty in achieving these objectives.

To satisfy the new requirement, analytical 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 organizations 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

This section gives a brief explanation on the two methods used and why they were selected for this trial.

2.1 FMEA – Failure Modes and Effects Analysis

Failure Modes and Effects Analysis (FMEA) is a well-established method, which has been in use since the beginning of the 1950s. Ever since, the method has been extensively described in the literature (e.g.: BS-5760:1991, Stamatis, 2003, ISO/IEC 31010:2009, Awad and Yusof, 2012, Harms-Ringdahl, 2013).

Over the years, this analytical approach has become a very important item among quality tools and has been increasingly adopted worldwide, especially in manufacturing industries (Awad and Yusof, 2012), thus rendering it a popular approach among quality specialists and managers.

This explains why application of FMEA was considered the "natural" choice from the beginning of this work. Additionally, the hosting company was already acquainted with it for use in maintenance and occupational safety management. Any readers not yet familiar with this method can refer to a comprehensive text-book specialized on the subject (Stamatis, 2003).

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. The most common 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 occurrence (O) and ability to detect the problem (D). RPN provides an extension to the qualitative analysis; it is a decision factor that delivers a relative risk ranking. The higher the value of RPN, the higher is the potential risk.

There are several application areas 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). 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 therefore costly. The second constraint also explains why this particular case-study, embracing a single key process, was designed to serve as a "test", or "demonstration case", joining analysts from the company itself and from academia.

A multidisciplinary team applied the method (both methods in fact). There was a "permanent" 5-members team, composed by 3 academics with different backgrounds and 2 senior technicians from the local company, both in managerial positions. However, many other participants, namely certain employees performing the tasks and those responsible for the processes under analysis, were enrolled on several occasions for discussing the details and help deciding the scores.

2.2 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/IEC 31010:2009). These guide words are simple words or phrases (e.g.: too little, too much, wrong order, too late, too early, etc.) that are applied to the intention of either a part of an installation or a process step (Harms-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 (Harms-Ringdahl 2013, ISO/IEC 31010:2009).

The technique was initially developed to analyze 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 analyze safety management vulnerabilities, and to assist in the improvement of safety management. Such adaptation resembles the current challenge in this work, with the difference that the focus moves from safety management towards quality 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 it was designated QF-HAZOP, to highlight this new application field.

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

This section is designed to present the main findings of this work. Using the same reasoning as in the previous section (methods), it is structured into two sub-sections, one for each application case.

3.1 Results of FMEA / FMECA analysis

This case-study was carried out as a pilot application case. It covered 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 a quite comprehensive one for a first trial. Roughly, the main process "Sales" is divided into 10 sub-processes, namely:

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

Based on internal documents and several brainstorming sessions, the research team (the permanent team members) produced checklists with anticipated failure modes, which were later validated by the process owners. Not all the failure modes were identified through these checklists; many others were recognized as a result of proactive discussions with those responsible for the process (within further brainstorming sessions). At this early stage, it is sometimes possible to identify opportunities as well, because a failure represents a "deviation" from the normal course of a standard procedure and, in certain (rare) cases, deviations can also have positive impacts, thus revealing an opportunity (see also Deviation analysis by Harms-Ringdahl (2013) for instance).

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

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

For identifying potential causes associated with failure modes, two approaches were used. One of them was the so-called SHELL model (or acronym), which enables the categorization of the components that could potentially generate risk. This model allowed to create 4 categories of causes divided into:

- **Software** – all intangible components, such as norms, rules, regulations, etc., which represent the normal "operational procedures";
- **Hardware** – all technical systems, equipment. or tools (e.g.: displays, controls, 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 previous three categories (L-S-H). These influences include organizational 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 traditional Ishikawa Diagram. In this case the diagram allowed relating causes-to-effects, 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

Table 2 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 unhappy 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

well as the detection (D) and occurrence indexes (O). Table 2 shows the criteria for evaluating severity.

The practical application of FMEA / FMECA is illustrated next, in Tables 3 to 6, using systematically the sub-process "Sales plan development" for demonstration purposes.

Table 3 shows the ten "failure modes" identified in this particular sub-process, together with the corresponding "effects". The list of failure modes (n=10) is the "common denominator" used to link all the tables (i.e., to link the sequence of results, from Table 3 to 6).

The effects of any failure are, commonly, the negative consequences on products and businesses. These effects represent a poorly managed process or organization and can be scored to measure the severity of the failure. An extract of qualitative analysis and valuation of risk (e.g.: severity scoring) is also shown in Table 3.

Once failure modes and effects are identified and scored for severity, the next step consisted in analyzing the "causes" related to each failure mode (Table 4). To carry out this assessment, the potential causes of each failure mode are scored with an occurrence index (O). This index helps identifying the most problematic causes (i.e., those 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 categorizing "causes" under the acronym SHELL, proved to be useful, because it simplified the assignment of scores to occurrence index (O). 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 4 shows the results of "causes" and "occurrence" for the failure modes under scrutiny in this case-study. To avoid unnecessary repetition of lines, the many causes found were grouped into 4 "sets" enough to accommodate failures with common sets of causes.

Finally, the detection index (D) rates how likely the control measures implemented by the company would preventively detect the failures and causes, as illustrated in Table 5. The scores given assess the

Table 3 Application example for "Sales plan development"– *failure modes & potential effects of failure* (FMEA/FMECA)

Failure Modes identified (n=10)	Potential effect of failure	S
- Stagnation in exploring new markets and customers - Lack of monitoring the market price levels	Loss of economic and financial flexibility	4
- Lack of gathering customer information - Sales history not available for a particular client - Not using forecasts for customer needs	Business loss	4
- Lack of information on availability of manufacturing capacity - Insufficient manufacturing capacity for galvanized steel	Disruption of production capacity	8
- Inadequate distribution of sales volumes in the sales plan (by product, market, customer) - Not developing partnerships with suppliers - Inefficiency in completing the company's orders	Increase in cost	4

Table 4 Application example for "Sales plan development" – *potential causes* of failure (FMEA/FMECA)

Failure Modes (n=10)	**Potential causes of failure (n=17 causes; 4 sets of causes)**	**O**
- Stagnation in exploring new markets and customers - Lack of monitoring the market price levels	- Absence of strategy to reach new customers - Outdated network for professional contacts - Insufficient information about competition - Technology and Equipment (Insufficient techno. requirements) - Insufficient data collection and processing of information	1
- Lack of gathering customer information - Sales history not available for a particular client - Not using forecasts for customer needs	- Failure to communicate with the customer - Insufficient data collection and processing of information - Insufficient information about competition - Poor assessment regarding the relevance of business - Technology and Equipment (Insufficient technological requirements)	3
- Lack of information on availability of manufacturing capacity - Insufficient manufacturing capacity for galvanized steel	- Inefficient information flow within the company - Unpredictability of orders (quantities / specifications) - Poor production planning	7
- Inadequate distribution of sales volumes in the sales plan (by product, market, customer) - Not developing partnerships with suppliers - Inefficiency in completing the company's orders	- Bad data analysis and results calculation - Breach on procedures - Insufficient data collection and information processing - Unfavorable economic situation	2

Table 5 Application example for "Sales plan development" – *control measures* (FMEA/FMECA)

Failure Modes (n=10)	**Control measures ***	**D**
- Stagnation in exploring new markets and customers - Lack of monitoring the market price levels	Monitoring the DC reporting Monitoring CRU index ORG_17	2
- 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 - Insufficient manufacturing capacity for galvanized steel	ERP X3 Portfolio balance	6
- Inadequate distribution of sales volumes in the sales plan (by product, market, customer) - Not developing partnerships with suppliers - Inefficiency in completing the company's orders	Sales plan ERP X3	2

* The control measures listed in this table use a company coding representation; most are administrative, software and procedures.

quality of the control measures applied, and unveil which sub-processes have better control actions.

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 prioritizing 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.

As already mentioned the several causes were grouped and coded into "sets" of potential causes.

Table 6 illustrates this coding process (VAT 1 to VAT 4) for "sales development plan". It also shows the relevant department associated with each failure mode and the final risk score (RPN). From the table one realizes that, in this sub-process, the set of causes coded VAT3 is critical due to its very high RPN index

Table 6 Application example for “Sales plan development” – *final RPN values* for “sets” of causes (FMEA/FMECA)

Code (sets of causes, see Table 4)	**Department**	**Failure Modes (n=10)**	**RPN**
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
VAT4	Business	Inadequate distribution of sales volumes in the sales plan (by product, market, customer) Not developing partnerships with suppliers Inefficiency in completing the company's orders	16

(336). In addition, both failure modes originate in the Production Department.

In the main process “Sales” and its 10 sub-processes, a total of 23 specific activities (management functions) were scrutinized. After repeating the analysis to all sub-processes, and considering all things, the “Sales” examination revealed around 54 risk factors (failure modes) that may arise from 38 different sets of causes, considering that certain failures have common causes. The many different causes (38 sets), classified by their respective RPN, were subjected to a traditional Pareto analysis (Figure 1), which helped to pinpoint the most critical ones.

From Figure 1, and according to the well-known 20:80 principle underlying the Pareto law, the authors considered that the five leading “sets of causes” should be examined more carefully. These critical causes are around 13% of the total number of causes, but contribute to ~60% of total “risk level” (total RPN index). After further analysis of these 5 cases, preventive /improvement measures were established, as shown in Table 7. These measures define the future path for improving the Sales process. Noteworthy, the corrective actions identified in Table 7 comprise two key components: “procedures” and “people”.

The management of the Production and the Quality systems should be well adjusted to the

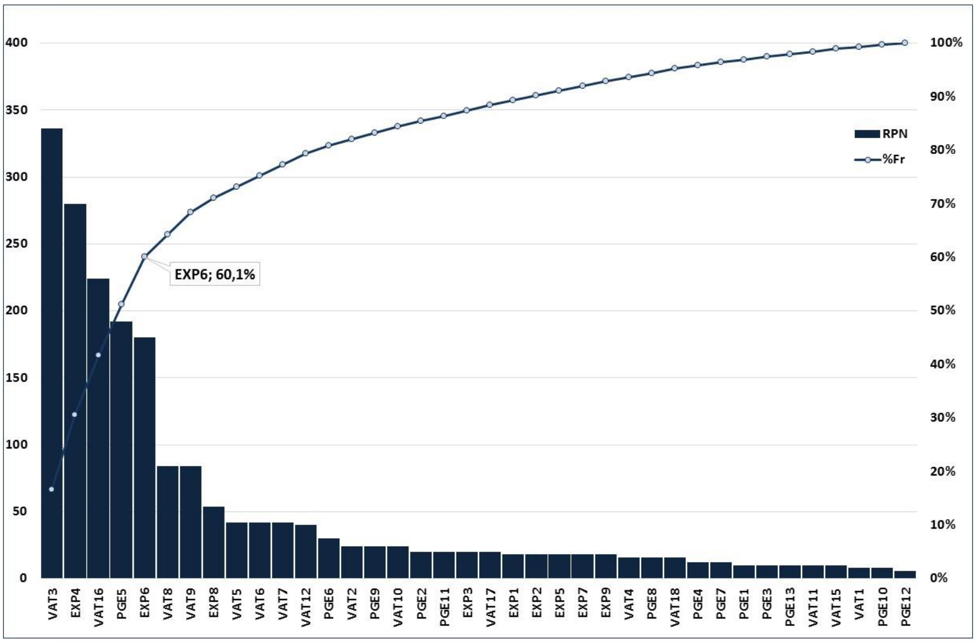

Figure 1 Application example. Pareto Diagram with RPN values for 38 sets of causes – Sales (all sub-processes)

Table 7 Improvement priority actions (all sub-processes of Sales**)**

Item	Improvement actions – Sales
VAT3	Monitoring and updating portfolios on a daily basis
EXT4	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

company's reality.

Information and equipment should always be available, minimizing bureaucracy and anticipating problems. For instance, through "*preventive maintenance and purchasing of spare parts"* and by "*improving the process of handling customer complaints*", the overall performance is expected to improve.

Moreover, the company's strategy must be tailored to market characteristics, in order to reflect the business risks and, therefore, allow setting an appropriate and well prepared response. To achieve this, 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"*.

In addition, 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 *"awareness of those in charge of the daily checking and 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. In other words, it is possible that the first method applied, whatever it is, has a leading influence on the results of the second application, since the problems (and potential solutions) are already known.

Nevertheless, the HAZOP application carried the authors to find out the **specific intentions** behind each failure mode, as exemplified in Table 8. This peculiarity, not used by FMEA, pushes the analysts to extend their understanding of the failure modes.

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 had been carried out first. Table 8 also shows an application example of the key-words.

Apparently, there is no evident 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

Table 8 Application example for "Sales plan development" – extract of QF-HAZOP showing specific intention (*in brackets*)

Sub-process	Key-Words	Failure Modes
1 Sales plan development		
1.1Company strategy		
Market	Less	Stagnation in exploring new markets and customers
(Market search)	Less	Lack of monitoring the market price levels
Costumers	No	Lack of gathering customer information
	No	Sales history not available for a particular client
(Organizing customer information)	No	Not using forecasts for customer needs
Operational	Less	Lack of information on availability of manufacturing capacity
(Monitoring manufacturing capacity)	Less	Insufficient manufacturing capacity for galvanized steel
1.2 Budget		
Business	Different	Inadequate distribution of sales 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 orders

is useful to establish priorities. Nevertheless, one should be cautious when dealing with RPN indexes, for 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 analysis.

4. Concluding remarks

This paper described a piloting 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". 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 any evaluation step based on ratings, can be quite subjective. The use of FMEA is likely to increase in the future, for there have been recent attempts to convert traditional (i.e., paper-based or spreadsheets) Process FMEA into an open architecture Process FMEA web-based system (Awad and Yusof, 2012). The same authors argue that this more dynamic web-based tool can further assist in analyzing and solving problems quickly and effectively

All in all, both approaches were considered adequate within this new field of application, i.e., to analyze and assess potential risks in quality management functions.

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AUTHORS BIOGRAPHIES

Filipe Perdigão holds a MSc degree in Industrial Engineering and Management, from the Faculty of Science and Technology, Universidade NOVA de Lisboa (FCT/UNL). He is currently an intern Consultant at SAP. At the time of this study, he provided a relevant participation in all the tasks, because this project was also used for developing his MSc thesis.
e-mails: f.perdigao@campus.fct.unl.pt and filipeperdigao3@gmail.com

Celeste Jacinto holds a Chemical Engineering, degree from Univ. of Lourenzo Marques, Mozambique and Universidade de Coimbra, Portgual. She has a PhD in Mechanical & Manufacturing Engineering, University of Birmingham, UK. Since 2003 Celeste Jacinto is an Assistant Professor with Habilitation at the Department of Mechanical & Industrial Engineering, Universidade Nova de Lisboa (FCT/UNL), Portugal. Research work focuses on the area of occupational and industrial safety. Previous employment, accounts for around 20 years in the Manufacturing Industry, as Production Manager, Quality Manager and Project Manager.
URL:http://xenofonte.demi.fct.unl.pt/mcj/, e-mail: mcj@fct.unl.pt

Sandra Lopes is Metallurgical and Material Engineer from Instituto Superior Técnico, Technical University, Lisbon, Portugal. She works for Lusocider – Aços Planos SA, a steelworks manufacturing in Portugal. At Lusosider she is the local Head of Department for Quality, Safety and the Environment (QSE Manager).
e-mail: Sandra.Lopes@lusosider.pt

Ana Sofia Matos is an Assistant Professor at Faculty of Science and Technology, of Universidade NOVA de Lisboa (FCT/UNL) since 2006. Ana Sofia received her PhD degree in Industrial Engineering from FCT/UNL in 2006 and her master degree in Operational Research and System Engineering from Technical University of Lisbon in 1997. She is the Quality Director of Metrovac (Laboratory for Vacuum Technology and Metrology of the Faculty of Science and Technology) since 2002. Ana Sofia is a permanent member of UNIDEMI – R&D Unit in Mechanical and Industrial Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa. Her areas of interest include Quality Management, Statistical Process Control, Metrology, Experimental Design and Taguchi Methods.
Corresponding author. e-mail: asvm@fct.unl.pt

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Disruptive Innovation Absorption Methodology, K³.P.I., Extension of Clayton Christensen Principles for Corporate Leaders and Its Followers

Alex EM Chenevier Founder of Managitech Ltd.
E-mail: alex.chenevier@managitech.com

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Abstract

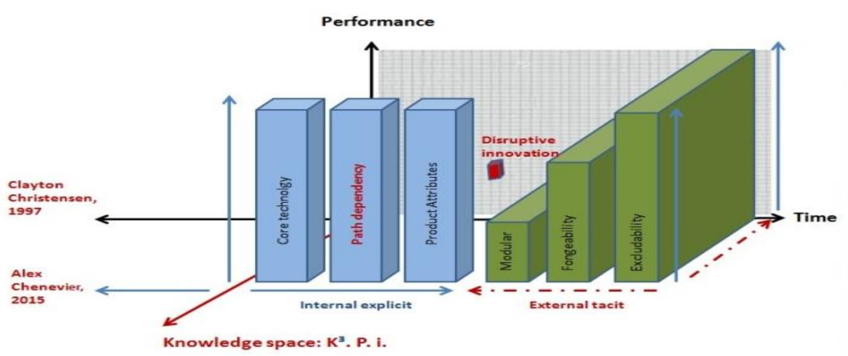

Fig. 1 Disruptive innovation methodology key^3 performance indicator℠

In The Innovator's Dilemma, published in 1997, Clayton Christensen – Harvard Professor – pinpointed the reasons that so many companies fail against the odds. 'In this revolutionary bestseller, Clayton Christensen demonstrates how successful, outstanding companies can do everything "right" and yet still lose their market leadership – or even fail – as new, unexpected competitors rise and take over the market. Why? Because the inner technological capabilities of established organizations have been arguably altered/hold up by board member decisions interpretation hindered by cognitive limitations i.e. decision making heuristics of managers e.g. expertise, experiences, networks, company contract ties build upon efficiency. What is the solution? The solution is to reconcile organizations with their technological potential, legitimately available for disruptive innovation absorption, by providing on a systemic manner a workable diagnosis and absorption framework which is non-judgmental. In this paper, the author introduce its logic incl. knowledge space, path dependency and knowledge fusing, ultimately surfacing a unified model, perhaps for the first time found as definite, quan- tifiable, measurable and therefore applicable in business terms i.e. the scientific equation of K³ey Performance Indicator℠.

Keywords: Innovation, disruptive innovation, innovation systems, absorptive capacity, strategy

1. Introduction

Despite lineage going back to when societies be- gan engaging in barter exchange, business models have only been explicitly catapulted into public conscious- ness during the last decade or so. Driving factors in-clude the emerging knowledge economy, the growth of the Internet and e-commerce, the outsourcing and off shoring of many business activities, and the restructur- ing of the financial services industry around the world (Teece, 2010).

Notwithstanding the legitimacy of these models, aforementioned intertwined factors have been scaling up the world economic machine to new layers of com- plexities. Specifically, organizations strategic crafting is found paired unsatisfactory. Internally, focusing too much on alignment and short term results will satisfy the balance sheet, but changes in the industry will blindside the firm sooner or later. Externally, too much attention to the adaptability side of the equation incl. adequacy and verisimilitude means building tomorrow's business at the expenses of today (Birkinshaw and Gibson, 2004).

This striking insight reveals in part that the conscious process by which information is gathered and used to assist in the decision making at all levels of an organization is technically slower than the pace of progress. The figures are self- explanatory, any one explicit information equals scientifically 300,000 tacit ones incl. anthropology, psychology, sociology, and economics. Further, explicit knowledge is about to double every few years, leaving us with an inexhaustible supply of facts, models, and concepts at our disposal (Morris, 2011).

This article reveals a methodology to articulate efficiently the explicit/tacit relationship into (I) a knowledge space (II) its path dependency and (III) the knowledge fusing (tacit side), ultimately surfacing a unified model, perhaps for the first time found as definite, quantifiable, measurable and therefore applicable in business terms i.e. the scientific equation of K³ey Performance Indicator℠.

1.1 ELIMINATE risk of irrelevant exploration, by seizing your organization definite territory i.e. your company's "knowledge space"

Explicitly, content knowledge is a continuous augmen- tation of the global basket of hard sciences, which has been emulating in all industries incentivized by social purpose along the line of firm history e.g. Dutch Bicy- cle, English sports, Japanese walkman, French Pasteur vaccination,. Explicit information or hard sciences to-date are augmented by tacit fusing i.e. research.

Recently, researchers have been able to disentangle this relationship i.e. explicit/tacit, by establishing a systemic dynamic based on a computation of categorized knowledge i.e. know-what, know-why, and Know-how within a firm. And, it is delivering innovation on a systematic manner. Further, it has also been providing the vehicle for understanding the specific characteristics of the innovation process in any organization (Jensen, M.,B., Johnson, B., Lorenz, E., and Lundvall, B-A, 2007).

The knowledge space provides unrivalled clarity on the technical trajectory's DNA and at the same time legitimate cognitive directions to absorb tacit knowledge.

This pillar research brought a shift in interpretation by opening a company analysis upon three axes, revealing a knowledge space. Indeed, upon the tried adage, "We do not pick up mushroom at the beach". Similarly, the opportunity that a Dutch tulip will be subject to research at Microsoft is highly unlikely. It would again otherwise distract the authenticity of the firm. Therefore, we come up therefore with a structuring factor that is definite, therefore exploitable, upon tractability i.e. company specific cognitive distance.

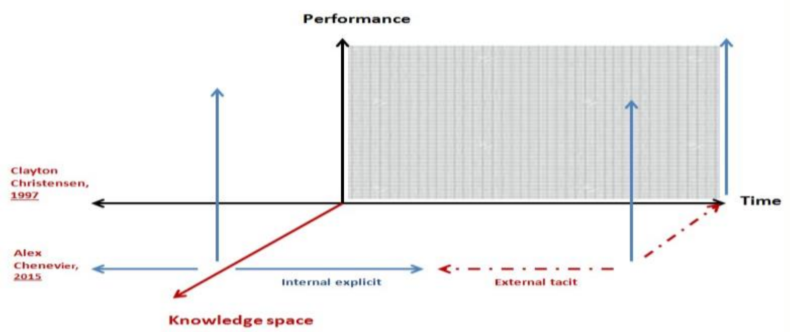

Fig. 2 It seizes the opportunity to compile all organizational rents due to the firm's resources & capabilities i.e. strategic assets, complementarity, scarcity, low tradeability, inimitability, limited substitutability, appropriability, durability.

2. RETREIVE within your knowledge space, your organisation's unique technological expertise, its "path dependency"

2.1 Path Dependency

Arguably, firms, lacking managerial framework, are subject to market failures because of resources based imperfections, differing in and out of the equilibrium as they can't operate in perfect market. This incapacity lies in the inability to captain firm technological trajectory tacit side, albeit available.

Indeed, boards' organizational plurality of expertise, hindered by cognitive limitations of the managers' heuristic decisions attached to their expertise, experiences, networks, cultural misinterpretations, company contract, build upon efficiency and therefore immediate results (Sebastiao, H., 2011), alleviate by essence and practice the future of technological trajectory epistemic knowledge distribution.

Foremost, in the "innovator dilemma" book published in 1997, Dr. Clayton Christensen extracted an economic pattern occurring identified tensions between actors i.e. economic maturity of established organizations vs. opportunistic management of outsiders, due to a new set of values applicable in every industry: disruptive innovation.

Since that inductive record, numerous academics have been building complementary theories, but management practitioners were still left without an axiological foundation.

To confound the existing knowledge space into workable business management blocks, Brian Glassman findings in co-creativity balancing common perspectives (procedural knowledge) and extremes perspectives (indigenous knowledge) brought pillar components to fulfill the knowledge space at right angles, around customer exploration, product boundaries, core technology boundaries, market molding, value proposition and synergy with know-how (Glassman, 2013).

The static knowledge filter highlights core technology and the products attributes. These two blocks are in pair spanning the historical technological trajectory and its today's status i.e. the visible innovation. Its opportunity to make a scientific link is down to the path dependency e.g. unwind continuous accumulation of knowledge.

Indeed, most of Fortune 500 has been encountering along the course of their histories dramatic changes, nevertheless a path dependency remains.

2.2 The nicotine is the path dependency of the ciga- rette industry.

E-cigarettes are battery-powered devices designed to look similar to regular cigarettes incl. the action of inhalation to mimic burning. A battery-powered vapor- izer heats up a cocktail made up of nicotine and a mix of chemicals that is then inhaled by the user. Because they contain nicotine they are unquestionably addictive (K.C. Sokol 2014).

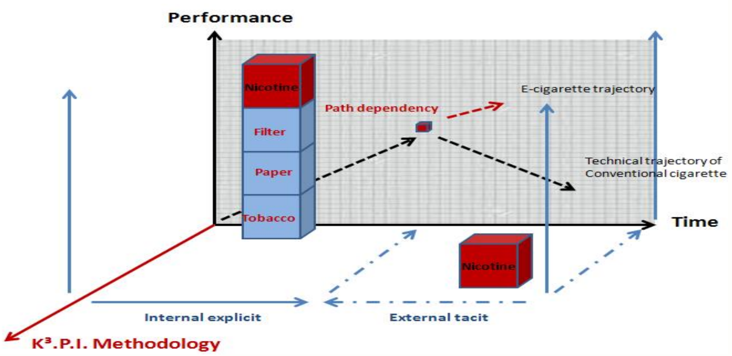

Fig. 3 Once this technical diagnostic is established, it gives us variable rationality i.e. a definite identified plat- form of explicit knowledge legitimately waiting to fuse tacit information on the prospect of absorbing disruptive innovation.

3. The path dependency is the new trajectory defining component of an established organization

In accordance with human nature, its society is perma- nently evolving and its organization alike. In the spe- cific context of profitable organization e.g. corporate, this goal is conditional to an improvement or "aug- mentation" upon the spectrum possibly defined as in- cremental, significant or disruptive. It is applying, in some sort, a novel idea of economic significance upon a justified price, typically allowing an organization to sustain or improve its profitability.

The idea-profitability tension means that an organization is not prepared to learn without safeguarding some degree of innovation certainty. The objective therefore lies in the promise that the knowledge creation will, at some point produces, a tangible result i.e. aligned in an economic significance manner while fusing the incumbent technical trajectory. This alignment is down to the incumbent's technological congruence.

In the context of disruptive innovation we actually observe a shift in the buying behavior, questioning the relevancy of improvement causality. Recently, some argue that disruptive innovation initiated from disrup- tors or outsiders are provoking a dislocation effect to the incumbent (Kandybin, 2015).

So why in the context of disruptive innovation, the incumbent absorptive capabilities do not meet the ap- propriate realities? Because disruptive innovation eco- nomics does not follow a technological congruence but a trajectory transformation.

Technical trajectory transformation or "by-expertise trajectory" means that we need to identify the right mobility among institutional diversity of knowledge (Cowan and Foray, 1995) between the old trajectory and the new one. This is where the path dependency becomes an essential asset that can be found scientifically with the economics of codification.

In this vein, from both theoretical and empirical viewpoints we cannot separate the analysis of knowledge production from the analysis of knowledge distribution. Structural conditions -the knowledge space and its path dependency-, at the same time, constrain human creativity in a recombinant and cumulative self-sustained and path-dependent production of new knowledge and innovation (Consoli and Patrucco 2004).

Indeed, the efficiency is not an intrinsic attributes of the codification of a certain type of knowledge, but is rather the result of the emergent properties of the system under consideration; it is hence a creator of expertise (Cowan, and Foray, 1997), (Hatchuel and Weil, 1995). New knowledge is stochastically determined by old knowledge. The development of intangible capital assets such as knowledge and competences determine the local external conditions and irreversibility of production factors that generate path dependence9, as per the K³.P.I. Methodology.

3.1 ACTIONATE your "path dependency" to ABSORB legitimate tacit information of disruptive nature, in "perfect market" (Amit, R., and Schoemaker, P. J. H., 1993)

Once this technical diagnostic is established it gives us variable rationality i.e. a definite identified platform of explicit knowledge legitimately waiting to fuse tacit information on the prospect of absorbing disruptive innovation, by retrieving on a scientific manner the discrepancies between the historical track of decisions made and vs. the unique technological expertise. New knowledge being scholastically determined by old knowledge, the aforementioned path dependency is the authentic codified knowledge platform for recombination.

To appropriate the asymmetric technological cognitive demand in perfect market, it implies a specific disruptive innovation transformation or process e.g. group of cubes of knowledge, scaling away on the name of modularity, fongeability and excludability i.e. the tacit dimension of the knowledge space.

Upon the non judgmental path dependency or platform of codified knowledge, the sociological science of knowledge provides the mechanical tools to apply a generation-recombinant mode opening ex poste and conditional distribution.

The former applies the incentivized modularity bridging localized blocks of complexity, later broken down in smaller blocks leading to inescapable several or unique disruptive technological stories, opening social purpose compliance i.e. true cultural authenticity of the firm.

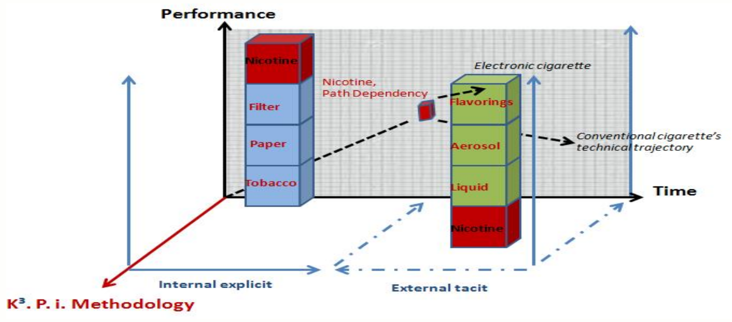

Fig. 4 Retrieved tacit knowledge in the cigarette industry

4. Conclusions

Its appropriation offers the opportunity to Fortune 500 type of companies' long established legitimate authenticity in their respective industries, to mature disruptive models repetitively, opting out from "false" sustainability albeit appearing compliant with estab- lished rules of risk management, repositioning the im- portance of sustaining innovation and inter industry endeavors.

The unified model is advocating the plurality na- ture of the board. Its appropriation offers the oppor- tunity to Fortune 500 type of companies' long estab- lished legitimate authenticity in their respective indus- tries, to mature disruptive models repetitively.

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Alex Chenevier, Founder of Man- agitech Ltd, based in Lyon and London, researcher/teacher & promoter of Inno- vation technology, digital applications, previously sales Director of web 1.0 startup based in Tokyo and Assistant to Vice-Presidents of financial practice at American operational consul- tancy in the City of London. Business Development Coordinator at Alexander Proudfoot, part of mar- ket-listed MCG (Management Consulting Group PLC). In 2009, Alex successfully qualified for a Performance and Change Management Diploma with Open Univer- sity in England. During the course of this master de- gree, the discipline of innovation and the specialty of disruptive innovation were identified for further de- velopment. These were to become the cornerstone of Managitech's rapid growth.

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Applying TRIZ Method and PID Control for Problem Solving in the TFT-LCD Manufacturing Process

Eric Huang[1] and Howard Huang[2]
[1]Department of Mechanical and Aerospace Engineering, University of California at Los Angeles, Los Angeles, CA, USA
[2]Department of Mechanical and Industrial Engineering, University of Illinois at Chicago, Chicago, IL, USA
E-mail: huangeric@ucla.edu
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Abstract

The advent of monitors changed people's lifestyles tremendously. The TFT-LCD has become the most widely used flat-panel display technology. A TFT-LCD consists of two polarization filters with a 90°difference in orientation and liquid crystal placed between them. The liquid crystal changes the light's direction and leads the light through both polarization filters. When voltage is applied to the liquid crystal, the light remains in a constant direction and is therefore blocked by the two filters. Continuous process improvement is essential and manufacturers employ traditional trial and error to search for quick solutions. However, the lack of comprehensive problem definition may cause the same or similar problems to occur repeatedly. This study aimed to identify and resolve issues in the TFT-LCD manufacturing process through a systematic approach. Function analysis is used to identify functional disadvantages: (1) liquid crystal overflows onto the PI and (2) the liquid crystal contains air. Cause–Effect Chains and Contradiction Analysis was then performed to identify engineering contradictions and corresponding parameters, such as (1) "Volume of moving object" and "Manufacturing precision" and (2) "Volume of moving object" and "Extent of automation". After applying the Contradiction matrix, inventive principle, "Partial or excessive action", is suggested. We propose applying the concept of PID control to vary the system output around the desired value and ultimately reach the desired value. Thus, the dispensing pressure accuracy can be enhanced, and the problems of liquid crystal overflow and air bubbles can be eliminated.

Keywords: TRIZ, flat-panel display, PID control

1.0 Background

The advent of monitors changed people's lifestyles tremendously. Dynamic diagrams can deliver complex information more easily than text or static images can. The cathode ray tube, the first monitor revolution, broke the barrier of information exchange. Now that flat-panel displays are available, consumers demand digital products, such as smartphones, laptop computers, and televisions, featuring lighter and thinner monitors. With their higher quality and lower price, flat-panel displays are quickly replacing cathode ray tube monitors and the "second monitor revolution" has begun.

The three most common flat-panel display manufacturing technologies are the plasma display panel (PDP), organic light-emitting diode (OLED), and thin film transistor liquid crystal display (TFT-LCD). A PDP operates similarly to a fluorescent lamp: small cells containing ionized gases are charged and release ultraviolet light to illuminate the screen. An OLED uses as an illuminating film to emit light through indium tin oxide (ITO) and a glass substrate. A TFT-LCD consists of two polarization filters with a 90°difference in orientation and liquid crystal placed between them. The liquid crystal changes the light's direction and leads the light through both polarization filters. When voltage is applied to the liquid crystal, the light remains in a constant direction and is therefore blocked by the two filters. By controlling the voltage, the transmission intensity of each RGB light can be determined. The TFT-LCD is fabricated using mature manufacturing technology and has a relatively low price and no screen burn-in problem; thus, the TFT-LCD has become the most widely used flat-panel display technology.

2.0 TFT-LCD Manufacturing Process

The TFT-LCD manufacturing process comprises an array process and a cell process. In the array process, a glass substrate is first washed to remove harmful particles; the substrate surface is coated with an ITO film through thin film deposition; the substrate is also coated with photoresist and then exposed to UV light under a photomask, which creates the desired shade shape; the area of photoresist exposed to UV light is removed using a developing process; ITO not protected by photoresist is etched away; the remaining photoresist is removed; and the ITO layer with the desired pattern forms. The aforementioned processes are iterated to generate multiple ITO layers. The final substrate array with functional circuits is called a TFT substrate array. The color filter (CF) substrate array consists of RGB color elements. The TFT substrate and the CF substrate are then subjected to the subsequent cell process.

The cell process starts when polyimide (PI) is placed on the substrate: PI is rolled and attached evenly onto the inner sides of both the TFT substrate and CF substrate. Then, the PI rubbing process ensures that the liquid crystal is aligned in the same direction; liquid crystal droplets are dispensed onto the substrate through the one drop filling process; sealant glue on the substrate encloses the liquid crystal; a spacer ensures a uniform gap between the TFT substrate and the CF substrate; and then the two substrates are hot pressed together to form a panel. After a functional inspection, panels are scribed and broken into pieces of the desired size. The final step is to attach polarization filters to both sides of the panel. The assembly drawing for an LCD panel is illustrated in Fig. 1.

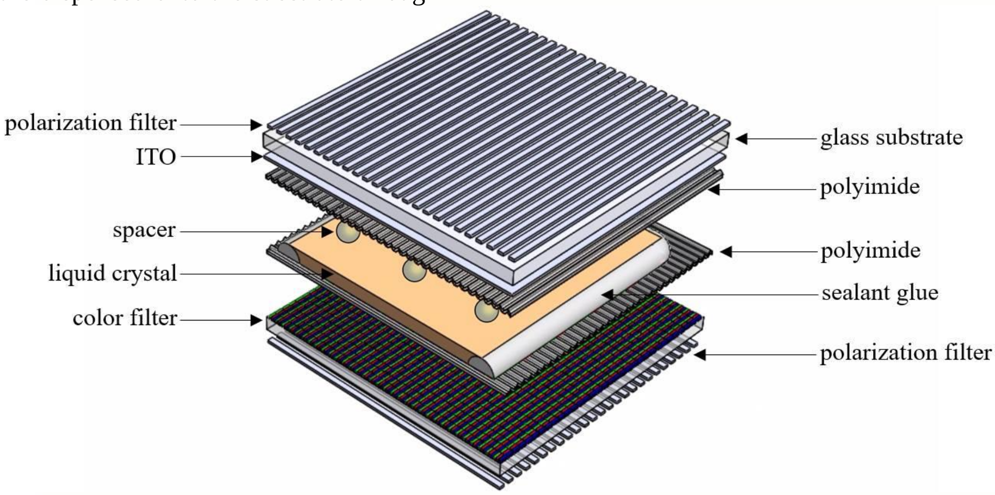


Fig. 1 Exploded View Diagram for LCD panel

3.0 Objective

Manufacturing defects may occur due to inappropriate material properties, improper process parameters, a lack of equipment precision, and an uncontrolled manufacturing environment. Inadequate process yield in TFT-LCD mass production may result in significant profit loss. Chen *et al*. (2016) proposed a real-time intelligent design method for parameter control that involves adding extra modules to a TFT-LCD, because of its high material cost. Continuous process improvement is essential to be competitive in the industry, and manufacturers employ traditional trial and error to search for quick solutions. However, the lack of comprehensive problem definition may cause the same or similar problems to occur repeatedly. This study aimed to identify and resolve issues in the TFT-LCD manufacturing process through a systematic approach.

4.0 Methodology

Many studies have addressed the use of TRIZ for product or process innovation in engineering fields. Sheu and Kuo (2012) integrated the contradiction matrix and inventive principles (CM/IP), the principle of separation, and the 76 standard solutions from substance field analysis to alleviate delamination issues in lead frame packaging of electronic components. Yeh *et al*. (2011) applied four-stage quality function deployment to investigate engineering contradictions and resolved these contradictions through TRIZ CM/IP. An environmentally friendly notebook was thus developed. Huang *et al*. (2015) integrated TRIZ and cluster analysis to develop effective rework processes for underfilled electronic components. Our study explored the TFT-LCD manufacturing process by using the TRIZ methodology to systematically analyze and resolve contradictory problems. The TRIZ tools and how they were applied are discussed in the following sections.

4.1 Function Analysis

Function analysis is used to clarify the functional relationships between components in an engineering system and identify functional disadvantages. The two primary functions of the TFT-LCD manufacturing system are as follows: (1) polarization filters polarize the white light and (2) the liquid crystal rotates the polarized light. First, we identified components of the engineering system and those of the super system. Components in the engineering system are material objects comprising the engineering system, whereas components in the super system are material objects outside of the engineering system but coexisting and/or interacting with its components. In the present case study, the components in the engineering system are polarization filters, the glass substrate, ITO, the CF, PIs, sealant glue, the liquid crystal, and spacers. The components in the super system are white light and air.

Second, an interaction matrix is used to exhibit the interactions (or physical contact) between all components of the engineering system and those of the super system (Table I). The matrix shows the specific functional relationship between components. The useful functions of the engineering system are as follows: (1) polarization filters polarize the white light; (2) ITO controls and aligns the liquid crystal; (3) the liquid crystal rotates the polarized light; (4) an RGB color module filter changes the white light into red, blue, and green light; (5) the spacers separate the PIs; and (6) the glue bonds the PIs. A review of the realistic manufacturing environment indicated two harmful functions as shown in bold: (1) liquid crystal overflows onto the PI and (2) the liquid crystal contains air (Table 1). A graph of function modeling is presented in Fig. 2.

Table 1 Interaction Matrix

From \ To	polarization filter	glass substrate	ITO	color filter	polyimide	sealant glue	liquid crystal	spacer	white light	air
polarization filter		-	-	-	-	-	-	-	polarize	-
glass substrate	support		support	-	-	-	-	-	-	-
ITO	-	-		-	support	-	control	-	-	-
color Filter	support	-	-		support	-	-	-	filter	-
polyimide	-	-	-	-		support	contain/twist	-	-	-
sealant glue	-	-	-	-	bond		contain	-	-	-
liquid crystal	-	-	-	-	**overflow**	-		-	rotate	**contain**
spacer	-	-	-	-	separate	-	-		-	-
white light	-	-	-	-	-	-	-	-		-
air	-	-	-	-	-	-	-	-	-	

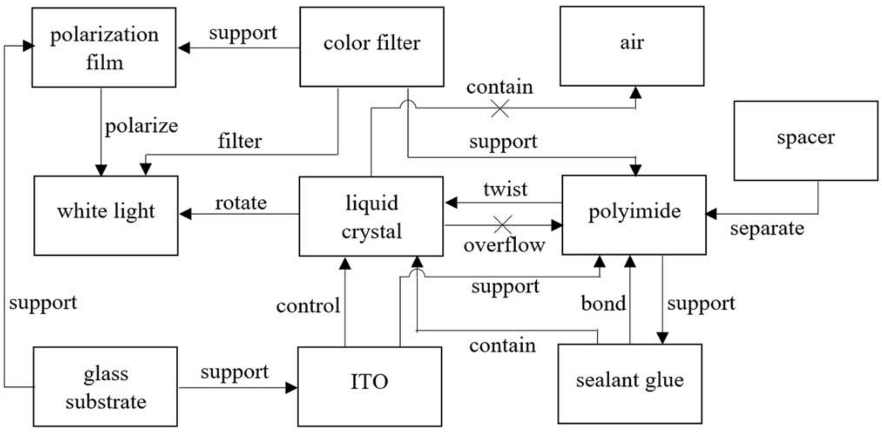


Fig. 2 Function Modeling

4.2 Cause–Effect Chains and Contradiction Analysis

The algorithm for creating a Cause–Effect Chains Analysis model involves first recording the target disadvantage and then determining the cause of the upcoming disadvantage. The step is repeated until the fundamental cause (key disadvantage) is identified. The Boolean values “and”, “or,” and “combine” are used to indicate the logical relationships between causes and effects. In Cause–Effect Chains and Contradiction Analysis (CECCA), the benefit (or what prevents improvement) of the key disadvantage is identified as the engineering contradiction to the target disadvantage. The target disadvantages and the benefit are then related to one (or several) of 39 engineering parameters (Mann 2002), as shown in Fig. 3. The target disadvantages (specific problems) are represented by engineering parameters (generalized problems); for example, the cause of liquid crystal overflow is either excessive liquid crystal injection or insufficient sealant glue—both causes are attributed to inaccurate dispensing. In CECCA, the engineering contradictions “liquid crystal overflow” and “easy manufacturing” relate to engineering parameters #7 [Volume of moving object] and #29 [Manufacturing precision] (and #38 [Extent of automation]), respectively. The presence of air bubbles is another target disadvantage, caused by insufficient liquid crystal injection. This cause is also attributed to inaccurate dispensing. “Presence of air bubbles” and “easy manufacturing” relate to engineering parameters #30 [Object-affected harmful factors] and #29 [Manufacturing precision] (and #38 [Extent of automation]), respectively.

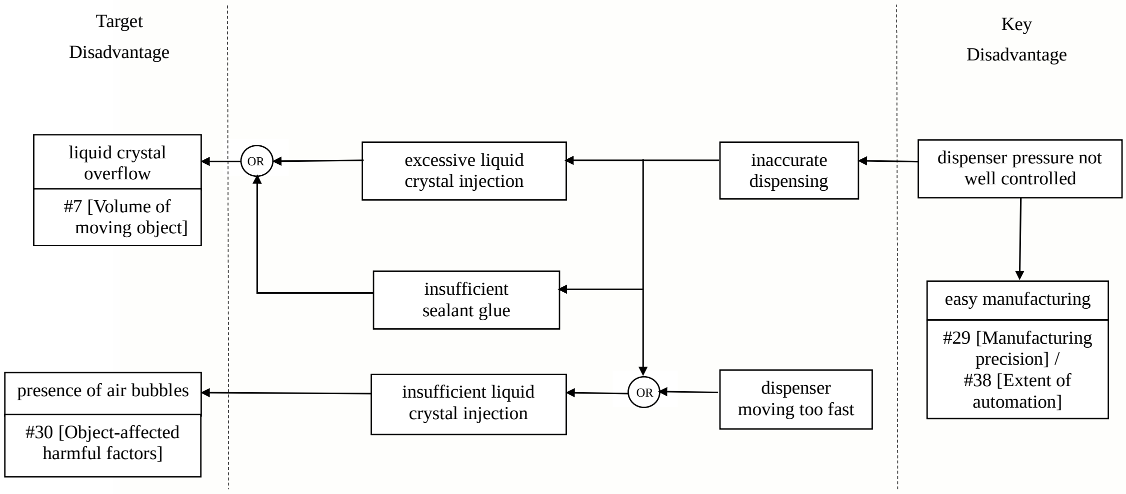


Fig. 3 CECCA

4.3 Contradiction Matrix and Inventive Principles

Altshuller, the inventor of TRIZ, studied engineering problems and their resolution by analyzing thousands of patent documents. He created the contradiction matrix (CM), which recommends inventive principles (generalized solutions) for engineering parameter contradictions. Inventive principles trigger ideas for specific solutions. The engineering parameter contradictions in our case study are shown in Table 2. After applying the CM, inventive principle #16 {Partial or excessive action} is suggested to resolve the engineering contradictions. This inventive principle states that when it is not possible to achieve the desired target, actions that yield values less than or even greater than the desired target can be considered. We propose applying the concept of proportional, integral, and derivative control (PID control) to vary the system output around the desired value (alternately more than and less than the desired value) and ultimately reach the desired value. Thus, the dispensing pressure accuracy can be enhanced, and the problems of liquid crystal overflow and air bubbles can be eliminated.

Table 2 CM and Inventive Principles

Worsen / Improve	#29 [Manufacturing precision]	#38 [Extent of automation]
#7 [Volume of moving object]	2, 16, 25, 28	16, 24, 34, 35
#30 [Object-affected harmful factors]	10, 18, 26, 28	3, 33, 34

5.0 Specific Solution – PID Control

In control theory, system output signal $y(t)$ is desired to follow reference input signal $r(t)$. To address uncertainties in either system identification or disturbances, a feedback controller is used to determine system input $u(t)$ with measured error $e(t)$, as shown in Fig. 4 (Franklin 2014). PID control theory suggests using a controller to calculate real-time $u(t)$ with Eq. (1), as shown in Fig. 5, where positive values K_P, K_I, and K_D represent proportional, integral, and derivative coefficients, respectively.

$$u(t) = K_P e(t) + K_I \int_0^t e(\tau)d\tau + K_D \frac{de(t)}{dt} \quad (1)$$

In our example system, $r(t)$ equals 1. Proportional control (P control) acts as a spring in a mechanical system. As P control is applied, $y(t)$ approaches $r(t)$, as shown in Fig. 6a. Although K_P can be increased so that $y(t)$ reaches $r(t)$ faster, $y(t)$ might overshoot or oscillate at a higher frequency. Therefore, P control combined with derivative control (PD control) is employed as a damping mechanism to smoothen $y(t)$. The example system output with PD control exhibits less oscillation, as shown in Fig. 6b. PID control accounts for past information and ensures that $y(t)$ reaches $r(t)$ eventually. The example system output with PID control reaches 1, as shown in

Fig. 6c. Li *et al*. (2012) maintained a constant temperature in the dispensing process by using a PID control algorithm and an AT89S51 single-chip microcomputer. In our case study, *r(t)* represents a desired constant pressure value in the liquid crystal dispenser. The pressure value should ensure steady liquid crystal dispensing; system input *u(t)* represents the pistol displacement of the liquid crystal dispenser; and *y(t)* represents the sensors value measuring the pressure in the liquid crystal dispenser. With a properly chosen K_P, K_I, and K_D, the controller stabilizes the pressure and therefore provides accurate dispensing.

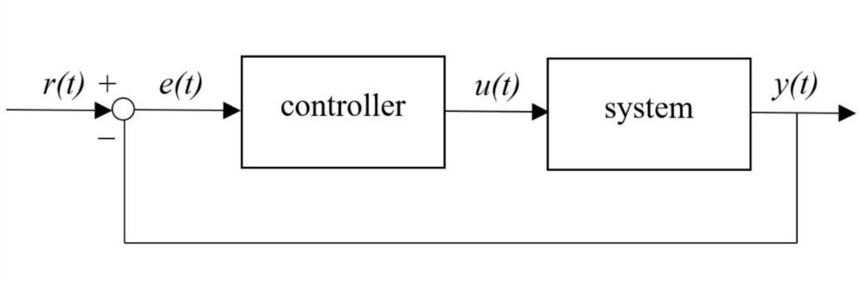


Fig. 4 Block diagram of feedback control theory

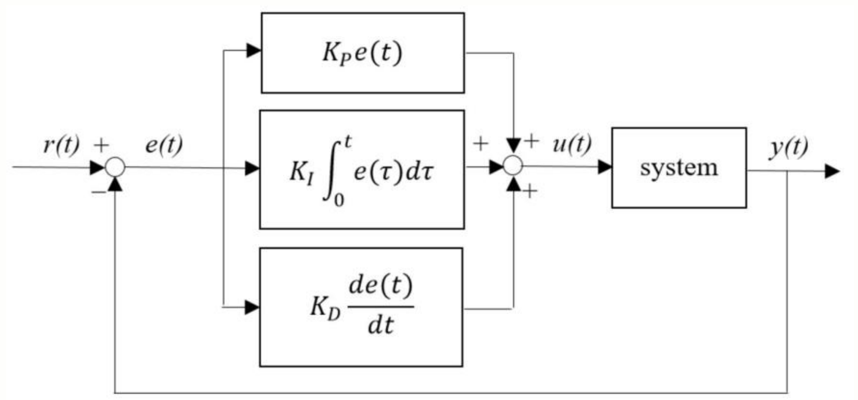
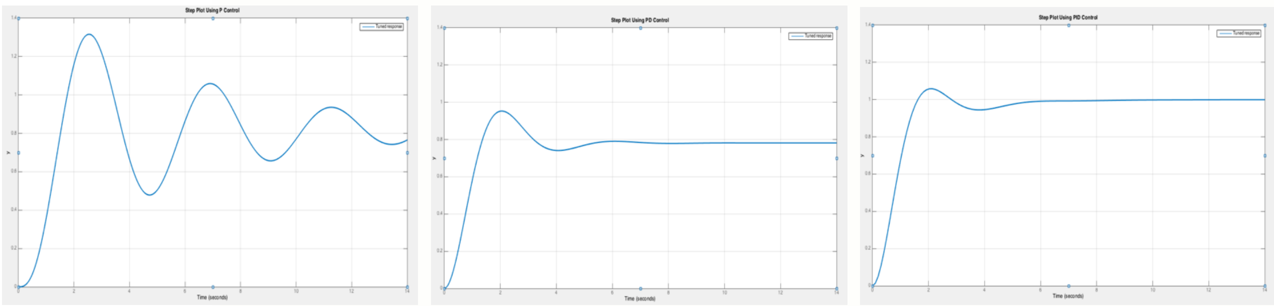


Fig. 5 Block diagram of PID control theory



(a) P control (b) PD control (c) PID control

Fig. 6 Example system outputs

Conclusion

This research improved the TFT-LCD manufacturing process by using the TRIZ systematic innovation process. Functional analysis was first used to identify two harmful functions: (1) the liquid crystal overflows onto the PI and (2) the liquid crystal contains air. CECCA was then performed to identify four engineering contradictions and corresponding parameters: (1) #7 [Volume of moving object] and #29 [Manufacturing precision], (2) #7 [Volume of moving object] and #38 [Extent of automation], (3) #30 [Object-affected harmful factors] and #29 [Manufacturing precision], and (4) #30 [Object-affected harmful factors] and #38 [Extent of automation]. Finally, considering inventive principle #16 {Partial or excessive action} suggested by the CM as a trigger solution, we employed PID control theory as a specific solution. PID control was applied to a liquid crystal dispenser to improve pressure control and thus achieve an accurate volume of liquid crystal. For future research, constant values of K_P, K_I, and K_D can be studied to enhance liquid crystal dispenser performance; for example, stability can be improved with a minimum lead time.

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Author Biographies

Eric Huang receives the M.S. degree from the Department of Mechanical and Aerospace Engineering at University of California, Los Angeles (UCLA) in 2017. He is interested in Control of Linear Dynamic System, Stochastic Dynamic System, Digital Control, Optimal Control, Robotics, Optimization, Applied Mechanics, and Mechanical Design.

Howard Huang is currently a graduate student perusing master degree of Mechanical Engineering in the University of Illinois at Chicago (UIC). He specialized in Kinematics of Machines, Mechanism Design and Applications, Computer Mechanical Graphics, and Computer Aided Manufacturing. He is also involved in research projects in the areas of Mechatronics, Solid Mechanics and Automation Engineering.

Resource Identification Method Based on Demand-Supply Thought Provoking Questions for Problem Solving

D. Daniel Sheu[1], Jealousy Hong[2]
National Tsing Hua University, Dept. of Industrial Engineering and Engineering Management
E-mails: dsheu@ie.nthu.edu.tw[1]; hong.jealousy@steam.ie.nthu.edu.tw[2]
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Abstract

The concept of resources in the TRIZ (Theory of Inventive Problem Solving) is that the problem solving tool for users to make the most use of existing free resources to solve problems with zero or near zero cost. Even though resources are one of the most powerful concepts among the TRIZ tools, there have been few systematic methods to identify resources for problem solving.

This paper proposes a set of systematic resource identification method using Function-Effect-Resource Checking with Thought-provoking Questions to locate available resources to solve a problem. These resource identification methods can review all the resources surrounding the system or super-system and use knowledge database to find the useful effects systematically and effectively, and also used to save cost while solving problems. Using the resource identification methods, a case, a vacuum device mechanism was developed to solve wafer breakage problem in chemical-mechanical polisher. The resource identification method can also be incorporated into any problem-solving approach to solve problems with minimum cost.

The contributions of this paper include: 1) Providing a set of systematic resource identification methods to solve problem with minimum extra cost, 2) Solving a wafer breakage problem in chemical-mechanical polishing process using the proposed resource-based problem-solving method with substantial cost savings to a company.

Keywords: TRIZ, Resource identification, Polisher, Vacuum Device, Resources-Oriented Solution Search

1. Introduction

1.1 Background and Overview

In traditional problem solving, in great majority of times, solutions were achieved by introducing new resources to solve the problems. There are two major deficiencies involved with traditional problem-solving using resources: 1) Users often use additional resources without taking advantage of existing resources around the system or replace defective components with good ones for solving the problems. This will need additional costs; 2) Most of the ways to identify resources were based on brain-storming type of random innovation. No systematic and effective ways to identify resources for usage. The purpose of this paper is to present a systematic resource identification method to identify useful resources to solve problems with minimum costs.

This paper also presented a real world example of semiconductor equipment wafer breakage avoidance by using systematic resources-based problem solving process proposed. The method was able to solve the wafer breakage problem by using an existing component to convert the original otherwise harmful centrifugal force into useful resource to avoid the wafer breakage during the semiconductor polishing process. This method can also be used for problem solving in other applications.

1.2 Literature Review

TRIZ is the Russian acronym of "The Theory of Inventive Problem Solving". It has been known as one of the most effective set of problem solving tools to solve difficult engineering problems. It was developed by Genrich Altshuller.

The concept of resources constitutes one of major fundamental philosophies of TRIZ which implies using existing resources to its maximum to either minimize cost of problem solving or converting harmful things into useful things.

Resources were things, information, energy, or properties of the materials that were already in or near the environment of the problem (Kalevi and Domb, 2002). In TRIZ resource analysis, six types of resources usually are identified: substances, fields, space, time, informational, and functional resources (Martin, 2005). So, Resources is one of the five most important key concepts which constitute fundamental TRIZ philosophies (Mann, 2007).

The concept of Resources was noted early in Algorithm for Inventive Problem Solving (ARIZ), Part 2 Analysis of Resources. It provides survey of the resources that can be used to identify physical contradictions. This is a key step in the ARIZ 85B processes (Altshuller, 1999).

Zlotin and Zusman (2005) identified six types of resources as follows:

- Substance Resources: Any substance (including waste) available in the system or its environment.
- Field (Energy) Resources: Any energy reserve.
- Functional Resources: The ability to jointly perform additional functions.
- Space Resources: Unoccupied space.
- Time Resources: Free time.
- Informational Resources: Information.

The importance and types of resources have been well explained and identified as stated above. However, on the issue of how to practically identify resources for usage, there has not been systematic, elegant, and practical way to be proposed. Mann (2007) did propose resource trigger lists and segmented it into the following major categories:

- Resources in the Environment
- Low-Cost /Plentiful Resources
- Material Resources
- Special Properties/Modifications of Resources
- Manufacture Process Type Resources
- Resources Associated With Humans

He suggested to use the above resource trigger list and the following questions to identify resources: “if system has components as useful resources?” and “how to transfer from harmful resources to useful resources in system?”, the answers were the strategies of resources identification. However, going through the above 6 categories of resources will be very laborious and time consuming as majority of the listed resources are not around the problem system and there are too many irrelevant attributes listed.

The identification of resources in Part 2 of ARIZ (version 85) using substance, parameters, and fields around a problematic system and searching from inside out in space and time dimensions is a good way to search for resources. However, this method in ARIZ is designed to search physical contradictions instead of resources for problem-solving. Introduction of parameters and fields is good for identification of physical contradictions but often adds complexity to identifying resources for problem solving.

A systematic innovation process (SIP) integrated the full phases of systematic innovation processes providing a structured process to enable companies to systematically identify business opportunities and key problems, solve problems, and leverage developed tools/products/technologies for cross-industry exploitations (Sheu, 2007 and Sheu, 2011). The Resource of SIP was to help to locate existing resources without additional cost and to turn harm into help.

TRIZ-CBR synergy provided a resource oriented search to make use of several TRIZ concepts, the relevance of available resource in a technical system as vector to drive problem solving activities and to transfer knowledge is emphasized (Guillermo, 2009).

2. Methodology

Section 2.1 explains the underling concepts for Resource Identification method. Section 2.2 explains the resource oriented solution process.

2.1 Resources Identification Method

The idea is to use any kind of resources existing around the system effectively to achieve the functions we want.

Two major modes of resource usage are turning wasted resources to wonderful usage (Waste-to-Wonderful, W2W) or turning harmful resources to helpful resources (Harm-to-Help, H2H). The authors suggest the term, W2W, as identifying something which has not being used for the intended purpose, for example problem solving in this context, and use it with zero or minimum costs. The term, H2H, refers to identifying any harmful resource and use it to our advantage. In the TRIZ environment, a resource can be any substance, field(energy), function, attribute, space, time, information, or even vacuum, void, or "nothing" which can be used toward some purpose.

The method proposed in this paper is based on function-effect-resource checking with thought-provoking questions to check and match either the direct functions or indirect functions (needed attributes to be changed or maintained) in Demand Side, and problem system's surrounding substance or field in Supply Side. Even though for simplicity, intrinsic resources such as space, time, information, vacuum, attributes, etc. are not explicitly listed, they are considered when checking against their function/attribute carrying components/substances. The systematic resources finding can help users to identify the free resources to solve problems and to achieve the needed functions quickly and effectively.

The research provides Function-Effect-Resource Checking with Thought-provoking Questions to match the Demand Side and Supply Side. The resource matching model is depicted in Figure 1.

Demand Side

There are two channels of matching on the demand side, namely Function channel and Effect Channel. The Function Channel matches the needed function (Direct Function) or needed attribute change/maintaining (Indirect Function) to solve the problem with the surrounding components/substances on the Supply Side. If any of the components/substance on the supply side can provide the needed function/attribute change, a solution idea can be obtained. The Effect Channel matches the capable Effects which can solve the current problem with the surrounding components/substances on the Supply Side. If any of the components/substances from supply side can provide such effect, a solution idea is obtained. Notice that the "capable Effects" are derived from the needed function/attribute change using Function-Effect database or Attribute-effect database. However, to reduce the search space on the capable effects, the method propose to preliminarily considering the problem surrounding and screen out those effects that are not likely present around the system. This preliminary screening is not required but strongly recommended to reduce the time needed for search.

The following part is Effect List. Users could use generic attributes and functions to search effects from some main knowledge databases. Those knowledge databases includes physical, chemical and biological effects.

Supply Side

The supply Side is to review all the resources as Resource List. The users need to check all the resources as components/substances within its super-system one by one. The super-system refers to the components and systems surrounding the subject system in space and time domain.

Mapping Process

Finishing the Demand Side and Supply Side lists, the users then use the Thought-provoking Resource Questions to ask each resource one by one as below:

- How to make the Resource to provide the needed Function? Check for needed Specific Function and Generic Function.
- How to make the Resource to perform the subject Effect? Check for preliminary filtered effects.
- How to make the Resource to provide needed Attribute Change? Check for identified needed attribute changes for both industry specific or generic attributes if they are different.

Notice that only substance components/ systems are listed as resources on the supply side to check against. When asking how the subject resource can provide the needed function/effect/attribute changes, all the fields, parameters, functions associated with this resources can be considered. They are free to be modified to achieve the problem solving goal. Because any field, parameter, function, space, time, or even information often are associated with certain substance/component/system, hereafter referred to as "core component". Consideration from the core components can make the thinking process more structured without losing sight on the corresponding parameters, fields, etc. If any of the above mentioned through-provoking questions identified a resource that can provide the needed function/effect/attribute changes, some solution ideas are located.

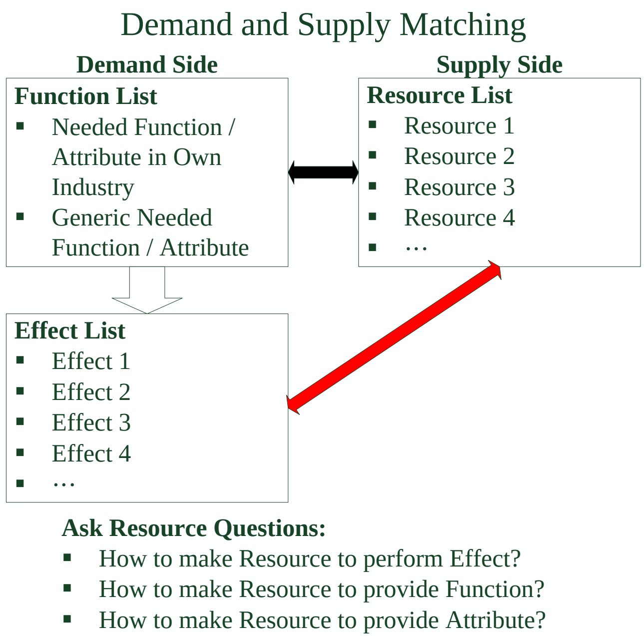

Figure 1. Resource Matching Model

2.2 The Resource Oriented Solution Process

The resource oriented solution process is to achieve the needed functions/attribute/effect using existing resources surrounding the system. It could also be combined with other TRIZ tools and find solutions for problem solving without needing extra resources.

The solution process of this research are illustrated in Figure 2 and its tasks are described below:

Step 1: Identifying problems. Function Analysis (FA) tool is used to identify problem points and locate needed functions to solve the problem. The main purpose of Function

Analysis is to locate disadvantages in the system and identify related components involved.

Step 2: Identify key problems. Even though FA can be used to identify multiple problems and any problem point can be used as the point-of-attack to solve problem, it is highly desirable to identify the key problems for point-of-attack instead of any problem. Solving problem at key disadvantages has many benefits. The point-of-attack is more focused thus affecting less areas in the system while achieving higher impact on the system and presumably use less resources. Cause Effect Contradiction Chain Analysis (CECCA) can be used to find the key disadvantages and contradictions in the problem. CECCA is an enhanced version over CECA (Cause Effect Chain) (Abramov, 2015) and RCA^+ (Root Conflict $Analysis^+$) (Souchkov, etc., 2006/2007) in that it explicitly provides contradictory parameters for problem solving. (Sheu, 2015). In this step, we derived from the target disadvantage on the surface to the key disadvantage at the root causes. Table 1 compares the advantages and disadvantages among CECA, RCA+, and CECCA.

Step 3: List all available resources within and around problem system. Similar to those resource identification steps in ARIZ, the scope of resource list can be from within the Operation Zone (OZ) to within the problem system to its super-system. It is shown in Table 2. Note that the Operating time (OT) is just to indicate when the problem occur and the resources considered should include those resources exist before during and after the operation time.

Step 4: Identify needed Specific Function, Generic Function, Effects, and Attrbute Changes to solve the selected key problem. First, the specific function(s) needed to solve the problem are identified. Then, the specific functions are converted into corresponding Generic Function(s) which, in turn, is used to identify possible Effects which can provide the needed function(s) or attribute changes using Effect database such as Oxfordcretivity or Goldfire software.

Step 5: Identify Resources to generate solution ideas: In this steps any or all of the three tracks of solution generating can be used. It includes Checking against each resource by asking 1) function-based thought-provoking question, 2) effect-based thought-provoking questions, and/or 3) attribute-based thought-provoking question.

The Thought-provoking questions used are:

1) (Function-based): How to make the subject resource to provide the Specific Function/Generic Function?

2) (Effect-based): How to make subject resource to perform the Effect? Going through the listed probable effects one by one.

3) (Attribute-based): How to make the subject resource to provide the needed attribute change?

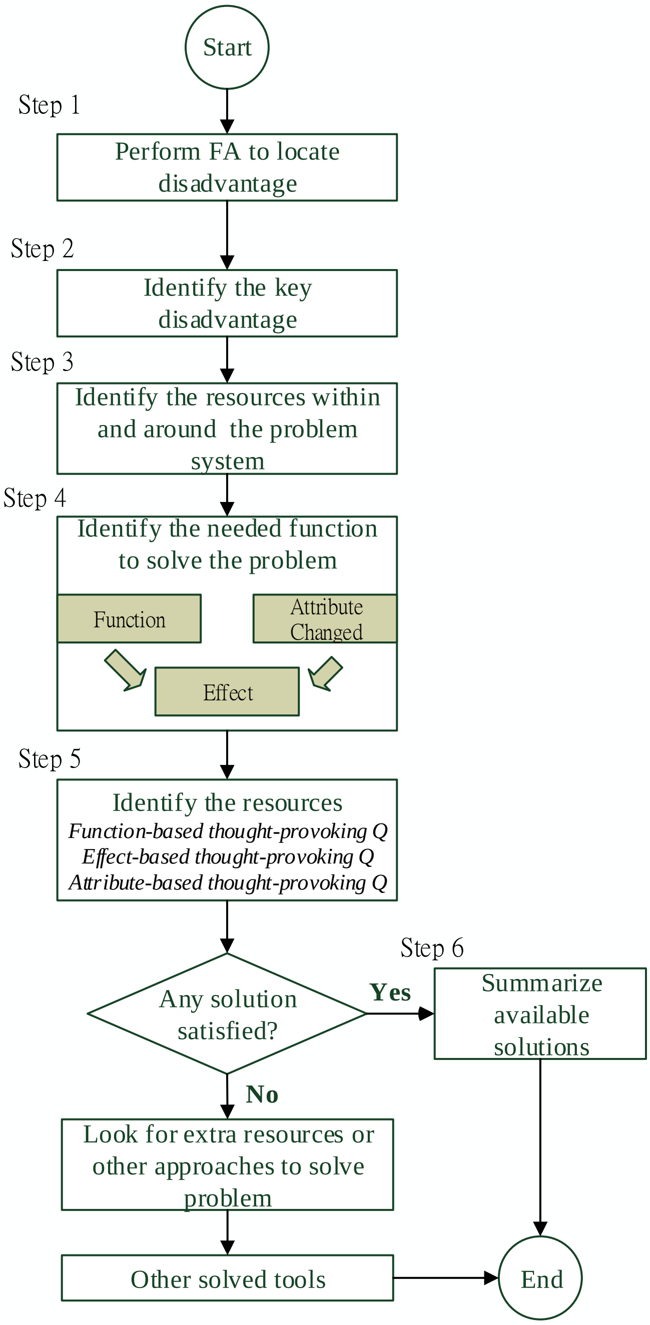

Figure 2. Resource Oriented Solution Process

Table 1. Comparisons on CECA, RCA+, and CECCA

	CECA	RCA$^+$	CECCA
Advantages	• Linkages among causes are well presented. • Root causes can be identified.	• Linkages among causes are well presented. • Root causes can be identified. • Contradictions can be identified.	• Linkages among causes are well presented. • Root causes can be identified. • Contradictions can be identified. • Specific contradictory parameters are identified. • Opportunity to breakdown into finer causes when assigning representative parameters for each disadvantage.
Disadvantages	• Unable to identify contradictions. • No representation of parameters.	• Specific contradictory parameter are not presented.	• None of the disadvantages in the left methods is present.

Table 2. Resources Searching Table (1)

Resources Searching Table (1)	
OZ(Operation Zone)**:**	**OT(**Operation Time)**:**
System:	
Resource List	
	Substances/Components
w/i OZ (Operation Zone)	
w/i System	
Super system	

If any of the above-mentioned thought-provoking questions can stimulate a solution idea, the subject resource can be used to solve the problem. Modification over the subject resource is allowed and may be needed.

Table 3 was designed to facilitate this Resource Searching process. The "Resource" column in Table 3 is to list the subject resource under consideration available from Table 2 one by one. The "Resource Question" column is to fill in the specific resource questions which can help us identify some solution ideas. The "Methods" column is to fill in the specific idea(s) that is thus conceived. The "Remarks" column is to fill in any remark or provide any pointer to specific diagrams, if any, which may be needed to explain the ideas better. This explains the overall process in Figure 1 in greater details.

Step 6: Summarize available solutions. The above steps analyze all the functions, attributes, and effects, by asking Resource Questions from the first resource to the last resource. Finally, we summarize, and possibly integrate, all possible solutions to generate a set of most suitable solution(s).

If the no satisfactory solution is found by using existing resources, the problem solver may need to identify extra resources and use other tools to solve the problem which is not the scope of this paper.

Table 3. Resources Searching Table (2)

Resources Searching Table(2)			
Needed Function:			
Needed Effect:			
Needed Attribute change:			
Resource Q.	How to make Subject Resource to perform the Effect?		
	How to make Subject Resource to provide Specific Function/Generic Function?		
	How to make Subject Resource to provide the needed Attribute change?		
Resource	**Resource Question**	**Methods**	**Remarks**

4. Case Study

The study shows successful usage of resource oriented solution process to solve the wafer breakage during polishing process in semiconductor industry, and the problem solving process is as below.

The purpose of polisher is to polish wafer to customer specifications. It's divided into fine polishing and rough polishing. The operation is to produce necessary thickness and surface flatness of the wafer and remove the defects such as abrasion, smudges, and pit from the prior processes. Total Thickness Variation (TTV) is commonly used for flatness measure. The side view of physical equipment that does polishing work schematized as Figure 4.

4.1 The Resource Oriented Solution Process for Problem Solving

Step 1: Identifying problems. The problem system of this case is polishing, and the main function is "Pad polishes Wafer". "Pad" is the main tool, "polish" is the main function, and "wafer" is the object. The components and functions are illustrated as Figure 5. In Figure 5, functional disadvantages are the "X" sign and dotted line, and are represented missing useful functions. To be aimed at functional disadvantages, the space between the pad and the wafer would have the momentary force for sucking the wafer during polishing. In polishing process, pad also abrades template, it would cause the template to be unable to have enough force to hold the wafer. Besides, slurry also could enter the space between the template and wafer, and that causes the template to loosen wafer in the middle of the polishing.

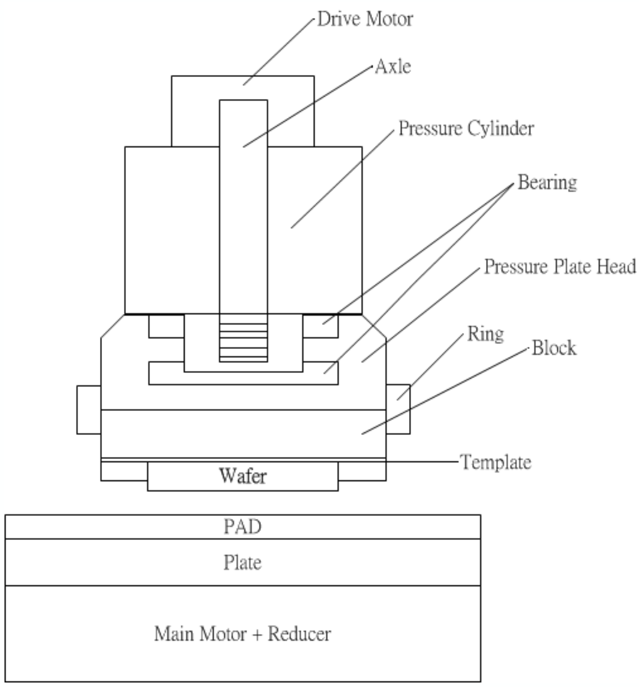

Figure 3. Side view of Polisher (Single Block)

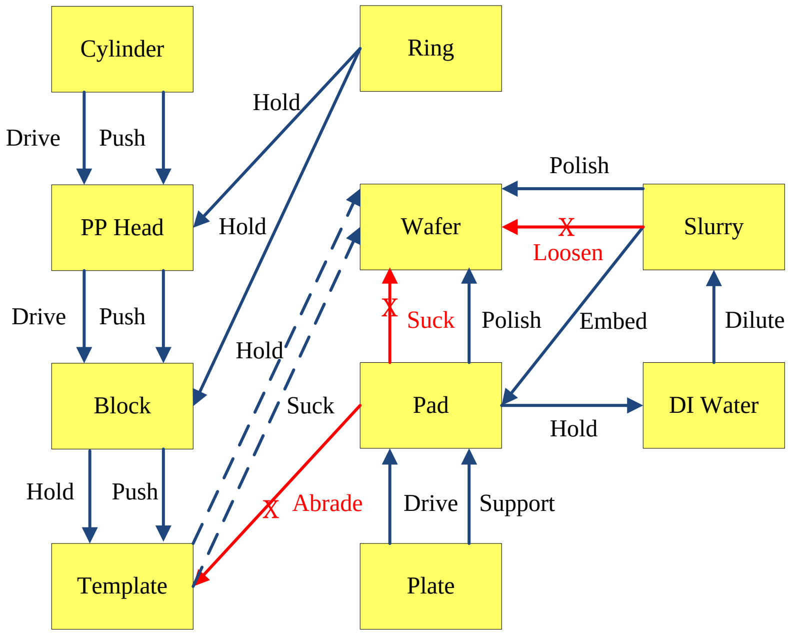

Figure 4. Functional Model of Wafer Breakage

Step 2: Identify key problem. In step 1, we identify multiple problems to understand the wafer breakage. In step 2, the research uses CECCA to identify that "the slurry and air would enter the space between template and wafer", it is a key problem. We need to think about one way to suck wafer without adding other equipment or components. Because there were three disadvantages to use additional tools. First, it needs to drill a hole as a center line for using pump to generate a suction force. To redesign the polisher structure would be more expensive. Second, many parts along the central line would have gaps, it needs more energy to produce vacuum. And third, vacuum leakage would happen between the moving parts. The solution would spend much higher costs (Sheu and Hong, 2012).

Step 3: List all available resources within and around problem system. The identification of resources starts from the operation zone to super system. Based on Figure 5, the components within operation zone are Wafer and Template, the components within system are PP Head, Block, Ring and Pad. Finally, the components within super-system are Slurry, DI Water and Air. These are illustrated in Table 4.

Step 4: Identify needed specific function, generic function, Effects, and Attribute changes to solve the selected key problem. "Slurry or air enters the space between the template and wafer causes not enough suction force for template to suck wafer" is the key problem of the case, and needed generic functions are "Move/Remove Liquid" or "Move/Remove Air". The study uses these key words to search useful effects in Oxford Effect Database. Oxford Effect Database mixes effects and applications, we need to filter the effects from these solutions. After searching, we could find that "Move Liquid" has 202 effects or resources, "Move Gas" has 132 items, "Remove Liquid" has 108 items, and "Remove Gas" has 67 items. And then, we use "Increase Force" to search in Oxford Effect Database, there are 149 items. With much effects and applications, we need one by one to identify the useful effects which could help to generate the possible solutions. Finally, there are twelve effects that can be used to develop the specific solutions, which are listed in Table 5.

Step 5: Resources generation by searching available effects. Figure 5 presents the concept of resources matching of this case. We use Thought-provoking Question to ask all the resources how to perform these effects. Finally, the study finds "Centrifugal Force" would be most possible to develop the specific solution and the resources searching results are shown in Table 6. During polishing process, wafer, template, PP head, block, ring and pad etc. all components would rotate/turn. Rotation would bring "Centrifugal Force". We could use centrifugal force to bring "Vacuum Suction" to remove the slurry or air between the wafer and template. The solution does not need any extra resource, and it could transfer "useless" resource to "useful" resource.

"Centrifugal Force" would be as the trigger effect solution to develop "Drill a vacuum line" as a specific solution. Wafer is the target, we could not drill a vacuum line in the wafer. Template is closest to the wafer, but it is too thin to drill a vacuum line. Pad and Block are the second components close to the wafer, but pad couldn't touch the slurry or air which are between the wafer and template. Block is thick and can be drilled a channels or lines in the body, it is most possible to use this idea.

Step 6: Summarize available solutions. Based on the foregoing thinking, the solution is to drill holes in the template and channels in the block. Centrifugal force could exhaust the air or slurry during the rotation for producing suction force to hold the wafer. In order to make sure the idea to be successful, we use this thinking to do a REAL experiment on the REAL polish equipment.

4.2 Experiment Design

In Figure 6, the prototype shows the side-view of the block. The coarse black lines are represented the channels. A block has four main channels, the length of the main channel is 12cm and diameter is 0.8cm. An oblique coarse black line represents a sub-channel, each main channel has two sub-channels. The sub-channel helps to enhance the ability to exhaust the slurry and air. The dotted oval line is shown as a side-view of template. The connection of main channel and sub-channel would be narrow, and Bernoulli's Law would be used to enhance vacuum suction. Figure 7 presents the idea. In order to avoid the backflow of air and water in the non-vacuum status while wafer begins to polish, it is necessary to add the one-way check valve on the outside of a main channel. Figure 8 is a picture of a real block and the circle mark represents location for drilling.

The idea was used in the case company and was proved to successfully reduce the wafer breakage. Originally, the frequency of wafer breakage for the case company was 30~40 times/month, and now has reduced to almost 0 times with this improved block. Further, a polish could save 18K USD/year for using this improvement. A patent has been applied to the improved block design.

Table 4. Resources Searching Table(1) for Study Case

Resources Searching Table(1)	
OZ(Operation Zone)**:** Wafer and Template area	**OT(**Operation Time)**:** During polishing
System: Pressure Plate Head assembly(PP Head, Block, Ring), Pad	
Resource List	
	Substance/Components
w/i OZ(Operation Zone)	Wafer, Template
w/i System	PP Head, Block, Ring, Pad
Super system	Slurry, DI Water, Air

Table 5. The most possible trigger effects of Move/Remove Liquid or Gas

Adsorption	Bernoulli Effect	Capillary Action	Centrifugal Force
Convection	Cyclone Separation	Diffusion	Freeze Drying
Gravitation	Pressure Gradient	Sorption	Vacuum Suction

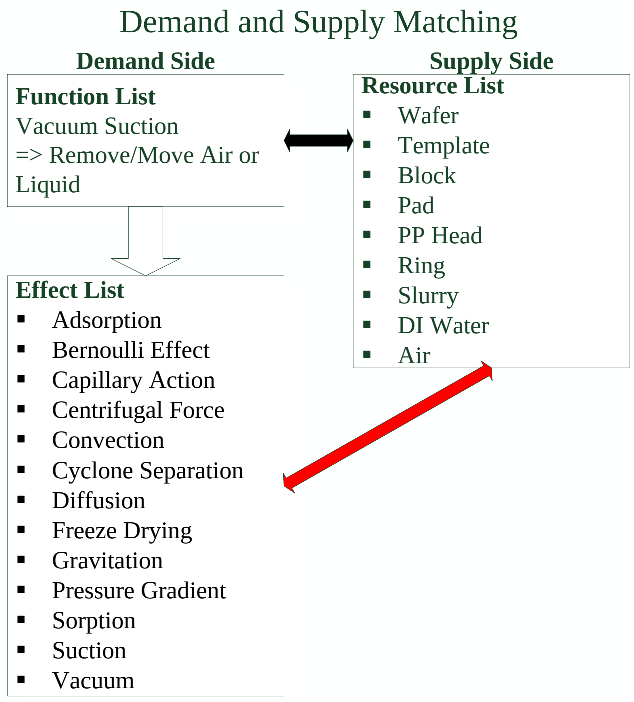

Figure 5. Matching Function/Effect and Resources for Study Case

Table 6. Resources Searching Table (2) for Study Case

Resources Searching Table(2)			
Needed Function/Attribute: Remove/Move Air or Liquid			
Needed Effect: Centrifugal Force/ Vacuum Suction			
Needed Attributes change: Increase Force/			
Resource Question	How to make Subject Resource to perform the Effect?		
	How to make Subject Resource to provide Specific Function/Generic Function?		
	How to make Subject Resource to provide the needed Attribute change?		
Resource	**Resource Question**	**Methods**	**Remarks**
Wafer	• How to make **Wafer** perform **Centrifugal Force**? • How to make **Wafer** provide **Vacuum**? **Suction**? • How to make **Wafer** provide **Force Increased**?	Turing Rotating	Can’t change target.
Template	• How to make **Template** perform **Centrifugal Force**?	Turing	Template is too thin

	• How to make **Template** provide **Vacuum Suction**? • How to make **Template** provide **Force Increased**?	Rotating	to generate vacuum.
Block	• How to make **Block** perform **Centrifugal Force**? • How to make **Block** provide **Vacuum Suction**? • How to make **Block** provide **Force Increased**?	Turing Rotating	Centrifugal Force: Make channels.
Pad	• How to make **Pad** perform **Centrifugal Force**? • How to make **Pad** provide **Vacuum Suction**? • How to make **Pad** provide **Force Increased**?	Turing Rotating	Pad couldn't touch the slurry or air which are between wafer and template
…	…	…	…

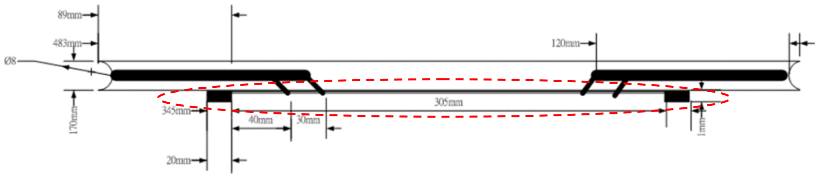

Figure 6. The Sketch for Drilling of Block.

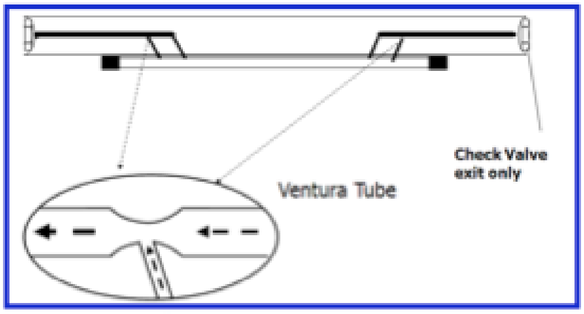

Figure 7. Using Bernoulli's Law to Enhance Suction

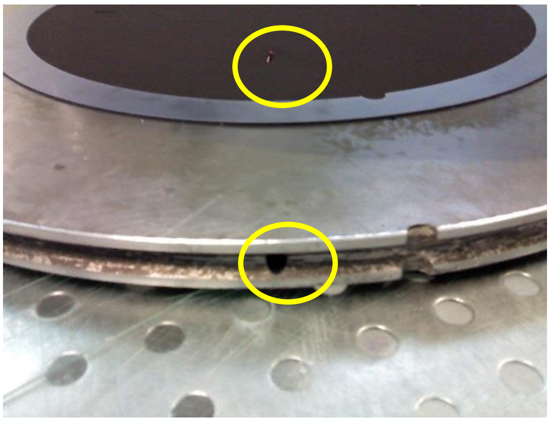

Figure 8. The Drilling Channel of Real Block

5. Conclusions

This study provides a set of systematic resource identification method based on demand-supply thought provoking questions for problem solving. In this solution process, resource is not only a solution generation tool, but also help users to use resource oriented search for solving problems without any extra resources and low cost to generate trigger solutions. Most systematic solutions use "Add" or "Exchange" to think about the resources usage, but resource oriented solution process uses the "Existing" resources to achieve the same function for problem solving. In the cost-oriented and high-complex-equipment industries, it can come up with great benefit, and also systematically raise the quality and quantity of patents systematically to help patent circumvention for increasing company competitive edge.

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AUTHOR BIOGRAPHY

Sheu, Dongliang Daniel is a Professor at National Tsing Hua University in Taiwan since 1996. Before then, he has 9 years of industrial experience in the electronic industries with Hewlett-Packard, Motorola, and Matsushita. Daniel received his Ph.D. degree in engineering from UCLA and MBA degree from Kellogg Graduate School of Management at Northwestern University. He also holds a B.S.M.E. degree from National Taiwan University and an M.S.M.E. degree from State University of New York at Buffalo. He is currently the President of International Society of Innovation Methods, Editor-in-chief of the International Journal of Systematic Innovation, and the Area Editor of Computers and Industrial Engineering, an SCI index International journal. His areas of interests include Innovation Methods. Design & Manufacturing Management, Equipment Management, and Factory Diagnosis.

Hong, Jealousy is a Ph.D. Candidate at Innovation Engineering & Management Laboratory, Dept. of Industrial Engineering and Engineering Management, National Tsing Hua University, Taiwan, R.O.C. His research interests include TRIZ, Equipment Management, and Statistics.

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