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ABOUT THE USE OF TRIZ FOR PRODUCT-SERVICE DEVELOPMENT

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ABSTRACT
The aim of this paper is to understand how the Theory of Inventor's Problem Solving (TRIZ) may be applied in the development of product-service combinations. The authors have analyzed TRIZ modules and tools under a PSS (Product Service System) perspective to extract some principles of particular interest for their development. Basing on the outcomes of such investigation, the authors propose a framework for the use of TRIZ-based tools in product-service design.

Keywords: Product-Service Systems, TRIZ

1. INTRODUCTION
A Product Service System (PSS) [1-2] can be defined as "an innovation strategy, shifting the business focus from designing (and selling) physical products only, to design (and sell) a system of products and services which are jointly capable of fulfilling specific client demands" [3].
PSSs are contracted on the characteristic to provide 'functions per unit' rather than merely hardware. In the aeronautical domain, it can be the case of providing *power by the hour* or *trust on wings*, instead of selling a jet engine. Car sharing, car-pooling [4] and leasing of baby prams [5] represent other examples of product-service combinations.
PSS means that the customer pays for using an asset, rather than its purchase, and so benefits from a restructuring of the risks, responsibilities, and costs traditionally associated with ownership [6].
Similarly, the supplier/manufacturer can improve its competitiveness as these solutions may be clearly differentiated from product-based offerings while simultaneously retaining asset ownership that can enhance utilization, reliability, design, and protection [6].
Although the PSS paradigm potential is widely recognized, its uptake in industry appears limited. PSS experts highlight that, although a lot of work has been done in this domain, in-depth and rigorous research is needed to develop models, methods, and theories [6-7].

2. MOTIVATION AND SCOPE
The concept of a Product-Service System (PSS) is typically considered a special case of servitization, a market proposition that extends the traditional functionality of a product by incorporating additional services [6].
However, the development of effective product-service combinations represents more than a simple bolting-on of services into the products [8]. Sharing, pooling or leasing not necessarily mean providing users of suitable PSS combinations, as the service aspects are often managed in isolation.
A great effort has to be done to rethink the "hard" part of design when conceiving a PSS. The main purpose of this paper is to discuss PSS development under a systematic innovation perspective, trying to answer the following questions

- How can industrial designers and engineers be supported by systematic innovation techniques when developing both the "hard" and "soft" part of a product-service combination?

The main aim of this paper is, therefore, to discuss how the Theory of Inventor's Problem Solving (TRIZ) [9] may support designers in conceiving innovative product-service combinations in the earliest phases of design.
The idea of using methods and tools for systematic innovation in PSS design is not new in literature. TRIZ has been already discussed from an eco-design perspective [10-15] and the 40 Inventive

Principles have been used as a reference to reason upon sustainability issues [16-18]. The authors have recognized, however, that eco-design and sustainability represent just a part of the overall movement towards the integration of products and services, therefore the aim of this paper is to approach this field globally.

3. RESEARCH APPROACH

The research approach may be described as qualitative and inductive. In order to evaluate TRIZ under a PSS perspective, the authors have initially defined the PSS challenges both by reviewing existing literature and discussing with experts in academia and industry. Several interviews and workshops have been conducted on the topic of Functional Product innovation, involving experts and practitioners mainly from the Swedish manufacturing industry. On the other hand, the authors have conducted several case studies regarding the application of TRIZ-based tools in new product development (e.g. [19]). These experiences have provided a solid base to discuss TRIZ strengths and weaknesses from a PSS perspective.

In this paper the author qualitatively discuss and map the different TRIZ modules on a generic PSS development process and show examples of how the inventive problem solving methodology may be applied in this context. The case study presented at the end of the paper illustrates more clearly how the application of TRIZ-based tools may be beneficial when reasoning from a product-service viewpoint.

In the concluding chapter, the authors summarize benefits and limitations of TRIZ-related concepts in the PSS domain, outlining a set of open issues driving future researches.

4. PSS DESIGN CHALLENGES

PSSs represent a big depart from consolidated business patterns since they decouple economic success from material consumption [20]. This shift implies deep changes in the way products are designed.

First, developing competitive and sustainable PSS solutions means being capable to “think outside the box” by combining heterogeneous elements in search for breakthrough solutions.

Then, knowledge dimensions not explicitly considered in the past, such as usage patterns, take-back, recycling and refurbishment has to be used as a decision base in the earliest phases of design. PSSs, in fact, extend product concerns to a lifecycle view and the availability of “downstream” knowledge assets in the early decision making phase is critical for the final product-service success.

Finally, solutions in this context need to be designed at a systemic level, understanding the value creation through the eyes of the final users. Once the needs have been gathered and clarified, it may be not trivial to identify the right solution space Methods and techniques of proven efficacy are needed to transform needs into requirements and to guide the design activity.

All these issues result in difficulty for companies to identify the right innovation trajectory in the earliest stages of design. Adequate supporting tools are needed to guide engineers and industrial designers in the definition of the product specifications, which means in generating design alternatives able to add value to the customer and the company.

5. TRIZ CONCEPTS UNDER A PSS PERSPECTIVE

Design is often seen as a problem solving activity where is not always possible to state the problem comprehensively in the first instance, where optimal solutions might not exist and where problem-solving activities revolve around compromises [21].

The design of product-service combinations is not an exception, and trade-offs between business performances, customer requests and environmental targets has to be found. From a closer point of view, major compromises have to be reached between production, marketing distribution, use, maintenance and recycling issues.

TRIZ for Radical Innovation

Plenty of methods and tools have been developed in the past to cope with the uncertainty, which characterize the conceptual design stage of a new product. TRIZ, in particular, has shown in several industrial contexts to be a powerful instrument in guiding designers towards the definition of innovative features for mechanical products.

This structured inventive problem-solving methodology aims to replace the unsystematic trial-and-error approach and to help engineers in "finding the right way" searching for a solution, by overcoming the psychological inertia which can impede to reach an optimum design (Figure 1).

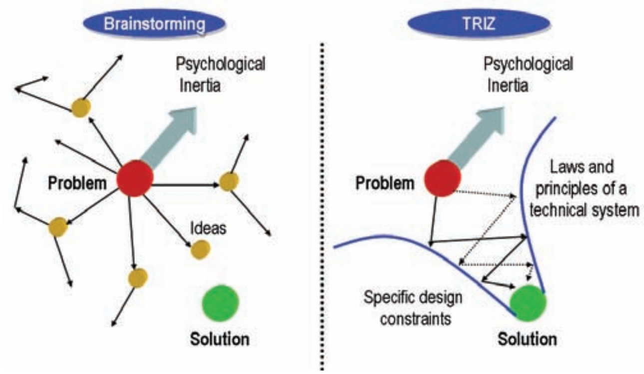

Figure 1. The TRIZ approach to overcome the psychological inertia in design

TRIZ is based on the hypothesis that a few universal principles of invention are the basis of creative innovation. Therefore, once identified and codified, they may be taught to people to make the process of invention more predictable.

This TRIZ *knowledge base* may support design teams in coping with the ill-structured nature of the PSS design problem, in which often one or more steps are either unknown or incoherent, there is insufficient information in the initial state and the properties of the goals are not fully specifiable in advance.

Compared to traditional idea generation methods such as brainstorming, synectics, lateral thinking, morphological analysis and mind mapping, TRIZ has shown to be very effective in solving problems characterized by unknown causes and unknown search directions [22], increasing both the quantity and the quality of subsequent design solutions.

TRIZ for New Service design

In spite of its origins, grounded in the technical area of engineering, TRIZ tools have demonstrated their viability also in the design of new services [16][23-25].

Although conflicts in technical areas are more tangible and easier to formulate, it is possible to detect service problems in the form of contradictions too, in spite of their intangible nature. Mass customization is a typical example of service contradiction [23]. It implies a service firm to be able to deliver personalized service offerings, based on individual customer requirements, to a large group of customers without incurring in additional costs.

Moreover, in New Service Design (NSD), conventional idea search methods, including brainstorming, lead-user research and learning about competitors [26], rely heavily on service designers' or customers' past experiences, which contain unavoidable psychological inertia. Thus, the adoption of TRIZ-based methods is likely to restrict the generation of creative and breakthrough ideas also in the service domain, offering room for the exploration of unknown paths.

6. A FRAMEWORK FOR THE USE OF TRIZ-BASED TOOLS IN PSS DESIGN

Moving form a generic PSS development model, the authors have tried to understand how TRIZ modules may guide designers towards PSS solutions really able to add value both to the customer and the provider.

Although a commonly agreed PSS development process model is not available in literature [2-3][6][11][27], the authors have outlined five generic phases in the design of product-service combinations (left in Figure 2).

- Identification of needs. Identification of an existing problem or need across a certain sector in the society, industry and/or businesses. The outcome of this stage is a clear definition of the problem/s to be tackled.

- Identification of the specific characteristics of a new product. It means understanding how to add value to the customer, how to structure the total offer, how resources may be used and optimized, etc.
- Mapping characteristics to problems. The designers have to hint for new ideas and provide directions for applications, e.g. understanding how to reduce the negative effect on the environment, etc.
- Developing the concept. Designers must translate requirements into specifications, solving the contradictions and finding the most suitable trade-off (if any) among the design parameters.
- Evaluating the concepts. The solution alternatives generated in the previous steps need to be compared and prioritized to identify the concept to be further detailed.

In the authors' advice, TRIZ tools may support design teams in taking the *right* design decisions in most of these five phases. The different TRIZ modules have been mapped on the generic PSS development process (right in Figure 2) and discussed in detail in the following sections.

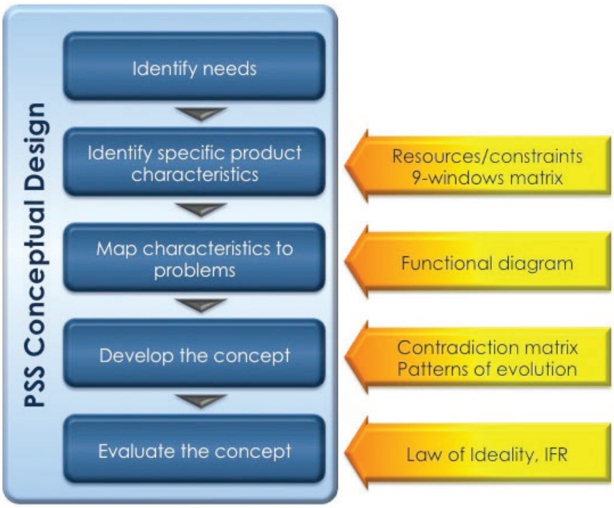

Figure 2. The TRIZ modules mapped on a generic PSS Conceptual Design process

Identifying specific product characteristics

Understanding what to build is one of the main issues in PSS design. Customers cannot always express their needs adequately, especially in cases where there are not outstanding solutions in an early phase and the Voice of the Customer (VoC) [28] is fuzzy. In this situation it is not possible to envision the solution space clearly and design decisions are often are based on "gut-feelings" or tacit knowledge [29].

However, according to Altshuller, the evolution of engineering system may be someway predicted. When the resources for an As-Is system improvement are gradually depleted, evolution slows down and inevitably the system transfers to a new level where the technical solution is replaced with a brand new one [9]. Innovation may be boosted again only by embedding new resources and considering new interactions. In such a sense highlighting the available resources is one of the keys to understand how a system is supposed to change. In the authors' view, the TRIZ 9-windows matrix (*System Operator*) may help the design team in expressing and hierarchically structuring all the resources contained in the system and to evaluate the possibility to join them to provide additional functions.

The *System Operator* tool divides "the world" into nine segments (Figure 6) that can be used by designers to think in terms of *Time* and *Space* while designing the PSS.

From a *Time* perspective, the matrix works similar to the activity modeling cycle proposed by Matzen and McAloone [30]. The *Present* dimension intuitively refers to the classical during-usage situation, and to the personas, values and requirements related to it. The *Past* dimension focuses on the pre-usage stage, which includes production, selling, buying delivering and installation of the solution. *Future* focuses on post-usage activities and resources, including the removal/disposal of the product and the elimination of the traces it may have left behind in the environment

From a *Space* perspective, the *Sub-system* level focuses on those resources typically considered when reasoning from the traditional hardware perspective and when the service is included in the product just as an add-on. At *System* level a broader range of possibilities is considered, both from the "hard" and "soft" side of design. Available resources at this point are all those elements that can influence the PSS offer, like service providers, software or knowledge. At *Super-system* level designers are pushed towards considering an even wider set of resources, the ones that to not typically fit in the classical domain of reference for the identified problem and that are not matched with the initial needs at a first sight.

The *System Operator* may encourage the design team to think in a much more holistic way about the design tasks. Consider, for instance, a very basic need such as "translating oral conversation into written text". This is intuitively matched with the activity of putting some text on paper, which is with the image of a pen (*Sub-system*) being used to write (*Present*). However, at *System* and *Super-system* level new resources come into play, such as the person holding the pen, the speaker, the desk, the environment. Then the focus may be shifted towards the pen in the *Past* - manufacture, shipping, un-packing, preparing to write, etc; and in the *Future* –what happens after people have finished to write (the notes are stored, the pen runs out, etc.).

Briefly stated, the point of this matrix is to overcome the psychological inertia of *Present* and *Sub-system* level thinking, by helping the design team in scanning through all the resources available to generate the desired function. One of the main advantages of the 9-windows matrix approach in a cross-functional scenario is that the tool is very intuitive to understand and use, and people with different backgrounds may contribute to the definition of the resource portfolio quite easily.

Mapping characteristics to problems

The new business view in the Product-Service Systems domain, focused on providing "functions per unit" seems to call for an intensified effort to understand the functional relations that characterize existing systems [31].

A PSS includes several product elements and service elements that are closely related each other. In such a context, the graphical representation of a product is an important aspect of the early design activity phase. PSS *blueprints* allow designers to handle the problem statements correctly, to point out inefficiencies and elaborate possible improvements [31].

PSS blueprint models are actually a topic of an ongoing debate in the PSS community, with several interesting contributions, but no final solution [27][32]. Among others, narrative tools or Enterprise Modeling languages (such as IDEF) have been proposed [27], but they have shown some limitations. They lack of representing the PSS from a technical perspective, and do not adequately support an in-depth analysis of the relationship between the heterogeneous system components.

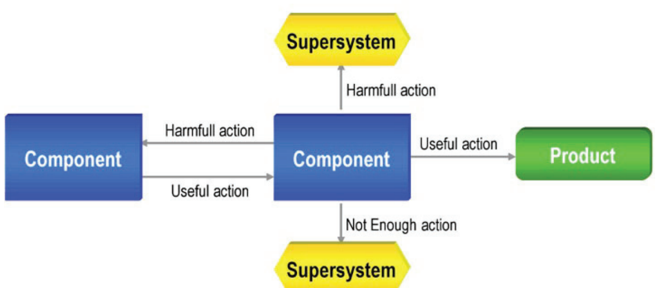

Figure 4: Example of TRIZ Functional Diagram applied to a product

In this context, TRIZ *Functional Diagrams* may be used to represent the interaction between the PSS and the surrounding environment in an easy understandable way. Functional Diagrams are simple cause-and-effect graphs used to show the relations between process functions, product parts or a mixture of each (Figure 4). Functional diagrams clearly show where harmful actions occur in the As-Is or To-Be system, and may support designers in recognizing, analyzing and proposing design alternatives to remove such bad effects. These diagrams may constitute a good reference base to analyze the system and to elaborate different design concepts.

Developing the concept

The development of an innovative product-service combination requires a particular propensity to depart from consolidated mental frames. Thinking outside-the-box, designers should aim for the development of breakdown solutions able to solve the inner contradictions that characterize a given system [20]. The TRIZ knowledge base may represent an important asset to support designers in systematically approaching in resolving such contradictions.

The Contradiction Matrix

The Contradiction Matrix collects a set of standard inventive principles, extracted from several thousands patent analysis, that are intended to solve almost every type of physical and technical trade-offs. Although conflicts in technical areas are more tangible and easier to formulate, it is also possible to define service problems in the form of contradictions, in spite of their intangible nature.

Back to the *mass customization* example the matrix may help in identifying win-win situation, without compromising either standardization (to achieve economy of scale) or customization. Previous works have shown how TRIZ principles may be adapted and applied in service design [33], and such principle may complement the traditional TRIZ hardware-focused approach and support the design of product-service combinations.

Patterns of evolution

TRIZ *Patterns of Evolution* may support PSS developers in forecasting how a given hardware is likely to evolve to address increasingly complex needs. Given the structure of the PSS offer, these patterns may help in optimizing its design of hardware to better comply with the given service specifications. On the other hand, these Patterns may be seen as a sort of foresight tools. They can someway predict how a technical system is going to evolve, therefore anticipating issues and problems that are likely to be addressed from a software or service perspective.

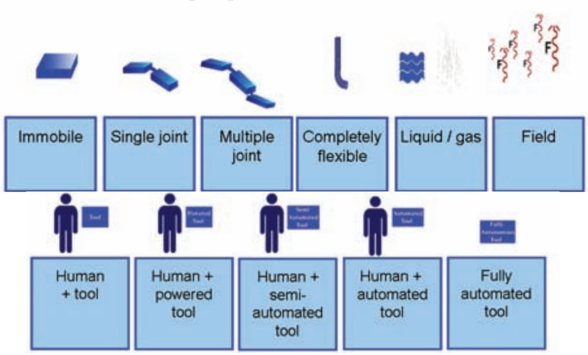

Figure 5. Dynamization and Decrease Human Involvement evolution patterns (CreaTRIZ™)

According to the TRIZ thinking, in fact, all the technological systems always evolve according to certain statistically proven patterns. These patterns - called the Laws of Evolution (Figure 5) - have been revealed through patents and other sources, and describe important regularities in the development of a technical system. After defining its position in the evolution map, the patterns simulate future developments of a product, suggesting engineers how to obtain a higher degree of "ideality" and, therefore, a higher degree of innovation for the hardware.

The theoretical basis for this analysis is the classical S-curve model [34]. Knowing these patterns helps to go from the features of the ideal final result to concrete solutions. Evolutionary patterns may be recognized in the service area as well. Through the analysis of many examples Berry and Lampo [35] have categorized five typical ways of redesigning service offerings (i.e., self-service, direct service, pre-service, bundled service, and physical service). This suggests that the patterns of service innovation can be predicted in a same way as technical innovation. By merging the hard and soft part of design from an evolutionary point of view, it might be possible to guide the designers mind towards developing PSS combinations characterized by an higher level of innovation and ideality.

Evaluating alternatives and concepts

The design of a new product-service may result in the elaboration of several design alternatives to be further evaluated. In the evaluation process the design team needs to benchmark different aspects of design at a time, and it may be not trivial to evaluate these solutions under a common framework.
Simulation techniques are usually applied to sort out which of the concepts maximize the input-output ratio for the company, reduce the impact on the environment or fulfill the customer requests. Basing the decision only on the outcomes of these simulations may be risky, since often companies miss adequate downstream knowledge to run reliable simulation models.
From a different angle, the PSS design activity may be seen as an attempt to close the gap between an *actual* usage situation and an *ideal* one, in terms of resource consumptions, time, costs, user satisfaction, etc.
This idea of increasing the *ideality* of a system is well known by the TRIZ community. *Ideality* may be expressed as a qualitative equation of benefits divided by the sum of costs and harms, where 'harm' may include technical, service or business factors.
According to TRIZ, an ideal system is a system that does not physically exist anymore, while the function is still performed. The ideal system does not occupy space, has no weight, does not need energy and maintenance, it delivers benefits without harms and in synthesis acts as a pure function.
Here comes the idea of benchmarking actual PSS alternatives against an Ideal Final Result (IFR), picking up the solution alternative that gets closer to the ideal target. In case none of the concepts copes with the IFR, a step back is taken and the ideas are evaluated on the base of a reduced IFR. This process may be iterated until a satisfactory solution is identified.
In the authors' advice, clear commonalities may be seen between the *ideality* concept expressed by TRIZ and the general aim behind the development of functional products. For this reason, the authors believe that the TRIZ tools may help designers in comparing different scenario alternatives by evaluating whether a new PSS performs well compared to the IFR. The *ideality* concept may provide the PSS community of a good reference framework to evaluate if a given design alternative may be able to meet customer high-level expectations. Closer an idea is to the IFR, more it is likely to succeed, since it would be able to satisfy higher level needs.
Although the IFR is a common reference point, the different stakeholders may have different interpretations of what should be included one step back from ideality. In this sense, the IFR schema may help the design team in categorizing and communicating the different customer preferences along all the project stages.

7. TRIZ FOR PSS DESIGN. A CASE STUDY

In this section a brief case study regarding the application of TRIZ in PSS design is presented. In particular, the authors have focused on the study of the need "travelling freely and safely with snowing road conditions". A common way to address this need is to develop, produce and sell anti-slippery devices (snow-chains, snow tires) with service add-ons (installation, repairing, etc.).
In this example the authors want to explore how this need may be addressed from a PSS perspective. Basing on the generic PSS development process, TRIZ-based modules have been used to elaborate and select the best alternative to cope with the customer request.

Identify specific product characteristics

Traditional anti slippery devices, such as snow chains, spiders, *Put-and-Go*, etc., are typically designed from a during-usage perspective (*Present*), addressing the need when it becomes manifested (i.e. these devices cannot be used in normal road conditions). Moreover, the designers' thinking mainly revolves around the wheel-tire-suspension system (*Sub-system*), not considering other aspects of the car/road/environment that may potentially contribute in addressing the need. They are usually sold as hardware, a physical device, requiring service add-ons in the pre- and post-usage stages (installation, removal, etc.).
Aiming to find a better solution for the identified need, the team starts reasoning upon available resources by using the TRIZ 9-windows matrix. In a first step, at *Sub-system* level, pre- and post-usage constraints and opportunities are clarified and addressed, and a set of solutions is built reasoning upon

the collected material. For clarity purpose, the identified solutions are mapped in the framework and shown in Figure 6. From a *Past* perspective, one of the scopes is to reduce or anticipate those activities that are typically performed to get the device up and running (installation) when the need become manifested. Snow tires are an example of solutions addressing the pre-usage stage, since they can be used with several road conditions and therefore installed and removed just once a year, in the beginning of wintertime.

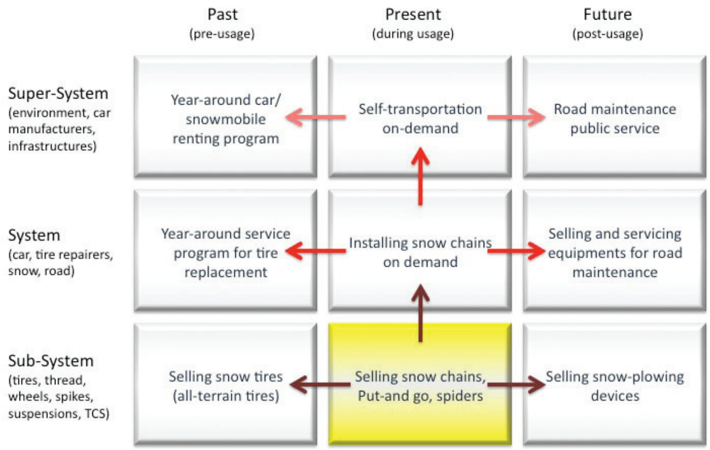

Figure 6. 9-windows matrix application example

From a post-usage perspective, the team reasons upon how to restore the initial situation, in terms of what has to be done to remove the cause for the need to emerge. Cleaning/repairing the road are examples of activities referring to the *Future* stage. Selling snowplowing devices may represent a solution from this point of view.

At the same time, a preliminary integration between products and services (*System* level) is conceived from a *Present* perspective. A new set of resources may be considered at this level, such as the car and all its equipments, the road, the tire dealer etc. This broader outlook may stimulate designers in reasoning upon which product-service combination may address the customers' need for mobility in such a peculiar situation. Installing show chains on-demand is an example of solution addressing the need from this perspective.

Reasoning at the pre-function stage, an interesting mix of product and service is represented by a year-around service program for tire replacement. In this case a long-term agreement is set between the tire dealer and the customer. The first will equip the car in advance with the most suitable tires/devices for the upcoming weather conditions. The latter will pay a fixed amount every year, covering both the costs of the service and of the hardware installed. Reasoning at post-functional stage, selling and servicing equipments for road cleaning and maintenance may represent another example of product-service combination.

At *Super-system* level, car manufacturers, rental companies, road infrastructures and the environment may be considered resources to be exploited to address the customer need. The main purpose at this step is to explore if the need may be satisfied replacing the hardware with a service. From a *Present* perspective, providing transportation on-demand, using different vehicles for different weather conditions, may represent a viable solution. In this case no product is sold to the final user, but the need is fulfilled by means of a service. From a pre-usage point of view, the matrix may push the designers to rethink the entire car business. What if the user won't pay for the ownership of a single car, but for the use of different cars, chosen day-by-day by the customer depending on his/her preferences? This solution can be thought as a sort of year-around renting program, delivering the user different solutions on the basis of its evolving needs and usage scenarios. Then, an effective program for road cleaning and maintenance may be thought as a solution from a *Future* point of view (e.g. installing a warming system on the road and asking the community of users to pay for that).

Map characteristics to problems

In this example, the *year-around service program for tire replacement* (*System-Past*) has been selected for further investigation. In this scenario, the car is serviced with new tires or new anti-slippery devices along the year, depending on the expected weather conditions. The customers do not pay for purchasing the device, but rather for the function provided, that is traveling safely whatever road conditions are meet. The PSS may be represented with more detail by means of a Functional Diagram. The extract shown in Figure 7 mainly describes service components, outlining harmful (continuous line) and useful (dashed line) interactions between the different parts of the PSS offer.

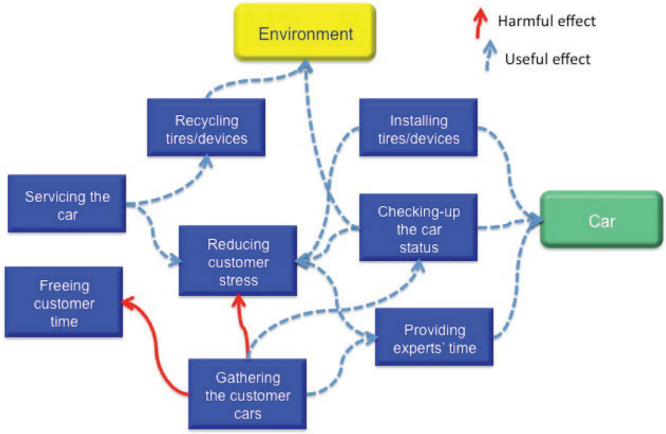

Figure 7. Extract from the Y-a service program for tire replacement *functional diagram*

In this case, *Gathering the customer cars* may have a harmful effects on the overall customer satisfaction. More frequent is the service, more time is lost fetching the car to the tire repairer. In general, this aspect of the service does not provide added value to the customer, instead it increases his/her stress and reduces his/her spare time. The Functional Diagram may represent an intuitive visual way to figure out the relevant contradictions in the PSS and provides a problem description ready to be analyzed with the TRIZ problem-solving tools.

Develop the concept

Both the TRIZ *Contradiction Matrix* and the *Patterns of Evolution* are powerful problem solving tools that can be adopted to cope with trade-off emerging developing product service combinations.

The previous section has outlined a typical example of service contradiction (freeing customers' time vs. having frequent car services) where no solutions are evident by common sense. The problem is therefore abstracted and mapped inside the *Contradiction Matrix*, in terms of *harmful side effects* vs. *waste of time*. Here the *Separation* principle is suggested to cope with the problem. Briefly stated, the customer time may be divided into *spare time* and *busy time*. In order not to waste customers' spare time, the tire repairer should service the car during the customers' busy time, as opposite to the traditional way of doing.

Here comes the problem of servicing the car while the customer is doing something else. It implies a radical shift on perspective, requiring the tire repairer to fetch the car instead of waiting for the customer to come. Innovative ideas on how to reduce both the operation time and the fetching time have to be found. Here again the *Segmentation* principle of TRIZ may suggest an interesting solution to cope with the problem. Customers may be divided into homogeneous groups that can be served together, e.g. customers working in the same company may be serviced together while they are at work and their cars are parked in the common company's parking space.

Evaluate the concept

In case several alternatives are developed, the IFR analysis may help in assessing which of the solution is closer to an ideal final outcome, both for the customer and the provider side. The evaluation has to be complemented, however, with physical data and reliable simulation models to verify the PSS viability from a business point of view. Although IFR does not tell exactly what the solution should be, it may orient designers preferences towards the direction that is intended to be more ideal and, in theory, more remunerative in the long term.

8. CONCLUSIONS

The innovation potential of TRIZ offers a unique possibility to create and deliver breakthrough product-service concepts. Although TRIZ is in its early days in the PSS domain, the pillars on which the method are built are fundamentally consistent with those directions necessary to the achievement of practical and economically viable product-service solutions.

The TRIZ approach is well known in industry, is based on solid and verified assumptions and is one of the most comprehensive problem-solving models currently available [36]. Design problems may be described in a structured manner, by capturing constraints and resources, and decomposed into a set of small, simpler problems where the inherent contradictions may be identified. Viable solutions concepts may be generated by accessing the TRIZ knowledge base to cope with the design trade-offs, then later evaluated and prioritized against their closeness to the state of ideality.

In PSS design, TRIZ offers an intuitive means to clarify the solution space, showing with a certain degree of reliability how a system is likely to evolve in the future. It stimulates creativity and helps in breaking the conventional designers' mindset and inertia. It encourages a holistic thinking, highlighting the importance of a co-evolutionary approach of both the hardware and the software. Finally, since TRIZ is a well-known tool, it may help in lowering the barrier to the adoption of a PSS-oriented thinking, supporting "traditional" manufacturing firms in making smoother the transition towards servitized organizations.

TRIZ, however, is still far to be a panacea for all kind of design related problems and shows severe limitations, which may limit its use in PSS design. On one side, the ability to handle multi-faceted and multi-hierarchical design problem is an evident limit for the methodology. Then, the core part of the theory, the Contradiction Matrix and the TRIZ knowledge base are not mature enough to deal with service-related issues. The adaptation of the methodology from a pure engineering context to a more service driven requires further expansion and re-interpretation of the core parameters and principles in the matrix, which may require years of development [38]. Last, but not least, a lack of ease in the integration of the methodology within more conventional product development tools is perceptible, as also underlined by Cavallucci and Luk [37].

Future works will focus on the further development and adaptation of systematic innovation tools for PPS and Functional Product design, aiming to develop a coherent methodology on how to specifically use TRIZ-based tools in this context.

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