NEEDS AND REQUIREMENTS – HOW TRIZ MAY BE APPLIED IN PRODUCT-SERVICE DEVELOPMENT

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Abstract

In Product-Service Systems development, understanding of the customers' use of goods seems vital, since the product per se is not sold but rather the performance it brings to the customers' processes in terms of added value. This changed business scenario insists on an integration of a service and a product perspectives in early design phases. However, the approaches to understand customers diverge. In this paper, a need matrix, from the economic theory of needs, and a requirement matrix, from the TRIZ methodology, are used to elaborate on integration aspects to understand customer statements. The comparison of these matrixes made the distinct logics apparent, and gave an indication for the necessity of another type of specification for PSS products. Also, the knowledge base for PSS methodologies has to be extended to encompass a part that visualizes non measurable aspects such as needs.

Keywords: Product-Service Systems, PSS, Product Development, Engineering Design, TRIZ.

1 Introduction

In recent years, the motivation towards creating a more sustainable society has led to the recognition that greening product design and production processes alone are not sufficient. Sustainable solutions that encourage more holistic thinking and strategic design planning are now receiving increased attention [1]. Seven major elements for a company considering the eco-efficiency of developing environmental friendly products or processes to reduce environmental impacts has been pointed out [2]:

1. Reduce the material intensity of its goods and services;
2. Reduce the energy intensity of its goods and services;
3. Reduce the dispersion of any toxic materials;
4. Enhance the recyclability of its materials;
5. Maximize the sustainable use of renewable resources;
6. Extend the durability of its products;
7. Increase the service intensity of its goods and services.

These elements are likely to produce high eco-efficiency in products and services if they are combined and achieved simultaneously in the product design [3].

The concept of Product Service Systems (PSS) has been observed as a part of an overall movement towards a service-based society where sustainability is in focus [4]. PSS can be described as a special case of servitization, where the *use* of an integrated product, service and system offer bringing added value to the customer is at the core [5]. Further, a PSS business case also entails a long-term commitment to provide 'functions per unit' over time. The PSS business view highlights product lifecycles, innovation possibilities and understanding of customer information as important issues to take into account in the early phases of the design process.

1.1 Purpose

In industry today, the uptake of PSS appears limited [6]. One reason for that might be that PSS represent a wide area of intervention, and a definition of a set of general and commonly agreed methods for PSS design seems not to be attainable [7][8].

Also, it can be argued that the intentions to integrate products and services include an integration of two basically distinct logics, for example, how to deal with the Voice of the Customer (VoC) [9] is built on two different approaches. In product development, described as problem-solving resulting in tangible goods, the customer statements are in general, early on, translated into requirements which relates to a specific solution or product, e.g., engineering parameters. Next, the requirements are turned into a product specification, consisting of a metric and a value, conveying the precise description of what the product has to do.

In service development, described as enabling activities resulting in intangible value, the customer statements are seen as being partly tacit, i.e., difficult to express and capture since they are embedded in the customer's context. Thus, customer statements are viewed as needs related to human goals and intentions. An integration approach entails not favoring one of the other, accordingly both views on customer statements has to be taken into account in the development processes for PSS. *The purpose in this paper is to, on the basis of a need matrix and a requirement matrix, elaborate on integration aspects to clarify the Voice of the Customer, and thus also contribute to the development of PSS applicable methods.*

1.2 Point of view for the study

The theoretical study presented in this paper is performed from a point of view of the research subject of Functional Product Development (FPD), namely the integration of two perspectives. The PSS paradigm correlates to and makes a frame for FPD. The differentiation of these two views is done to firmly establish FPD research for the purpose of engineering design, and, especially, the early phases of product development. In these early design phases the VoC is identified and the concept design decisions settle the product. A need driven approach to product development gains interest in the FPD research concept, however, also recognizing that needs turn into requirements in later stages of product development. In accordance with this point of view, a need matrix is analyzed in relation to a requirement matrix to provide new insights for product development. The requirement matrix is discussed in terms of shortcomings for a PSS paradigm, not for its constraints for 'traditional' product development.

The choice of TRIZ [10] as a provider of the requirement matrix in this study is made because of three main reasons. First, it is used in industry. Example of the application of TRIZ in industry may be found in different sectors, such in the automotive, aeronautical, chemical, textile, and food domain [11]. Second, it is described as a structured inventive problems-solving approach, and, third, it provides access to a matrix with engineering parameters (including a matrix of principles to guide innovative solutions). Commonly, in product development needs are not differentiated from each other, rather used interchangeably [12].

An obvious choice when focusing human needs might be the well-known Needs Hierarchy by Maslow [13]. Basic human needs are organized by their relative prepotency in the hierarchy, starting with physiological needs in the bottom, social needs in the middle and, at the top, self actualization needs. Yet, these kinds of needs are apt to explain a view of 'a complete human being'. Such needs are not practical in product or service development, since the fulfillment of them is not dependent on goods and services. Instead, within an economic theory of human needs, Max-Neef [14] has categorized representation of needs into a needs matrix, also suggesting possible types of satisfiers (which will lead to products and services). The choice of Max-Neef's matrix of needs and satisfiers is done on the basis that it, of course, gives access to a need matrix (including examples of solutions), but also because of its similarities to the requirement matrix. The similarities make it doable to compare and contrast needs and requirements.

The VoC can be categorized in three ways according to the degree of customer involvement and responsibilities in the product development process [15]. First, VoC can occur in a design process *for* customers. In this case the design activities are customer oriented, but managing and handling the VoC are company specific tasks. Second, it can occur in a design process *with* customers, the basis for this approach is similar to the previous, but, commonly, the customer is involved in the evaluation phases of suggested solutions and products. Third, VoC can occur in a design process *by* customers, here the concept of 'lead-users' are vital [16]. In such a case, VoC takes the expression of a modified or new product developed by the lead-user, the company's design process starts from there and the lead-user's product is used as a mediating object for the VoC.

Commonly in industry, the responsibility to deal with VoC is a marketing issue, in a Needfinding [17] process it is suggested that product developers directly interact with customers. A main principle in Needfinding is to look for needs not solutions, thus it is oriented towards innovative and new products. Due to this it is important to discuss and generate concept ideas away from the customers place. Product developers are trained in handling data on products (i.e., requirements), thus there are challenges to deal with data on customers (i.e., needs). In this paper, which is underpinned by a Needfinding view, the design for customers is in focus, and the statements that represent needs and requirements in particular.

The disposition of the paper is as follows; a mapping of TRIZ and the conceptual design for sustainable products, or PSS solutions, are made to provide an overview of application areas. After this quite general presentation, TRIZ as the requirement matrix is outlined, i.e., the engineering parameters and the inventive principles. Thereafter, the need and satisfier matrix is presented. The paper ends with a section where the needs and requirements are discussed in order to reflect on some implications.

2 TRIZ – an overview

Originating from the former Soviet Union, TRIZ started off as a theory to support the solution of innovator's problem. Since then, the theory has been further enhanced, and still is. Today, TRIZ is more a methodology, i.e., encompassing theory, methods, a knowledge base and tools to handle design contradictions and uncertainty in innovative design problem processes [18]. The knowledge base incorporated in the methodology makes use of past designers knowledge in order to eliminate the opposing aspects which characterize the design of a new product.

2.1 Why using TRIZ in product development?

Product development can be seen as problem-solving activities where an optimal solution is the goal. However, in the case of developing innovative products, the design activities typically asks for the analysis and resolutions of major conflicts between diverging goals. In such a situation, it may not be possible to state the problem comprehensively in the first instance, thus optimal solutions might not exist and problem-solving activities revolve around compromise [19], or suitable trade-offs. For this kind of design problems, the TRIZ methodology seems promising, since the systematic approach is powerful for resolving contradictions.

The TRIZ methodology, moreover, embeds a well-structured inventive problem-solving approach whose application replaces the unsystematic trial-and-error method used in the search for solutions in the everyday lives of engineers and developers. This innovative potential may help designer in overcoming their psychological inertia which can impede, mainly in the conceptual design phase, to reach the best possible design (Figure 1). Psychological inertia is an indisposition or "stuckness" to change due to human programming. It represents the impossibility - as long as a person is guided by his habits – of reaching the best solution since it may lie outside the inventor's field of expertise [20].

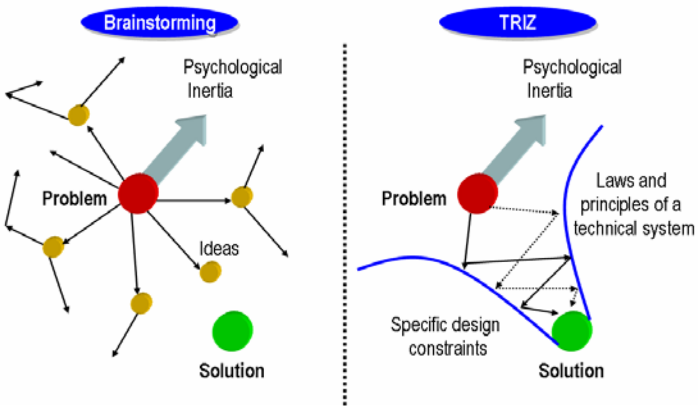

Figure 1. The TRIZ approach to overcome the psychological inertia in design

2.2 TRIZ from an eco-perspective

TRIZ methodology has shown to be a valuable instrument in order to guide designers towards the definition of innovative solutions and products, also in the area of eco-design [18][21][22]. The introduction of such systematic methods into sustainable design may help, therefore, in reducing the innovation risk [23]. Taking on an eco-perspective in product development, requires innovative ideas and the involvement of new stakeholders. An eco-perspective, and as discussed also a PSS, opens up the solution space and calls for the design team to have capabilities for continuous innovation [24]. Innovation, however, has been traditionally equated as 'high risk', and many organizations have been reluctant to devote precious resources in the development of "risky" sustainable products, processes or services [23]. So, on one hand, the solution space in the design of sustainable products is much wider and more articulated than in common product or service design [25]. On the other hand, designers must consider, in parallel with normal product design issues, also communicational, social and economic aspects, which are difficult to manage from a purely technical level [25]. Here, TRIZ can provide a structured way to handle such contradictions, but the lack of ease in integration of the methodology with more conventional product development tools is recognised [26].

3 Mapping of TRIZ modules from an eco-perspective

Optimal solutions are not doable in complex development cases, an over-riding trend of technology and business evolution is towards increasing "Ideality" [23]. Ideality may be expressed as a qualitative equation of benefits divided by the sum of costs and harms, where 'harm' can specifically include environmental impacting factors. It drives the design towards an "Ideal Final Result" (IFR) – a design that is the best that can be envisaged. TRIZ offers a collection of generic supporting technology trends which can help users evolve their design towards this increased "Ideality".

Figure 2 (i.e., an example of a TRIZ Functional Diagram), shows a cause and effect diagram which visualise the interactions within the system, where the harmful and useful actions can be elaborated on to provide IFR, the product at right in Figure 2. Such visualization is used to trim the harmful parts of a given system to move it closer to "Ideality". Main scope for trimming a system towards "Ideality" is to understand where harmful actions appears in the system and then to remove, reduce or prevent them, typically by eliminating the component which cause the bad action.

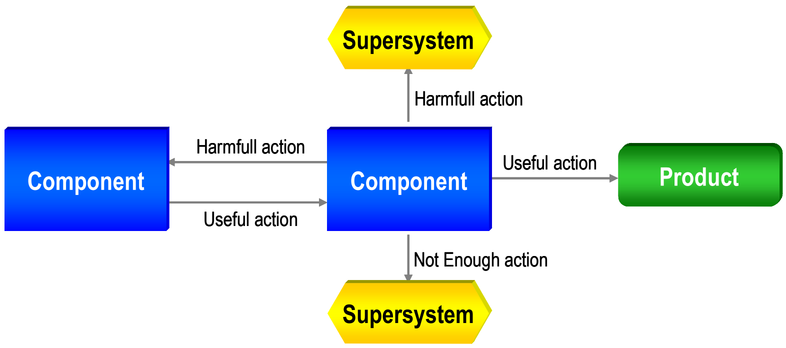

Figure 2: Example of a cause and effect visualization

For this study and from the literature related to the development of sustainable products [1][23][18][21][22], a generic view of the conceptual design phase for new product development is outlined in five main phases (left in Figure 3). This is done to map TRIZ modules according to how they might be applied in order to guide developers designing based on an eco-perspective, and, hence, also provide a framework for the use of TRIZ (right in Figure 3).

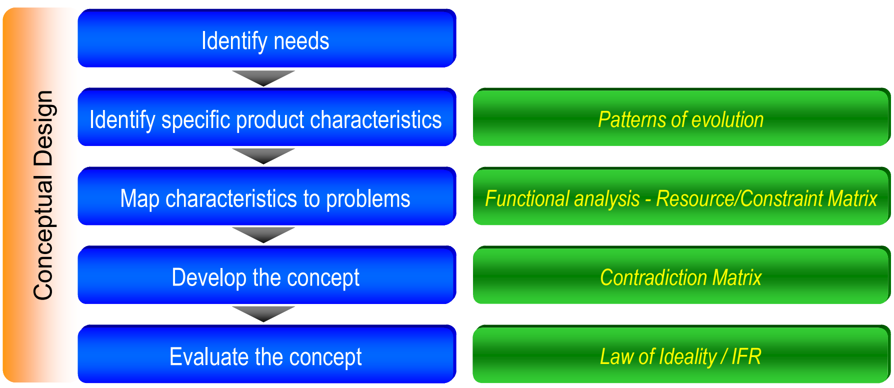

Figure 3. The use of TRIZ in sustainable products design

Starting from the top left in Figure 3, the main phases are:

- *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 definition of the problem/s to be tackled.
- *Identify the specific characteristics of a new product*: identification of characteristics in terms of how to add value to the customer, how resources may be optimized, how to reduce the negative effect on the environment, etc.
- *Map characteristics to problems*: once innovative features have been pointed out, the designers have to hint for new ideas and provide directions for applications.
- *Develop the concept*: after having identified the functional requirements of the new solution, designers must apply to translate them into more technical terms, trying to solve contradictions and make trade-offs among design parameters.
- *Evaluate the results and test*: several solution alternatives may be generated in the design. They have to be compared and sorted in order to identify the concept to be the subject of further improvements.

The literature review has shown that TRIZ does not support identification of needs. The methodology is technical oriented and strongly focused on product functions, so this gap was not unexpected. Thus, starting from the top right in Figure 3, the suggested TRIZ modules are:

- To *identify the specific characteristics* of a new product the module Patterns of Evolution is suggested. A basis in TRIZ thinking is that all technological systems evolve according to certain statistically proven patterns. These patterns – Patterns of Evolution – have been revealed through patents and other sources and describe common treads between evolving systems. The early conceptual design stage may benefit from the use of the module, since its application may help designers in reasoning in terms of "how to obtain a higher degree of Ideality" and, therefore, in proposing alternatives and concepts characterized by a higher degree of innovation.
- To *map characteristics to problems* the module 9-windows matrix is suitable in this phase. The 9-window matrix may be applied to help express and make a hierarchical structure of all the elements of the systems and to evaluate the possibility to join them in order to provide additional and hidden functions. The 9-windows matrix deals with the past, present and future dimensions of a component, the subsystem and the super-system, e.g., product lifecycles or s-curves.
- To *develop the concept* the contradiction matrix (which maps engineering parameters on inventive principles) is suggested, but can be modified as done by Chen and Liu [18]. Within this module, the matrix of engineering parameters which we in this paper call a requirement matrix is part of the content, hence will be discussed later on.
- To *evaluate the concept*, the module Law of Ideality (IFR) seems suitable. The development of new sustainable products includes several design alternatives to be evaluated. Each proposal is characterized by a different degree of innovation, and it may not be trivial to evaluate these solutions from an eco-perspective. The assessment of the innovative potential of these design alternatives can be based on the Law of Ideality.

4 A requirement matrix applicable for product concept development

Chen and Liu [18] have demonstrated the feasibility of the TRIZ methodology for eco-innovative design. They have mapped each of the seven major elements for a company in considering the eco-efficiency in development (in this paper outlined in the list 1-7 in the introduction section) to the 39 engineering parameters of TRIZ to show how eco related issues may be addressed by the methodology. By doing so they can conclude that the contradiction analysis (another module in TRIZ) is not required for solving eco-design trade-offs.

Table 1: The 39 engineering parameters

1. Weight of moving object	11. Tension, pressure	21. Power	31. Harmful side effects
2. Weigh of binding object	12. Shape	22. Waste of energy	32. Manufacturability
3. Lenght of moving object	13. Stability	23. Waste of substance	33. Convenience of use
4. Lenght of binding object	14. Strenght	24. Loss of information	34. Repairability
5. Area of moving object	15. Durability of moving object	25. Waste of time	35. Adaptability
6. Area of binding object	16. Durability of binding object	26. Amount of substance	36. Complexity of object
7. Volume of moving object	17. Temperature	27. Reliability	37. Complexity of control
8. Volume of binding object	18. Brightness	28. Accuracy of measurement	38. Level of automation
9. Speed	19. Energy spent by moving object	29. Accuracy of manufacturing	39. Productivity
10. Force	20. Energy spent by binding object	30. Harmful factors acting on object	

Table 2: The 40 inventive principles

1. Segmentation	11. Beforehand cushioning	21. Skipping	31. Porous materials and membranes
2. Taking out	12. Equipotentiality	22. Converting harm into benefit	32. Color changes
3. Local quality	13. Reverse	23. Feedback	33. Homogeneity
4. Asymmetry	14. Spheroidality	24. Intermediary principle	34. Discarding and recovering
5. Merging	15. Dynamism	25. Self-service	35. Parameters and properties change
6. Universality	16. Parcial or excessive action	26. Copying	36. Phase transitions
7. Nested doll	17. Another dimension	27. Cheap short-living objects	37. Thermal expansion
8. Anti-weight	18. Mechanical vibration	28. Substitution of mechanics	38. Strong oxidants
9. Preliminary anti-action	19. Periodic action	29. Pneumatics or hydraulics	39. Inert atmosphere
10. Preliminary action	20. Continuity of useful action	30. Flexible shells and thin films	40. Composite materials

However, the components of the contradiction matrix, the engineering parameters (Table 1) and the inventive principles (Table 2) still visualize an interesting interaction. The 39 engineering parameters express improving and worsening features, and the 40 inventive principles may help designers resolve a significant operational or design contradiction, bringing to radical invention.

5 A needs matrix applicable for representing needs

Max-Neef [14] emphasize that human needs have to be understood as a system, since all human needs are interrelated and interactive. To demonstrate the interaction, he has organized needs into two categories, i.e., existential and axiological, se Table 3. The matrix is illustrative and not normative or conclusive; hence, it merely gives examples of possible types of satisfiers. The matrix of satisfiers might vary considerably if put together by individuals or groups from diverse cultures [14].

In table 3 the left vertical column, nine needs based on value or quality judgment are listed. At the top horizontal row four existential needs are listed. The suggested satisfiers can give rise to different economic goods. For example, looking at the fields Doing and Understanding the satisfiers investigating, studying etc give rise to goods such as books, laboratory tools, computers etc. [14]. The matrix is suggested to be used as a base for discussion for diagnosis, planning, assessment and evaluation of the VoC.

Table 3: Matrix of needs and satisfiers, from Max-Neef [14]

Needs according to: existential categories / axiological categories	Being	Having	Doing	Interacting
Subsistence	Physical health, mental health, equilibrium, sense of humour, adaptability	Food, shelter, work	Feed, procreate, rest, work	Living environment, social setting
Protection	Care, adaptablility, autonomy, equilibrium, solidarity	Insurance systems, savings, cosial security, health systems, rights, family, work	Co-operate, prevent, plan, take car of, cure, help	Living space, social environment, dwelling
Affection	Self-esteem, solidarity, respect, tolerance, generosity, passion, sense of humour...	Friendship, family, partnership, relation-ships with nature	Make love, caress, express emotions, share, take care of, cultivate, appreciate	Privacy, intimacy, home, spaces of togetherness
Understanding	Critical conscience receptiveness, curios-ity, astonishment, rationality...	Literature, teatchers, method, educational policies, communica-tion policies	Investigate, study, experiment, educate, analyse, meditate	Settings of formative interaction, schools, academies, communi-ties, family...
Participation	Adaptability, recpetive-ness, willingess, deter-mination, dedication, respect...	Rights, responsibilities, duties, privileges, work	Become affiliated, co-operate, propose, share, interact, express opinions...	Settings of participa-tive interaction, parties, associations, commu-nities...
Leisure	Curiosity, receptive-ness, imagination, recklessnes, sense of humour, sensuality...	Games, spectacles, clubs, parties, peace of mind	Day-dream, brood, dream, remember, give way to fantasies, have fun, play...	Privacy, intimacy, spaces of closeness, free time, surround-ings, landscapes
Creation	Passion, determination, intuition, imagination, boldness, rationality, curiosity...	Abilities, skills, method, work	Work, invent, build, design, compose, interpret	Productive settings, workshops, cultural groups, spaces for expression...
Identity	Sense of belonging, concistency, self-esteem, differentia-tion...	Symbols, language, religions, habits, values, norms, memory, work...	Commit oneself, inte-grate onself, confront, decide on, recognize oneself...	Social rhytms, every-day settings, matura-tion stages...
Freedom	Autonomy, self-esteem, determination, pas-sion, boldness, toler-ance...	Equal rights	Dissent, choose, be different from, run risks, disobey...	Temporal/spatial plas-ticity

6 Discussing integration opportunities

For companies aiming for PSS businesses with an eco-perspective, insights into the lifecycle dimensions seem vital. A long-term commitment is commonly part of the PSS business idea. By this, a possibility to modify or replace the goods which provides the customer with the contracted functions or performance in use occurs, hence innovation possibilities prevail.

From an eco-perspective the innovation potential is interesting, since such aspects can be considered in a more continuous way, however, also contributing to increased complexity in early design, as well as managing several lifecycles. TRIZ methodology offers a structured way to deal with innovative sustainable concepts. However, the methodology is not a panacea for all kinds of design related problems and shows limitations, for example, how to identify needs, and as a complication does not communicate needs to the following stages. Still, insights into such tacit, contextual qualities of human activities are important for the development of PSS. So, one constraint for the potential of TRIZ to effectively address multi-faceted, multi-hierarchical problems of eco-design is related to its potential to handle these problems in a holistic way.

The role of needs in PSS is considered as central due to a shift in focus, from the goods itself to the use, and added value, it provides for the customers. In this way, understanding requirements in relation to the goods is not enough. Accordingly, to achieve PSS the distinct perspectives of the VoC have to be integrated, i.e., a view of needs and requirements, to support lifecycle decisions in early phases of design. Examining the engineering parameters showed in Table 1 and the existential/axiological needs in Table 3 makes it evident that the design logics between products and services are diametrically opposed. The same situation occurs when comparing the inventive principles in Table 2 and the satisfiers in Table 3. These two views do not talk the same language; in fact, they do not even support a common vision for the development task. These two views are opposing also in other dimensions, for example:

- Stringency vs. flexibility
- Quantitative vs. qualitative
- Measurable vs. assessed
- Low level of abstraction vs. high level of abstraction
- Detailed view vs. holistic view

However, combining the two views can provide better decision base. For instance, by using the needs and satisfier matrix, the needs ‘Doing’ and ‘Protection’ along with the satisfier ‘co-operate’ indicate a willingness of the customer to perform some activities to contribute to a better product. In relation to the requirement matrix, the product developers might be able to consider engineering parameter 35. ‘Adaptability’ differently, perhaps leading to a new product.

Yet, not discussed by Max-Neef, a company start in their core business, for example as a manufacturer of mobile phones. ‘Looking for needs not solutions’ is a challenge for product developers when using the matrix, due to focusing on a ‘mobile phone’ the needs are turned into requirements of that phone. How to do to change the product developers’ mindset into, for example ‘communication’? A change in mindset is likely to have an effect on the design intent and, as a consequence the design space becomes wider providing for PSS important innovation opportunities.

The engineering parameters (used in the contradiction matrix in TRIZ) help product developers, deal with contradictions. In product development requirements are in contradiction most of the time, and the product developers have to struggle to make trade-offs. In industry today, companies present themselves as customer oriented, thus one important aspect to consider when doing trade-offs is the fulfillment of the VoC. The insights into the VoC hence depend on the characteristic of the generated, obtained or gathered customer data, and, consequently what the VoC tells the PSS developers to fulfill. Archetypically, in product development additional aspects to the engineering parameters are weighted in the trade-off activities, for instance cost, access to material, internal resources. An understanding of the needs, which can be seen as a rationale for a chosen requirement, provides information that is useful.

The task to analyze and categorize the representation of needs into the same level of abstraction is difficult, here the need matrix can be useful. Having a list of, or a matrix of, needs does not mean that *all* needs have to be fulfilled by the product, since all identified needs might not be useful for the product at hand. Remember that they have been generated with the mindset on needs; hence the data is far richer than product related data. Still, having information of those seemingly ‘worthless’ needs can be a determining factor for the next generation of products. The list as such provide a knowledge base for the VoC, and having a ‘design for customer’ view the company can use it to translate needs into requirements. However, turning needs into requirements is a process where contradictions have to be handled. In this translation process a needs/requirement matrix could provide ‘inventive principles for contradicting need/requirement solving’. An extension of a TRIZ-like contradiction matrix for PSS complexity might be able to bridge the distinct logics between needs and requirements?

7 Concluding remark

This paper embarked from the purpose to, on the basis of a need matrix and a requirement matrix elaborate on integration aspects to understand the VoC. This effort was made to contribute to the development of PSS applicable methods, especially the integration of a service and a product perspective on customer statements. A generic view of the conceptual design phase for new product development has been presented and suggestions for which TRIZ module to use in the stages respectively have been made.

Moreover, in the comparison between the requirement matrix and the need matrix the distinct design logics became apparent, but also gave an indication for the necessity of another type of specification for PSS products. A PSS specification might consist of an extended part where qualitative needs can serve as a rationale to provide deeper understanding of requirements, and in turn provide additional guidance for trade-offs. Consequently, for PSS methodologies the supporting knowledge base has to be extended to encompass a part that visualizes non measurable aspects such as needs.

Further studies are needed to map the possible intersection in the translation process of needs into requirements. A case where a heterogeneous design team is involved is identified and a study is initiated. The identification of a possible intersection will provide valuable data to propose a method able to model and address contradictions in early PSS design. Such a method is likely to help companies to deal with the difficulty of lowering risk and increasing the potential for innovations in PSS product development.

Further, to study the possibility to integrate Axiomatic Design techniques in the TRIZ methodology seems interesting. Although TRIZ is recognized as a powerful tool for generating innovative solutions, AD principles may be helpful in the early design stages to better define the problem to be later addressed with TRIZ [27].

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