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The Journal of the European TRIZ Association (ETRIA) has been set up to accomplish the following tasks:

- Promotion of research and development on organization of innovation knowledge in general and particular fields by integrating conceptual approaches to classification developed by artificial intelligence and knowledge management communities,
- International observation, analysis, evaluation and reporting of progress in these directions,
- Promotion on an international level of the exchange of information and experience in the Theory of Inventive Problem Solving TRIZ of scientists and practitioners, of universities and other educational organizations,
- Development of TRIZ through contributions from dedicated experts and specialists in particular areas of expertise.

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Content

Advanced Innovation Design Approach: towards Integration of TRIZ Methodology into Innovation Design Process

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The papers presented at the 17th TRIZ Future Conference 2017 demonstrate results of scientific research in the field of TRIZ methodology and challenges of TRIZ applications in industrial innovation process, entrepreneurship, career development and education. The Theory of Inventive Problem Solving (TRIZ), originally created by G.S. Altshuller and his co-workers [1], has been further developed in two recent decades, and is regarded today as one of the most comprehensive, systematically organized invention knowledge and creative thinking methodologies [2]. Nevertheless, the integration of TRIZ basic principles and tools into all phases of new product development and design process is still relatively low and fragmental. In the cross-industry study, performed by the Offenburg University among 162 R&D managers and engineers of German industrial companies in 2016-17, the TRIZ tools rank with 14% in fifth place of the top five methods supporting innovation process, after brainstorming (76%), engineering design methods (31%) [3], diverse creativity techniques (29%), and Quality Function Deployment (21%), as illustrated in Figure 1.

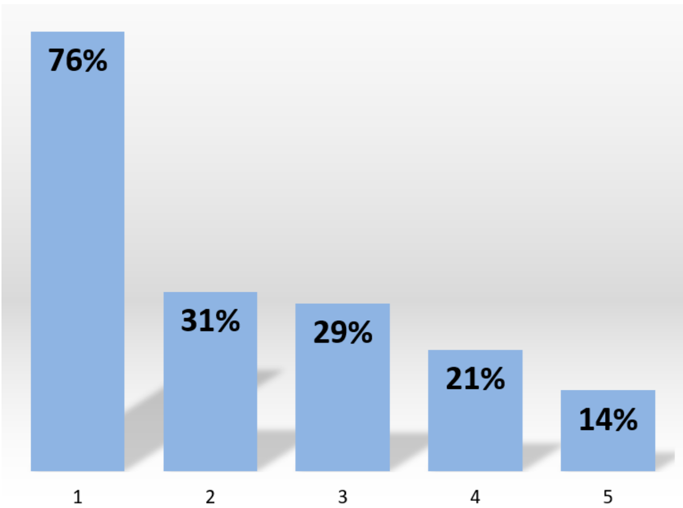

Figure 1. Top five methods supporting the innovation process in industrial companies: 1 - brainstorming (76%), 2 - engineering design methods (31%), 3 - creativity techniques (29%), 4 - Quality Function Deployment (21%), 5 – TRIZ tools. (Multiple response, n= 162).

This experience, among other consequences, may lead to a thorough reconsideration of the existing tools supporting different phases of the innovation design process, and result in the necessity of a novel joint-development platform, to enhance, to merge and to better integrate TRIZ and other techniques into all phases of the innovation process and design practice.

An attempt to initiate such activities has been made in the cross-industry research project "Innovation Process 4.0" run at the University of Applied Sciences Offenburg, Germany in co-operation with 10 German industrial companies in 2015-2017. The research consortium has conceptualized the Advanced Innovation Design Approach (AIDA) as a holistic methodology for enhancing innovative and competitive capability of industrial companies. AIDA can be considered as an open mindset, an individually adaptable range of strongest innovation techniques such as comprehensive front-end innovation process, advanced innovation methods, best tools and methods of the TRIZ methodology, organizational measures for accelerating innovation, IT-solutions for Computer-Aided Innovation, and other innovation methods, elaborated in the recent decade in the industry and academia [3, 4, 5, 6].

The innovation design process of the future with self-configuration, self-optimization, self-diagnostics and intelligent information processing and communication, is understood in AIDA as a holistic system comprising following typical phases with feedback loops and simultaneous auxiliary or follow-up processes: definition of the business strategy and models, uncovering of solution-neutral customer needs under consideration of technology and market trends, identification of the needs and problems with high market potential and formulation of the innovation tasks and strategy, systematic comprehensive idea generation and problem solving, evaluation and enhancement of solution ideas, creation of innovation concepts based on solution ideas, evaluation of the innovation concepts as well as implementation, validation and market launch of chosen innovation concepts. AIDA also postulates the principle of completeness in identification all major process data in the phases of innovation strategy formulation, problem analysis and definition, idea generation, problem solving and new concept development.

The AIDA implementation in the companies should help to significantly improve their innovation processes, to enhance the competitive capability and to contribute to the innovation-friendly climate in general. However, industrial companies have different needs regarding optimization of their innovation ability, which may depend on companies' industrial or business sector, business model, business trends including the financial results, company size and structure, complexity of products, innovation outcomes (product, process, service) and other factors. Thus, a method to systematically identify, to structure, and to evaluate key innovation performance parameter of industrial companies will help enhance their innovation strength.

The Advanced Innovation Design Approach was refined and further developed for the application in the field of process engineering in the context of the EU research project

"Intensified by Design - Platform for the intensification of processes involving solids handling" within international consortium of 22 universities, research institutes and industrial companies [7]. In the initial phase, following 10 easy-to-use AIDA tools were proposed for practical test and evaluation:

1. TRIZ based brainstorming: generate ideas with 40 TRIZ Inventive Principles.
2. Tool for systematic problem solving and moderation of innovation workshops with TRIZ.
3. Inventor-Tool for solving of bottle-neck problems based on inventive algorithm ARIZ.
4. Innovation potential analysis: comprehensive identification of customer benefits and needs with high market potential.
5. New concept development: implementation of the selected innovation tasks into new concepts with high market potential.
6. Root-conflict analysis [8] and anticipatory failure identification: tool for elimination of harmful effects and secondary problems.
7. Process mapping: tool to capture process intensification requirements and to identify problems and contradiction within an existing process.
8. Systematic and creative cost cutting for products and processes.
9. InnoMonitor: tool for continuous monitoring of innovative capability of companies.
10. Database of organizational measures for enhancement of innovation capability.

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A Comparative Analysis of Praxiological Networks and Selected IDEF Models

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Abstract The paper presents the results of a comparative analysis of praxiological networks and selected IDEF models. The typical praxiological networks formed from a number of praxiological chains and the Integration Definition (IDEF) models No. 0 and 3 were taken into consideration. Both of the ways of modelling were considered as the tools of design methodology and generally characterised in terms of their structures and selected assumptions related to their usage. The identification of inputs and outputs, subjects, objects and intermediaries of actions was carried out for the models. The selection of their elements and relations within them as well as the analysis of the problems associated with control and realisation of processes were performed for them. Eventually, it was possible to describe the similarities and differences for both ways of modelling and to formulate recommendations on their usage. Finally, the possibility of the integration of these two ways of modelling was discussed.

1 Introduction

Beneath different ways of modelling the formal models may be found. They include e.g. systemic modelling, cybernetic system for modelling flows and control as well as praxiological chains applied to represent actions. Systemic and cybernetic modelling may be conducted in reference to objects or processes while praxiological modelling is especially useful for analysis or synthesis of processes.

Integration Definition (IDEF) models are related to the ones mentioned above. Considering the great possibilities of application of all of the introduced ways of modelling, it seems reasonable to conduct a comparative analysis of the praxiological networks and selected IDEF models, therefore selected information about them was presented in the parts 2 and 3 of this paper.

2 Praxiological models of actions

An extraordinary kind of a process is an action considered as the process conducted only by a human being, incorporating the influence of consciousness, intentions and the ability to make decisions on functioning [1, 2]. Praxiology supplies models constructed and used especially for modelling actions. These include the praxiological chain and the ones obtained by linking a number of such chains together when a sequence of chains, a praxiological dendrite or a network are built. The praxiological chain is probably the simplest praxiological, formal model of an action. It consists of three elements which are the subject of the action, the tool (the intermediary of the action) and the object of the action [3]. It may be presented in a graphical form (cf. [2, 3, 4, 5] as well as Figure 1) or using formula 1 [2, 3, 4, 5]:

$$C_1 = \langle x_1, y_1, z_1 \rangle, \quad (1)$$

where C_1 refers to the praxiological chain, x_1 represents the subject, y_1 represents the tool and z_1 represents the object.

The most general aim of using the praxiological models is to analyse and/or synthesise relations of support between the chains representing separate actions in the context of ensuring the effectiveness of the actions. The supporting action always incorporates as its object the subject or tool of the chain being supported (though generally the supportive relation exists in reference to the object of the supported chain). The relation of support between the chains C_1 and C_2 (the chain C_1 is supporting the chain C_2) is represented by the formula 2.

$$C_1 \vdash C_2 \quad (2)$$

Sometimes, the most important element of the supporting chain may be indicated in the context of the relation of support. Therefore four types of supportive relations between two chains C_1 and C_2 are generally distinguished (formula 3) [3, 5]:

$$C_1 \vdash C_2 \Leftrightarrow x_1 \left| \frac{x_2}{z_2} \right. \vee x_1 \left| \frac{y_2}{z_2} \right. \vee y_1 \left| \frac{x_2}{z_2} \right. \vee y_1 \left| \frac{y_2}{z_2} \right. \quad (3)$$

where
C_1 refers to the supporting chain
C_2 refers to the supported chain
$e_1 \left| \frac{e_2}{z_2} \right.$ represents the relation when the element e_1 of the chain C_1 supports the element e_2 of the chain C_2 relative to the subject z_2 of the chain C_2.

The above-mentioned relations of support were also shown in Figure 1 [3].

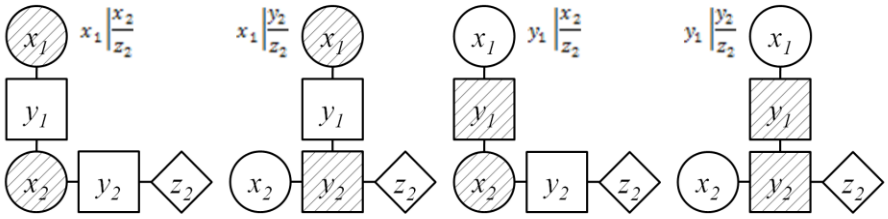

Fig. 1. Four types of direct supportive relation between two praxiological chains [3]

A praxiological chain is a representation of an action in terms of its realisation. An external process control factor (considered as another action) may be presented as a chain supporting the analysed one (cf. Figure 1).

3 IDEF0 and IDEF3 models

IDEF0 is a method for modelling i.a. processes and actions. It allows one to indicate the functions performed by the analysed system in reference to the modelled process [6, 7] as well as means needed to fulfil these functions. The obtained functional model represents the structure and functions of the analysed system as well as the flows of materials and data related to the functions fulfilment [6].

The basic part of the IDEF0 model is normally shown in a graphical form as a box representing the function of the whole system (or its selected subsystem). The box is surrounded by a set of arrows in order to present proper inputs and outputs of the conducted process [7]. The location of the arrow always should refer to the item it represents. The general rules in this area are as follows [6, 7]:

- controls (data) inputs are placed at the top of the box
- mechanisms (especially staff and equipment) inputs are placed at the bottom of the box
- material and data (which are processed) inputs are placed at the left side of the box
- material and data (which are obtained) outputs are placed at the right side of the box.

The described diagram is presented in Figure 2 [6].

As 'mechanisms' are considered all of the resources inevitable to conduct the modelled process except for the materials or data normally processed while fulfilling the basic function presented in the box.

The boxes may be connected with each other in order to present more detailed functions fulfilled by the subsystem of the analysed system [6] so a set of related functions (and processes) is obtained.

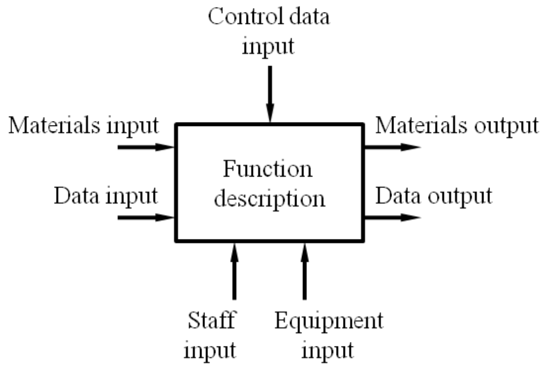

Fig. 2. IDEF0 basic diagram [6]

IDEF3 method may be presented as a tool for describing processes, considered as the sets of subsequent operations (or actions), in the context of the sequence and causality of these operations. What is more, one and the same process is also analysed or synthesised here as a set of subsequent states of the processed object [7].

The method provides two kinds of process description which are as follows [7]:

- process flow – represented by a graph showing the sequence of operations applied to the object (the boxes representing the operations are called units of behaviour)
- object state transition network – graphically represented by a scheme of the sequence of states combined with (the sequence of) operations (units of behaviour).

An exemplary process flow graph, together with an appropriate object state transition network scheme is shown in the Figure 3 (cf. [7]).

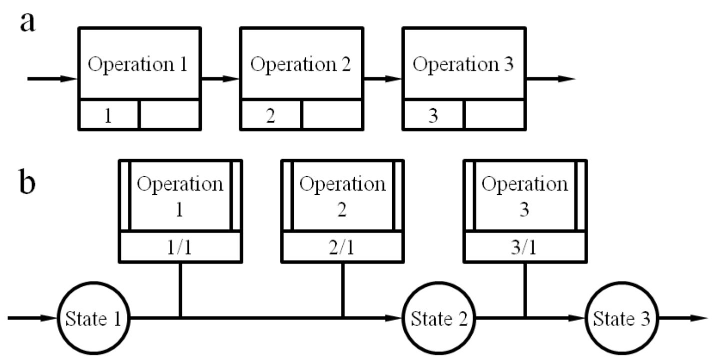

Fig. 3. An exemplary process flow graph (a) together with a corresponding object state transition network scheme (b)

The process shown in the Figure 3 consists of three states of the processed object undergoing three operations. The aspect of process control is not formally presented in the obtained models.

The possibility of indication of the elements typical for praxiological chains in the IDEF0 and IDEF3 models was discussed in the next part of the paper.

4 Application and integration possibilities

The IDEF0 basic diagram referring to a process may be represented using a set of praxiological chains. In this case the main process leading to the fulfilment of the function should be presented as a praxiological chain. The elements of the chain would refer to the staff (the subject) and equipment (the tools) used in the process. The impact of control would be represented using another chain supporting the previous one.

Though having no ‘natural’ input and output incorporated, the praxiological chain may be used in the way to model a flow. In order to obtain such an effect an additional assumption should be introduced. The tools present in the chain are divided into two groups: the one including the equipment used (as it was stated above) and the one incorporating the object before processing. The object of the action (the element of the first above-mentioned chain) is considered then as the object after processing (cf. [4]; the described approach was used in the example presented in Figure 4). For the IDEF3 method a translation of the object state transition network scheme to a sequence of praxiological chains could be considered as well.

The both (praxiological and IDEF) analysed methods of modelling have many similarities. However, the most important difference between them is the definition of action (described in the part 2 of the paper) considered as a process which is to be modelled. Because of the above-mentioned assumptions, the IDEF0 model seems more useful when modelling some selected aspects of processes, especially when no direct reference to human influence on these processes is taken into consideration. The praxiological model is in some way more general though definitely developed for analysing and synthesising the processes conducted by human beings or organisations (in general). On the other hand, lots of the industrial processes though automatically conducted, are initiated by human beings (e.g. a machining process performed by a CNC milling machine according to the machining program code). In this case there is no obstacle to use praxiological models if only the person initiating the process is considered as the subject of an action.

Considering the differences between the constructions of the praxiological and IDEF models as well as between the scopes of their application due to the understanding of action, a concept of the direct integration of the models does not seem reasonable to the author of the paper. However, while solving practical problems in real circumstances, the presented modelling methods could be applied in parallel (independently of each other). Such an the approach was presented on the simple example of a part of a steel bracket manufacturing process. Manufacturing operations taken into consideration covered cutting the necessary part out of a steel plate (together with cutting out the holes in the part) using a laser cutting machine and bending the part to obtain the bracket using a bending brake. Both of the machines are operated by their individual operators, and the manufacturing operations are conducted according to the technological documentation supplied by a production engineer. All of the obtained models were shown in Figure 4 and described below.

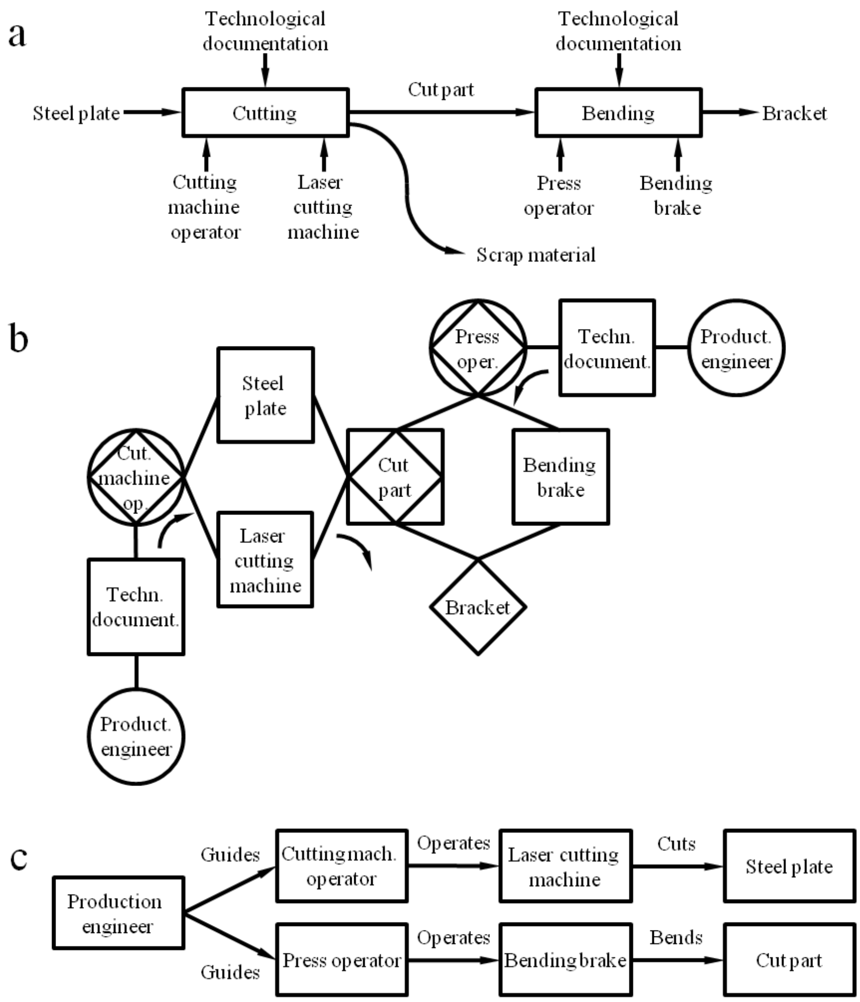

Fig. 4. Models of the analysed process: IDEF0 (a), praxiological chains combined (b), selected functions modelling typical for TRIZ (c)

The IDEF0 model of the part of the manufacturing process (Figure 4a) allows one to analyse the flow of the manufacturing feedstock, semi-finished product and product within the process. The flow is complemented by the manufacturing operations conducted in the process (at the chosen level of its decomposition) and supplies of the necessary resources inevitable to obtain the final product which are delivered at each step of the process.

The praxiological model (Figure 4b) presents the issue in another way. Here the most important relations are the relations of support which occur between the actions realised by different people involved in the manufacturing process. The main concern addressed by the model is the structure of relations between the actions which allow to obtain the desired final product. Of course, different tools are needed to perform these actions, and their use is individually assigned to each subject.

The above-mentioned approaches may remind one of the models constructed according to the function analysis introduced by some of the TRIZ guidelines (cf. [8]). A function modelling scheme related to the analysed example was shown in Figure 4c. In order to construct such a model, the manufacturing line (consisting of the two machines and their operators) and the production engineer are considered as a system together with the manufacturing feedstock, semi-finished product and final product occurring as its elements (according to the transitions between the states of one and the same concrete /material complex/, cf. [9]). The obtained model allows one to analyse the manufacturing process in terms of the functional relations which occur between the elements of the system where the process is conducted. Consequently, it helps to identify the weaknesses of the system [8]. The scheme shown in Figure 4c presents only the main useful relations between the selected elements. A complete function analysis would lead to a model incorporating different types of relations (harmful, poorly controlled, etc.) [8]. It is clear that the cut part causes wear of some parts of the bending brake while banding, therefore the identification of such a harmful relation gives possibility of modernising the system.

5 Conclusions

Considering a great number of approaches and tools which may be used during designing processes a question occurs ‘What does it mean exactly to design a process?’. Definitely the answer should be: to design (or plan) all of the operations (or actions) included in the process and inevitable for its realisation. The analysed praxiological models, IDEF methods and function modelling are in this case helpful. But the answer could be more complex. A complete project of a process should not include only the sequence of actions but also the sequence of states of the processed objects as well as the resources inevitable for conducting the process and the function relations between the elements of the system modelling the circumstances where the process is conducted. This state of affairs justifies the application of all of the above-mentioned models and methods especially when aiming at the improvement of effectiveness and efficiency of the analysed processes (cf. [6]).

Considering all of the described methods, the use of praxiological chains is the most universal method of modelling actions. It could be easily adapted to the specific practical or methodological circumstances. On the other hand, the construction of the IDEF schemes probably makes their practical application (e.g. in the industrial circumstances) less complicated.

The definition of action incorporated in the praxiological models leads to the conclusion that the most natural circumstances for using the praxiological chains occur when directly referring to the activities of people.

The IDEF0 model seems to incorporate some features of the praxiological networks model and also some of the cybernetic model which was not described in the paper though (these are e.g. the input and output enabling the occurrence of flow(s), the control input (or support) and the representation of the means needed to fulfil the function).

Function modelling delivered by TRIZ may be considered as an another way of modelling processes which corresponds with the above-mentioned ones.

All of the presented methods of modelling processes complement each other, therefore it seems reasonable to consider the use of each of them while preparing the works connected with the designing or modernisation of processes (choosing the proper models will depend on the aim of the conducted analysis or synthesis). What is more, they always should be supported by introducing other methods related to the evaluation of the possible effects of the proposed solutions.

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A framework of forecasting techniques as a checklist to minimize the likelihood of product design failures

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Abstract TRIZ is intended to support, among the others, the forecasting of future versions of technical systems. In this sense, the Laws of Evolution of Technical Systems range among the most powerful methods to predict possible product development patterns. The violation of these laws supposedly represents a trigger of product flops, due to an unnatural evolution of systems. It can be argued that such an infringement mainly regards the structural level of the product, also because TRIZ is mainly concerned with the description of physical components and their interactions. As it is well acknowledged from the design field, structures are essential ontological domains of products, but other dimensions are likewise relevant. First, other fundamental characterizations are represented by the product behaviour and function, whose definition might however differ with respect to its conceptualization in TRIZ domain. Second, the individuation of a more abstract goal is attracting increasing attention as a means to denote the designer's intent and the purpose of the product in terms of human utility. By analysing lists of remarkable product failures, the author claims that reasons of fiascos cannot be fully explained by violation of TRIZ principles. Hence, other product ontological domains might be involved in unsuccessful product launches. To this aim, the paper proposes a framework comprising different forecasting and evolution models, which are sorted according to their reference to said ontological domains. For instance, dynamic Kano models are associated to the evolution of product requirements and functions. The claimed utility of the framework is the possibility of verifying whether any of the most reliable evolution patterns is infringed in new product development projects. Besides attempting to complement TRIZ body of knowledge with external models, the definition of the presented framework discloses the need for researching evolution of human needs more accurately.

1 Introduction and background

Despite the availability of several valuable design methods that supposedly guide towards successful innovation (with TRIZ ranging among the most prominent ones), the number of products that thrive in the marketplace is extremely low [1]. At the same time and somehow surprisingly, the literature about failures is not abundant. Knowing failures better might prevent designers from repeating approaches and product development strategies that do not work, at least in certain circumstances. The long-term goal of the present research is the full investigation of the power of observed regularities, known trends, invariants and forecasting techniques in terms of explaining business failures of new products. More specifically, the paper stems from two main author's considerations, as in the followings; each of them are extended in bespoke subsections of the present section.

First, one of TRIZ's main objectives is the forecasting of technical systems. This is unlikely the most acknowledged reason for the existence of TRIZ [2], but Altshuller's Laws of Evolution of Technical Systems (LESE)[1] represent one of the best-defined and articulated instruments for forecasting activities.

Second, as TRIZ provides directions for systems' evolution, this means that only a subset of product development patterns is viable. Deviating from the identified directions relentlessly results in failures. However, it can be pointed out that the violation of the LESE cannot be considered as the only driver of flops. In addition, as the directions foreseen by TRIZ instruments are multiple and they do not address to the most successful new product version systematically, other criteria should be introduced and juxtaposed to the LESE. Although the objective of defining a unique and good solution might not be pursued anyway, different forecasting criteria can contribute in the avoidance of failures.

In this sense, the paper is concerned with the identification of forecasting methods and frameworks that might complement the functioning of the LESE. An overall schema is built based on the Function-Behaviour-Structure (FBS) ontology. The framework highlights that regularities of changes associated to certain dimensions require research efforts in light of the general scope of this work.

1.1 The evolution of engineering systems in a TRIZ perspective

The popularity of TRIZ instruments has recently attracted attention, as this can represent a proxy of the level of complexity and sophistication at which Altshuller's theory is used in the practice. As for the LESE and other versions of

[1] Alternative definitions are to be found at https://matriz.org/wp-content/uploads/2016/11/TRIZ-Glossary.pdf

evolutionary patterns and trends, indications from [3] and [4] are not in full agreement. It is possible to assert that these tools range among the most known TRIZ instruments, although their popularity does not surely reach that of Inventive Principles, probably the most ready-to-use TRIZ technique.

However, the relevance of the LESE is not negligible, especially in the design field, in which Cavallucci and Weill [5] have firstly proposed to use them at an operational level. This is facilitated by the consideration that TRIZ Laws are satisfyingly capable of systematising the accumulation of human knowledge applied to products' evolution. Attempts have followed to study the potential development paths for technical systems by exploiting the knowledge included in patent databases [6] and/or the expertise of skilled people [7]. The evolutionary nature of products and their associated target to increase ideality, also by reducing the consumption of resources, has logically resulted in juxtaposing LESE and trends with eco-design tools [8, 9]. In addition, the LESE are proven instruments to forecast the introduction of disruptive technologies [10], as well as to individuate parts of systems to be subjected to enhancements primarily, although some methodological shortcomings are still present [11].

1.2 Origins of product development failures: beyond the attempted infringement of system evolution laws

As anticipated, the knowledge about product fiascos is not abundant to date [12]. A shared characterization of failures is likewise missing. In the last few years, some samples of unsuccessful product development stories has surfaced in the literature [12, 13], as well as websites (including specific webpages of news outlets); interestingly, the Swedish Museum of Failure has been inaugurated in 2017. All the described items might represent a good starting point to investigate the reasons for failures in innovation initiatives.

If the 13 biggest product flops (according to Business Insider[2]) displayed in the mentioned museum are analysed, it is arguable to conclude that the infringement of any of the LESE can be detected in these cases. A similar conclusion can be inferred by analysing the business flops included in [13]. In a qualitative way, the explained reasons of failure consist in inaccurate business exploration, penetration of market domains that do not fit with the mission of certain brands, fulfilment of users' needs that resulted extremely irrelevant. This broad classification performed by the author is unsystematic and surely addresses just a subset of potential motivations behind unsuccessful product launches; however, the arrangement and functioning of components does not surely arise as a fundamental driver of unsuccessful stories. This makes it possible to put forward that the explanatory

[2] http://www.businessinsider.com/products-that-flopped-in-sweden-museum-of-failure-2017-4/?r=US&IR=T

power of the LESE might be limited with respect to prediction of successes or failures. Consistently, as clarified in [14], the LESE address a set of product development opportunities, but additional criteria, even not pertaining to the engineering domain, should determine which direction is the most suitable.

The need for integrating knowledge from other fields is far from surprising, if forecasting difficulties in the early design phases are considered [15]. The paper proposes a preliminary framework for integrating TRIZ tools with other forecasting techniques in order to explain failures and guide decision making in product development in a more structured way.

2 Maturity of forecasting criteria applied to different product dimensions – proposal of a framework

The above overview has highlighted how TRIZ forecasting instruments are capable of monitoring just some aspects that are critical to success and failure. In order to focus on the product dimensions that require to be designed and managed (and which can consequently evolve), the paper exploits the most diffused ontology of technical systems, i.e. FBS, that characterizes them according to different hierarchical levels. With respect to the original model [16], the fundamental ontological elements stand in:

- The Function, i.e. the designed capabilities of a system to change some parameter in the external world (e.g. raise a burden, rotate a shaft, attenuate a vibration), as foreseen by the designer's intent;
- The Behaviour, i.e. the complex of physical laws and the working principles from any discipline (e.g. chemistry, biology) which enable the display of the desired Functions;
- The Structure, i.e. the network of interacting components and physical elements that allow for the correct display of the Behaviour.

The practical employment of the classical FBS model has required an extension towards the consideration of other factors, according to new challenges posed by engineering design. In this sense, the design community has accepted the introduction of novel and more abstract ontological levels [17, 18], which can be considered relevant if the discussed reasons of flop are taken into account. To the scope, the Goal is introduced in this description standing for the purpose products are expected to achieve in terms of fulfilling people's needs. The complete GFBS (Goal – FBS) model is shown in the left side of Table 1. The central column of Table 1 illustrates what external evaluators perceive when modifications of the corresponding dimensions occur. These external manifestations can be considered as the key motivators of people's acceptance or rejection of innovations, since they pertain to what is actually perceived about products' advantages. They are therefore related to the habits that should be potentially modified to use these new systems. The trends potentially regarding the manifestations shown in the central column are reported in the right column of Table 1. According to author's best knowledge and evaluation, three fashions are used to mark the degree of acceptance of the tendencies concerning each hierarchy. More in details:

- Underlined trends concern models recalled in a rich body of literature that have been validated and are implemented in forecasting techniques or used for decision-making. Illustrative references include, beyond TRIZ LESE, patterns of technological change [19] and S-curves of Innovation [20].
- Trends in italics regard evolutionary hypotheses that are included in a dispersed body of knowledge and have not observed the development of a unified model yet. This is the case for example of the Dominant Design model [21], which, despite its popularity has not seen implementations in the design field [22]. At the same time, studies on dynamic effects concerning quality attributes as defined in the Kano's model [23] have received empirical support. However, they are not ready to be effectively employed at the operational level yet, despite recent efforts [24].
- Trends in bold types are associated with open issues in the design field, which require the fine-tuning of general-purpose tools, as claimed by several literature contributions [25, 26].

Product/system dimension	***External Manifestation***	***Associated trends***
Goal	Fulfilled needs	**Evolution of human needs**
Function	Attained benefits	*Dynamic of customer preferences, e.g. with Kano*
Behaviour	Governing physical principles, technologies	<u>Technological change</u>, <u>S-Curves</u>
Structure	Elements, parts, relationships	<u>TRIZ laws of Evolution</u>, *Dominant Design*

Table 1: Complete GFBS model for studying the evolving product aspects to be designed and managed

The LESE and the Dominant Design are associated to the Structure level, since they overall envision (the former) and dictate the timing of (the latter) transformations that regard components, interactions and arrangements of products and technical systems. As for the LESE, they might regard other dimensions, but the structural level is considered largely predominant.

Technological change patterns and S-curves are mainly inherent to the Behaviour level, as they address the timing and conditions for radical transformations of principles underlying the functioning of artefacts, when the incumbent technologies are no longer capable of fulfilling greater degrees of performances. It is worth noting that the S-curve model has progressively been incorporated into the TRIZ body of knowledge, although with slightly different meanings [27]. In a certain sense, the process of integrating knowledge from other fields may be already seen as an expansion towards product ontologies that involve TRIZ to a more limited extent.

As for changes concerning Functions and people's consequent benefits, the research of pertinent contributions has been mainly addressed at quality management and customer satisfaction studies. The most mature attempt to monitor regularities of transformations seemingly regards the use of Kano's method, as clarified above. The potential effect played by changes in fulfilled functions and enjoyed benefits on success/failure of radical innovations is investigated in [12, 28], but this does not support forecasting activities.

According to the performed investigation, no contribution strives to identify changes of product goals and fulfilled needs at a very general level. Despite the availability of several classifications of needs originating from psychology literature, studies are lacking that observe changes in the relevance of various needs. In this context, it is possible to mention few studies that could be considered relevant for a reference background. Oleson [29] suggests that individuals tend to consider less physiological and more hedonistic needs during their lifetime. Besides individuating gender differences, the contribution points out how this phenomenon impacts on their increasing willingness to pay for fulfilling the needs they perceive as the most pressing. Ahmad and Mehte [30] highlight that, in mobile phone industry, user needs significantly influence the evolution of devices after a first phase in which the evolution of technologies plays a major role. Needfinding [31] is a strategy to observe customers in order to discover their real necessities, i.e. which benefits are desirable and in which context. The outcomes of the application of the strategy emphasize that needs are normally not expressed by customers, although they exist at a latent level in terms of currently experienced problematic situations.

3 Discussion and conclusions

Products and technical systems evolve, as TRIZ theory puts forward unequivocally – such an evolution, still according to TRIZ reading, is dictated by determinants and regularities. According to the author's view, TRIZ tools (and specifically the LESE) are not sufficient to figure out new versions or generations of new products. An empirical demonstration is provided, in the sense that product innovation failures cannot be explained just by violation of the natural evolution of technical systems, as intended by TRIZ. This is evident in many failure cases described in the literature or in other sources. It is claimed here that other regular patterns might regard product aspects that are not focused on when TRIZ tools are typically in play, i.e. the structural dimension. Besides, it is highlighted that certain invariant phenomena are acknowledged in the literature that regard other product ontological domains. Some of them are exploited to streamline forecasting methods and/or used as references for designing. The main results of this preliminary investigation are summarized in Table 1 – they can result useful according to different perspectives, as follows.

With reference to the TRIZ community, some research areas are suggested that can beneficially integrate TRIZ body of knowledge within technical systems and forecasting. This has somehow taken place with regard to the integration of S-curves, which originate from a different discipline.

As for design science, a relevant open issue is highlighted, i.e. the lack of studies about possible regularities in the modifications of reference needs fulfilled by product generations, e.g. some cars shifting from mere means of transportation to status symbols. This represents an input for the author's future work.

In terms of the general objective of the research, the proposed framework is a first reference to be used as a checklist in order to minimize the likelihood of product failures. Indeed, the framework juxtaposes the LESE and other circumstances and criteria to be considered when developing new products. Consistently with the aims of the research, the proposed criteria pertain to variegated aspects, from technical ones to dimensions that involve human behaviour and preferences.

A major limitation of the present study is the lack of a test to verify the utility of the mentioned framework, which could give rise to conflicts among the whole criteria that have not been noted at a theoretical level. The situation is further complicated by the recalled missing information about evolution of needs. Eventually, the findings might be biased by some reported assumptions and beliefs, e.g. the possibility of using different forecasting tools to reduce the number of product development failures.

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A systematic literature review of TRIZ used in Eco-Design

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Abstract

Creativity has emerged as a driving force to innovation processes and systems' design for the manufacturing industry of future generations. Despite the growing importance of value creation of innovation processes and strategies in general, companies are still faced with the challenge of measuring the outcome of innovation processes in particular. Many creative assessment methods for innovation can be identified from literature, such as Theory Inventive of Problem Solving (TRIZ) and morphological analysis. For example, researchers combine or integrate TRIZ with other methodologies such as life Cycle Assessment (LCA) and Life Cycle Engineering (LCE), to help design engineers and practitioners to create, evaluate and select the best solution in order to meet the business' objectives for eco-product and sustainable manufacturing. The integrated methods can solve main contradictory problems, particularly engineering requirements from the concept of eco-design analysis to eco-product, sustainable manufacturing and application. Review work on the literature focused on research and development of TRIZ, LCA, and LCE, showed that the mentioned methodologies have been widely and successfully implemented. This review work provides an in-depth analysis of identifying and finding issues of strengths, weaknesses and outcomes of the TRIZ when combined with LCA, LCE, Eco-efficiency and other integrated methods for eco-production and sustainable manufacturing. The results show that using creativity assessment methods and eco-design methods facilitates decision-making process in early stage of conceptual design for sustainable manufacturing.

Keywords: TRIZ, morphological analysis, creative methods, problem solving, eco-design

1 Introduction

In recent years, industrial organizations and companies are experiencing a growing pressure related to environmental issues and costumers' satisfaction needs, and the use of creative methods is playing an important role in the quest to meet such expectations. Creative methods as a concept have been gaining a great importance and increasing popularity across various domains, especially for eco-design during the conceptual stage. Therefore, many companies use creative methods as a driving force for eco-product design and its development to stay competitive. Product development (PD) is introduced to interpret the customers' needs into product design and manufacturing. Furthermore, PD involves a series of activities such as material selection, manufacturing process design, prototyping, testing and validation, and product marketing. The literature analysis in the field of creativity assessment ─ in particular, eco-design oriented approaches for innovative and eco-product design ─ shows that many creativity assessment methods and tools have been developed [1, 2]. Even though there are a lot of creative methods and tools developed and research done by academia, the majority of companies and industries have not yet established eco-design practice in their principal product development activities [2].

Currently, sustainability is required to combat environmental pollution, global warming, energy and economic poverty, etc. and has become a critical topic for the society. Hence, engineers and designers must take into account the effects of their decisions on the environment and ecosystem. Sustainability needs to be implemented at early stages of a product's life cycle in industry. However, current PD activities in manufacturing industries are mostly focused on quality, cost, energy consumption and production [3, 4]. The selection of eco-design of conceptual phase of the product, manufacturing process and raw material, play an important role to minimize adverse impact on the environment in order to achieve sustainability [5, 6]. Thus, the engineers and designers must introduce "green" criteria into the framework of selection criteria for conceptual design. To aid engineers and designers in determining and select the suitable design, manufacturing eco-process and materials, many methods have been developed in order to meet companies' specifications, sustainability requirements and satisfaction of customers' needs and expectations [6].

The purpose of this study is to provide information about what is currently performed in connection to creativity assessment methods particularly, when TRIZ is combined with Life Cycle Assessment (LCA), Life Cycle Engineering (LCE) and other sustainability assessment methods for eco-design process. Through this, existing issues and knowledge gaps in the practice of creativity assessment methods and tools for systematic engineering creativity, mainly TRIZ in this paper should be identified. This paper focuses on specific objectives as following:

1) Identification of systematic creativity assessment methods for problem solving in combination with other methods for eco-design used in conceptual phase for last 17 years;

2) Analysis of TRIZ as a creative assessment method in combination with eco-design used in conceptual design for sustainable manufacturing.

From the literature review, this study intends to answer the following questions:

- What are the implications and results of different creative and analytical methods within eco-design?
- Which tools of systematic design are more effective for eco-design implementation?
- Where TRIZ has been implemented in terms of eco-design practices?

2 Background on Conceptual (Eco) Design

Identification of needs and product planning, together with other design activities are known in literature. Eco-design is a product design process [7, 8] that describes the consideration of the ecological performance during product development, whereas the ecological performance refers to the interference of the product with the environment [9, 10].

Conceptual design is one of early and very important initial stage for development a new product stage in PD [11]. It is beneficial to maximize the cost and lead-time; and maximize the quality of the product, flexibility and customers' satisfaction. There is an improved study in considering the precise decisions on the design concept and material selection concurrently at the early stage of product development.

The early consideration of conceptual design in PD process is very crucial to achieve cut down PD time, production cost, and quality defects. For example, previously, manufacturing process is conducted at the detailed design stage, means until to this stage the critical issue regarding manufacturing process is not recognized and obviously it is too late to determine the constraints impose by manufacturing process. It is very complicated to design the product without selecting the materials at the early stage of design. The development of the new product can be derived from the customers' needs or modification from an existing product [11]. The complex design is constantly under pressure of time and budget constraints thus the cost of error is high at this stage. Over the past two decades, much effort in a variety of disciplines has been made at developing, applying and integrating systematic engineering creativity approaches to eco-innovation and creative thinking in eco-design process/product.

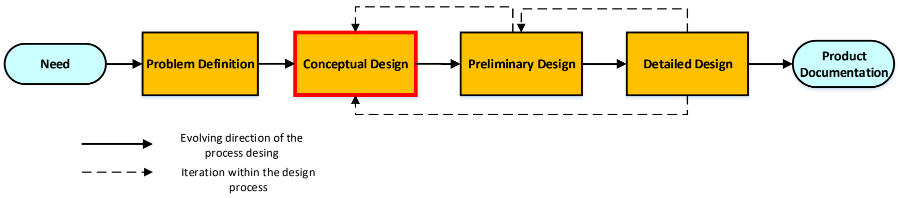

Fig. 1. Main steps of the engineering design process [11].

Figure 1 shows a generic model of the engineering design process consisting of a few linear steps according to Pahl and Beitz [11]. The process is, of course, more complicated as different factors of the sustainability aspects of the eco-design (legal, environmental, economic, social, and technical) need to be considered simultaneously, which requires involvement of experts from various disciplines and departments. TRIZ, Morphological Analysis (MA) and Design Thinking are some of the most widely used approaches for idea generation today. Generally, an idea generation technique is the starting point of innovation, mainly used in conceptual design. Therefore, the generation of creative ideas is the first and foremost stage of new product eco-design and innovation. Initially, in-depth review of articles is to identify and categorize problems regarding to using TRIZ and LCA for eco-design and their categories are depicted in this paper.

3 Review Framework

While carrying out a comprehensive review of identified methodologies, a review framework that allows for the involvement of the most relevant issues to conceptual design was employed. For each methodology, issues such as the origin and status of the methodology, from well-established to experimental, were looked into. As part of the review, various assessment creative methods developed based on the identified methodologies were appraised. The data requirements of these methods and their application to conceptual design activities such as planning, product development, design, construction, operation and maintenance were looked into. This allowed the strengths, weaknesses, potential applications, data, inputs, outputs and applicability at various companies for the various methods to be identified.

4 Research Methodology

Many creativity assessment methods and tools in early stage of conceptual design can be identified from literature. Information about best practices of TRIZ in systematic engineering creativity methods was gathered through a review of international literature. The focus of the TRIZ literature review was academic literature for the years of 2000 to 2017. The reason for this focus on new academic literature is based on the purpose of the study to provide information about the current best practices of TRIZ as the most common method of systematic engineering creativity in combination with LCA for eco-design product/process. This study put a specific focus on TRIZ, since this method address several application cases from different point of view. In order to meet the aim of this paper a literature review was performed. It was based on 34 papers, selected out of 100, found during May 1 to June 31, 2017 in Scopus using the following combination: 'eco-design' AND "TRIZ" OR "Morphological analysis" OR "LCA" AND "conceptual design", also illustrated in Figure 2. Only research papers (no books) from year 2000 until 2017 were searched for, and the search fields were Title, Abstract and Keywords. A relevant paper in this study is considered to be a paper that describes the most used "method OR tool" integrated with sustainability issues and "product design" OR "engineering design" in "conceptual design" and/or "systematic engineering creativity" TRIZ and MA. The 34 articles addressed the integration of LCA with application of TRIZ approach and other creative methods and tools in conceptual design were analyzed in Table 1.

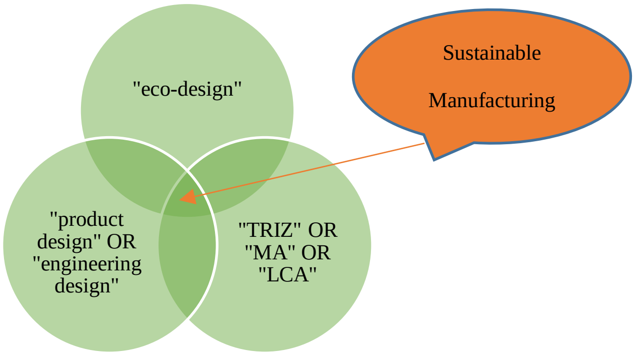

Fig. 2. An illustrative of the search word combination.

The literature study of 34 papers were selected by using the following evaluation steps:

Step 1. Evaluation regarding the title and keywords. If considered relevant → Step 2.

Step 2. Read the abstract and after that do an evaluation of the abstract regarding the whole paper is potential of being relevant. If considered to have a potential → Step 3.

Step 3. Read the whole paper.

5 Overview results of TRIZ and Its Application in Eco-design

In this section, we report our analysis of the literature we have reviewed. We start by highlighting some of the recent related reviews.

The "Theory of Inventive and Problem Solving", also known by its Russian acronym TRIZ, was developed by G. Altshuller [12, 13] to propose a framework for the construction of methods to identify and solve problems arising during the evolution of technical systems. TRIZ is an organized method for problem solving, which can be applied for eco-design. Altchuller [12, 13] stated that TRIZ can be aimed for minimizing energy requirements, as well as complexity of engineering products. Therefore, both TRIZ experts and eco-design community try to involve TRIZ tools for eco-design [14]. In general, eco-design is aimed to create environmentally friendly products over their life cycle [15]. Generally, TRIZ application attempts for eco-design toward eco-efficiency refer to decrease energy requirements [14, 15, 16, 18, 19], pollution [14, 16], materials [15, 16, 18], toxicity [15, 16] or increase of recyclability [16], durability [16], the sustainable use of renewable resources [16].

Generally, TRIZ consists of different tools, which are applied for idea generation. Previous studies support that some of them present a special interest in eco-design. The most generally applied for eco-design TRIZ tools are contradiction matrix, forty inventive principles, evolution patterns, ideality and trends of engineering system evolution. Applying TRIZ to transition from product to service innovation requires general eco-parameters transfer to the contradiction matrix parameters [18]. Inventive principles in general can accelerate eco-design. Inventive principles from the contradiction matrix can be used after identifying an improvement parameter [21]. Next, the evolution rules may arise for eco-products [21]. Among trends of engineering system evolution, some trend lines can point out improvements to the ecological evolution, like macro-scale to-nano scale, energy transmission, or can be used to identify unnecessary system complexities, while others point out causes of negative effects [22].

In addition, environmental friendly solutions are formed based on stand-alone TRIZ and in combination with other theories. Synergy of Case Based Reasoning (CBR) and TRIZ [17, 21] are most common within the research. Authors also integrate TRIZ in LCA [20, 23, 24, 25, 26]. TRIZ evolution patterns, CBR and simple LCA can be integrated [15, 27] in a way that first TRIZ patterns move inventors in an conceptual field, then CBR helps to realize the concept and using LCA the effectiveness and improvements of the new design in comparison with other methods is revealed [15]. There are also some comparisons of TRIZ method in combination with eco-design strategy wheel [28] and LiDS-wheel tool [22].

Table. 1. Selected literature survey of TRIZ combined with other approaches for eco-design

References	TRIZ combined with	Method Applied in
(Low et al., 2000) [18]	TRIZ	Product to service eco-innovation Adaptation to eco-centers service solutions
(Liu and Chen, 2001) [16]	TRIZ	Product green innovation design method
(Low et al., 2001) [29]	TRIZ	Green service manufacturing
(Chen and Liu, 2003) [30]	TRIZ and Quality Function Deployment (QFD)	A supporting tool for designers to invent novel, useful, and environmentally friendly products
(Kobayashi, 2005) [20]	Life cycle Planning (LCP) and Eco-efficiency	Product design based on life cycle planning
(Chou, 2009) [31]	TRIZ	TRIZ is used to support R&D to create innovative product design ideas
(Yang and Chen, 2010) [21]	CBR and TRIZ	Eco-design
(Chulvi and Vidal, 2010) [22]	TRIZ (Trends) contra LIDS	Eco-design
(Chakroun et al., 2010) [26]	TRIZ and LCA	Agriculture technologies
(Russo et al., 2011) [23]	LCA criteria a brand new index, called the “IFR index”,	Apply to European small medium enterprises
(Russo et al., 2011) [14]	TRIZ (Laws of evolution)	Assess and innovate a technical system Vacuum cleaner example
(Trappey et al., 2011) [19]	TRIZ, QFDE, BPN, LCA	Product development

(Yang and Chen, 2011) [27]	TRIZ, LCA, CBR	Designing eco-products
(Negnyet al., 2012) [17]	synergy of TRIZ and CBR	Chemical process preliminary design
(Durieux and Teulon, 2012) [32]	TRIZ	Eco-design and Innovation on IT Services
(Yang and Chen, 2012) [15]	TRIZ evolution patterns, CBR and LCA and	A forecasting novel model to acquire innovative ideas Identifying a new eco-product design
(Mogensen and Rousse, 2012) [33]	TRIZ	A systematic eco-design approach for Lithium-ion batteries
(Kallel et al., 2013) [36]	Eco-innovation in Product Phase	Integrating ecological aspects into the innovation process
(Russo et al., 2015) [25]	LCA and TRIZ	Greener products (European Project-REMAKE) eco-innovation in SMEs
(Vidal et al., 2015) [28]	TRIZ contra Eco-Design Strategy Wheel	For eco-innovation of ceramic industry products
(Taheri et al., 2015) [37]	Product Evolution Exploring Model (PEEM)	A model for capturing the information of technological products and processes
(Taheri et al., 2015) [38]	TRIZ and reative measurement applied to industry	Measuring inventive performance of R&D teams
(Cherifi et al., 2015) [34]	TRIZ	To help the designer to make a decision
(Davide and Marco, 2015) [24]	TRIZ and LCA	Contradiction prompter, which integrates TRIZ in LCA
(Russo et al., 2015) [25]	An eco-design methodology based on two abridged LCA tools (eVerdEE [1] developed by ENEA [2] and the French Standard NF 01-005) plus TRIZ	Product development

	[3] Eco-guide-lines is present	

[35] Focuses on creative idea generation process in company's environment. It constructs more guided approach to sourcing creative stimuli. As a guiding approach, TRIZ (contradiction matrix, inventive principles) turns out to be an appropriate tool for to increase creative performance.

6 Discussion and Conclusions

The main objective of this work was to analyze and review several works in the literature on creativity assessment methods e.g. TRIZ in combination with other techniques. The analysis focused mainly on the combined use of two well-established systematic creative methodologies of TRIZ and MA approach for eco-design in order to enhance and improve the product design and development process.

In this work, journal articles pertaining to the combined TRIZ approaches from 2000 to 2017 were reviewed and analyzed. The strengths and weaknesses of the combined methods and their application in the specific cases were also highlighted. The combined techniques were also analysed separately. This paper also elaborates on details of the combination of methodology, specifically details related to both TRIZ combined with LCA and MA combined with LCA. The combined TRIZ-LCA and MA-LCA approaches were the most commonly used techniques to deal with eco-design of the product development in the early stage of conceptual design. However, their drawbacks have also been encountered. This paper also reviewed the important benefits of the combined TRIZ-LCA and MA-LCA approach. Some of the benefits of the combined TRIZ approach obtained from the literature reviewed are listed below:

- The integration of TRIZ with LCA improves the overall process of new product development, from concept to integrated management information.
- With combination of TRIZ and LCA can reduce the flaws for eco-product.
- TRIZ-LCA-LCE could be used to reduce the negative components during the product design stage and development stage.

TRIZ plays a significant role in eco-design enhancement. Forms of its application studied and included a variety of tools from TRIZ, which used in eco-design in addition with other concepts and tools widely used.

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Application of TRIZ Concepts to University Career Development Education

A practical example of lecture activity with TRIZ

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Abstract Unpredictable globalizing society currently requires university students to design their own career as an independent individual. So, career development education, which is now also popular in Japan, should be customized assuming diversifying student back grounds. The educational activities tend to be talks lectured by business persons invited from leading companies. Special working culture in Japan is also a main lecture topic particularly for international students. Some lucky students may find clues applicable for their own career development from such lectures, but the other does not recognize the contents useful for their futures. This paper introduces an application of TRIZ to a university career development education under the assumption that all of the students will need to get over the sequence of problems, which are recognized as contradictions in TRIZ, on their career development. The authors used the TRIZ tools: "if then but statement", "separation principles" and "40 inventive principles" in the lecture entitled "Introduction to Career Development Theory" aiming to demonstrate the process of problem definition and solving. The students firstly defined recognizable problems in their university lives with the "if-then-but statement". Then they generated the solution ideas with other TRIZ tools. Most of all students proactively extracted problems and smoothly cooperated with their colleagues to generate solution ideas. We obtained positive feedbacks from the students and thus concluded that TRIZ is a practical tool for career development education.

1 Introduction

Currently in Nagoya University, educational activities for career development, which are provided mainly for Japanese students, are lecture talks by business persons invited from leading companies. Some lucky students may find clues applicable for their own career development from such lectures, but the other does not recognize the contents useful for their futures.

Recent globalization has affected university environment including Nagoya University, Japan. Nagoya University has started Global 30 International Program (G30) since 2011, where the students study subjects in English [1], while the other programs educate students in Japanese language. The students in the program do not have model case to follow, so they are also required to design their own career as an independent individual.

The authors, two international student advisors and a career support advisor are in charge of career development education for the G30 students mainly through a lecture course “Introduction to Career Development Theory”. This lecture course was started initially aiming to teach the international students in G30 special working cultures in Japan.

Career development education may not have been a significant topic for typical Japanese students who are going to be employed by Japanese company in their university life. Many Japanese companies adopt simultaneous recruiting of new graduates assuming life time employment of them. Although recent business environment makes this system less sustainable, typical Japanese companies still put more stress on the students’ potentials rather than their specific attributes such as language skill, specific knowledge, research achievements and others. So, both the students and faculties tend to assume that the companies design the employees’ career path and employees follow the design.

This system may be a special case applicable only in Japan. So, the authors have noticed that additional contents that are useful for all the participants in the lecture through the interaction with the G30 students who are originated from various back grounds; Some are from east Asian countries and others are from European countries. This means that future career plan also have varieties and how to develop their career must be more important for them.

This paper introduces an application of TRIZ to our career development education under the assumption that all of the students will need to get over the sequence of problems, which are recognized as contradictions in TRIZ, on their career development. In the lecture, the TRIZ tools: “if-then-but statement”, “contradiction matrix”, “separation principles” and “40 inventive principles” [2, 3, 4] were introduced to demonstrate the process of problem definition and solving. The students firstly defined recognizable problems in their lives with the “if then but statement”. Then they generated the solution ideas with other TRIZ tools.

2 Motivation of using TRIZ for career development education

One of the options of a lecture for career development education was introducing employment situations of the students’ countries. This idea, however, was considered to be not realistic, because it seems impossible for the authors to be familiar with the fluctuating employment situation more than the native students.

Self-analysis activities, where students are encouraged to define the future goals with detailed plans by clarifying their advantages and disadvantages, may be a typical candidate for satisfying the demands of such students with various backgrounds.

While these options are under a stereotype that one should define a goal, John D. Krumboltz pointed that unpredictable events play important roles for effective career development in 21st century; So, one should actively take advantage of the events. This idea, “Planned Happenstance Theory [5]”, more agree with the situation of G30 students who are with various backgrounds and need to survive this unpredictably fluctuating age than the conventional activities.

The authors concluded the main concept of TRIZ, especially a conflict of two parameters are resource for innovation, is a practical methodology to demonstrate how to actively take the advantages of future unpredictable events. The unpredictable events often include problems, unreasonable contradictions that normally depress people. But, the students equipped with the perception that a conflict is resource for innovation fearlessly challenge such problems to accumulate successful experiences. According to the “Planned Happenstance Theory”, this accumulation of successful experience should be recognized as realistic career development.

3 Overview of “Introduction to Career Development Theory”

The lecture course of “Introduction to Career Development Theory” is a liberal arts subject for G30 students composed by 15 weekly lectures. The lecture starts with 30-minute explanation about general topics related to career development that includes employment situation and working culture in Japan. Then, the 30 - minute explanation is followed by group activities for problem solving, where TRIZ tools were proactively used.

The following is the syllabus of this lecture; “The students firstly analyse the challenges faced by currently existing occupations and learn scientific approaches for problem solving (such as the 40 inventive principles defined by the theory of inventive problem solving) in group work activities. Then, they will be asked to make strategies to get over the challenges to raise awareness on the importance of career planning. The students each finally independently researches on the strategy for own future career path referring the experience in the group work activities and introduces the research results at final presentation."

The students were firstly asked to brain storm problems observed not only in career development but also in daily lives including news. Then, "If then but statement" was introduced as a significant strategy to understand a problem. Here, it was stressed that a problem is defined as conflict of parameters and students were asked to extract the conflict embedded in a problem observed around them by using the format of "if-then-but statement"; if we make a change, something positive happens, but something negative also happens. The students were also asked to generate solution ideas through group discussion by using TRIZ idea generation tools such as "40 inventive principles".

4 Outcome of the TRIZ activities

Twenty students of various nationalities participated in this lecture course and joined the activities introduced above. Students proactively extracted problems and smoothly cooperated with their colleagues to generate solution ideas guided by the authors' instruction. Most of the students successfully generated a problem and defined conflicts from them by using "if-then-but statement",

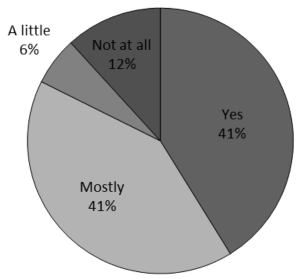
A few students did not understand this activity requiring extra support to define a problem and extract "if-then-but statement" from it. This problem may have been caused by the abstractness of the activity confusing the students. The authors support, explaining the activity intention, "A problem includes contradiction that is systematically defined by "if-then-but-statement" successfully released the students from the confusion and activated their mind to pick up the problems.

Table 1 shows some examples of problems and conflicts extracted from the problems as "if-then-but statement" and the solution concepts provided by the students by using 40 inventive principles.

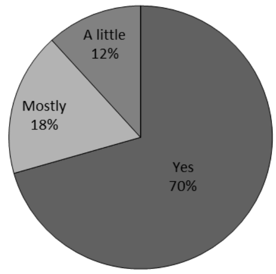
Fig.1 is the result of the student evaluation performed at the end of the final lecture. Seventeen students submitted the sheet. One can see that positive feedbacks about the lecture content were given by 70 to 80 percent of students. Thus, the authors conclude that majority of the participant students understood the lecture content recognizing TRIZ tools introduced in this lecture is ingenious as expected.

Table 1 Example of "if then but statement"

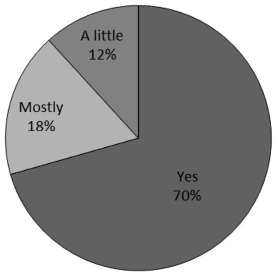
Problem: New PhD graduates are struggling with getting job in research institutions.
If-then-but statement: If the requirements for enrolment and graduation from PhD courses are made more difficult, then the quality of PhD holders will be higher, but the students are discouraged to join PhD courses.
Solution ideas: (1) Release veteran researchers from tenure to make way for fresher ones. (2) Train PhD students with job market skills. (3) Decrease the number of PhD candidates. (4) Raise the level of requirements for PhD course
Problem: Overworking of Japanese workers damage their health.
If-then-but statement: If the employers give more vacations to the workers, then they would be healthier but it may negatively affect the company business performance.
Solution ideas: (1) Labor law should set limit working hours. (2) Productivity must be improved (3) The workers should know that long time working is bad for their health (4) Managers should evaluate the workers on the basis of output rather than working time.
Problem: Traffic jams cause inconvenience in mobility.
If-then-but statement: If more people use public transportation, then the traffic jams on the road will be reduced, but people might not get the convenience of door-to-door transportation.
Solution ideas: (1) Implement better traffic management techniques (2) Build more roads, fly overs to reduce traffic (3) Improve infrastructure for better public transport system (4) Encourage car sharing
Problem: Maternity harassment in the workplace in unacceptable
If-then-but statement: If countermeasures against maternity harassment are made, then working conditions for females improve, but the implementations need to change the mindsets of the individuals in the working places.
(1) Modify current regulations about maternity harassment to be more specific. (2) Companies should implement stronger support for mothers. (3) Companies should take responsibility to inform the employees not harass maternity persons about the regulation.



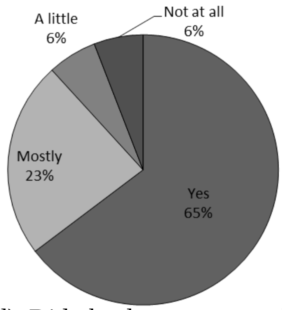
(a) Did you proactively join the lecture?



(b) Did you understand the contents provided in this lecture?



(c) Do you think the lecturer taught with passion and ingenuity?



(d) Did the lecture properly use teaching materials and method?

Fig.1 Results of lecture evaluation

4 Discussions

The authors believe that our challenges have opened the door of new career education from a novel view point by using the TRIZ tools. The TRIZ tools were introduced as strategies to define and solve problems allowing the students to proactively think about their future challenges.

The participant students has successfully defined problems “if-then-but statement” and generated specific solution concepts as shown in Table 1. The students’ reaction in Fig.1 indicates that TRIZ tools have practical contents for university lecture activities such as the lecture “Introduction to Career Development Theory” to demonstrate how to get over unpredictable events in their life.

According to the authors’ experience on problem solving workshops so far, the lack of strategy to guide the students into effective group discussion causes uncontrolled divergence of group discussion. In such case, some group even fails to summarize group opinions. On the contrast TRIZ obviously includes specific strategy to define a problem as a conflict of two factors. “if then but statement” is an effective guideline for clear and specific problem definition. In addition, problem solving tools such as “40 inventive principles” can be shared across academic disciplines.

The group discussion in the lecture, however, could not step into detailed analysis about the solution concepts. The authors were initially expecting the students to cooperatively solve global issues such as global warming and terrorisms, but we faced the problem that the validity of the solution concepts is not feasible and evaluable. Some problems shown in Table 1 may be concerned in their daily life, but the topics are too complex to be tackled by a few hours of group discussion in this lecture.

As the next challenges, the topic of discussion may need to be more limited to more specific problems in the students’ daily life. Solution concepts for such problems can be practically solved and proposed in reality. Considering that a career may be developed by solving problems encountered in daily life, such near-by problems are more preferred to be topics for the group discussions than currently unsolvable global issues.

5 Conclusion

The authors have introduced a novel approach for career development education by using TRIZ assuming that all of the students will need to get over the sequence of problems in their future career development. The TRIZ tools such as “if then but statement” and “40 inventive principles” were introduced and used for group working in the lecture, “Introduction to Career Development Theory” aiming to demonstrate the process of problem definition and solving. The students firstly defined recognizable problems in their lives with the “if-then-but statement”. Then they generated the solution ideas with other TRIZ tools. The students successfully extracted problems to generate solution ideas. We obtained positive feedbacks from the students and concluded that TRIZ is a practical tool for career development education.

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Automation of conceptual design stage of framed buildings projects using TRIZ function modelling in BIM environment. A case study.

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Abstract In the article we present step-by-step automated TRIZ function analysis of a framed structural system. The analysis has been performed in BIM environment using Revit © software and tools for visual programming. The article includes an introduction and experimental model description and the main body consisting of Interaction and Function matrixes construction, functional diagram creation, ranking and trimming. The paper ends with conclusion and discussion.

1 Introduction

Automatic search for new ideas will significantly reduce the amount of time spent on projects and minimize the probability of errors occurrence further [1]. Due to this, we propose a prototype of software that will support search for ingenious solutions of technical problems at an early design stage of frame buildings projects.

For this research we developed a program using visual programming tool Dynamo [2] realized in Revit software environment. After a user creates a Building Information Model (BIM) of a framed building, this program performs the following algorithm of actions: construction of the intersection matrix, identification of functions of the model`s elements, construction of the functional model, ranking of elements and trimming. In this research we obtained a result that allows designers to automatically analyse and exclude non-functional elements from the model and further propose a solution to prevent unfavorable functions of its elements.

The key advantage is that this analysis is being done on early design stage before deep structural analysis which is time and cost consuming.

In the article we provide a description the software prototype based on a frame building design case study.

2 Experimental model descriptions

In order to carry out the experiment a two-story framed structure (Fig. 1a) was constructed in Revit software. It includes 8 columns, 4 foundations, 1 slab and 12 beams. The choice of this composition of structures is justified by better visibility for representing the results. Despite the fact that the selected model does not include a large number of elements it includes all the main categories of elements which are widely used in framed structural systems.

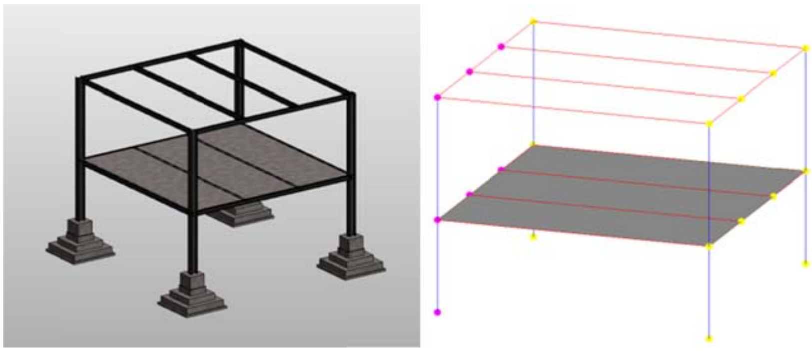

Fig. 1. Experimental model. (a) Physical, (b) Analytical

Geometrical characteristics (cross-section of beams and columns, thickness and spatial dimensions of the slab and foundations) are not taken into account and do not influence the results of the experiment. We consider functions which are performed by the elements. In order to present this idea as clearly as possible, it was decided to analyze the analytical model where each element is represented as a primitive (Fig. 1b).

The nodes of connection of individual elements are represented in simplified form. Yellow nodes are hinged connections and violet are rigid ones.

3 Interaction and function matrixes construction

The script analyzes the elements of the model and creates a matrix. The interaction matrix for the analyzed model looks as shown on Fig.2.

	1. Foundation	2. Foundation	3. Foundation	4. Foundation	5. Column	6. Column	7. Column	8. Column	9. Beam	10. Beam	11. Beam	12. Beam	13. Beam	14. Beam	15. Slab	16. Column	17. Column	18. Column	19. Column	20. Beam	21. Beam	22. Beam	23. Beam	24. Beam	25. Beam
1. Foundation					+																				
2. Foundation						+																			
3. Foundation							+																		
4. Foundation								+																	
5. Column	+								+	+					+	+									
6. Column		+								+	+				+		+								
7. Column			+								+	+			+			+							
8. Column				+					+			+			+				+						
9. Beam					+			+		+		+	+	+	+	+			+						
10. Beam					+	+			+		+				+	+	+								
11. Beam						+	+			+		+	+	+	+		+	+							
12. Beam							+	+	+		+				+			+	+						
13. Beam									+		+				+										
14. Beam									+		+				+										
15. Slab					+	+	+	+	+	+	+	+	+	+		+	+	+	+						
16. Column					+				+	+					+					+	+				
17. Column						+				+	+				+						+	+			
18. Column							+				+	+			+							+	+		
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20. Beam																+			+		+		+	+	+
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23. Beam																		+	+	+		+			
24. Beam																				+		+			
25. Beam																				+		+			

Fig. 2. Interaction matrix of the experimental model

InfluenCing element

Exposed element

	1. Foundation	2. Foundation	3. Foundation	4. Foundation	5. Columns	6. Columns	7. Columns	8. Columns	9. Beam	10. Beam	11. Beam	12. Beam	13. Beam	14. Beam	15. Slab	16. Columns	17. Columns	18. Columns	19. Columns	20. Beam	21. Beam	22. Beam	23. Beam	24. Beam	25. Beam
1. Foundation																									
2. Foundation																									
3. Foundation																									
4. Foundation																									
5. Columns	C																								
6. Columns		C																							
7. Columns			C																						
8. Columns				B+C																					
9. Beam					C			B+C		B		B	B	B											
10. Beam					C	C			B		B														
11. Beam						C	C			B		B	B	B											
12. Beam							C	B+C	B		B														
13. Beam									B+T		B														
14. Beam									B+T		B														
15. Slab									C	C	C	C	C	C											
16. Columns					C																				
17. Columns						C																			
18. Columns							C																		
19. Columns								B+C																	
20. Beam																C			B+C		B		B	B	B
21. Beam																C	C			B		B			
22. Beam																	C	C			B		B	B	B
23. Beam																		C	B+C	B		B			
24. Beam																				B+T		B			
25. Beam																				B+T					

Fig. 3. Function matrix of the experimental model

The script analyzes the data received from the Interaction matrix and generates Matrix of functions according to the established rules. The matrix is shown on Fig. 3.

Legend used in the function matrix: C – compress; B – bend; B+T – bend and torque; B+C – bend and compress.

4 Functional diagram creations

According to the received data, Functional Diagram (Fig. 4) is constructed on the drafting view in Revit. The blocks of element are created as Revit families. Arrows and notes are created using lines and text.

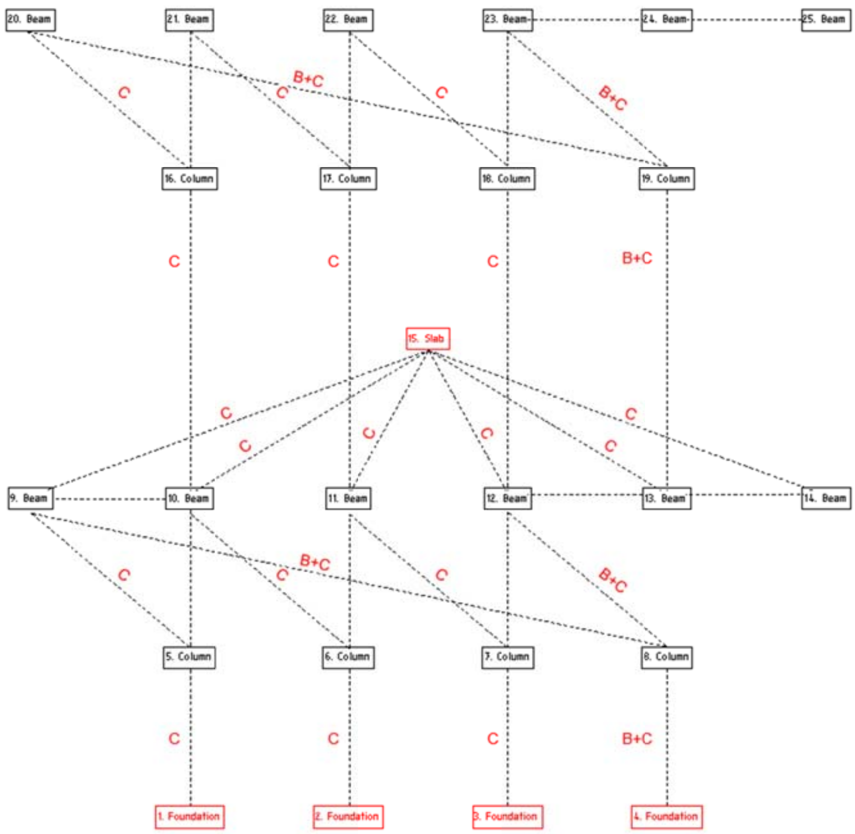

Fig. 4. Functional diagram of the experimental model

5 Ranking

According to ranking rules, the elements of the model are assigned a ranking factor and a rank. We have introduced the following rules: 1) Elements fall into 3 categories "A" - high importance of elements; "B" - average significance of elements; "C" - low significance. 2) So-called harmful functions are assigned a certain number of negative points: Compress - (-1); Bend - (-2); Torque - (-3). 3) So-called positive functions are assigned a certain number of positive points Stretch - 1; Hold - 2.

The rank of the element is represented as follows:

R = (-X)N+Y (1)

Where, X is the sum of negative points for the element;

N - the letter designation of the group;

Y - the sum of positive points for the element.

Table 1 Ranking results

Element`s name	Closeness to the target function	Presence of negative functions	Presence of positive functions	Ranking factor	Rank
1 Foundation	A			A	1
2 Foundation	A			A	1
3 Foundation	A			A	1
4 Foundation	A			A	1
5 Column	B	-1		-1B	3
6 Column	B	-1		-1B	3
7 Column	B	-1		-1B	3
8 Column	B	-3		-3B	4
9 Beam	B	-12		-12B	9
10 Beam	B	-6		-6B	5

11 Beam	B	-10	-10B	8
12 Beam	B	-8	-8B	7
13 Beam	B	-7	-7B	6
14 Beam	B	-7	-7B	6
15 Slab	A	-6	-6A	2
16 Column	C	-1	-1C	10
17 Column	C	-1	-1C	10
18 Column	C	-1	-1C	10
19 Column	C	-3	-3C	11
20 Beam	C	-12	-12C	17
21 Beam	C	-6	-6C	13
22 Beam	C	-10	-10C	16
23 Beam	C	-8	-8C	15
24 Beam	C	-7	-7C	14
25 Beam	C	-5	-5C	12

6 Trimming

According to results of ranking the program identifies elements that are subjects for trimming and elements which design, geometric dimensions, material, the way of installation are need to be considered in more detail.

Results of trimming:

1. Removal of elements occurs only if they fall in the category “C”;

2. Elements with harmful functions are highlighted in the model.

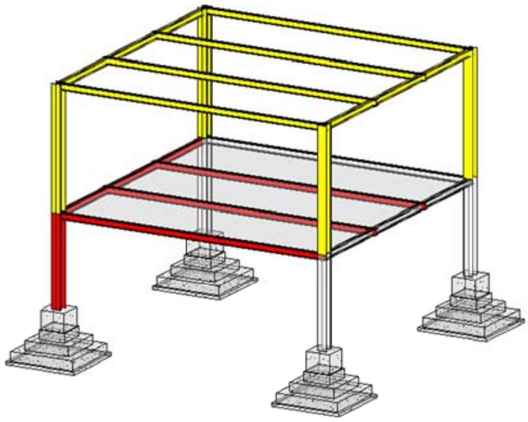

Fig. 5.Highlighting elements after trimming

A list is formed and divided into two graphs as described above. Elements in the list are in order of decreasing rank from the less functional elements to more ones. Thus, the higher the element in the list, the higher probability for it to be excluded from the model or changing its function.

Table 2 Trimming report

Elements for trimming	Elements requiring attention
20. Beam (17)	9. Beam (9)
22. Beam (16)	11. Beam (8)
23. Beam (15)	12. Beam (7)
24. Beam (14)	13. Beam (6)
21. Beam (13)	14. Beam (6)
25. Beam (12)	10. Beam (5)
19. Column (11)	8. Column (4)
16. Column (10)	5. Column (3)
17. Column (10)	6. Column (3)
18. Column (10)	7. Column (3)

7 Conclusion and discussion

Presented case study shows that such TRIZ [3] tools as function analysis and trimming can be applied in framed structural systems design. Modern design software [4] allows engineers to perform such analysis directly in BIM environment. However, the need for some stages of functional analysis realization in construction software can be discussed. For instance, the Interaction Matrix can be excluded from the functional analysis since it is positioned as a sub-step to construction of the functional matrix. Furthermore, the same algorithm of actions was repeated for both stages, so the stage of constructing the interaction matrix can be embedded into the algorithm of functional matrix construction. The same can be said about construction of a functional diagram. The functional diagram is quite clear and easy to use for manual analysis of small structures, however, with software implementation on large projects the need for its construction can be discussed. The program accurately excludes the possibility of errors during analysis of the model and the interaction matrix and functional diagram can be created and shown optionally.

With regard to further research, the development of ranking rules for wide range of structural schemes and assessment of additional groups of elements would make functional analysis in construction field more accurate and reliable.

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Combining discrete event simulation, data analysis, and TRIZ for fleet optimization

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Abstract Theory of inventive problem solving (TRIZ)-based methodologies enable solutions to multi-objective problems comprising two or more evaluation parameters to be found by defining the technical contradictions and setting the physical contradictions and the system of contradictions. However, most methodologies only address identification of the classical TRIZ system of contradictions. This paper proposes a method for identifying the generalized technical contradictions and their related generalized physical contradictions by using simulation data. A didactical example drawn from a real fleet cost reduction problem shows how to use them together with TRIZ methods and simulation means. The outputs of the proposed algorithms provide a minimum set of relevant technical and physical contradictions. Algorithms' time complexity allows addressing systems described with many variables.

1 Introduction

Design of experiments (DoE) and simulation are well known methods that can be mobilized for understanding the relations among the parameters of a system. This knowledge can then be used to achieve and/or optimize the performance of various aspects of the system. In this kind of problem, the parameters are separated into two main groups: (1) performance evaluation parameters (EPs) that facilitate evaluation of the performance of the system and (2) action parameters (APs) that allow designers or optimization algorithms to seek a solution in accordance with the problem's objectives. In this paper, we consider multi-objective problems with more than two EPs, the objectives of which cannot be satisfied with the initial model of the system. The only possibility of obtaining a solution satisfying the objectives is to change the model of the existing system to a new one that enables the achievement of the desired result. TRIZ-based methodologies enable accomplishment of this goal by analyzing qualitatively, on the one hand, correlations among the EPs in order to define the technical contradictions (TCs) and, on the other hand, sometimes cause effect relations between APs and EPs in order to set the physical contradictions (PCs) and the system of contradictions. It has been shown in previous works that it is possible to take advantage of the numerical data produced during the optimization process to identify contradictions and improve the efficiency of the optimization process [1–

7]. It has also been reported that the initial situation analysis efficiency could be improved using the mean of data analysis tool [8–10]. These studies address identification of the classical TRIZ system of contradictions but not of the generalized system of contradictions. References [1–7] use TRIZ knowledge and engineering knowledge to obtain the information related to the contradictions. References [8–10] require data analysis expertise in addition to knowledge about the studied system in order to disclose contradictions from data.

Eltzer and De Guio [11] showed that there is a link between DoE optimization and TRIZ thinking and proved that the classical TRIZ system of contradictions cannot be used systematically to describe the problem, i.e., there are situations in which no TRIZ contradiction exists (see Figure 1). In order to cope with this situation, they proposed the generalized system of contradictions (Figure 1). Subsequently, various researchers analyzed the problem of identifying generalized contradictions from data and proposed various techniques. For instance, Rasovska et al. [12] proposed different heuristics to obtain generalized TCs. However, their algorithms had a problem in that they required information about the number of parameters possessed by the searched contradiction. Consequently, Dubois et al. [13] proposed strategies for providing this information and facilitating the use of the heuristics provided by Rasovska et al. [12]. Another theoretical problem posed by their heuristics is that they do not provide all the contradictions; thus, the problem solver had no knowledge of whether a good contradiction is missing.

To rectify this problem, Lin et al. [14] proposed a brute force algorithm that can describe all the generalized TCs obtainable from the experimental table. The positive point of this approach is that it facilitates investigation of the importance and frequency of the generalized TCs in the data of real problems. They showed that there are often numerous generalized TCs in a problem. The other advantage of the algorithm is that the contradiction disclosing is completely automatic. However, there are two problems with this algorithm. The first is a computing time problem. The search for all the generalized TCs is recognized as an NP hard problem; specifically, the brute force search time increases exponentially with the number of EPs possessed by the problem. Thus, this algorithm cannot be used when there are more than 13 EPs in the experimental table. The second problem is that there are often many contradictions; as we cannot solve all of them, the practical question is how to select the most interesting one? In this paper, in order to cope with this problem, we propose the utilization of the Pareto concept during the contradiction search. When dealing with two EPs, the identification of the Pareto set of the design of experiment is quite straightforward; thus, classical TRIZ contradiction can be easily disclosed even without an algorithm. However, when dealing with more than two EPs, the link between the Pareto concept and the generalized TCs is not disclosed until know. In an n-dimensional evaluation space, the Pareto set of the EPs represents also the conflicts preventing achievement of the goal. We propose adopting the Pareto concept to define the generalized TCs.

Following the same strategy as that for generalized TCs identification, Lin et al. [15] proposed a brute force algorithm that identifies all the generalized PCs linked to a given generalized TC. The positive and negative points of this algorithm are similar to those described previously for the generalized TC identification algorithm. In this paper, to obviate these problems, we use an alternative approach based on discriminant analysis of the Pareto set of a binarized version of the experiment.

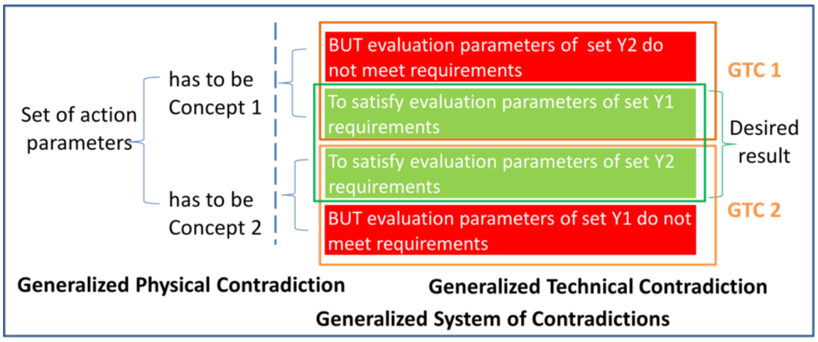

Figure 1: The generalized system of contradictions

The remainder of this paper is organized as follows. Section 2 presents our proposed methodology for identifying the generalized technical and physical contradictions and outlines how they can be used together. Section 3 provides a didactical example drawn from a real fleet cost-reduction problem shows how they can be used in combination with TRIZ methods and simulation means. Section 4 presents concluding remarks.

2 Proposed methods and framework of the methodology

This section first provides major concepts and new methods (Subsections 2.1 and 2.2) that are employed in the framework of the proposed problem-solving methodology, which is described in Subsection 2.3.

2.1 Obtaining generalized TCs

2.1.1 Generalized TC identification methodology

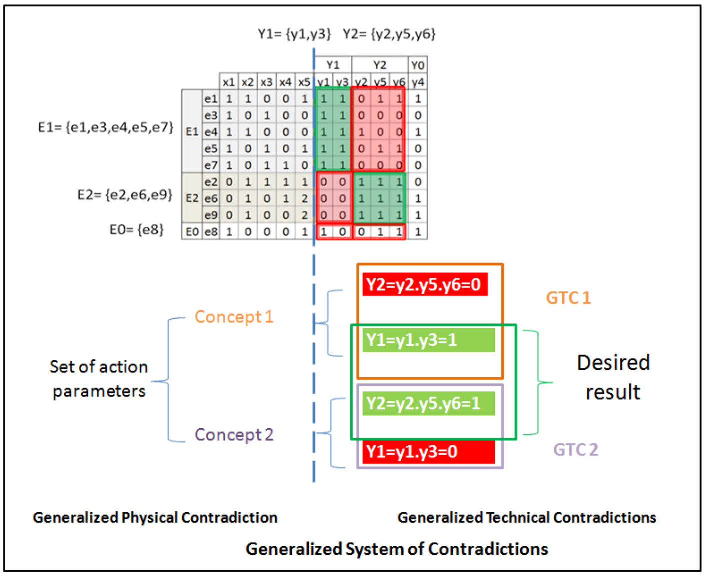

Figure 2: Link between binary matrix and contradictions.

The steps in the generalized TC identification methodology are as follows:

1. **Define the objectives and simulate the model**. At the initial stage, define the objectives, provide a behavioral model of the system linking APs and EPs, and express the objectives with EP ranges. Build or, if already available, use a simulation model of the system linking APs and EPs. Seek a solution to the multi-objective search or optimization problem based on the DoEs performed on the simulator and/or optimization algorithms driving the simulator's sequence of experiments.
2. **Compute a binary matrix from the experiments performance table.** Compute this binary matrix by assigning ones to the EP values reaching the objective and zeroes otherwise.
   If the matrix contains a line without "zero" value, the problem is solved—it is an optimization problem. If a better solution is desired, return to Step 1 and provide more challenging objectives; in which case it is assumed that there is no experiment satisfying the current objectives.
   If each column of the binary matrix contains at least one "one" value, go to next step; otherwise, provide a new rule for defining the ones and zeroes of this column. Indeed, if a column contains only zeroes for a given parameter, it is not possible to state a contradiction involving this parameter even if it exists. In this case, we propose to proceed as follows: define a threshold value within the range of the outputs of the experiments for this parameter. This threshold shares the experiments in two sets: those that are the best (less bad in our case) considering the objective, and those that are the worst considering the objective. Assign

ones to those that are the best values from the objective point of view and assign zeroes to the others. For example, assume that the range of values of the output of the experiments is 1–10, and that the objective is to reach at least a value of 15 for this parameter. If we define the threshold as nine, then for all the experiments, a value equal to or greater than nine will be assigned the value one. At this stage, the binary evaluation matrix can be used to identify generalized TCs.

3. **Compute the Pareto set of the binary evaluation matrix**. Each line of the matrix defines a generalized TC. Any two lines of the matrix that have the same binary profile define the same generalized TC. For example, Figure 3 shows the Pareto points of the binary matrix given in Figure 2. Among the nine experiments, only four belong to the Pareto set. However, it can be seen that rows e6 and e9 have the same binary profile; thus, these rows define the same point in the EP space. Any pair of points of the Pareto set contributes to a different system of contradictions. Thus, here we have three possible pairs of points for defining the system of contradictions, i.e., P1-P2; P2-P3; P1-P3.
4. **Express the concepts of the system of generalized TCs.** This process is as follows. Consider two points Pi and Pj of the Pareto set. The EPs involved in the concepts of the generalized TCs are those for which the value is different in Pi and Pj. For example, if EPP is the subset of evaluation parameters involved in the concepts of the generalized TC, then concept Yi is the logical conjunction of the evaluation parameter of EPP, with a value equal to one in Pi. Similarly, the concept Yj is the logical conjunction of the EP of EPP, with a value equal to one in Pj.
For instance, considering P1 and P2 in Figure 3, EPP is composed of y_2, y_5, y_6. The concept Y_1=y_5.y_6 and the concept Y_2 = y_2.

	EP					
↓ experiments	y1	y2	y3	y4	y5	y6
e1	1	0	1	1	1	1
e2	0	1	0	0	1	1
e3	1	0	1	0	0	0
e4	1	1	1	1	0	0
e5	1	0	1	0	1	1
e6	0	1	0	1	1	1
e7	1	0	1	0	0	0
e8	1	0	0	1	1	1
e9	0	1	0	1	1	1

(a)

		EP						
	↓ experiments	y1	y2	y3	y4	y5	y6	
Pareto	e1	1	0	1	1	1	1	*P1*
Pareto	e4	1	1	1	1	0	0	*P2*
Pareto	e6	0	1	0	1	1	1	*P3*
Pareto	e9	0	1	0	1	1	1	*P3*
	e2	0	1	0	0	1	1	
	e3	1	0	1	0	0	0	
	e5	1	0	1	0	1	1	
	e7	1	0	1	0	0	0	
	e8	1	0	0	1	1	1	

(b)

Figure 3: (a) Initial binary matrix of Figure 2; (b) corresponding Pareto points.

2.1.2 Additional comment about generalized TC identification.

The following comment is related to the computing time for finding the contradictions. Technically, the Pareto set is computed using an algorithm. There are many algorithms present in the literature and various software are available on internet for finding the Pareto set of a finite number of points. The time complexity of this type of algorithm is $O(N.M^2)$, where N is the number of EPs and M the number of rows. This complexity must be compared with the brute algorithm for identifying all the generalized contradictions as defined and presented by Lin et al. [16], which is greater than $O(M^2.2^N)$. Clearly, the proposed methodology is much faster. The reason is that the generalized TC obtained from the Pareto concept is a subset of the set of all generalized TCs defined by Lin et al. [16]. For instance, for this example the application of the algorithm presented in [16] provides 117 pairs of concepts involved in generalized TC. Intuitively, we felt that number too large and that not all of the obtained contradictions are interesting for problem solving. The practical problem is therefore to choose among them because defining and validating them is tedious and time consuming. In our example, we significantly reduced the number of pairs of concepts; indeed, we now have three instead of the 117 obtained using the approach proposed in [16]. The algorithm proposed in this paper found the contradictions and filtered them based on the Pareto concept.

2.2 Finding the generalized PCs

Once the generalized TCs are provided, to complete the description of the system of contradictions, it is necessary to find generalized PC(s) that can cause the generalized TC. As we are working with data we propose to discover the generalized PC using a discriminant analysis method. More precisely, we propose to apply the SVM-based algorithm developed by Lin [17] and interpret the results. This interpretation will provide hypotheses about the generalized PCs. Subsection 2.2.1 provides rules for interpreting the output of the discriminant analysis and conjecture generalized PCs.

2.2.1 Method for identifying generalized PCs linked to a generalized TC

The Pareto set of the binarized matrix used to identify the generalized TCs is a representation of the conflicts that prevent the system achieving the goals. In the previous step (Subsection 2.1) we used it to find the generalized TCs that are behind this Pareto set. In this subsection, we use it to disclose, thanks to a discriminant analysis approach, the AP values that cause the Pareto, which will allow disclosing of the conflicts of the values of the APs behind the Pareto set.

The discriminant analysis is performed with the SVM-based algorithm developed by Lin [17]. The input of the algorithm is a table in which the experiments are described by the AP and the associated binary matrix of EP (i.e., a table such as that in Figure 2). We propose to apply the discriminant analysis with two different options: (1) take the whole matrix of experiment; (2) take a subset of this table that only contains the experiments linked to the pair of points P that are involved in a specific generalized TC we want to “explain” with the APs.

The outputs of the discriminant algorithm are numbers called weights; they are used to analyze the AP values that provide a discriminating effect between two sets of values of each EP—e.g., for a given EP, the experiences are separated into two sets, those that satisfy the “one” values for this EP and the others. An example of the output of the SVM discriminant analysis is given in the table in Figure 4(b), crossing APs and EPs. In the table, positive weights indicate that the value of the AP has a positive effect on the former set, whereas negative weights indicate that the value of the AP has a positive effect on the latter set. The weight can be compared for each EP separately: the higher the absolute value of the weight, the more important is the AP value for explaining the set. For instance, in Figure 4(b), EP4 weights vary from 12 to -3. Zero weight values mean that the AP value has no influence for explaining any of the two sets. Values for which the absolute value is small compared to the value in the same column with the maximum absolute value can also be considered as having a negligible influence. For instance, in Figure 4(b), the weight of the AP value 6 for EP2 is 0.1, which is less than the hundredth part of the maximum value of the highest weight of EP2, which is 22 (in terms of absolute value).

Pareto points of the binarized matrix

EP1	EP2	EP3	EP4	
0	1	1	1	**P2**
1	0	0	0	**P1**

(a)

Output of the discriminant analysis algorithm

AP	EP1	EP2	EP3	EP4
AP=1	-3	15	15	12
AP=2	-3	15	15	12
AP=3	-3	15	-3	-3
AP=4	-3	14	-4	-3
AP=5	-3	8	-4	-3
AP=6	-3	0.1	-4	-3
AP=7	2	-9	-4	-3
AP=8	4	-16	-4	-3
AP=9	4	-20	-4	-3
AP=10	4	-22	-4	-3

(b)

Tagged output of the discriminant analysis algorithm

AP	EP1	EP2	EP3	EP4
AP=1	-3	15	15	12
AP=2	-3	15	15	12
AP=3	-3	15	-3	-3
AP=4	-3	14	-4	-3
AP=5	-3	8	-4	-3
AP=6	-3	0.1	-4	-3
AP=7	2	-9	-4	-3
AP=8	4	-16	-4	-3
AP=9	4	-20	-4	-3
AP=10	4	-22	-4	-3

(c)

Output of the discriminant analysis algorithm tagged and mapped to the Pareto set

AP	EP1	EP2	EP3	EP4	
AP=1	-3	15	15	12	*P2*
AP=2	-3	15	15	12	*P2*
AP=3	-3	15	-3	-3	
AP=4	-3	14	-4	-3	
AP=5	-3	8	-4	-3	
AP=6	-3	0.1	-4	-3	
AP=7	2	-9	-4	-3	*P1*
AP=8	4	-16	-4	-3	*P1*
AP=9	4	-20	-4	-3	*P1*
AP=10	4	-22	-4	-3	*P1*

(d)

Figure 4: Steps for mapping the binary EP matrix and the output of the discriminant analysis

We propose the following steps for disclosing generalized PCs (see also Figure 4):

1. Tag the zero values of the Pareto points of the binary matrix of the EPs in red and the ones value of this matrix in green (Figure 4(a)).

2. Tag the output of the discriminant analysis such that the positive weights are tagged in green, the negative weights in red, and zeroes or inconsequential values in white. (Figure 4 (b)→(c)).
3. Compare each row of the tagged EP matrix to each row of the tagged output of the discriminant analysis matrix. Map the similarities onto the output of the discriminant analysis matrix (Figure 4 (c)→(d)).
4. Deduce from the obtained "augmented" matrix the conflicting sets of values of the APs explaining the conflict between two points of the Pareto set. In the example given in Figure 4(d), values 1 and 2 of the AP explain the result about P2 and values greater than seven of the AP explain P1. Thus, these two subsets of values of the AP explain the generalized TC related to the points P1 and P2.
5. Hypothesize (formulate) a system of contradictions from the previous results and check its validity (with data, simulation, other data analysis techniques, expertise about the system, etc.). In the example in Section 3 for instance, ANOVA techniques [18] were used to validate the hypothesis about the effects and interactions of PA on PE provided by the discriminant analysis.

2.2.2 Additional comments about generalized PCs

It is clear from the previous example that the method for producing the generalized PC requires no additional knowledge from the environment of the system before the validation stage. Thus, we believe that it can be easily computerized. The tagging process has a polynomial complexity whereas the algorithms proposed to date for getting the generalized PC from the experiment table in the literature have an exponential complexity. Thus, our proposed method should be much speedier that the other computerized methods proposed for identifying generalized PCs.

The SVM-based discriminant algorithm was chosen instead of other methods for the following two reasons. The first reason is linked to our previous remark. The output of the SVM-based discriminant analysis can be easily interfaced to other algorithms to identify the generalized PCs. The second reason is that SVM-based methods use a discriminative model that requires no explicit hypothesis of the function between AP and EPs. For instance, in some other methods it is necessary to provide a model of the link between AP and EPs prior to the discriminant analysis.

To the best of our knowledge, our proposed methodology for identifying the generalized PCs is the first to allow a direct mapping between the outcome of discriminant analysis of the experiment table and the Pareto point of the binary matrix.

2.3 The global methodology framework

The global framework of the methodology is executed within a loop and gives feedback. It comprises the following steps:

1. At the initial stage, define the objectives, provide a behavioral model of the system linking APs and EPs, and express the objectives EP ranges.
2. Build or, if already available, use a simulation model of the system linking APs and EPs. Seek a solution to the multi-objective search or optimization problem based on the DoEs performed on the simulator and/or optimization algorithms driving the simulator's sequence of experiments.
3. Following Step 2, if all the objectives cannot be reached, compute the binary matrix out of the experiments performance table. Otherwise, if all the objectives can be reached, the problem is solved and the process ends. If a better optimization solution is desired, return to Step 1 and provide more challenging objectives.
4. Identify the generalized TCs with the method proposed in Subsection 2.1
5. Identify the generalized PCs with the method proposed in Subsection 2.2
6. Check the obtained contradictions.
7. Address the contradictions with TRIZ-based methods.
8. Evaluate the results and eventually improve them by returning to Step 1 to update the objectives.

3 Case study

In this section, use of the methods proposed in Section 2 is demonstrated with a didactical example drawn from a real fleet cost-reduction problem. It is clear that in the method proposed in the previous section it is not necessary to know the problem context in detail in order to identify the contradictions. In some situations, when the DoE and the objectives are already available, the contradictions can be hypothesized without any additional knowledge of the situation. Of course, more knowledge is necessary during the contradictions evaluation stage and the contradiction overcoming stage. The example above is chosen and presented so that the reader can understand the contradictions obtained by the numerical method at least afterwards and "validate" them or accept them as plausible. Some readers, especially TRIZ practitioners, may find the contradictions from the description of the problem.

The case study deals with the optimization of a subset of the fleet of vehicles of a foundation for disabled people. The fleet comprises four types of vehicles, which we here denote 9P, 7P, 5P, and 4P where the number before the "P" indicates the number of available seats in the vehicle. Some of the vehicles are customized for transporting one or two wheelchairs (7P, 4P). They are used to convey residents and perform the activities of the technical department. At the beginning of the study, the vehicles were clustered and assigned to different departments of the foundation. The management of the foundation hypothesized that it could be possible to reduce the cost of the fleet by grouping the vehicles into one group and centralizing the management of the demand. We were asked to check this hypothesis. Moreover, it was expected that the greenhouse gas emissions of the fleet should be reduced simultaneously. We were challenged to improve the initial situation by reducing costs and gas emissions by thirty percent and maintain or improve the satisfaction rate.

3.1 Checking the grouping hypothesis

To compare both the initial fleet management and the proposed one, the EPs used were the user satisfaction rate (SR), the global cost of the fleet (Cost), the internal greenhouse gas emissions (IG), and the total greenhouse gas emissions (TG) (internal and external). Costs and greenhouse gas emissions could be computed in terms of average annual use. The major issue was how to reduce costs and greenhouse gas emissions while maintaining the user satisfaction rate higher than 98%. The user satisfaction rate measures the rate of fulfilled orders. The initial APs were the user demand and the number of 9P, 7P, 5P, and 4P vehicles. The random user demand distribution was designed from samples of previous months' demands. As the demand distribution is fixed, only the four remaining APs were kept. Both the initial and proposed systems were simulated on a discreet event simulator (Witness). A full factorial design was performed; the number of levels of each AP was the initial size of the fleet. It facilitated validation of the assumptions of the board: the merging of the fleet demand management enables reduction of the costs while maintaining the satisfaction rate. Figure 5(a) provides the different binarized evaluation performances showing that the objectives have not yet been achieved.

To better this solution, let us get the contradictions related to the Pareto front of the binary matrix. The Pareto set of the binary matrix is reduced to the two first lines of the matrix. They represent 89 experiments among the 320 experiments of the DoEs. The concept involved in the generalized TCs deduced with the method described in Subsection 2.1 are Y1=(EP1>0.99) and Y2=(EP2<6700).(EP3<2000).(EP4<3000). The concepts of the generalized PC obtained with the method described in Subsection 2.2 are C1=(9P≥7).(5P≥3).(7P≥3) and C2=(9P≤2).(5P≤2).(7P≤1) within the context of the grouping solution.

The positive and negative weights resulting from the discriminant analysis, performed on the entire set of experiments Figure 5(b) and on the experiments of the binary matrix Pareto set Figure 5(c), suggest that lower values of each AP characterize P2 and the higher characterize P1. Comparison of the weights for each EP's column separately indicates that only the 9P=1 and 9P=2 have a positive effect on the gas emission performances and that the influence of other AP values is negligible, at least for 5P, 4P, and 7P. This assertion is confirmed by the main effect plot on the EP and other ANOVA analysis of them. This can be explained as follows: most of the demand is on the 9P vehicles, which are the ones having the highest gas emissions per kilometer. Note that this effect is dampened on the analysis of the experiments involved in the generalized TCs in Figure 5(c). The P2 can be explained as follows: when AP values are sufficiently low, the main function "transport people" is not performed (satisfaction rate is low) and then of course there is much less gas emission and costs are reduced. However, as soon as the main function is well performed (P1), many more vehicles are required, thus leading to unsatisfactory costs and gas emissions. In this example, we assumed that most of the readers accept this contradiction. Note that the contradiction was not obtained by understanding the system, but only with data analysis of experimental data. This means that in complex cases or in consulting situations where the TRIZ expert does not know much about the system, this methodology can be used to prepare TRIZ sessions. The experts of the system have to explain or validate the contradictions instead of finding them. It can also be used for building the problem-solving team.

Experiments results (partial)

Objectives			
>0.99	<6700	<2000	<3000
SR	Cost	IG	TG
0.42	2181	1188	1790
1.00	8074	2952	4421
0.69	4083	2024	3037
0.99	7141	2923	4377
0.45	2501	1273	1919
0.46	2790	1298	1958

Binarized performances of all results

EP1	EP2	EP3	EP4	
SR	Cost	IG	TG	
0	1	1	1	**P2**
1	0	0	0	**P1**
0	1	0	0	
0	0	0	0	

(a)

Discriminant analysis on all DoE

	EP1	EP2	EP3	EP4	
AP	SR	Cost	IG	TG	
9P=1	-3	15	15	12	*P2*
9P=2	-3	15	15	12	*P2*
9P=3	-3	15	-3	-3	
9P=4	-3	14	-4	-3	
9P=5	-3	8	-4	-3	
9P=6	-3	0.1	-4	-3	
9P=7	2	-9	-4	-3	*P1*
9P=8	4	-16	-4	-3	*P1*
9P=9	4	-20	-4	-3	*P1*
9P=10	4	-22	-4	-3	*P1*
5P=1	-3	7	0.4	0.6	*P2*
5P=2	-3	1	0.0	0.0	*P2*
5P=3	3	-2	-0.2	-0.3	*P1*
5P=4	3	-6	-0.2	-0.3	*P1*
4P=1	-3	4	0.1	0.1	*P2*
4P=2	3	-4	-0.1	-0.1	*P1*
7P=1	-5	10	0.7	0.3	*P2*
7P=2	1	3	-0.2	-0.1	
7P=3	2	-3	-0.2	-0.1	*P1*
7P=4	2	-9	-0.2	-0.1	*P1*

(b)

Discriminant analysis on P1 and P2 experiments

	EP1	EP2	EP3	EP4	
AP	SR	Cost	IG	TG	
9P=1	-4	8	8	8	*P2*
9P=2	-4	8	8	8	*P2*
9P=3	-1	2	2	2	*P2*
9P=4	Do not provide points on the binary Pareto				
9P=5					
9P=6					
9P=7	-4	-4	-4	-4	
9P=8	4	-4	-4	-4	*P1*
9P=9	4	-4	-4	-4	*P1*
9P=10	4	-4	-4	-4	*P1*
5P=1	-0.4	2	2	2	*P2*
5P=2	-0.2	2	2	2	*P2*
5P=3	0.3	-2	-2	-2	*P1*
5P=4	0.3	-2	-2	-2	*P1*
4P=1	-0.4	2	2	2	*P2*
4P=2	0.4	-2	-2	-2	*P1*
7P=1	-1	2	2	2	*P2*
7P=2	-5	-1	-1	-1	
7P=3	3	-1	-1	-1	*P1*
7P=4	3	-1	-1	-1	*P1*

(c)

Figure 5: Grouping solution analysis: EP performances and AP SVM discriminant analysis.

3.2 Beyond grouping solution by solving contradiction

Finally, in the AP space, from the data we learn that the number of vehicles of each type has to be high in order to perform the main function (good satisfaction rate) and low in order to reduce costs and gas emissions. Three solutions have been proposed to tackle this contradiction: (1) partial subcontracting of the demand, (2) upgrading, and (3) starting date range management. Each of these solutions allows having more vehicles available at the operating time, and less otherwise. Subcontracting is an available resource with a good satisfaction rate, as it was tested by the company. The “upgrading” concept can be implemented in the framework of upgrading constraints and rules (e.g., 5P can be replaced by 9P). Finally, depending on the type of activity to be performed with the vehicle for a given demand, there might be a range of tolerances for the starting date of the vehicle.

Each solution was first simulated and evaluated separately. Each of them improved the conflict between satisfaction rate and cost. This assertion was stated by comparing the Pareto sets of the experimental[1] outputs and of the grouping solution. Nevertheless, only subcontracting and starting date management enable simultaneous achievement of satisfaction rate and costs objectives. It can be seen in Figure 6(a), which shows the solutions and the Pareto points in the binarized matrix when applying the subcontracting resource, that no solution achieves all the objectives. For this reason, we again applied the same methodology on the obtained model of the system. The P2 of this new system is the same as that in the initial system, but P1 evolves into P1’, where the cost and internal gas emissions achieve the objectives.

Let us now consider the results of the SVM discriminant analysis (Figure 6(b)). The zero values in the white squares indicate that the APs (9P, 5P, 4P, 7P) do not anymore predict in a discriminant manner the satisfaction rate and the total gas. This means that the model of our system cannot provide us with a PC from the TCs. In other words, the discriminant analysis output tells us that we do not have in our model the APs that cause the generalized TC. Thus, it is necessary to include in our model at least one new AP that influences the total emission, preferably without degrading other performances. The type of motorization is an AP influencing the gas emissions. Indeed, the initial fleet is equipped with diesel engines. The use of this new AP[2] enables introduction of the possibility to use electrical or hybrid engines to satisfy all the objectives. Let us notice that the use of electrical engines or hybrid engines instead of diesel engines without any of the previous solutions (subcontracting, upgrading, or starting date range management) degrades the cost of the grouping solution, and therefore does not enable achievement of the objectives. Let us also look at the interesting methodological point disclosed here with discriminant analysis: the methodology indicates to the problem solver that his/her optimization model is not complete enough to state a

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[1] Here, we highlight that it is the Pareto of the real data of the evaluation parameter matrix and not of the binarized data.

[2] The type of motorization is also used in the first model to compute gas emissions and cost, but not in the model for the design of experiment as an action parameter. The introduction of this parameter can also be seen as dynamization of this parameter in our model.

contradiction, and gives him/her an orientation about the parameter to be found (in our case, the parameter has to influence gas emissions).

We improved the model by combining the three initial principal solutions that we checked initially for overcoming the TC (subcontracting, upgrading, and starting date range management). Each of these solutions improved the initial solution. Consequently, we obtained several combined solutions that satisfied the objectives.

To improve this solution with no other goal, we can use optimization; however, we would have to return to step 1 of the methodology described in Subsection 2.3.

Binarized performances

EP1	EP2	EP3	EP4	
SR	Cost	IG	TG	
0	1	1	1	**P2**
1	1	1	0	**P1'**

1	1	0	0
1	0	1	0
0	1	0	0
1	0	0	0
0	1	0	0
0	0	0	0

(a)

Discriminant analysis on all DoE

	EP1	EP2	EP3	EP4
AP	SR	Cost	IG	TG
9P=1	0	-7	12	0
9P=2	0	-7	12	0
9P=3	0	0	-3	0
9P=4	0	12	-3	0
9P=5	0	12	-3	0
9P=6	0	11	-3	0
9P=7	0	0	-3	0
9P=8	0	-7	-3	0
9P=9	0	-7	-3	0
9P=10	0	-7	-3	0

	EP1	EP2	EP3	EP4
AP	SR	Cost	IG	TG
5P=1	0	9	1	0
5P=2	0	7	0	0
5P=3	0	-7	0	0
5P=4	0	-10	0	0

4P=1	0	1	0	0
4P=2	0	-1	0	0

7P=1	0	11	0	0
7P=2	0	5	0	0
7P=3	0	-8	0	0
7P=4	0	-8	0	0

(b)

Figure 6: Subcontracting solution: EP performances and AP SVM discriminant analysis.

4 Conclusion

The proposed method based on the mathematical concept of Pareto optima of the binarized matrix of EPs for defining the generalized TC is easy to implement.

The method for finding the generalized PC is based on SVM discriminant analysis. We also used this methodology in two other case studies, one dealing with cutting steel process optimization and the other with the optimization of a picking process inside a warehouse. The method worked well, and ANOVA techniques were sometimes useful to validate the contradictions. We noticed that in simple cases, ANOVA techniques enabled identification of classical TRIZ system of contradictions directly, which is not the case when dealing with more than two EPs, or when several APs interact together in a generalized PC. The advantage of this approach is that it can deal with many APs and EPs, and bypasses the limitation of the exact algorithm provided in [15]. The example also showed that the method can inform the problem solver when new APs are required in the model and on which EPs they have to act.

Further case studies will be conducted to evaluate the performance of the proposed methodology.

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Developing a method to aid engineers in finding solutions for functional problems

Literature research, including biomimetics and TRIZ

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Abstract Nature provides a nearly endless resource of evolved systems and incredible inventions: a great source of knowledge that is currently barely used in engineering design.

In this paper, research is done how the theory of inventive problem solving (TRIZ) can aid engineers in finding solutions for functional descriptions of problems, using existing solutions from different disciplines; but most notably, how biology can be added to the (existing) set of solutions. One of the main questions is how to structure biological information using TRIZ.

Engineers that use this method might find new, innovative, and possibly biomimetic solutions, often improving the eco-efficiency and multifunctionality of systems. Challenging problems in the development of this method are amongst others, the construction of a database system, quantifying and extracting biological phenomena, dealing with the hierarchical structure of natural systems, and the transfer of knowledge between biological and technical systems. It is suggested that using TRIZ' functional analysis as basis for the database entries will aid in successfully integrating biomimetic solutions into the existing TRIZ method.

To provide background information on the discussed subjects, the paper also includes an introduction to some methods and tools that deal with the automatic extraction and databasing of knowledge in the form of Physical Effects, the state-of-the-art of combining TRIZ, and a brief introduction of biomimetics and several TRIZ tools.

1 Introduction

The aim of this paper is to shed light on the development of a method for engineers to aid in the ideation phase of the design process. Based on functions, the user can search an extensive database of solutions from physical, chemical, mathematical and biological resources.

The research on the development of such a method starts with a background research on biomimetics and TRIZ, and a literature search on the combination of the two. The papers found in the literature search are used to form a picture about the state-of-the-art of the subject matter, and find out what tools of the TRIZ-method are used.

By analyzing the strengths and shortcomings of a selection of existing tools used for ideation, challenges and requirements for a new tool can be found.

The theory of inventive problem solving (translation of the Russian acronym TRIZ) was originally developed by Genrich Altshuller, after studying many existing patents, he found that there were patterns in invention and very few inventions were completely new. Most relied on commonly used solution principles instead of pioneering new inventions, and therefore new inventive problems could be solved by structurally applying previous experience [1], [2].

Biomimetics (also often called biomimicry) is the study of imitating elements of nature to solve human problems. The term was introduced by Otto Schmitt when he was designing a physical device that mimics the electrical action of a nerve [3]. This is however far from the first example of biomimetics; the Chinese tried to fabricate an artificial silk and Leonardo da Vinci designed flying machines by studying birds in flight. More recent examples are the development of Velcro, water-repellent surfaces based on the lotus leaf, and even modern composite materials, inspired by the cellulose fibers in wood.

With this large source of 'biological patents' that may hold many solutions for currently existing problems, or that can improve current technologies, designers can tap into many years of biological evolution. The main difficulty with this method is to find and extract the relevant information. Some methods have tried to incorporate biomimetics in a structured design approach, which will be discussed later in this paper.

2 Literature Study

To sketch the current research going on in the field of combining biomimetics and TRIZ, a paper search was conducted. Using those search terms in Scopus (abstract, keywords and title), 32 papers were found, analyzed, and displayed in Table 1 at the end of this document.

In analyzing the papers, they were sorted on their relevance to the search terms; one result [4] was omitted immediately, since it contained little to no scientific value to this research. The other papers were placed in categories as described in the following paragraph.

While all papers contain both search terms, not all combine both concepts. Figure 1 shows in which way *biomimetics* and *TRIZ* are used. Five groups were identified in the paper review: the first group of papers contains both TRIZ and biomimetics, but fails to connect the two. The second group contains no direct links to TRIZ and/or biomimetics, but provides summaries of the available papers, is based on the general TRIZ idea of abstraction, or contains no TRIZ or biomimetics in the main part of the paper. The third group uses one or more TRIZ-tools in a biomimetic design process. The fourth group adapts TRIZ to include biomimetics. The fifth, for this project the most promising group of papers, uses TRIZ to structure entries to a database containing biomimetic solutions.

Since one of the main questions of the report is how to structure biological information using TRIZ, it is interesting to see what tools researchers in the field have used in their research, and thus are already familiar with. The bottom row of Table 1 shows that the *contradictions* and *40 Inventive Principles* are the most frequently used tools, followed at a distance by the *Function Analysis* (resp 17, 16 and 9 papers). *BioTRIZ* and *PRIZM* are two tools that are often mentioned in the set of papers, and are based on the original TRIZ Contradiction Matrix. The other tools are part of TRIZ and/or ARIZ (Algorithm of inventive problem solving).

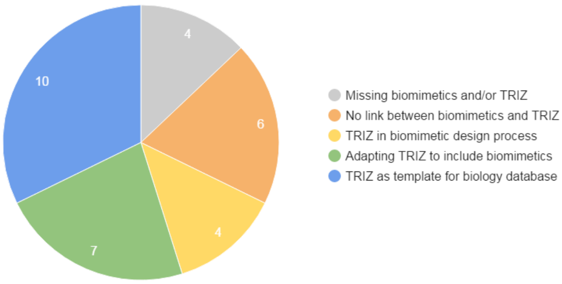

Figure 1: Classification of papers; colours match those in Table 1

BioTRIZ: The development of BioTRIZ started at the beginning of this millennium by Drs. Olga and Nikolay Bogatyrev, together with prof. Julian Vincent [3], [5]. They adapted TRIZ to a 'green' version that includes the successful principles and ideas to develop new solutions inspired by nature, rather than technology. They analyzed about 500 biological phenomena, analyzing functions at different levels of hierarchy. They also analyzed about 2500 conflicts and their solutions in biology. Six fields of operation were established, by the 'mantra' *things do things somewhere;* all actions with any object are defined. *Things* mean the substance and structure of the object; *do things* meaning transformation of energy and information; *somewhere* points to the time and space of the object. The contradiction matrix is then restructured using these six operational fields. By re-organizing the conflict statements and inventive principles, the PRIZM matrix (translated from Russian: the modernized rules of inventive problem solving) is constructed: a 6-by-6 matrix that stems from the original TRIZ contradiction matrix.

A very similar 6-by-6 matrix was constructed from the researched biological effects, pairing other inventive principles to the cells; this matrix is called BioTRIZ, and can be used to apply biological knowledge to technical problems. Using this method, the user can access knowledge from biology, without directly being inspired by nature.

In this research, a difference between original TRIZ and BioTRIZ was found; mainly caused by the difference in how natural and technological systems are created. For example, in biology there are two types of polymers: proteins and polysaccharides. While people have produced over 300 polymers, none of these are as versatile or responsive as the biological ones.

In [3], this difference has been visualized by arranging both engineering TRIZ and BioTRIZ according to their size and amount of conflicts in the field of operation. From this, it was concluded that while engineering heavily relies on energy and substance, the studied biological solutions are mostly found in the fields of information and structure.

3 Existing Tools

The paper research in the previous paragraph unveiled several tools that are currently used to include biomimetics in a design process. Added to this set are some tools that are used in general TRIZ-methods. Finding the strengths and shortcomings of the analyzed tools will provide valuable information for the development of a new tool or method.

AskNature: The webpage and underlying database of *AskNature* provide an insight in what biomimetics can offer an engineering designer [6], [7]. It features a collection of over 1600 biological strategies, biologically inspired ideas, resources to teach and learn about biomimicry, and collections on common subjects in its database (eg. *'Energy in nature', 'life-friendly packaging', 'managing waste'*).

The content is classified in The Biomimicry Taxonomy [7], which defines a hierarchy of functions and attributes. The page of a biological strategy provides a summary of the relevant literature, connecting focal biological systems, the hierarchy (sub- and super systems), and resulting functions.

While the AskNature repository provides a starting point for finding inspiration, it lacks a quantitative definition of the described functions, and the database is but a fraction of the information available from nature.

Biomimetic database: Besides developing BioTRIZ, Julian Vincent and his team also created a database of biological effects, which would be accessible publicly, so other researchers could use and add to the database [8], [9]. This database was used and modified by the European Space Agency (ESA) in their Ariadne-project [10], but unfortunately, no copies of both the original and the ESA-database are to be found. However, the articles referred to before do provide an insight in how the structuring of the database was achieved.

A disadvantage of the database is that it only contains qualitative descriptions, which might prove valuable in early ideation phases, but for practical purposes a quantitative description is necessary.

TechOptimizer is a program that was developed to provide a digital program and user interface for several TRIZ tools. Even though the information in this program is rather old, originating from early 2000, it still provides an interesting example of how a tool can actively help the engineer come up with solutions outside of their own field of expertise. It includes tools to find an inventive principle to a contradiction, to create a functional diagram, search through a database of effects, find *Trends of Evolution* and so on.

The part of the program that is relevant to this research, is the *Effects*-module, containing over 4,400 effects from different areas of knowledge [11]. The effect page contains a short description, related effects, advantages and limitations, a formula to how the effect is related to other parameters, conditions, and at least one reference. However, not all this information is available for every effect; a lot of pages only have a short qualitative description of the effect. This might be enough for ideation, but a qualitative description is often necessary in the rest of the design process. Also, this module currently does not contain effects from the biology area.

Physical Effect research: More recent research efforts by a team of the Volgograd State Technical University discuss and test several methods on automatically processing physical data. Several systems have been developed to retrieve information on basis of *Physical Effects* (PE: elementary causal link of physical phenomena and processes), automated synthesis of the *Physical Operating Principle* (POP: structure reflecting interrelations of PEs and phenomena which result in the execution of the function) and automatic replenishment of the *Physical Effects* database. To try and automate the design process, the systems have been combined into a complex [12].

This database of PEs can be constructed automatically from natural language texts, as is described in, for example [13]. A database is constructed when a specialization is selected; existing PEs need to be updated if new information is available, and new PEs can be added if they fit within the specialization. The algorithm then searches for information in a variety of sources, such as scientific libraries and magazines, patents, and some unpublished sources. Details of this procedure are unfortunately hidden in a paper by Fomenkov et al. [14], which was not available at the moment of writing this paper. The procedure is mentioned to be quite labor-consuming, therefore, research on automation has been executed [12], [15].

Lexical analysis: In the previous example, natural language analysis was already mentioned as a method to extract important information from written text resources. Julian Vincent referred to lexical analysis in [16]: "Since biology is one of the most complex of sciences, biologists will always be needed for effective information transfer, although the lexical analysis by Chiu and Shu [17] would provide a useful 'front end' to the biological part of the process"

In a previous paragraph the biological database was briefly explained; Chiu and Shu recognized that compiling a comprehensive database is challenging because of the explosive information growth in biological sciences and the dynamic nature of biological knowledge. Using natural language processing and text mining as an alternative to databases, avoids having to categorize biological phenomena for engineering purposes.

In their research, Chiu and Shu describe a method to systematically bridge the biology and engineering domains, using natural language analysis. Keywords that are meaningful for biologists might not occur to engineers due to differences in domain vocabularies. For example, if the required function is to clean something, for a biologist the keyword 'defend' makes sense, since cleaning is simply the defense against dirt. Details of this method are found in this and other papers by Chiu and Shu [17].

Integrating TRIZ Function Modeling in CAD Software: An interesting research on a similar topic has been executed by Hans Bakker, with help of Leonid Chechurin and Wessel Wits [18]. It provides a link between *Computer-Aided Invention (CAI)* and *Computer-Aided Design (CAD)*, by developing a tool that generates a TRIZ Function Model from an existing assembly in a CAD-program (SolidWorks). It creates an interaction matrix and subsequently suggests functions for the available interactions.

4 Development of the New Method

This chapter will summarize the challenges and steps needed to complete to develop a new method in using TRIZ to find solutions in all fields of existing 'inventions'.

From the previous chapters, the following challenges are extracted:

- Dealing with imperfection in nature, and engineering's drive for perfection/repeatability
- Hierarchical structure of biological systems
- How to bridge engineering and biology and ensure transfer between the disciplines
- How to fill, structure and access database:
    - Where to find data
    - How to extract data
    - How to quantify effects

Possible steps to include in the method algorithm are described below:

- Use TRIZ to find problem definition
    - *Function analysis, Su-Field*
- Select function to 'improve'
- Search for function in database
    - Database is structured similar to Tech-Optimizer, but also includes biomimetics → structured according to *TRIZ Functional Analysis*
    - Filled semi-automatically using *Physical Effects* as described by Fomenkov et al, and using natural text analysis as described by
    - Classify database entries on 'completeness'
- Rate and rank suggestions
- Pick solution
- Transfer to original problem (database entry can give suggestions on this)

Please note that these are mere suggestions for the algorithm, and by no means a complete method. Extensive testing and evaluations are necessary to complete the method.

5 Conclusion

In this paper, research was done on integrating biomimetics in a method to aid engineers in coming up with solutions. A literature research and reviewing other similar tools yielded a set of challenges that need to be overcome for such a tool to become valuable. The main challenge is to extract information and get it to the end user; this can be done by (automatically) building a database or natural text analysis, but both methods are less than ideal. It is suggested to create a database using natural text analysis, and structure it according to *TRIZ Functional Analysis*. The Functional analysis was chosen because it is often used in the found set of papers (see Table 1) and is relatively easy to get a basic understanding of. The value of biomimetics itself is already proven in the plethora of successful applications as mentioned previously and found in literature.

6 Discussion and Recommendations

While this research provides a starting point for the development of a tool to aid engineers, it is by no means a complete method, and its functionality has not been proven. More research is needed on how to effectively execute all method steps, with a special focus on how to fill the database with valuable information. After the method has been finalized, case studies with engineers (or engineering students) need to be conducted to confirm the effectiveness. Such a study has been described in for example [19].

It is also wise to seek collaboration with a professional biologist to assess the biological correctness of the information in the database and ensure a fluid transfer between the disciplines.

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Table 1: Papers used in literature search; publication date, # of citations, TRIZ-tool used. 1st column indicates categorisation, 2nd column whether full-text (green) or abstract (red) was used.

Result No.	*Reference*	*Year*	*Cited by*	*Functions*	*Contradic.*	*40IP*	*9 Windows*	*Su-Field*	*IFR*	*S-curve*	*Dwarfs*	*Trends*	*Resources*	*BioTRIZ*	*PRIZM*
1	[20]	2016	0												
2	[21]	2016	0												
3	[22]	2016	0		x	x									
4	[19]	2016	0						x						
5	[23]	2015	0		x	x									
6	[24]	2015	0	x											
7	[25]	2015	1	x	x	x	x								
8	[26]	2015	0												
9	[27]	2014	3	x				x							
10	[28]	2014	0		x	x									
11	[29]	2014	1		x	x	x	x	x	x	x		x		
12	[30]	2014	0						x						
13	[31]	2014	2	x	x			x	x						
14	[32]	2013	0	x	x										
15	[33]	2012	2		x	x									
16	[34]	2011	1											x	
17	[35]	2011	6	x		x			x			x			
18	[36]	2010	0		x	x									
19	[37]	2010	2												
20	[38]	2010	1		x	x									
21	[39]	2010	4		x	x									
22	[16]	2009	40		x	x								x	
23	[40]	2008	21		x	x								x	x
24	[41]	2007	32					x							
25	[4]	2007	0												
26	[10]	2006	0												
27	[3]	2006	304	x	x	x	x							x	x
28	[42]	2006	2			x	x							x	x
29	[43]	2006	4							x					
30	[44]	2005	0		x	x									
31	[5]	2005	21	x	x	x									
32	[45]	2002	172	x	x				x			x			
Total				**9**	**17**	**16**	**4**	**4**	**6**	**2**	**1**	**2**	**1**	**5**	**3**

Forecasting of product and technology development using heuristic-systematic approach

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One of key problems in industrial development relates to prediction of future needs of customers. Many companies create own development strategies based on intuition that rarely consider market development and changes in needs of customers. The aim of this study was to apply heuristic-systematic approach to perform forecasting of product and technology development on specific examples including Technological, Economical, Ecological and Social changes. Presented approach to forecasting is characterized by modelling of the system to be forecasted, data acquisition and analysis of relations between the system and its super system and subsystem. Specific tools like functional analysis, contradictions, system opera-tor or S-curve analysis were implemented in the fore-casting process. The precise definition of the forecasting problem is the first step of the process. This helps to define aim of the forecast and the expected, project-oriented outcome. Next, knowledge acquisition stage takes place followed by analysis of results and interaction between elements of the knowledge network. As a result, barriers and limitations in the product development significant in the future were defined. Based on the example of vehicle development it was concluded, that in nearest years the most significant development in this industry will relate to change of the drive energy source from gasoline to electricity. This is thus a direction that should be taken by research teams to adopt to the future market. As of today, technology related to electric vehicles does not meet the future requirements. It is necessary to solve problems related to energy storage. Application of this approach makes it possible to assess the development of specific products and technologies. This approach is applicable in all industries and services and helps to define the proper direction of development of products and technologies that will solve the future problems.

Introduction

Modern world changes very rapidly, both in terms of social and technological changes. It is thus very important to know in advance what will be the need of a customer in the future to address them correctly. Knowing the future few years before it happens may significantly reduce the cost of new product development, because without an accurate prediction, there will be higher risk of redesigning goods for the needs to be satisfied in the future. According to [1], the smallest cost of redesign is located at the early stage of the design process and it increases rapidly thereafter. It is thus very important to know, what the future will be like at the stage of concept development, that can take place many years before the actual product will be released to the market.

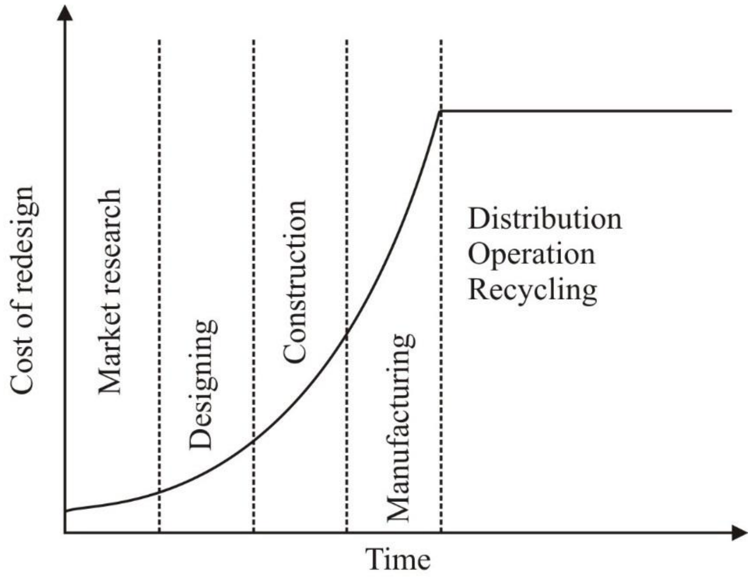

Fig. 1. Cost of redesign in various stages of product or technology lifecycle, based on [2].

Application and development of forecasting methodologies is widespread today. There are many methods that allow to predict how the world will look like in the nearest years or tens of years. According to [3], there are four main groups of forecasting models. The first one is the causal model, in which the relationship between the variables and the result is at least acknowledged to exist or is well described. In this model the analysis is concentrated on the big picture, the super-system of the analyzed object and its relations with other systems and sub-systems [4]. The second group is the phenomenological models in which the forecast is being based on the past events. As an example, mathematical regression is being used for forecasting by extrapolation of the past data [5]. Next group of forecast methodologies is monitoring and mapping in which forecast is based on information and indications, that the technology being analyzed is going to change due to for example a recent invention or other research finding. The core of this method is to monitor the behavior of the system and to identify any possible changes within the system, that may be of impact in the future [3]. The last group of forecasting methodologies is intuitive modelling in which the forecast is based on intuition, without any apparel or understood relationship between elements of the analyzed system. Intuition may lead to acceptable results, but very often it is often limited to the subjective feelings and thoughts. Evolution of forecasting methodologies is shown on fig. 2.

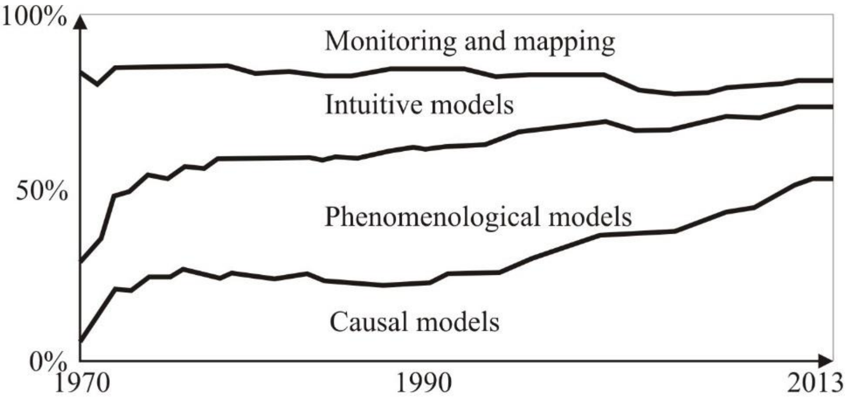

Fig. 2. Forecasting models being used in the last 50 years. Based on [6].

Fifty years ago, intuitive models were in possession of the biggest share of forecasting methodologies, with casual models just starting to appear. Now, casual models have dominated the forecasting methodologies share, significantly reducing the percentage of use of the intuitive models. What is interesting is that monitoring and mapping methods are still at the similar level, throughout the fifty years. Forecasting of technology development helps to understand the future needs of the customers and current limitations, that have to be overtaken in order to satisfy those needs in the future. In the presented case study, systematic forecasting of technology development based on the FORMAT methodology [7] was used to extract limitations of vehicle for everyday use design in 2030 and then heuristic concept-development approach using Synectics [2], [8] was implemented to define set of possible solutions to the presented problem.

System to be forecasted

Applying causal model of technology forecasting it is important to define the scope of the forecast, the expected outcome and system-to-be-forecasted (STF). This allows to direct the forecast to the right track from the beginning of the work, reducing the amount of time spent on the forecasting process. In this case study, STF was defined as <vehicle for everyday use>. The activity aimed at designing a new innovative (smart and intuitive) vehicle for everyday use in order to satisfy the future needs of customers and communities. As an outcome of the forecast it was expected to answer the question: “What sub-system of vehicle will be the most relevant making the system innovative (smart and intuitive) in 2030 worldwide. What will be the significant sub-system (internal element or system of the vehicle) to be developed in order to satisfy future requirements of communities?”.

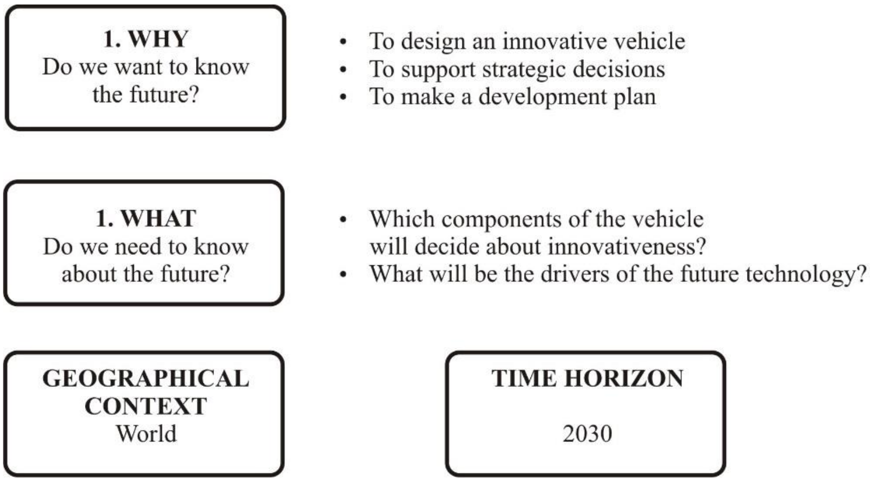

Fig. 3. Definition of the scope of the forecast

Knowing exactly the aim of the study and having defined the system to be forecasted, it was possible to model the system at the functional level, define its super- and sub-systems as well as to formulate set of potential problems based on the System Operator logic.

Modelling of the forecasted system

Functional modeling was performed to extract the main function of the STF as well as useful and harmful functions being realized by it. The main function of the vehicle for everyday use was defined as <to transport>, the input as <energy>, <object in point A> and the output as <object in point B>. Object means both the passenger and the payload, depending on the type of vehicle for everyday use being used. It may be both commercial vehicle and a car. Useful functions, defined as performances of the system, were defined as <to store things during transport>, <to protect the transported object> and <to make pleasure>. Harmful functions, being expenses, were mostly connected to energy consumption, traffic jams and environmental impact. Reformulating the above functions into the form <System-to-be-forecasted><verb><noun> makes it possible to isolate the functions being realized by the vehicle for everyday use.

Table 1. Useful and harmful functions of the vehicle for everyday use and their outcome

<vehicle for everyday use>	Useful functions	**<to transport><object>** <to make><pleasure of driving>
	Harmful functions	< to make><accidents> <to use><energy> <to burn><fuel> <to make><traffic jams> <to pollute><environment> <to use><roads> <to make><noise>
<vehicle for everyday use><makes>	<people in place B> <pleasure> <accidents> <pollution> <consumption> <noise> <traffic jams>	

There are also other systems, that allow to obtain the same results as the vehicle for everyday use, for example bus, train, tram, bike, motorcycle. Those systems greatly influence the behavior of the forecasted system, because they share the same super-system and most of the subsystems. Alternative technologies are being used to define the super-system of the STF and are of significant importance in the forecasting process [7]. In this case study, super-system was defined as the entire transportation system represented by the alternative technologies and sub-system was defined as the specific sub-systems of the vehicle based on the functions being realized. The defined functions, super- and sub-system of the vehicle for everyday use, the set of parameters describing the evolution of the system were defined and structured in the System Operator logic.

Table 2. System operator for the vehicle for everyday use.

	Past: 2000	Present: 2015	Future: 2030
Super-system: Transportation system (Alternative technologies)	Less people travelling **More CO2 emissions** Less active pubic transport lines **Less people living in cities** Less LPG production	More people travelling **Less CO2 emissions** More active pubic transport lines **More people living in cities** More LPG production	More people travelling **Less CO2 emissions** More active pubic transport lines **More people living in cities** Less LPG production
System: a vehicle for everyday use	**Less people travelling with a car** Less cars on the roads **More fatalities caused by cars** Higher consumption of fuel **Higher cars density on the roads**	**More people travelling with a car** More cars on the roads **Less fatalities caused by cars** Lower consumption of fuel **Lower cars density on the roads**	**More people travelling with a car** More cars on the roads **Much less fatalities caused by cars** Much lower consumption of fuel **Slightly lower cars density on the roads**
Sub-system: expenses (Vehicle subsystems)	Less alternate fuel drive systems (electric, CNG) **Low battery capacity**	More alternate fuel drive systems (electric, CNG) **Slightly more battery capacity**	Much more alternate fuel drive systems (electric, CNG) **More battery capacity**

System Operator makes it possible to extract problems that limit development of technology in the currently known form. Although cars are very well adopted to present needs of customers it is visible, that in 2030, vehicles will be safer, greener and will be powered by alternative sources of energy. This change is being forced not only because of limited amount of fossil fuels, but also due to strict political limitations being applied more and more often in Europe. The problems defined using system operator logic that occur at present and will have an effect in the future are as follows:

- lower LPG production for automotive applications showing risk that conventional fuels are going to decline,
- increasing share of people leaving in cities than in rural areas,
- bigger number of train and city communication lines,
- limited energy capacity for batteries.

Contradiction formulation and problem forecasting

Based on the defined problems coming from the application of the system operator logic, the problems were reformulated to the form of contradictions both for the super- and sub-system of the vehicle for everyday use. The first problem is related to the reducing production of LPG, that is forecasted to end by 2030. This indicated, that the production of other fossil fuels may be limited in the future as well. This leads to contradiction involving use of natural resources and energy supply for vehicles, that is shown on the fig. 4.

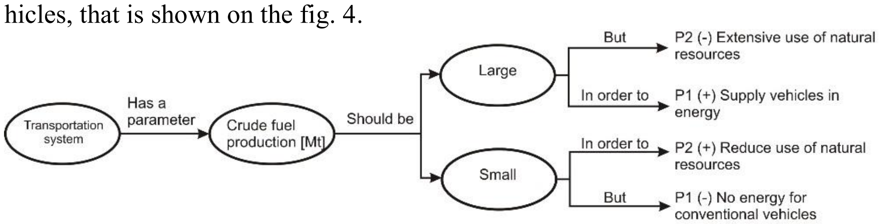

Fig. 4. Contradiction analysis for the transportation system.

The desired outcome would be to supply vehicles in energy with reduced use of natural resources, which means increased share of alternative fuel sources in automotive industry. Having noticed the increased share of renewable energy in electricity nowadays and expected numbers in the future (Eurostat data), it may be observed that one of the most promising technology of the future World in 2030 is the electric drive. Today, electric vehicles are being limited by the energy capacity of batteries, that is another contradiction to be discussed here on the fig. 5.

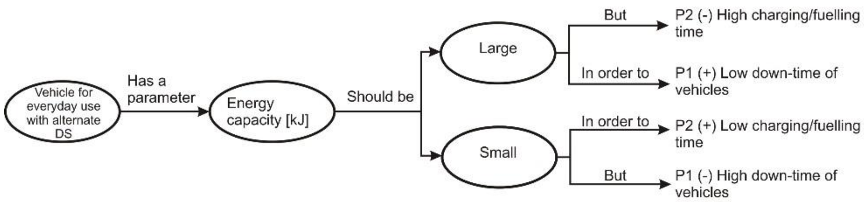

Fig. 5. Contradiction analysis for the transportation system.

The desired result would be to provide the low down-time of the vehicle with simultaneous low charging time. This problem, although specific for electric vehicle, is also present for other alternate fuel vehicles like CNG/LNG vehicles, in which the energy capacity is also much smaller compared to gasoline systems. Based on the contradictions above, the inventive problem to be solved in order to satisfy the future needs of the customers is “to design a fueling (charging) system that will provide low down-time of a vehicle by providing low fueling (charging) time”.

Heuristic concept development

For the concept development, heuristic method Synectics was used. Since the inventive task was already defined, it was possible to start the process of concept generation using analogies. There are four analogies in Synectics: direct, personal, symbolic and fantastic [2]. The result of concept generation of each analogy is presented in table 3.

Table 3. Results of the concept generation using analogies.

Direct analogy	**Personal analogy**
<exchange><battery>like in<remote> <charging>like<trolleybus>	I<wind up>like<a toy> I<charge>like<a induction charger>
Symbolic analogy	**Fantasy analogy**
like<animals drinking from the river> like<sun light gives energy to plants>	<charging through external field> <charging by shooting laser beam>

Based on the obtained results of the concept generation by analogy, the following concepts were created. In the remote controller, batteries are not being charged, and the down-time of the remote is reduced to minimum by replacing used batteries. Similarly, when flashlight stops working, after replacement of battery it may operate further without need of recharging. Another possibility is to continuously supply vehicle with electric power by continuous charging like a trolleybus. The last solution was adopted by Hyundai in the real-world operation. Personal analogies made it possible to define solutions like induction charger with no need of a wiring during fueling, that can provide fueling whenever the vehicle stops and charging by applying mechanical energy to be converted to the electricity. Symbolic analogy was an inspiration for the charging system with smart and intuitive joint system that will allow to connect the vehicle to the fast charging grid. Fantasy analogy on the other hand involved wireless charging from underground power lines. Some of the ideas are already being researched, for example the wireless method of battery charging that is currently under investigation by Stanford University [9].

Conclusions

Knowing the future is possible. Applying systematic approach in forecasting based on causal models, it is possible to extract limiting problems in development of technical systems and to address them at present and preparing for the future today. TRIZ tools are very helpful in forecast formation, especially System Operator and contradiction analysis, that were implemented in this case study. As a result of the forecast, set of problems limiting today's technology development was defined. In 2030, the amount of alternate fuel vehicles is expected to dominate on the market, but currently there is no fueling system that can answer the needs of customers in the future. As a result, problem solving approach using Synectics was applied to develop set of potential solutions that may significantly improve the performance of the electric vehicles in the future with the reduction of expenses, what will increase the ideality of the vehicle of everyday use.

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Generating New Product Ideas with TRIZ-derived 'Voice of the Product' and Quantum-Economic Analysis (QEA)

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Abstract This paper addresses one of the biggest problems today in technical TRIZ-consulting and in TRIZ methodology: far too few ideas generated using TRIZ yield commercially successful products. One of the main reasons for this is that while voice of the customer (VOC) is the main input for generating and screening new product ideas, it, unfortunately, may not reflect customers' wants and needs correctly. In order to address this issue, the author has proposed to supplement VOC with the more objective 'voice of the product' (VOP), which is derived using TRIZ tools, such as the Trends of Engineering Systems Evolution and Main Parameters of Value (MPV) analysis. Using VOP in combination with VOC meets customers' wants and needs better than using VOC alone, thus increasing the chances for the new product's commercial success. Practice shows, however, that even though the product ideas delivered by TRIZ-consultants fully meet customers' wants and needs, TRIZ clients are often unable to commercialize these ideas. In this paper, the author proposes to engage Quantum Economic Analysis (QEA®) in the new product development (NPD) process as a screening tool to reject ideas that, although technically promising in terms of VOC and VOP, the client is unlikely to be able to commercialize. This will increase the success rate of TRIZ consultants and will make NPD more efficient. The paper includes a brief case study illustrating the importance of using QEA in NPD in general and TRIZ-consulting in particular.

1 Introduction

One of the biggest problems today in technical TRIZ-consulting and in TRIZ methodology is that not enough ideas generated using TRIZ yield commercially successful products. Therefore, some clients think that TRIZ generally yields impractical ideas, which hardly contributes to the popularity of TRIZ across the world.

One of the most serious reasons for this is that classical TRIZ neglects business and market needs. In their report, Ilevbare, Phaal, Probert, et al. [1] clearly expressed a common attitude toward TRIZ: "TRIZ has its major strength in its ability to solve difficult innovation problems in a systematic and logical manner. However, it appears to pay little attention to linking the inventive problems and their solutions to market needs and drivers. Therefore there exists the unpleasant possibility of TRIZ providing a solution to a problem which has little or no profitability or commercial benefit to an organization."

This situation may be explained by the fact that, historically, TRIZ was totally focused on technical solutions with high levels of creativity (see Altshuller's book [2] for the definition of creativity levels). Therefore, TRIZ practitioners traditionally have thought that revolutionary/breakthrough solutions are always better than those that require fewer changes in the engineering system/product under development. This approach is normally well-received by the clients, but despite imparting a 'wow factor', practice shows that too often it results in solutions that either do not meet voice of the customer (VOC) or are too difficult to implement by the clients, and, so, these solutions have no business impact.

Modern TRIZ, however, has developed tools such as Main Parameters of Value (MPV) analysis [3 - 6] and the voice of the product (VOP) approach [7], which are aimed specifically at addressing business and market needs. These tools make it easier to meet the VOC, but, still, they do not afford TRIZ-consultants a very high success rate.

This is, in fact, a common problem for any new product development (NPD) process, e.g. the Stage-Gate process [8]. One of the main reasons for this is that the voice of the customer (VOC) is the main input for generating and screening new product ideas. Unfortunately, VOC may not reflect customers' wants and needs correctly.

In order to address this issue, in previous papers the author has suggested the following improvements to modern TRIZ methodology:

- An algorithm for supplementing VOC with the more objective 'voice of the product' (VOP) [9], which is derived using TRIZ tools, such as the Trends of Engineering Systems Evolution [10] and MPV analysis, and
- An algorithm for Product-Oriented MPV analysis [11] that helps find the best match between VOP and VOC, thus making it possible to identify whether the new product being developed will meet the customers' wants and needs.

Using VOP in combination with VOC meets customers' wants and needs better than using VOC alone – and this increases the chances for the commercial success of the new product.

Practice shows, however, that even though product ideas delivered by TRIZ-consultants fully meet VOC and VOP, and are proven to be feasible, TRIZ clients are still often unable to implement and commercialize them.

The probability of successfully implementing these ideas in a product may be significantly increased by utilizing the TRIZ-assisted Stage-Gate process [12]. Nevertheless, even with this, clients often fail to commercialize successfully implemented solutions, which is disappointing for TRIZ-consultants.

The author has previously suggested [13] taking another step to address this problem by implementing the Quantum Economic Analysis (QEA®) approach in TRIZ-consulting.

The QEA theory was originally developed as a tool for business consulting by Shneyder, Katsman and Topchishvili [14] and further advanced by Topchishvili Malkov and Tunitsky [15]. The authors of the QEA theory use it as a tool for devising brand development strategies [16]. For example, QEA helps to identify what changes to the company are needed in order to maximize the probability of business success.

QEA states that if a business is to be successful, the combined levels of development of (1) the company, (2) its product, and (3) the target market must fall within the set of "allowed" combinations that the authors of QEA derived by analyzing multiple business cases. If a business's combination is not within this set, it will unlikely be successful regardless of how good the company and the product are and how big the target market is.

This approach allows business consultants to identify the right business strategy, as shown in the recent book by Khlebnikov, Alperovich and Yatsina [17].

As the author of this paper has suggested [13] QEA may be applicable not only in business consulting, but in technical TRIZ-consulting as well, albeit for a different purpose. In TRIZ-consulting, QEA may serve as an NPD screening tool to reject ideas and concepts that, although they are technically promising in terms of VOC and VOP, the client is unlikely to be able to commercialize. This will increase the success rate of TRIZ consultants and will make NPD more efficient.

Applying QEA in TRIZ-consulting is not so straightforward, however. One of the reasons for this is that not all TRIZ projects relate to new products: many of them are aimed at developing new technology or equipment for manufacturing an existing product that remains unchanged. In this situation the original QEA approach is unsuitable.

The objectives of this paper are: (1) to address the above problem, and (2) to integrate QEA into the innovation roadmap alongside modern TRIZ tools, such as VOP and MPV analysis.

2 Method

In order to achieve the objectives of this paper, the following fragments of the original QEA [14, 15] are employed:

- Identification of the levels of development of the company, its product, and the target market – see Table 1 for characteristics of each level;
- The specific combinations of these levels that allow business to be successful (further referred to as Allowed Set).

The Allowed Set consists of the following 13 combinations:
P1-C1-M0; P1-C2-M0; P2-C1-M1; P2-C2-M1; P3-C1-M1; P3-C2-M1; P3-C2-M2; P3-C3-M2; P3-C3-M3; P3-C3-M4; P4-C2-M2; P4-C3-M2; P4-C3-M4;
where P1…P4, C1…3 and M0…4 are the levels of the product, company and market development respectively.

Table 1. Characteristics of the product, company and target market levels of development

Level of development	Development Level Characteristics		
	Product (P)	Company (C)	Market (M)
0	N/A	N/A	Very few consumers - early adopters only
1	Product level of development is determined as in regular TRIZ S-curve analysis, e.g. as described by Litvin and Lyubomirskiy [10]	Company can access up to $3,000,000 in capital	New consumers appear, but they keep using previous product as well
2		Company can access from $10,000,000 to $100,000,000 in capital	Mass consumer is switching to the new product, completely abandoning previous
3		Company can access over $100,000,000 in capital	All potential consumers are already using new product
4		N/A	Consumers are leaving the market and switching to a newer product

In this paper, fragments of QEA are integrated into the TRIZ-assisted Stage-Gate NPD process [12] alongside such tools of modern TRIZ as Function Oriented Search (FOS) [18], Cause-Effect Chains Analysis (CECA) [19], VOP [9], MPV analysis [11], TRIZ-based patent circumvention [20, 21] and the author's Comprehensive Analysis [13].

3 Results

The proposed TRIZ-assisted Stage-gate NPD process, which includes QEA-based screening, and VOP and MPV analyses, is shown in Fig. 1.

As can be seen from Fig. 1, QEA-based screening is used at Gates 1 through 3 of the process in order to reject unpromising ideas (Gate 1), concepts (Gates 3) and prototypes (Gate 3), i.e. those that do not meet the Allowed Set.

In NPD projects, QEA is directly applicable as a screening tool. However, in projects aimed at new technology/equipment for manufacturing an existing product, it is necessary to use the level of development of the technology or equipment in QEA-based screening – rather than product level of development (see Table 2).

Table 2. Objects whose development levels have to be used in QEA-based screening

What is under development	Objects whose development levels have to be used		
	Product (P)	Company (C)	Market (M)
New product	New product	Company	Market for the new product
New technology/equipment for manufacturing existing product	New technology or equipment	Company	Market for the existing product

Comment: In Fig. 1, QEA-based screening is not shown at Gates 4 and 5. At these gates it is less important because the levels of the product and its market development at these points are unlikely to change, as is the level of company development, which normally remains unchanged during the entire NPD process.

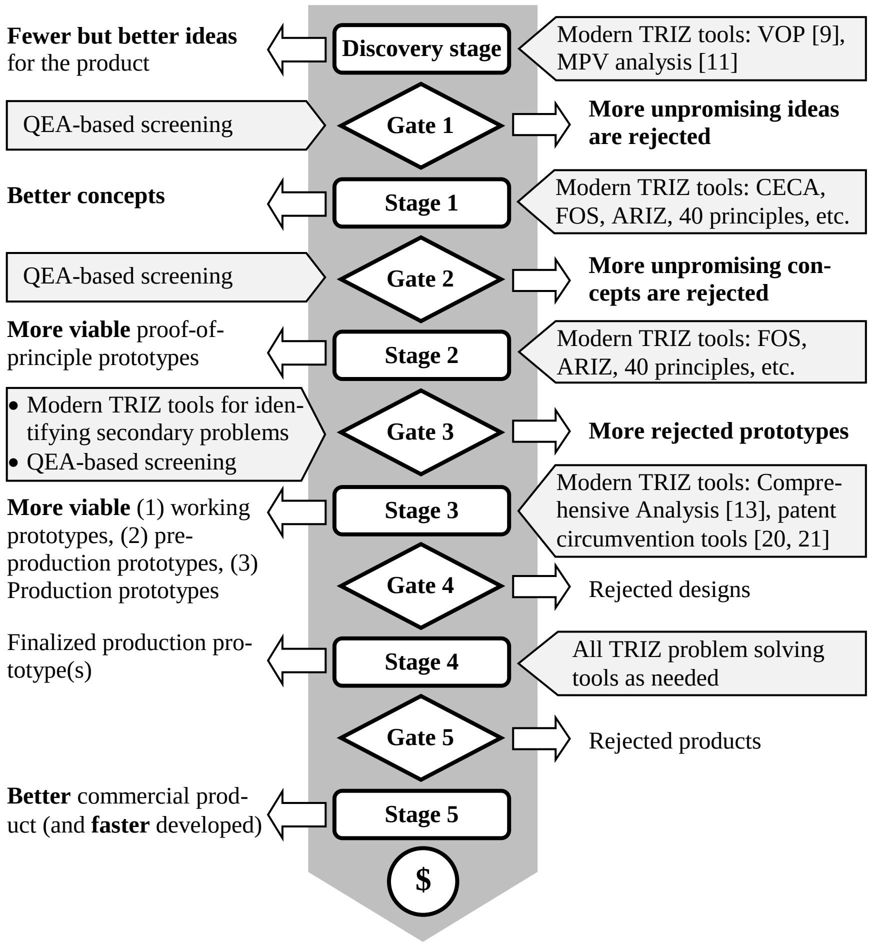


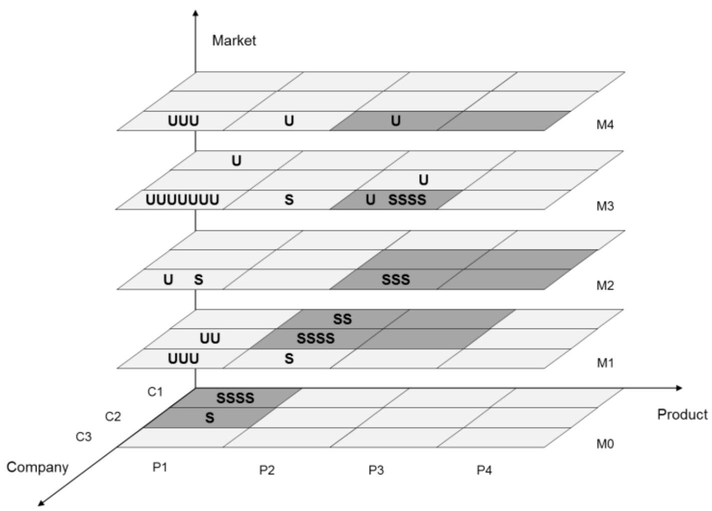
Fig. 1. TRIZ-assisted Stage-gate NPD process that includes QEA-based screening

4 Case study and discussion

The proposed approach of using QEA for screening solutions generated during innovation TRIZ-consulting projects, was experimentally validated by the author and two of his colleagues [22]. The results of this work may be used as a case study illustrating the potential benefit that this approach could yield.

In paper [22] the authors studied 42 solutions, just a portion of those generated in 114 TRIZ-consulting projects, which the authors were able to identify as commercially successful (resulting in a commercial product) or unsuccessful.

The results of this study are presented in Fig. 2 below.



Legend: P1…P4, C1…C3 and M0…M4 - levels of product, company and market development.
Gray cells represent the combinations within the Allowed Set.

Fig. 3. Distribution of successful (**S**) and unsuccessful (**U**) solutions across the levels of the product, company and market development

As can be seen from Fig. 2, out of the 42 analyzed solutions, 21 were successful and 21 were not, i.e. the success rate of TRIZ-consulting in these cases was only 50%. It has to be noted that clients tried to implement all 42 solutions, wasting a significant amount of time and money on the unsuccessful ones.

If QEA-based screening had been implemented, the 22 solutions outside the Allowed Set in Fig. 2 would have been rejected, and of the remaining 20 solutions, only two would have been unsuccessful. This means that the success rate would have been increased to 90%, which is a noticeable improvement.

It is worth noting that the QEA-based screening proposed in this paper can be employed not only in the Stage-Gate process (Fig. 1), but in other NPD processes as well, such as Design for Six Sigma and Service Design for Six Sigma [23].

5 Conclusions

Based on the results of this research, the following conclusions can be made:

- QEA-based screening can be an efficient tool to evaluate the business potential of technical solutions and reject unpromising ones at early stages of NPD.
- The TRIZ-assisted Stage-Gate process enhanced with QEA (Fig. 1) can dramatically improve the efficiency of TRIZ-consulting, thus addressing one of its biggest problems: neglecting business and market needs.
- Integrating QEA into the TRIZ innovation roadmap could eventually increase the popularity of TRIZ around the world.

Acknowledgments

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Innovative interaction design approach based on TRIZ separation principles and inventive principles

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Abstract Under the pressure of the continuous requirements for high performance products, user experience attracts more and more attention. Consequently, designing interactive products is called for bringing usability and comfort to support people in their working. Traditionally, products are engineered as systems to perform a set of functions. They may show satisfactory performance from engineering perspective, however it often presents inadequate capability on user experience. To balance the weight between final product performance and user experience, this paper attempts to resolve this contradiction in design phase. On the basis of function definition and allocation (allocate to automation and human) studies, we categorize the detailed design into two classifications. One is design for automation function that involves an elaborate object, which can be composed with structural components, mechanisms, or control components. The other is design for ergonomics that denotes human intervention in the process of system operating, which can be described as identifying what kind of behaviour that human will generate. In order to estimate the final product performance and user experience, the separation principles and inventive principles from the TRIZ methodology are used to analyse the interactions between user's behaviour and product's behaviour. A case study is shown to illustrate the feasibility of proposed innovative design method in eliminating the contradiction between product performance and user experience. The proposed method contributes to detailed design phase, and the design object can be a complex machine, equipment, system, or simple product.

1 Introduction

Typically, product (system) is designed and developed from a technology-centered aspect. These methods underline that design works are started from a set of functions [1, 2]. Many products require user to interact with them to achieve their goals. They may show the satisfactory performance from engineering perspective, however, it regularly presents inadequate capability on user experience [3]. In this study, user experience indicates users' perceptions and responses from unsafe to comfortable regarding the results of using a product or system. User-Centered Design (UCD) approaches [4] provide some useful principles for this issue. They hold that user information (needs, wants, limitations, etc.) should be paid extensive attentions at each phase of the design process. However, these approaches are not applied extensively due to some limitations, such as time-consuming and costly on data collection, information loss in the transmission process, etc.

It is significant that user information can be concerned in the early design phase. Many existing studies [5-7] mainly focus on CAD simulation and Virtual Reality that concerning the users quite late when the CAD model is already generated [8-10]. The reason of the contradiction between product performance and user experience is that users usually take part in prototype testing phase and some alterations may be required from ergonomics perspective. In general, once the design decisions have been made, design iteration may be required due to the user intervention testing. Additionally, protective devices or additional procedures are brought in to ensure the user's safety and health. However, they may bring negative impacts on productivity and product performance. Furthermore, some measures seem to useless once the prototype has been made [11]. These problems can be avoided in the design phase if usage situation can be considered thoroughly in design phase.

In order to eliminate this contradiction, usage situation should be considered in the design phase rather than prototype testing phase. Considering the output behaviour of product (system) associates with the product performance and user experience, this paper provides a behaviour analysis method based on TRIZ separation principles and inventive principles for innovative interaction design. The proposed method is on the basis of the function (task) allocation method that known as a decision-making method whether a function will be performed by human or technology (hardware or software) or mix of both [12]. In this paper, design works involve both product perspective and user perspective. Product perspective refers to an elaborate object, which can be composed with structural components, mechanisms, or control components. User perspective indicates ergonomics that use requirements about the reliability, usability, security, etc. This paper mainly focuses on detailed design phase, and the design object can be a complex machine, equipment, system, or simple product.

The organization of this paper as follows. The behaviour analysis method based on TRIZ separation principles and inventive principles that how to generate the solutions in the design phase is presented in next section. Then a case study is shown to illustrate the feasibility of proposed innovative design method. Last section draws the conclusions and future work.

2 Behaviour analysis method for interaction design

A general cognition of interaction design is to develop usable and user-friendly product that interacts with human [3]. Normally, interaction design requires concerning the end-user's activities when they interact with product. In particular, usage situation should be considered thoroughly in design phase. A function-task-behaviour framework is proposed to assist designers to consider the human factors and ergonomics (HFE) in the early design phase, and it is under review by International Journal of Production Research. To specify these framework will take a long length. This paper mainly focus on the approach of solution generation in detailed phase.

2.1 Function definition and allocation

Basically, the primary task of interaction design is to understand use requirements. There are many studies (see literature [13]) regarding how to gather these requirements and to discuss this issue beyond the scope of this paper. In this paper, function analysis that denotes how to define the function from requirements is not introduced.

As function allocation is the key process of interaction design, it can balance functional requirements and use requirements. In this paper, interaction design mainly concentrates on the functions that allocated to both technology and human. Based on the function definition and allocation studies [12], in this study, design works are considered not only to develop the product itself, but also to ascertain the user behaviour of the usage situation. Here the globalisation principal of TRIZ is applied. Semantic description of function is a verb plus object, and it is often completed by defining several tasks. Concerning the interaction design refers to the functions performed by both technology and human, we assume an elementary function can be completed by one or two tasks and we define the task implemented by technology as technical task, as well as the task performed by human as socio-technical task. In this study, we add duration information to SADT to describe the task (Fig. 1). It refers to the length of time from the beginning to the end of this activity.

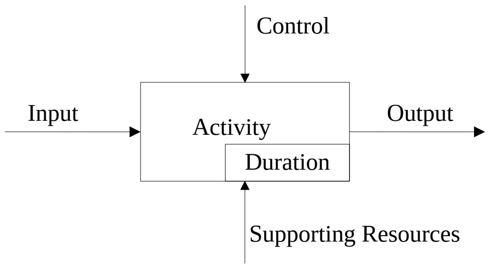

Fig. 1. Notation of the improved SADT

This illustration means: under control, carry out the activity by certain supporting resources, after a period of time (duration), input is transformed into output that signifies intended function. In general, implementing a specified function requires a series of tasks are carried out according to a given pre-defined chronological sequence. Each task has an input and the output that can be the input or control of the other task. Duration information can assist designer to make the decision of the starting time of each task. After task planning, interactions between technical task and socio-technical task in the timeline can be obtained.

2.2 Behaviour analysis method

Actually, behaviours are the real outputs of the system (product), reveal the physical characteristics of the product and reflects product performance [14]. Literature [15] on the Function-Behaviour-Structure framework, the behaviour is described as the action that is executed from the structure to complete the function, and indicates "how structure fulfils the function". Therefore, the technical behaviour can be defined as a characteristic of the structure which can be directly derived from the structure, such as translation, rotation, vibration, etc. It represents all characteristics that technical tasks were performed by the structure. Similarly, user behaviour represents all characteristics that socio-technical tasks were carried out by the users (i.e. press, push, pull, lift, move, etc.). In this step, detailed design fundamentally differ from most engineering design studies, we categorize it into two categories. One is design for technical task that involves an elaborate object, which can be composed with structural components, mechanisms, or control components. The other is design for socio-technical task that denotes human intervention in the process of system operating, which can be described as identifying what kind of behaviour that human will generate.

In this study, detailed design primarily deals with these interactive tasks by analysing the behaviour interaction between technical task and socio-technical task. We can learn these interactions in timeline based on task planning that mentioned in the last section. These interactive problems can be considered as technical contradictions technical task and socio-technical task [16, 17]. TRIZ separation principles and inventive principles are used to resolve these contradictions.

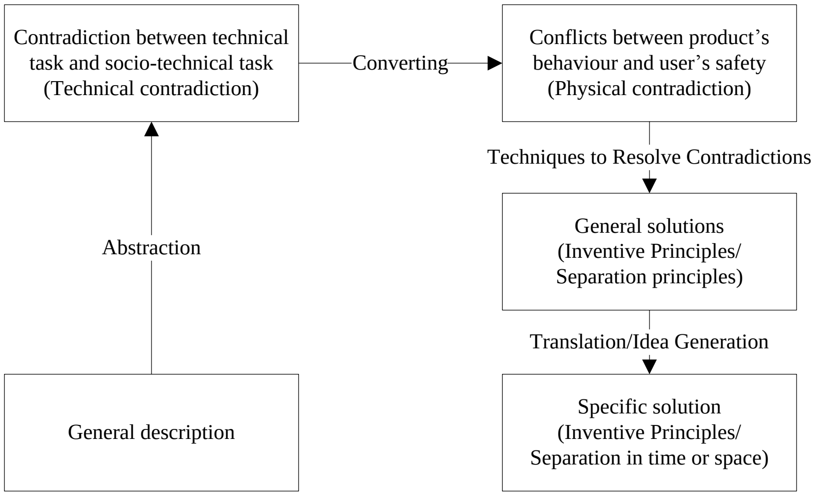

Fig. 2 The general model of the behaviour analysis method based on TRIZ separation principles.

The contradiction can be converted to the conflict between product's behaviour and user's safety, and the product's behaviour is the parameter in the interaction design problem. General solutions for these interactive task are: (1) assign these tasks in the different working zone (separation in space); (2) reallocate these task's order and avoid these task overlaps in the timeline (separation in time); (3) ensure the behaviour of technical task must meet the requirements of the user's safety and health (inventive principles). In order to ensure the usable and comfort of user experience, these interactions are rated in two categories unsafe and usable. If there are any potential hazard phenomenon in the interaction zone that will be harmful to user's health and safety, we consider the interaction in this zone as unsafe. Otherwise, we think it as usable. For example, in the process of electric drill operation, the interactions between user and the electric drill will happen (Fig. 3).

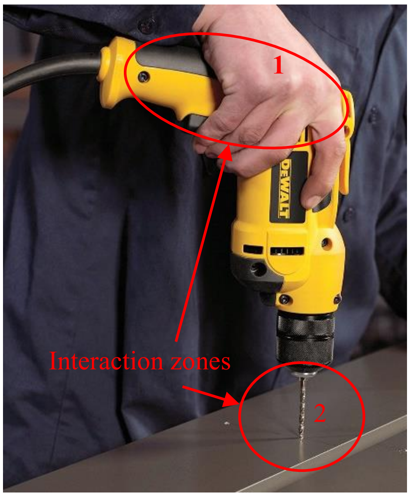

Fig. 3 Interaction zones in the process of drill working

There are two interaction zones, 1) the handle and button zone, 2) the drill working zone. There are not any potential dangerous phenomenon in handle and button zone, the interaction is usable. However, in the drill working zone, the debris are produced around caused by the high speed rotation bit. Small dusts can fly into the user's eyes and cause discomfort. Some metal debris and suddenly broken drill may puncture the skin or other body tissues. The interaction in this zone is unsafe.

3 Case study

To verify the proposed method, we improve the existing corded electric drill as an example. Although some protective devices (glasses, safety cloth, etc.) are required to wear before operating, however, few users follow it because these protective devices will decrease the user experience. In order to eliminate the contradiction between product performance and user experience, the usage situation of electric drill should be learned first. It takes three steps: (1) assemble the electric drill; (2) power on; (3) drill the hole. By conducting the function allocation and task planning, these steps are illustrated in SADT representation (Fig. 4). The interaction of between user and product in the time distribution is shown in Fig. 5.

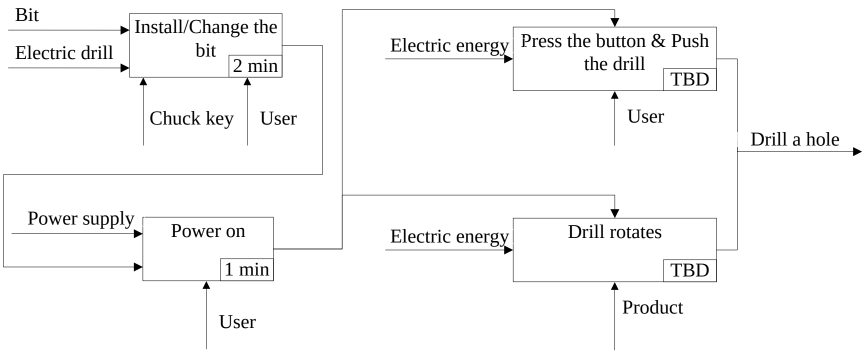

Fig. 4 Function allocation of the existing drill in improved SADT illustration

	Task	Executor	Starting time	Duration
T_0	Install/Change the bit	User	0 min	2 min
T_1	Power on	User	2 min	1 min
T_2	Press the button & Push the drill	User	3 min	TBD
T_3	Drill rotates	Product	3 min	TBD

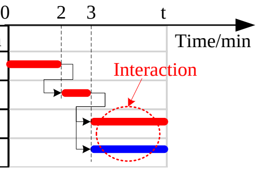

Fig. 5 Interaction of existing drill between user and product in time distribution

As discussed in last section, there is a contradiction (unsafe interaction) between T_2 and T_3. In this case, we did not change the main function and structure of existing drill. Separation in space is adopted to resolve this contradiction. Follow the separation principles, the solution of redesign is to assign these tasks in the different working zone. General solution is to add some protective devices in the electric drill to prevent the product's behaviour and user's behaviour in the same zone, and the protections should be installed before drilling. Fig. 6 shows an available solution for this contradiction.

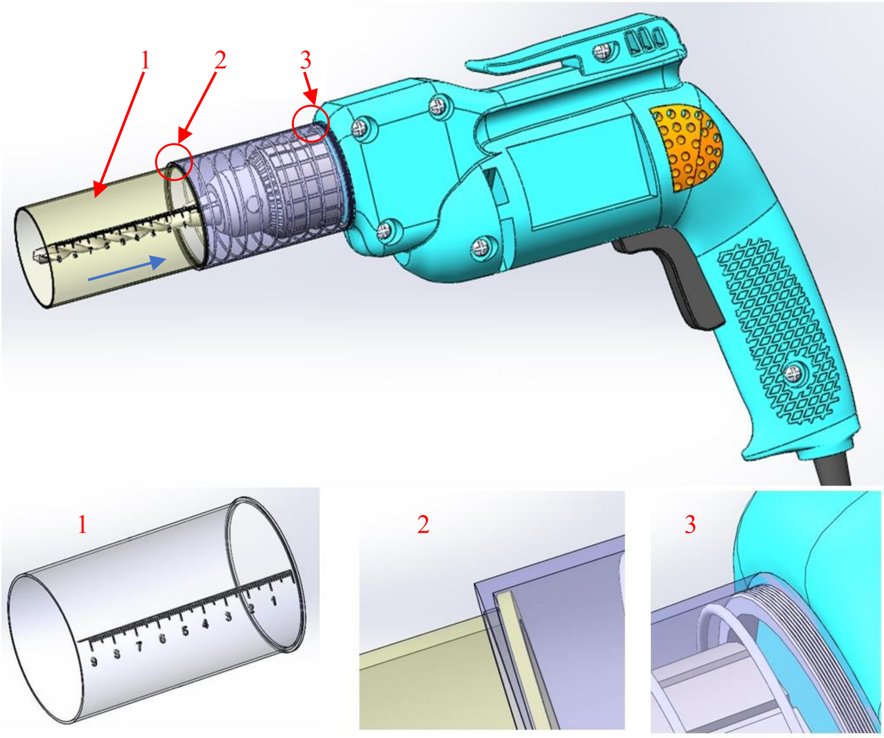

Fig. 6 Solution of the redesign of the existing drill

There is a spring in tube 3. In the process of drilling, tube 1 will move into tube 3 along with the direction of blue arrow. The graduated scale is also designed in the protective devices for knowing the depth of hole in the process of drilling. This case shows that conducting behaviour analysis method can help designer to learn the usage situation and identify the potential dangerous circumstances in design phase, and provide guidelines to carry out the detailed design works. This case showed us that using TRIZ early in design process, allowed to propose new solution that designer con not find.

4 Conclusions and future work

This paper presents a behaviour analysis method for eliminating the contradiction between product performance and user experience in the design process. This technical contradiction can be converted to physical contradiction in the Process of Resolving Technical Contradictions. The separation principles and inventive principles from TRIZ are used to resolve the physical contradiction. The proposed method contributes to interaction design of a complex machine, equipment, system, or simple product in detailed design phase. We propose to consider the usage situation in the design phase to find out the potential hazard circumstances that threaten user's safety and health. By employing the proposed method, the contradiction between product performance and user experience can be eliminated in the design phase. Through a case study, the effectiveness and feasibility of the approach are verified.

The future works are also called for developing this method in detail and apply it in practice in a suitable manner. Currently, we are integrating this method in a CAD software based on its application programming interface (API).

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'Liberty vs. Love': The Principal Contradiction of Human Culture

(2) The 'Liberty vs. Love' Contradiction and 'Ethics' at the Personal Level

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Abstract This is the second report of applying the TRIZ/CrePS Methodology to the social filed. A basic hypothesis, found in the first report, is " 'Liberty vs. Love' is the Principal Contradiction of Human Culture unsolved throughout the human history". The present study has investigated and extended it further. In short: Liberty is the First Principle of Human Culture, while Love is the Second. These Principles however contain various Contradictions, inside Liberty, inside Love, and between Liberty and Love. Both of these Principles are motivated by Ethics, which distinguishes Good from Bad deep inside the human heart. Thus the key to reduce/solve the 'Liberty vs. Love' Contradiction should be Ethics. However, Ethics is set and taught by society and evolving with history. Structural relationships of 'Liberty, Love, and Ethics' at the personal level are investigated.

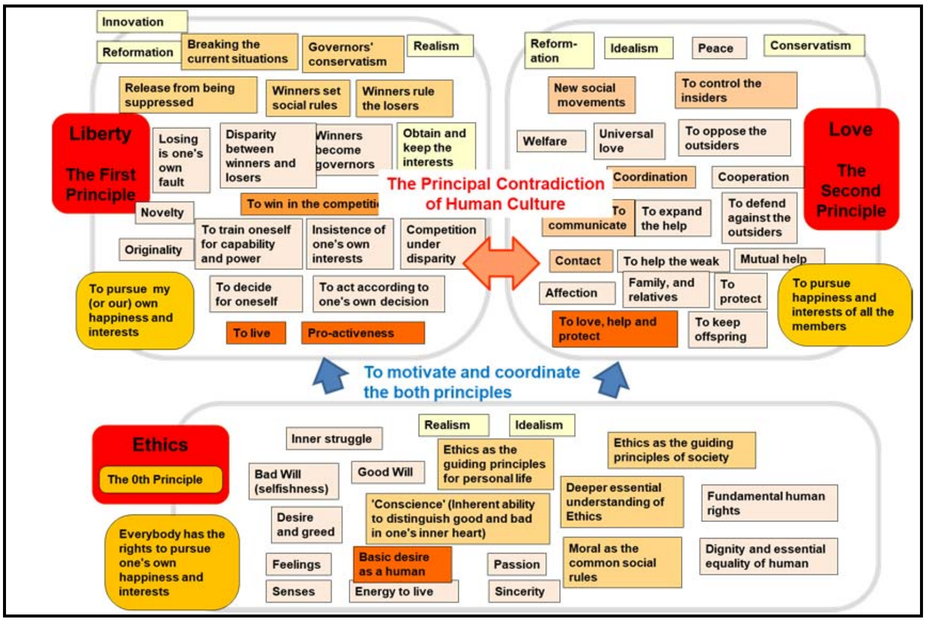
0. Introduction

This is the 2nd report of applying the TRIZ/CrePS Methodology [1] to social problems and of revealing the root contradictions underlying the Human Culture.

Last year [2], I applied TRIZ/CrePS to the problem of 'Poverty in the Japanese society'. Using the book "The Low-living Elderly" (Takanori Fujita, 2015), I visualized its logic. At the root of the poverty problem, there exist arguments, among people, blaming the poor themselves for their poverty, opposing mutual help and rescue by social welfare. I realized that the philosophy of Liberty does conflict with the philosophy of Love at the root. Then I obtained a hypothesis as follows:

Basic Hypothesis: 'Liberty vs. Love' is the Principal Contradiction of Human Culture and left unsolved in Human History. Liberty (and its extension) is the First Principle of Human Culture, while Love (and its expansion) the Second Principle. 'Liberty vs Love' is the Principal Contradiction of Human Culture (including the contradictions inside Liberty as well as inside Love). Both Liberty and Love are motivated by Ethics and may be coordinated by it.

Fig. 1. Structure of 'Liberty, Love, and Ethics' in the Principal Contradiction



I have found various causes making the Principal Contradiction so difficult to solve. Especially, the real and ideal situations of 'Liberty vs. Love' are not yet revealed well at the personal nor social levels.

In the present study, the Basic Hypothesis has been investigated further. The relationships among 'Liberty, Love, and Ethics' are investigated mainly at the personal level. They are studied in relation to the growth stages of human (i.e., baby and child, kid at schools, youth, middle, and elderly). Then, many keywords relevant to 'Liberty, Love, and Ethics' are collected and their relationships are investigated by use of a visual diagram, as shown in Fig. 1.

The diagram is helpful for revealing the structure of the relationships among 'Liberty, Love, and Ethics'. Thus the Basic Hypothesis has been revised and extended much as described in the following sections 1. through 5.

The present paper tries to figure out the main structure of the problem without referencing articles and thoughts by numerous people on individual details.

1. The 0th Principle of Human Culture: Ethics

(1) At the bottom of human heart, there exist the senses and feelings and also basic desires and greed. Ethics serves to distinguish Good from Bad deep inside

the human heart. Ethics is formed to be common understanding of guiding principles of personal and social lives for each society.

(2) Contents of Ethics, i.e., what are Good and what are Bad, are formed by societies more or less differently and evolve in the history of the Human Culture. Ethics is acquired after birth through various experiences and educations. Then, what is inherent and common for the human kind? I suppose 'the ability to distinguish Good from Bad in the depth of human heart' is inherent and common for human kind. I call the ability ‘Concience’, after redefining its conventional meaning of ‘Good Will in the human heart’. (Cf. Human babies of any birth origin have the ability of learning to speak a language of the raising family/community, wherever raised.)

(3) Human Culture has been based on Ethics and pursuing to extend Liberty and expand Love. The keys to coordinating and solving various conflicts/contradictions of 'Liberty vs. Love' are basically found in Ethics. Hence Ethics is regarded as 'The 0th Principle of Human Culture' in the present study.

(4) The conventional term 'Moral' has a strong nuance of 'Obedience' to social rules reflecting traditional hierarchical human relationships. However, the history of Human Culture has obtained the concept of 'Essential Equality of Humans'. The Fundamental Human Rights with this Equality concept is the core of thoughts on Ethics in the modern world.

(5) Essence of the 0th Principle: Ethics = ‘Everybody has the rights to pursue one's own happiness and interests'.

2. The First Principle of Human Culture: Liberty

Human Culture takes 'Liberty' as its First Principle and aims at extending it further.

(1) Liberty = 'To decide for oneself, to act according to one's own decisions, and to live'. Every action makes different influences and results, and it sometimes succeeds while other times fails. Knowing such situations, one has to think, decide, and act as one thinks best. This way of thinking and acting at ones' best is supposed to result in maximizing the possibility of survival and newly developing the Human Culture.

(2) Liberty conflicts mutually. Since people want common things while the resources are limited, people's desires (‘Liberty’) inevitably collide, and there emerge competitions. Liberty aims at 'Winning in the Competitions'. One has to train oneself to get physical strengths, experiences, intellects, resources, etc. beforehand, and to think, decide, and act in proper ways. Winners obtain the things they wanted while Losers fail in obtaining them and may even lose their own lives. Survival of the stronger (with higher capabilities) in the Competitions is the natural rule in the world of living things.

(3) People's desires 'To Win in the Competitions' make the Competitions severe more and more. In the society with severe competitions, people apt to live in awkward relationships. As the results of repeated competitions, the gaps between the Winners and the Losers expand gradually and the disparity eventually become fixed more or less.

(4) The Social Winners who won the competitions repeatedly start to rule the whole Society. The Winners build new Social Rules which are favorable for them. The Winners try to maintain their own ruling positions. Thus, realism and conservatism prevail among the Winners (and also in the society).

(5) The Social Losers under the situations of being ruled and oppressed want to get released. Breaking the current unfavorable situations, and Reforming the current Social Rules become the targets of new movements in the name of Liberty, with the viewpoints of Idealism. Such Reformations have made new epochs in history.

(6) 'To decide and act for oneself' often generates epoch-making developments of Human Culture, especially in the fields of Science & Technology, Arts, etc.. It is the source of originality and novelty, resulting in Innovation. This fact is the basis that Liberty is regarded as the most important principle for developing Human Culture.

(7) Essence of the First Principle: Liberty = 'To pursue my (or our) own happiness and interests'.

3. The Second Principle of Human Culture: Love

Human Culture takes `Love' as the Second Principle and aims at expanding it widely and universally.

(1) Love = 'to love one's children, one's family, and one's neighbors, and to help and protect them’. The prototype of Love is the affection by mothers to their children. It originates in the instinctive behavior, for human (just like other living things) to protect and raise their children, for leaving offspring. Expanding Love to one's family and neighbors, to everybody around, and further universally is a final target for Love as the Second Principle of Human Culture.

(2) Love helps the weak and the people in trouble. 'To help one another mutually and widely' is the original direction for Love as the Second Principle. For this purpose, Love wants to make contact and communicate with people, and to cooperate with people under mutual understanding.

(3) Love tries to coordinate people in order to seek Harmony among people in the group. When the members' insistence of Liberty is strong and different, achieving harmony becomes rather difficult. One solution is to conciliate the member who was insisting his Liberty so as to stay in cooperation in the group. Another solution is to approve the opinion of the insisting person and to ask other members for their understanding (or to conciliate them). In these two solutions,

Love is trying to find some compromise among the group members' Liberty for the sake of Harmony in the group.

(4) Love tries to find Cooperation of a diversity of Liberty while keeping their mutual respects. It is desirable that each member of the group understands the differences in members' opinions and interests, and cooperates in coordination as a group while keeping mutual respects. This is possible when the group members understand that the differences can compensate the weakness of individual members and can make the group better/stronger as a whole. In other cases when an opinion (Liberty) of some members is new and meaningful, such member(s) may be separated from the original group to form a new group independent but having a (loose) relationship with the original group.

(5) Another prototype of Love is related to the sexual reproduction of offspring. It has the nature mostly common as the Love mentioned above, but is specific in its exclusiveness in pairing. Wanting and choosing a partner is motivated much by instinctive desire and feelings, and often meets competitions. Finding good partners and living fruitful marriage lives are important tasks for individuals and for society.

(6) For the purpose of protecting the Family (or Insiders), Love tries to resist/defend against the Outsiders. Love tries to define the members to protect (Family, or Insiders), and to build a Wall around and to defend against Outsiders. For banding the Insiders together, Love sometimes tries to control the opinions and actions (Liberty) of the members, resulting in the standing positions of Conservatism and Realism.

(7) Love, trying to defend the Insiders, generates a Conflict at a higher social level. (E.g., Patriot Love of the people in one country and Patriot Love in the neighboring country caused wars often.) .

(8) To Love everyone (i.e. Universalization of Love, Philanthropy) is the genuine goal of Love. Love aims at giving Help to all the people especially those in poor situations in the social disparity. Trials to change the society in such a direction are the movements of Reformation and Idealism. With the international world-wide scope, they become the movement for Peace in the World.

(9) Essence of the Second Principle: Love = 'To pursue happiness and interests of all the members'. The range recognized as 'all the members' (i.e., Family in a wider sense, Insiders) is crucial in this concept.

4. Conflicts and Contradictions between Liberty and Love

Conflicts/Contradictions emerging inside Liberty and inside Love are mentioned already. Here we discuss on Conflicts/Contradictions between Liberty (pursuing My/Our own happiness/interests) and Love (pursuing happiness/interests of All the members).

(1) A person has made up his Decisions and Actions (Liberty), but some other persons around try to stop him for the sake of Love. Persons around, especially in leading/protecting positions, think that such decisions and actions are wrong or risky. The person thinks "Even though my decisions and actions are risky, it is necessary to take the risk for the success in future". But the others advise "Stop them, or you would certainly fail and get a big damage". Which position is appropriate? It depends on the situations.

(2) Love asks for Mutual help and Cooperation for the sake of happiness and interests for all the members, but some member may refuse them because they do no match his/her own happiness/interests (Liberty). Since Liberty pursues one's own happiness/interests at maximum, this type of conflicts emerges very often.

(3) Liberty wants to finalize an issue by Competition or Fighting, but Love wants to settle the issue in a peaceful way without Fighting. It is natural for Liberty to finalize any issue by means of Competitions or Fighting to decide which wins. Love does not want Fighting but wants to achieve coordination, harmony, and peace among the members. For settling the issue, Love needs to be respected as a mediator and the Mediating solution must convince the both sides.

(4) Social Winners are going to build new social rules and to start ruling the society (Liberty). Love sometimes protests against the new social rules and the way of ruling, claiming that they would violate the happiness and interests of all or some of the members. Love sometimes starts a new movement with the claim.

(5) Social Losers sometimes raise a Reformation movement for the release from oppression (Liberty). Love usually agrees with the purpose of the movement but sometimes opposes against the measures and processes of the movement, because of their violation of happiness and interests of all or some of the members.

(6) Love wants to strengthen the bandage of the members, in order to defend against the threats and attacks from outside, and sometimes tries to control and restrict the opinions and behaviors (Liberty) of the members.

(7) When Love is sensitive in distinguishing the Insiders from outsiders and is narrow-minded, the people other than the Insiders are often excluded from the community of Insiders and hence their opinions and actions (Liberty) are not approved; this causes conflicts between the Insiders and the Outsiders.

5. The Role of Ethics to Liberty and Love

Ethics motivates both Liberty and Love, and coordinates them to reduce/solve the Principal Contradiction 'Liberty vs. Love'

(1) Even though the contents of Ethics (i.e., 'What are Good and What are Bad') differ depending on society and have been evolving with the history of Human Culture, Conscience (the ability to distinguish Good from Bad deeply in the heart) is supposed to be Inherent (and hence common) in the human kind. Hence, it is important that Ethics is understood properly in the heart of individuals and is prac-

ticed appropriately. This is crucial for Liberty and Love to be practiced by individuals and by society in their genuine spirits as the Principal Principles of Human Culture. Ethics is the key to reduce/resolve the conflicts/contradictions existing inside Liberty, inside Love, and between Liberty and Love.

(2) Insufficient understanding/practice of Ethics ruins the spirits and practices of Liberty. The followings are some of such examples.

Ruin the pro-activeness <== Being passive, enervated, irresponsible, following others blindly, etc.

Ruin the originality, novelty <== Following precedent cases, conventional, copying, imitation, etc.

Ruin the challenging <== Seeking safety, shrinking, avoiding the responsibility, etc.

Make Competitions inappropriate <== Backdoor admission, cunning, doping, judgement juggling, secret rule violation, corruption, bribery, etc.

Obtaining one's interests unfairly <== Threatening, corruption, falsification, fraud, robbery, killing, etc.

Building new social rules improperly <== Slavery, class system, restricted voting rights, colonial system, etc.

Misleading the Movement of Reformation <== Terrorism, armed uprising (on the movement side), suppression, media control, etc. (on the ruler side)

(3) Hence for Liberty to be respected, the thoughts and actions in the name of Liberty should be in accordance with Ethics, namely they should come from not Bad Will but Good Will of the persons. Practical guideline for ensuring this point is to keep following the Fundamental Human Rights, especially Concept of 'Essential equality', in the claim of Liberty and in the field of Competition. It is important to understand and practice 'Essential Equality as a human', instead of 'Uniformed Equality' and of ‘Obedience in traditional class system’.

(4) Insufficient understanding of Ethics ruins the spirits and practices of Love.

Ruins the affection <== Indifference, dislike, cruelty, abusive treatment, etc.

Ruins the help <== Neglect, disregard, etc.

Ruins the protection <== Disregard, closing the eyes, etc.

Ruins the coordination <== Non-cooperation, lack of understanding, cold heart, selfishness, insistence, rejection, etc.

(5) Hence Ethics is the foundation of Love. Love is based on the tender heart (an aspect of Ethics) of everybody. With such a tender heart, one can help, cooperate, and coordinate with others. With a tender heart, one may avoid claiming selfish Liberty and hence reduce the factors causing the conflicts between Liberty and Love. Even though Love has its general philosophy to spread it widely and universally, its sense of specifying the Insider members forms big barriers against widening of Love. It is important to have the Ethics based on the concept of 'Essential Equality as a human', and to communicate with people widely for understanding the history and current situations of the society and the world.

(6) One more point we should note particularly is the fact that Greed of human, especially the desire for money, is endless. In the current world, money is

the biggest factor for distinguishing the Social Winners. The rich people are the Social Winners and the current social system is made favorable for them. That is the capitalism economy and the capitalism social system. The capitalism social system has generated big disparity and various serious problems in Japan and in the world. We should make efforts for reforming the social system in this point to incorporate the redistribution of wealth more widely. This is the current important issue of Liberty, the issue of Love, and the issue of Ethics as well.

Conclusion

The present study investigated further the Basic Hypothesis of 'Liberty vs. Love' as the Principal Contradiction of Human Culture and extended and strengthened it. Especially the structure among 'Liberty, Love and Ethics' has been studied at the individual personal level. Various forms of contradiction inside Liberty, inside Love, and between Liberty and Love are considered and Ethics is regarded as the fundamental key to reduce/solve such contradictions. It is noted that Ethics differs depending on society and evolves in history, but the concept of 'Essential Equality as a human' is recently understood to be the core of Ethics. Following the Fundamental Human Rights is revealed to be the practical guiding principle for reducing/solving problems of Principal Contradictions. The issue will be investigated further, at the group/organization level next.

The whole investigation reported here has been guided by the TRIZ/CrePS methodology [1]. Recognizing a problem in the Real World, defining the problem to be analyzed in the Thinking World, and understanding the present system and the ideal system (of the problem) have been carried out so far to some extent. Generating solution ideas and building conceptual solutions (in the Thinking World), and implementing solutions (in the Real World) need to be carried out as big tasks in future. Systems thinking and contradiction philosophy in TRIZ/CrePS are especially useful for investigating this fundamental and complex social problem.

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Note: THPJ: TRIZ Home Page in Japan, URL= http://www.osaka-gu.ac.jp/php/nakagawa/TRIZ/eTRIZ/

Multiscreen Analysis for Team Strategy Development

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Abstract Nowadays corporate organizations normally hold a structure where discipline-based teams maintain a certain degree of homogeneity in skill set, still must respond to a very dynamic environment, in terms of technical and operational aspects and change of project scope in a short time. In such a scenario, the ability to formulate an effective development proposition for the team both with strong individual buy-in is critical. The scientific literature presents many examples of methods for group management, but most of them are focused on the best allocation of resources in the present time for a given set of project requirements. Only a TRIZ-enhanced version of the SWOT approach presents a method to improve organizations, products, services and processes and provides a detailed and complicated template for better resources management with a time development plan. Nevertheless, it demands an intensive effort to compile it and little focus is given to team resiliency, capability and growth. This paper presents a simplified Multi-Screen based approach successfully tested to identify a multi-year team development strategy for a technology team focusing on the energy sector. The workgroup is considered as the engineering system to analyse. In the nine-windows version the Multi-Screen approach proves its effectiveness paving the way to depict the overall landscape that shapes the technical skills the team is called to fulfil, the technologies to focus upon and consequently identified the needed development patterns at subsystem level, that is, for subgroups and individuals, in the spirit of TRIZ as a tool for personal creativity development, a research topic initiated by Altshuller himself. The modular structure allows to work in subgroups with different focus and offers a flexible tool for dedicated follow up sessions.

1 Introduction

The capability of fast adapting to rapid change has become more and more instrumental in the last few years, involving both large companies and individuals; the Fourth Industrial Revolution or Digital Industrial Revolution will only enhance this need, since it shows an unprecedented dynamic: the pace of continuous breakthrough has been observed to evolve at an exponential rather than a linear pace

[1], involving virtually every industrial segment; the new emerging technologies are already showing a major impact on companies, that need to rethink their business model: along with the change in the ecosystem also the operating teams need to continuously improve. Large corporations, e.g. GE, already formulated the steps through the digital revolution, underlying the need to redesign their operating model. Many global observers, i.e., the European Commission [1], the World Economic Forum [2], the TED Organization [3], recognize that the 4th Industrial Revolution will force a modification of customer expectation, product development, collaborative innovation and organizational forms. Most of the influencing corporate leaders, like Erik Brynjolfsson, Marco Annunziata, Jeremy Howard [3] underline how the most important challenge of the next decade will be the ability to adapt fast enough, since the industrial internet will cause a major pivotal change and almost everything about the workplace will be completely different. It will be instrumental to have the right tools to timely reshape the professional identities and working procedures. The TRIZ community already recognized the value that the methodology can bring to the business and management space. V. Souckhov [4] recognized how the extremely dynamic business environment required tools to leverage innovation in companies at the required pace; extensions of TRIZ to business has been already explored by Souchkov and D. Mann [5], who wrote a dedicated contradiction matrix, enhancing the potential of the methodology for this space. This has been grounded by the statement that being technological systems and business systems both generated by the human mind, TRIZ thinking patterns can well apply in both cases. Souchkov already recognized the need of increasing dynamization and growth for companies to sustain success; dynamic growth implies continuous change. He stated the importance of trends to formulate a solid founded forecasting and roadmapping, investigating most of the TRIZ tools, underlining the need to expand the subject of TRIZ application for business and create a dedicated body of knowledge. All these statements are nevertheless always formulated at very high level and it is often difficult to understand how to translate these suggestions on a daily basis at the level of work groups and middle management. In particular, Multi-Screen Analysis, whose potential is described in the following Paragraphs, is just listed as one among the possible helpful tools to enhance success and innovation level, without special focus on strategy, or business and management- related examples.

2 Multi-Screen Analysis in Business Environment

G. Alsthuller initially described the Multi-Screen-Analysis in the nine-screen version [6] as a powerful tool to develop creative imagination, describing the innate mastery of such a vision as the distinguishing quality of the highest talented innovators. More recently V. Souchkov [7] started to employ it for innovation road mapping, describing how to use it to identify and structure resources for the future evolution of the system under analysis, with special attention to issues emerging from the transition between different evolution stages. According to his approach Multi-Screen-Analysis can be mostly helpful to analyse issues related to fast dynamic changes. In fact, from a detailed Multi-Screen-Analysis it is possible to list changes, problems and challenges experienced by the system of the previous and of the next generation respectively. The next generation can be described and so the problems related to its development, arising from super- and subsystem evolution, can be formulated and solved. Applying Multi-Screen-Analysis to the development of teams, Souchkov's most relevant question formulated for Engineering Systems [7] can be rewritten also in terms of people skills in addition to functionalities: which will be the new functionalities and skills required by the next generation Supersystem? This approach has been selected for the workout precisely for this reason.

In [8] TRIZ has been analysed as an effective enhancer of SWOT Methodology (Strengths, Weaknesses, Opportunities and Threats), being SWOT Analysis the most common technique for situation analysis of organization and strategic planning. The SWOT-radar-screen-analysis proposed by Microsoft takes advantage of Multi-Screen-Analysis applying SWOT methods and concepts at all levels, Supersystem, System and Subsystem. The resulting template consists of a huge complicated matrix: for each cell the content results from the output of brainstorming sessions, but the methodology does not suggest how to structure them. When team development only is the main objective this approach will require an excessive allocation of time and it offers no visual anchor to help workout participants to work on very quickly. Moreover, in our case the resolution of conflict was not explicit and fell rather into the category of roadmapping, forecasting, people development; in the proposed SWOT analysis staff and business units belong to the subsystem, so do workteams, while knowledge, learning paths and core competencies are grouped into the system/internal resources category, making it difficult to consider all these aspects as whole for a dedicated strategy session. There is also no focus on people's skills.

In [9] TRIZ tools like contradictions, Inventive Principles and Ideal Final Result are discussed as SWOT enhancers; a spiral model is also shown, that is, a diagram representing an architectural roadmap, using quantitative indicators; this again looked very complicated for the scope of our workout: while very promising for processes, it is not oriented to people and teams, since team problems and challenges are not always easy to quantify.

3 Application Example: Multi-Screen based Strategy Workout

At GE Global Research Munich, a strategy Workout took place, in order to reshape the long- and medium-term strategy of a team which focused on a subset within electrical technologies. Goal of the Workout, for which a whole day for the entire team was allocated, was to identify an efficient and practicable path to re-tune the workgroup strategy and focus areas with an express intent to rejuvenate the program

deck which was showing signs of plateauing as also the impact of the R&D efforts beyond the energy sector. The starting point was the assessment of the focus areas and the long-term strategy keeping in mind the major trends in the energy and industrial sector such as 4^{th} Industrial Revolution and Electrification.
Historically homogeneous (in technology) specialists have been organized in teams with a large spread of experience, spanning a few years to few decades with individual personality traits. It is the experience of the authors that this span in experience and personalities results in timekeeping challenges to capture everyone's opinions when using traditional tools such as brainstorming and workouts.
Since the strategy workout was intended to result in clear actionable technical efforts at the end of one day it was felt that classical team brainstorming techniques and even Design Thinking approaches could get challenged.
The TRIZ based strategy session jumped up as an interesting alternative since:

1. Multiscreen approach ensures a technology based common denominator for the discussion
2. It sketches scenarios based on clear presentable data that helps arrive at shared outcome especially on technology trade-offs
3. Subset of team involved in preparing the Multiscreen approach acts as a catalyst during main strategy session

A TRIZ- based strategy brainstorming scheme was prepared. Among the tools listed in Paragraph 2, the Multi-Screen approach in its traditional nine-windows version was proposed. As explained in Paragraph 2, the Multi-Screen analysis tool was selected fir its proven effectiveness in the Innovation Roadmapping space, simplicity, and visual impact; the other described approaches would have required significant time to be readapted and explained to the team. The template shown in Figure 1 was prepared; the cells were pre-filled by the team TRIZ expert facilitator, the lab manager and one machine design expert: they spent roughly 4 hours to prepare the template, presented to team at the very start of the workshop.
In this model the electric machine team was considered as the Engineering System, observed in its evolution in time: Past System cell captured how it originated gathering experts coming from different pre-existing groups. The Present System cell reflected the contemporary team composition. The Supersystem row is at all times composed by the internal landscape, that is, all GE- related entities with which a work relationship was established so that they could be considered as funding sources; observing the evolution at this level is crucial to foresee the upcoming scenario in order to be able to react and adapt to fast changes; it also gives a framework to identify potential new funding sources, both internal and external to the company. The subsystem consists (at all three considered times) of the list of the different skills, expertise and resources offered by all team members, such as:

- Electric Machine Design

- Computational Electromagnetism
- Multiphysics

as well as the tools provided to them. During the workout, Past and Present cells have been presented as already filled; the Future Supersystem was as well pre-filled to provide suggestions for further thought; the remaining Future System and Subsystem cells were compiled in the form of open questions to trigger the thinking process, as shown in Figure 1.

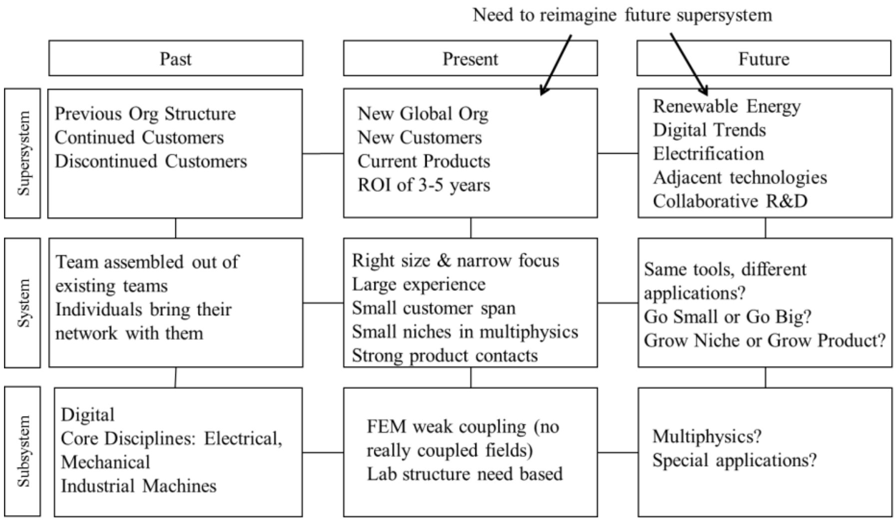

Figure 1: Multi-Screen Analysis

Different strategic options were identified, mirroring the current status (Present System) and the medium-long term evolution (Future System); the team was accordingly split into workgroups, each called to focus on system and subsystem open issues as depicted and redefined in Figure 2. The team members had no previous TRIZ training, nevertheless everybody accepted this approach and the given tasks very well; everybody was immediately able to work on all the points when prompted the Multi-Screen analysis scheme with remarkable engagement. In the afternoon sessions, the different workgroups discussed separately and gathered again at the end on the workshop day for a report-out session, during which, along with a new complete picture for the entire Future Supersystem, System and Subsystem columns, a new team template was complied with more than 20 action items distributed among all team members, categorized as short-, medium- or long-term, covering all aspects of the modelled System/Subsystem proposed open points. In this way, a good compromise between core expertise focus and new technology exploration was found with a precise allocation of tasks and resources. The generated template resulted of immediate use for subsequent meeting to follow up on the activity progress. An excerpt is shown in Figure 3.

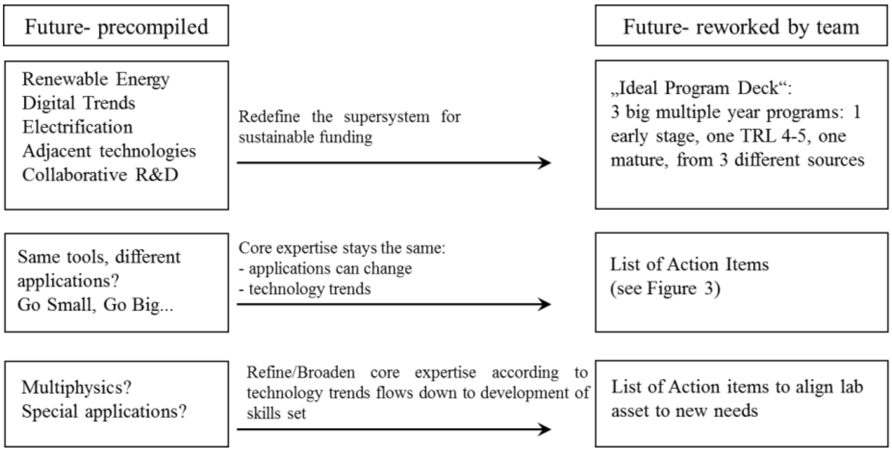

Figure 2: Multi-Screen Analysis Takeaways

Action Item	Owner	Term	Report-Out
Motor for O&G applications	Team Member 1	medium/long	December
Sensorless control for specific project	Team Member 2	short/medium	
Tighter integration of machines & drives	All	long	

Figure 3: Workout results: action item list

4 Contradictions for Team Strategy

During the workout preparation, some contradictions emerged and were listed, to be proposed to the team for extra inspiration as needed. This brought to the challenge of using the descriptions in terms of generalized parameters at a high level of metaphorical abstraction, which makes it less apparent for a team of engineers with deep technical focus and training to work on it at a strategical level. Nevertheless, two possible formulation of a same contradiction are reported for documentation: a thorough deep analysis on how to use the contradictions correctly in business environment is beyond the scope of this paper. As shown in figure 5, the high-level Engineering Contradiction is translated into TRIZ generalized parameters from two points of view. These are reproduced below:

1. Current Technology driven point of view: the improving parameter is shape, intended as a more and more refined design of the devices; worsening is stability of composition of the team
2. Management point of view: if the team keeps focusing on well-known projects, productivity in the short-term will improve; in the middle- and long term the team is at risk of excessive specialization and less open to explore new technologies and methodologies.

Even if the representation in terms of TRIZ generalized parameters can seem meaningful, the suggested inventive principles do not appear easy to use, since a lot of metaphorical thinking effort is needed to translate them into practical ideas: thus, this classic approach has been set aside for subsequent sessions, reinforcing the confidence in the effectiveness of the Multi-Screen analysis.

Engineering Contradiction	
IF	Team works on traditional, IO* projects
THEN	improves, strengthens core expertise
BUT	less flexible, funding scattered and volatile

*IO: Incremental Optimization

Improving	Worsening	Inventive Principles
Shape	Stability of composition	33. Homogeneity
		1. Segmentation
		18. Mechanical Vibration
		4. Asymmetry

TRIZ generalized model of contradiction and solution

Improving	Worsening	Inventive Principles
Capacity/Productivity	Amount of Substance	35. Parameter Changes
		38. Strong Oxydants

Figure 5

5 Multi-Screen Analysis as a Personal Development tool

As previously stated in Paragraph 1, it is widely recognized that the biggest issue of near future will be to fast adapt to the new job market requirements, since everything about industrial reality will undergo a radical change. The challenge will be to fully develop the personal and professional potential in a continuously changing scenario; individuals will need to acquire the newly needed skills and avoid excessive compartmentalization [10]; since jobs will be changing in nature, it will be needed to redesign profiles and skillsets to live up to the new necessary kind of workforce profile, and new tools will be essential to help second-skilling, career resiliency, flexibility and ability to refocus. Sometimes skillsets are required that are not even available on the job market, so also at company level retooling the staff is instrumental; therefore, it is essential to timely identify the directions and the tools to plan how to retrain people in the needed direction, especially nowadays when the enormous offer, especially in the MOOC-sphere, can lead to confusion or not optimal decisions, with resulting waste of time and resources. Moreover, many people need to mindshift [10], that is, find a pivot in career and organizational focus. Very often people hear the suggestion to visualize themselves some years ahead; since the skillset required in the future reflects the mutation of the Supersystem, again the Multiscreen Analysis can be used at individual level for career plan development, identification of the pathway to retool oneself in the most efficient way to be able to adjust to an ever-changing environment. The proposed procedure reflects the same approach followed for work teams, only refocused at individual level. The subsystem components are the list of all the person's skills, as they develop form Past to Present. The transitions foreseen for the Supersystem will help trace the pathway to effectively list which new skills to develop, that is, what to learn, allowing to timely prepare for the next transition. The individual could keep such a scheme as a living document, adding a column for each career transition, to help visualizing the next step. Such an approach could be of interest also for Human Resources Departments.

6 Conclusions

In this paper a discussion about the need of a powerful tool for team strategy and planning has been proposed, as an answer to a working environment which is expected to undergo a major transformation within the next decade. The Multi-Screen Analysis, among the TRIZ tools already investigated for application in the business and management space, has proved to be very successful: it was very quickly and extremely well received during a pilot strategy workout at GE Global Research Munich, and it led naturally to compile a list of action items for each team member, covering all aspects of the modelled System/Subsystem proposed open points. Its effectiveness makes it also a very promising tool for people coaching and self-coaching.

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The 40 Inventive Principles to conduct negotiations - Strategies and tactics to solve conflicts in communication

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Abstract Communication is conflict and agreeing with another person or party within a negotiation sometimes looks as the ideal final result: not achievable, but serving as a guideline towards finding a common solution. Putting communication problems this "TRIZ-way" quickly raises the question, if the 40 Inventive Principles (IPs) could be applied – and if so, what the expectable solutions during a negotiation process would be. This contribution takes the 40 IPs of TRIZ and mirrors them with the contributions of three selected, contemporary communication experts and their publications: R. B. Cialdini, M. Schranner and F. Schulz von Thun. What starts like a checklist for communication strategies and tactics becomes an evaluation of the universality of the 40 IPs: The often ventured guess in technics, that some IPs are more often to be applied than others, is confirmed for a non-technical field here, based on three negotiation and communication experts.

1 Introduction

It is stated, that we try to bring about compliance about four hundred times – a day [3, p. 11]. When arguing with another person, or group of persons, we try to convince people about what we see as the best solution – and vice versa. All these situations refer to communication. The paper tries to answer the question, if the 40 Inventive Principles (IPs) could be applied for bringing about compliance in communication. This paper is targeting at those who usually work with the 40 IPs. It does not explain them, but aims at a better understanding for them by using them in a non-technical field of communication, and probably the most difficult situation in communication: negotiation.

The paper does not plunge into the dialectics of communication; neither does it explain the preparation, strategy, the getting into and out of a deal. It rather highlights the universality of the 40 IPs – or rather was this the question in the beginning of this investigation: Are the 40 IPs universal in nature when conflicting objectives in communication is considered? Can the 40 IPs contribute to persuade a negotiation partner and to make that other party comply with a request? It does not even make any difference, if it is business negotiation or private negotiation. We seek for compliance and negotiate all the time, may it be about money or what it will be for dinner. Whenever two parties try to lead their way towards success, a conflict emerges.

2 Negotiation is Conflict

The base in negotiation was laid by the Harvard Concept in the beginning 1980, a project, which dealt with all levels of negotiation and conflict resolution [4], offering a step-by-step strategy for *mutually* acceptable agreements in all sorts of negotiation. It suggests principles such as "separate people from the problem" or "do not bargain over positions" or "insist on objective criteria" to simplify the negotiation process. In this approach (in German: *Das Harvard Konzept*), the focus is always on how to attain win-win agreements between two parties – a situation that (in TRIZ wording) might be seen as a (non-reachable) ideal.

But negotiations, persuasion, compliance and conflict resolution are difficult, aren't they? If they would not be, they would probably be just called cooperation, a situation that offers all kinds of information that is needed to see the same objective for both parties. It is the basic element of all negotiations that different interests collide and therefore two parties do *not* cooperate. Such a situation is mostly 'enriched' by incomplete information, emotional reaction, pressure, time and/or other constraints.

In contrast to the above mentioned ideal win-win situation envisaged by the authors of the Harvard Concept [4], in this paper, the focus is according to the central part of systematic innovation philosophy: The author tries to offer tangible tactics to help to actually 'eliminate compromise' [7, p. 179], here between the negotiating partners. The focus is such that the objective of the negotiation is to reach the best of all possible solutions – for oneself. Nevertheless, one is negotiating for one's own advantage, and the counterpart is always to be considered as a partner. Schranner avoids wordings as "opponent" and even considers bank robbers and hostage-takers as "partner" [9, p. 15], because without this vis-à-vis or counterpart, the negotiation would not take place at all.

These ideas of best solution for oneself and to only be able to reach it with the counterpart as the negotiation partner is also the standpoint taken by his other publications (e.g. [9, p. 14] and [10, p. 15 ff.]), that will be considered further. Most of them state, that most difficulty in negotiation emerges when the conducting status / the lead is handed over - and cannot be taken back any more [e.g. 9, p. 14]. Additionally, it is helpful to know the techniques to bring about compliance, because otherwise we can easily fall victim to the pull of a well-designed influence process of our counterpart [2, 3]. Last, the background behind all negotiation is communication, which led to integrating basic conversation models [12, 13, 14]. The overall aim is to reflect on how to eliminate conflict in a negotiation to one's own advantage. And this resulted in the leading question, if TRIZ and especially its well-known 40 IPs within could help.

3 Focus and Structure

The main reason for selecting this focus was the consideration, that avoiding conflicts in a negotiation would shift the whole setting from negotiation to any variant of acceptance, cooperation or ignorance. If one party considers one solution as best, but the other considers another solution as the best, the aim is to enforce the one best solution for oneself in the course of a negotiation. The ideal final situation of a negotiation would be the one, where both parties find the one solution that suits both parties best – and (make) think of it so, when the negotiation is over.

Negotiation *is* conflict, and this is considered as trigger for using the 40 IPs in such a situation. In this paper, the techniques and strategies most commonly and effectively used by three well-known negotiation and compliance experts should be depicted; no own ideas are given, as the author of this paper does NOT consider herself as a communication or negotiation professional. She merely takes the strategies and tactics published by three well-known communication and negotiation experts and mirrors them to the TRIZ Inventive Principles (IPs).

The author's inspiration for the structure of this paper came from Christian M. Thurnes, who applied the 40 IPs to Lean Operators, and presented a list that can primarily be used in production and logistics [15]. The structure of the paper at hand follows his suggested "somewhat like a dictionary" [15, p. 1]-style: First, the number of the IP is given, followed by its title. Here, unlike the inspiring source [1], no additional information according to the wording of the Inventive Principle is given in order not to stress on the paper's length even more. Then, if imaginable, specific suggestions for negotiation and compliance strategies and tactics (with some examples for better understanding) are given. Depending on the source, suggestions are given in form of an actively formulated, personal hint, others are formulated in a passive way. Altogether, solutions are given that can be cherished by beginners and experts in any negotiating and compliance process alike. The ideas for these strategies and tactics came only from three main authors, the author if this paper has focused on.

The first is the German negotiation expert, former bodyguard of the former Bavarian minister-president F. J. Strauss and former negotiator for the German Ministry of the Interior, where he was also responsible to lead negotiations with hostage-takers and bank robbers: **Matthias Schranner**. As founder of the Negotiation Institute in Zurich, he is offering consulting and advice in negotiation fields ranging from business, politics to private cases. He published several books on how to design and lead difficult negotiations and convinced the author of this paper by providing a clear checklist-like overview of how to achieve most of a conflicting situation. A comprehensive list of his publications is shown in the end [9, 10, 11]. This paper mainly refers to Schranner's checklist in [9], where he enumerated 16 practical issues that help prepare, lead, end and finalize any negotiation to one's own advantage – and thus does not necessarily envisages a win-win situation, as former approaches (such as the Harvard Concept [4]) do.

The second is an American experimental social psychologist and professor of the Department of Psychology of the Arizona State University, Tempe: Prof. **Robert B. Cialdini**. He intensively studied the psychology of compliance and published a first leading book on it in 1984. Apart from major tests and a several-year-long period of participant observation he gained major insights by posing as a compliance – aspiring – professional himself. He found out the main principles, why a request stated in a certain way will be rejected, while a slightly different formulation will be accepted [2]. Cialdini names 7 main categories that serve as weapons of influence: Reciprocity, Commitment and Consistency, Social Proof, Linking, Authority and Scarcity [2].

The third is the German psychologist and expert for inter- and intrapersonal communication and Professor of Psychology at University of Hamburg: **Friedemann Schulz von Thun**. He has published a widely recognized trilogy of standard text books [12, 13, 14], developing a number of comprehensive theoretical models to help people understand the determinants and processes of inter-personal exchange and their embeddedness in the individual inner states and the outward situation, and is widely taught in universities, and vocational skills trainings.

Although other authors with their sources and ideas came into play during the elaboration of the paper, e.g. [3, 16] or the 36 Chinese Stratagems [6], the focus is on those three authors named above in order not to go beyond the scope of this paper's idea. Also, there already existed sources seeing e.g. China's 36 stratagemmas in the light of the 40 IPs [such as 17]. So the paper highlights the work of

- M. Schranner, who delivered a pragmatic checklist for negotiation,
- R. B. Cialdini, who categorized main principles for influencing people and bringing about compliance, and
- F. Schulz von Thun, who developed (among many other ideas) a widely-known communication model.

These authors, especially the two psychology professors, refer to further books and papers highlighting empirical testing, behavior measurements and even brain activity and other body analysis, which the author of this paper, who is engineer by profession, is not inclined to do herself - by lack of competencies for psychological, social psychology, behavioral and/or medical (e.g. brain and other body) analysis.

4 Negotiation and Persuasion Strategies and Tactics for the 40 IPs (Version September2016)

This triangular set of strategies and tactics focused on in this paper will not be explained in too much detail, but depicted briefly under the IP that the author of this paper found most suitable to assign it to. For understanding the background of Schranner's checklist, Cialdini's principles and Schulz von Thun's model more deeply, the sources given in the end of the paper have to be studied – a recommended reading not only for negotiators. In this paper, their main negotiation approaches are taken and their main ideas assigned to the 40 IPs of TRIZ, with the main objective to resolve conflict in negotiation. As an overview, 10 main strategies and tactics from the three authors focused on is given (*Table 1*).

Table 1: Main strategies and tactics formulated by the three communication experts in the mirror of the 40 TRIZ Inventive Principles (Overview)

TRIZ Principle	M. Schranner	R. B. Cialdini	F. Schulz von Thun
01	Divide roles in negotiation groups		Four-sides model of communication;
02	Decision maker's role		
03	Negotiator's role Location of negotiation		
04	Commander's role		
05	Collect as much information as possible; visualize information	Principle of Linking, "Social Proof", Principle of Consensus	
06	Checklist for negotiation		
07	Formulate target areas		
08	Reciprocity; subjunctive form	Principle of Reciprocity	Four-sides model of communication
09	Consider targets from future perspective		
10	Prepare negotiation well		
11	Formulate target area		
12	Identify similarities	Principle of Liking	
13	Walk in the shoes of the partner		
14	Formulate demands and give anchors		
15	Exchange roles in negotiation team		
16	Ask questions; deliver few arguments;	Principle of Scarcity; Principle of Commitment and Consistency	Four-sides model of communication
17	Motives of partner; Acting-the-fool		Four-sides model of communication; Find out motivation
18	Voice, loudness		
19	Time frames		
20	Giving signs of understanding		Four-sides model of communication

21	Ending the negotiation		
22	Show respect		Four-sides model of communication
23	Give feedback	Principle of Consensus	Four-sides model of communication
24	Repartition into different roles		
25		Principle of Commitment and Consistency; "Framing"	
26	Listening carefully	Giving reasons	
27		Sounding logical	
28	Voice influence		
29	-	-	-
30		Principle of Authority	
31	Pauses are important		
32	-	-	-
33		Principle of Linking, "Social Proof", Principle of Consensus	
34		Principle of Authority; Principle of Scarcity	
35	Talk little, listen carefully	Principle of Scarcity; Principle of Authority; Principle of Reciprocity	Four-sides model of communication;
36	-	-	-
37	"Framing"	Principle of Reciprocity	Four-sides model of communication
38	-	-	-
39	Choice of location		
40	Bring alternatives		Four-sides model of communication

Each principle will be simply named; for a presentation in more levels of detail, the reader should refer to [1] and/or [7]. The strategies and tactics to conduct negotiations in communication are briefly described hereafter and mainly refer to the above named authors.

Principle 01: Segmentation

Most important, Schranner suggests to divide any negotiation in distinct steps: 1. Preparation, 2. Strategy definition, 3. Going into the negotiation, 4. Finding ways to negotiate, 5. Leaving a dead end and 6. Finding an agreement [9, p. 16].

As important, he states, that personal proximity / closeness to the other party and negotiation are hardly compatible [9, p. 35]. To prevent too much mental or personal closeness, one should never go into an important negotiation situation alone. Being fixated on a precise aim is good for focus - but bad for analytical listening. He suggests to set up a negotiation team and make the team members take over different roles (*Figure 1*).

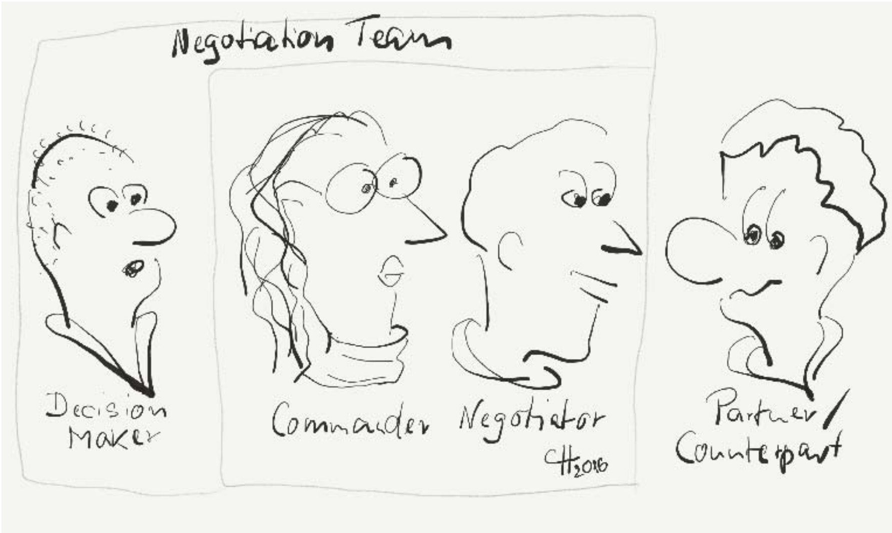

Fig. 1. Negotiation team members and roles, acc. to Schranner [9, p. 35]

His approach is to lead a difficult negotiation as a team, consisting of three members, the negotiator, the commander and the decision maker. These three roles will be depicted later. Within this principle of segmentation, the main idea is highlighted: to split up into different roles and assign them to different persons within a negotiation team. This is considered especially important in stressful situations, where premature (re-)actions are to be avoided.

Principle 02: Extraction (Extracting, Retrieving, Removing, Taking out)

One role within the negotiating team [9, p. 38] is the "decision maker", who should only show up twice: once in the beginning and in the end of a case. Apart from that, he should not have any direct contact to the opposing party, but in the end he is the person who decides about what is accepted or not – and who is responsible for the decision. This prevents the negotiating team from all-too-early concessions due to an emotional or other involvement of the person.

Principle 03: Local Quality

The second role within a negotiation team should be the so-called "negotiator" [9, p. 36], who presents himself as responsible for the negotiation and is the face to the opposing party – or the firewall on other words. He should neither be interested in the content of the negotiation nor in the relations to the other party, but should be interested in a good result and/or price. He needs readiness for conflict, resolution and stress resistance.

Schranner [11] also highlights the importance of choosing an adequate location for the negotiation, giving reasons why important negotiations in business are often situated in well-chosen restaurants.

Principle 04: Asymmetry

The third and last role is provided by the so-called "commander" [9, p. 37] who stays in the background and remains quiet during the negotiation. He supervises the negotiation and only interacts when he can support a personal or emotional relationship and common ground between the parties to smooth the path between them.

Principle 05: Consolidation (Merging)

Research and collect as much information as possible about your negotiation partner, the company or the person, even if the information seems to be irrelevant in the beginning. This is often cited in communication literature, esp. by [9, 10, 11].

Use an information board that is visible to all team members of the negotiation team, especially to the negotiator. All information, including strategy and objective should be visible, especially since the negotiator as face to the opposing party should always know the direction to go and should be able to consider all information, categorize it and add to it by writing directly on the board. (See also Principle 17).

Social scientists state the social proof effect: "The principle states that one means we use to determine what is correct is to find out what other people think is correct. ... We view a behavior as more correct in a given situation to the degree that we see others performing it." [2] "The principle of social proof says so: The greater the number of people who find any idea correct, the more the idea will be correct." [2] "Especially in an ambiguous situation, the tendency for everyone to be looking to see what everyone else is doing can lead to fascinating phenomenon called pluralistic ignorance. A thorough understanding of the pluralistic ignorance phenomenon helps immeasurably to explain a regular occurrence in our country that has been termed both a riddle and a national disgrace: the failure of entire groups of bystanders to aid victims in agonizing need of help." [2]. This effect can be used in convincing the other party by arguing that a number of other people are of the same opinion.

Principle 06: Universality

Using standardized procedures, e.g. to prepare any negotiation by using the same checklists, is suggested. Such checklists are provided e.g. by [9, p. 44 ff.]. They imply preparing questions such as: What are the motives for a negotiation? What would be a sufficient solution? What are maximal and minimal targets for the negotiation? ... The entire questionnaire to prepare a negotiation is available on request at info@schranner.com [9, p. 47] and will not be detailed in this paper. Be aware, that Schranner also highlights, that too much preparation with regards to contents can be counterproductive [10, p. 39 ff.] but reflects at the same time, that negotiation is not a matter of intuition [10, p. 143]. (See also Principle 10).

Principle 07: Nesting (Matrioshka, "Nested doll")

Never formulate a target point that you would like to reach, as a point limits too much the negotiation process and turns you inflexible. Rather formulate a target range, an area of fulfillment that you would be satisfied with if an agreement is found within [9]. Wrap your aim into another, formulated a little wider, and this one again into one formulated a little wider, so that the target is not a point any more, but a wide area, resembling a target disc, in which any hit would do.

Principle 08: Counterweight (Anti-weight)

In any negotiation, one should observe the principle of reciprocity, which means that you should never give something away just like that to prevent your counterpart to think that he would have gotten even more. In case the other party agrees to your offer, then he probably does so with suspicion. To give an example, consider selling a car. If your counterpart offers a price and you deliberately agree upon it, the other party could think that something is wrong with the car. Instead, when the price is suggested by your counterpart, you could say that with a price like that, the winter tires and then the foot mats are not included. This is what is called an integrative negotiation [9, p. 92]. Always integrate other objects with the main object, so you can be more flexible in the negotiation process.

Reciprocation is also a method literature widely suggests [2, 11] as a device for gaining another person's compliance. It produces a yes-response to a request by relying on the fact that we try to repay, in kind, what another person has provided us. If someone does us a favor, we should do the same to that person in return. [2] This can be seen with birthday greetings, Christmas cards, party invitations, gifts and the like. By means of the reciprocity rule, then, we are obliged to the future repayment of favors. The negotiation tactic for us is to find an offer, that the other party will accept and to gain one in return. A contrary consequence of this rule, however, is an obligation to make a concession to someone who has made a concession to us [2].

Another idea, especially to be applied in difficult negotiations, is to speak in the subjunctive form of possibility. Schranner suggests wordings such as "possibly", "perhaps", "a possible alternative" and combine them with weakening words such as "if", "in the case of", "eventually" and so on. All these formulations prevent from focusing too early and leave space for real negotiation [9].

Principle 09: Prior Counteraction (Preliminary anti-action)

When formulating a target area, [9, p. 26] recommends the SMART-formula, an acronym for: **s**pecific, **m**easurable, **a**cceptable, **r**ealistic and **T**ime. For being specific, concretize what you want to reach. The target must be measurable: what is supposed to happen to reach your target? Then ask yourself, if you can accept all consequences of the negotiation. How do other people, family and so will react if you will lead the negotiation as planned? Acc. to Schranner [9, p. 26 ff.], the realistic estimation of your own target is probably the most difficult aspect in the negotiation process. He suggests to consider future developments rather than past experiences to estimate a realistic target. And last, time and duration of the negotiation should be limited.

Principle 10: Prior Action (Preliminary action)

Prepare the negotiation well beforehand (see checklist under Principle 06) and take the lead right in the beginning of the negotiation. Have a number of alternatives ready. The more alternatives there are at hand, the bigger is one's power [9].

Bring your negotiation process into a timeline. This can be done before the negotiation start, e.g. by separating different steps that should be controllable one after another during the process, e.g. 1. Dismount and remove aggression, 2. Build trust, 3. Gain information about your counterpart's position, 4. Bring about compliance [9, p. 28]. This also requires a definition of a maximum target, the optimum result one could reach - and a minimum target, something that must come true to negotiate further. Be aware of the fact that not reaching the minimum target set in advance would lead to stop the negotiation. In case of a team negotiating, this minimum should be formulated and written down in advance to be clearly communicated to all team members [9, p. 25].

Principle 11: Cushion in Advance (Beforehand cushioning)

When formulating a target area, include buffers that will allow you to remain flexible during negotiation. Start the negotiation with a high request, creating the advantage of a cornerstone now on the table that cannot be ignored any more. Your counterpart will have to react somehow and will deliver important information for you.

Before the negotiation starts, the strategy how to reach the target area should be clear. The strategy is the corridor, in which the negotiation moves forward (*Figure 2*). One such example could be to go for time gain, e.g. by simulating a telephone call in between, the latter being a tactical step within the strategy of gain in time.

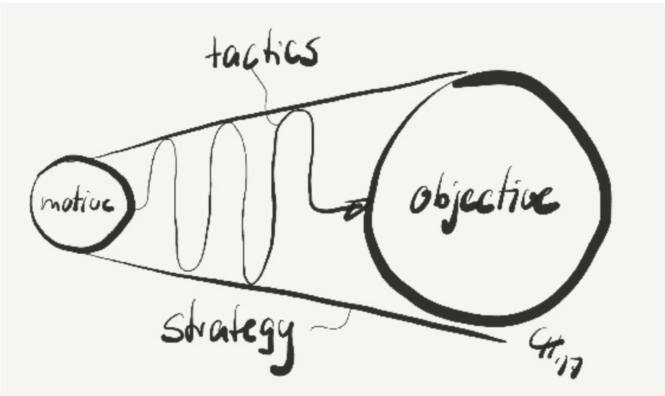

Fig. 2. Motive, strategy, target area (=objective) and tactics acc. to Schranner [9, p. 51]

Principle 12: Equipotentiality

Any request or demand should always be as realistic as to still offer a so-called Zone of Possible Agreement (ZOPA) [9, p. 69]. Search for common ground and other similarities between the two opposing parties and concentrate on them. This is a task, that also can be taken over by the commander, as he listens carefully and provides new alternatives to the negotiator.

Negotiate for something, never against somebody, is what Schranner strongly recommends [9].

Principle 13: Do it in Reverse ("The other way round")

Try to walk in the shoes of the counterpart. How does he see the situation? What is his motivation to react in a certain way? Flexibility in seeing the situation through the eyes of your counterpart, offers you new ways of understanding his (re-)actions.

Principle 14: Spheriodality (Curvature)

Imagine the formulation of a request, demand or offer like angle and reach on a shooting range. Who fires at high angle, will reach low. Who fires at low angle, will reach far (*Figure 3*).

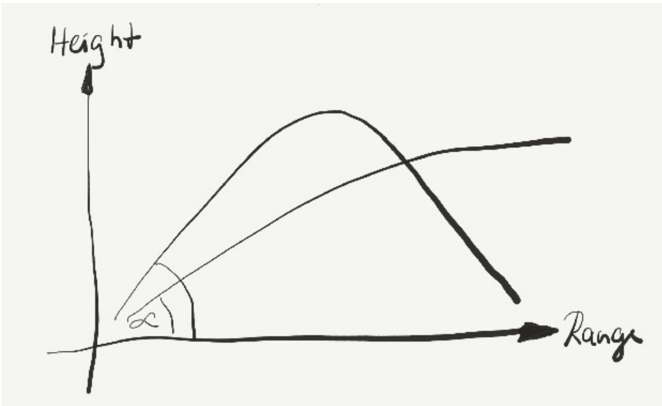

Fig. 3. Reach and launch angle of a request, acc. to Schranner [9, p. 70]

Principle 15: Dynamics

If a situation gets too emotional for the negotiator, he/she should be exchanged by another person taking over his/her role. This could also be done by changing roles between the negotiator and the commander [9].

Principle 16: Partial or Excessive Action

Instead of formulating a request that lies within the ZOPA, formulate one that lies way lower or higher than that. If you do not want to make your counterpart believe that the first is what you are heading for, formulate it in subjunctive form. In both cases, watch the reaction of your counterpart and learn from it.

Formulate it such that if the agreement cannot be found the same day / week /..., your boss will end the negotiation – and ask how your counterpart thinks about how to proceed.

Deliver as few arguments as possible, as you want to convince and not to entertain in a negotiation. The more "right" arguments you deliver into the negotiation for the other side, the more you display weak points. This strategy suggested by Schranner means to be scarce in terms of arguments. The more reasons and arguments are delivered, the more one is attackable. A wise negotiation partner will motivate and praise or complement. Do not step into the trap of accolade [9, p. 94].

As example for excessive action, one could refer to Cialdini's principles of Commitment and consistency: "Social psychologists claim that if someone can get someone to make a commitment (that is, to take a stand, to go on record), one has set the stage for an automatic and ill-considered consistency with that earlier commitment. Once a stand is taken, there is a natural tendency to behave in ways that are stubbornly consistent with the stand." [2] This principle of making a counterpart stay consistent to earlier commitments is a strategy that a negotiator can try to push his counterpart into. It will be taken up under Principle 25: Self-Service again. (See also Principle 25).

As to the Principle of partial action, Cialdini's concept of scarcity for influencing people is considered. He claims that scarcity helps to influence people such, that everyone fears loss: "The idea of potential loss plays a large role in human decision making. In fact, people seem to be more motivated by the thought of losing something than by the thought of gaining something of equal value." [2]. This principle of scarcity in literature suggests for the negotiator to understand what the other party is going to lose instead of the gains. To lose face also belongs to that idea.

Principle 17: Transition into a new Dimension (Another Dimension)

The model that immediately is cited when it comes to communication is Schulz von Thun's [12, 13] four-sides model (also: communication square or four-ears, four-Schnabel model). The four sides of any message are: fact, self-revealing, relationship and appeal (*Figure* 4).

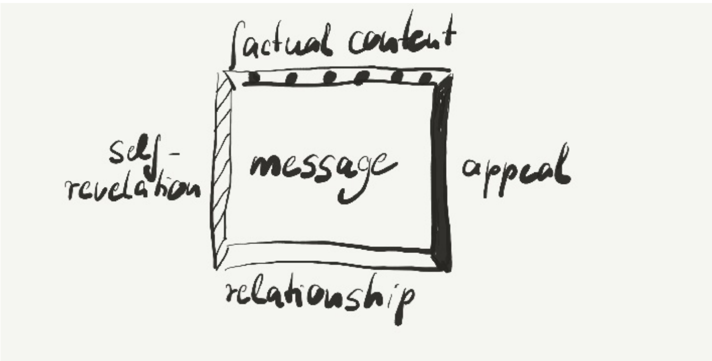

Fig. 4. Fours-sides model of communication, acc. to Schulz von Thun [12]

According to this model, every massage shows four facets, although not the same emphasis might be laid on each. Every layer can be (mis-)understood individually. For better understanding, Schulz von Thun's often-cited example of a couple in a car is given, with the lady as the driver and the man as front-seat passenger. If the man says: "Hey, the traffic lights are green!" one might understand as a matter of fact, that there is a green light, that probably was also seen by the driver. The self-revealing facet might be, that the man is in a hurry and wants the lady to drive faster. The relationship aspect might be the man feeling superior and/or trying to give advice. And the appeal might be to make the lady drive faster. Now, it depends on the lady, how she will understand the simple phrase spoken by the man. The emphasis on the four layers can be meant and also understood differently, which is a major reason for misunderstandings.

Almost all authors, not only the ones focused on here, highlight the importance of different layers or faces of a simple message (see also [16], who classically states that "one cannot not communicate" or communication as a *Conditio sine qua non* in human life), so this idea will be repeated in more than this principle, see also the ideas of rising the stress level in communication, that will be depicted later.

This many-facet aspect of a message is the reason for Schranner [9, p.36] to set up a negotiation team, in order to separate rational from emotional and other aspects in it. Additionally, he advises the person in the team, who has taken over the role of the negotiator, to always (and already in the beginning of a negotiation) ensure the other party that he, the negotiator, is depending on one or several higher instances. This could be done by giving jurisdictional reasons that he will not be the one and lonely decision maker, but that for him and thus for the counterpart, there will be other institutions or levels of hierarchy to agree with [9, p. 36].

All authors, especially Schulz von Thun [14, p. 114] and Schranner [11], highlight the importance to distinct a motive of a person from its position. The motive refers to the intent, the interest or reason behind a position. The position is what can be seen, but interests and reasons are the part beyond the water line of an iceberg. All cited authors suggest to find out, what the real motive of a person might be, although we all tend to take positions. An example might be that the real motive behind a threat is perhaps not to lose one's face or to display helplessness.

Schranner also suggests to double-check any information the counterpart is handing into the negotiation. It might also happen that the other party is dealing with information to mislead your team. Misunderstandings and giving too much trust into a single, non-checked information from your counterpart can lead to unforeseeable consequences [9, p. 30 ff.]. Schranner even suggests to use an information board to make all heard and double-checked information visible to the team members, very much like the whiteboard seen in some American crime series, where portraits, names and other information is stuck and written down for the time of the investigation. (See also Principle 5).

Another tactic named by [9] and assigned to this "higher dimension" Principle, is acting the fool [9, p. 84]. Acting the fool and asking for explanations or what one does not understand almost automatically leads to making the counterpart speak and perhaps telling us more than he/they wanted to.

Principle 18: Mechanical Vibration

Watch your voice, how loud it is and if it is high or low. You might show more information by the sound of your voice than you want to; this hint cited by all authors seemed most suitable for the principle at hand.

Principle 19: Periodic Action

Schranner [9] formulates time frames for each negotiation step or phase. If you estimate e.g. 30 min for a subject on an agenda, you as negotiator have all the right to end the issue after half an hour – if preferred. And you have the right to prolong the issue – if you like. Clear time frames can ease the lead of a negotiation.

Make pauses between the steps in which you do not talk about the negotiation with your counterpart; this being a hint frequently formulated by Schranner [9, 11].

Principle 20: Continuity of Useful Action

If an acceptable suggestion is proposed by the other side, give sign that the suggestion is according to your imaginations [9]. Never say too early that you accept the offer. The acceptance of a suggestion will be examined, when there are many alternatives on the table that can be evaluated reciprocal. Be aware that the negotiation is only done, when the money is on your bank account – when the case of a sales deal is considered.

Principle 21: Rushing Through (Skipping)

If your counterpart makes unrealistic suggestions, tell him that for now/today the negotiation will be over [9]. You may add that this is the decision of a higher instance; and ask your counterpart, if he sees a way to proceed.

Another tactic according to Schranner [9] is to concise that there are already many things both sides agree upon. Observe the other party while expressing the parallels, and use subjunctive form to keep open all options.

Principle 22: Convert Harm into Benefit ("Blessings in disguise" or "Turn Lemons into Lemonade")

Schranner [11, 9] emphasizes to always show respect towards your counterpart partner, no matter what he suggests or how he behaves. Thank him for any suggestion, as far out of reach at it might be. Use all such conversation to understand more deeply the real motives of your counterpart, no matter how unrealistic they might be. (See also Principle 23).

Principle 23: Feedback

Schranner [9] highlights the following possibilities to give feedback, easy to be seen under this TRIZ-Principle: Thank your counterpart for any suggestion he makes, even if you cannot agree upon it. (See also Principle 22).

He also suggests to give feedback always in terms of understanding how the counterpart might feel, *never* on his situation. One will never be able to understand your counterpart's situation, as you have never been into it. Rather express that you have had the same feelings, but never that you have been in the same situation. The situation is always different for different people, but feelings (e.g. responsibility, eager, anxiousness, ...) might be experienced the same way by different people. Show comprehensiveness for the other party's feelings, not for the situation.

He also suggests to ask why your counterpart is frowning, or how he might re-formulate your own suggestion alternatively so as he can better accept it.

Keep from evaluating the other party's arguments or suggestions. Evaluation means locking in a situation or decision that might be too early to do so.

Principle 24: Mediator ("Intermediary")

The setup of a negotiation team with negotiator, commander and decision maker is what finally aims at having an intermediate part between the person who decides and the counterpart. According to [9] this repartition into different roles offers many advantages, such as not plunging into the negotiation too emotional, being able to analyze and synthesize the situation in parallel.

Principle 25: Self-service

A suitable negotiation tactic might be to start with a little request in order to gain eventual compliance with a related larger request. According to [2], this tactic is called the foot-in-the-door technique. [2, p. 55]. Dutton [3] explains it also vice versa: If the target is to gain compliance for a smaller request, one could ask for a larger request first. If this is neglected, one can more easily gain compliance for the smaller request by making a detour. This indirectly also refers to the idea of our wish of staying consistent to earlier commitments depicted earlier. (See Principle 16: Partial or Excessive Action).

These ideas of detour are often referred to, also by Dutton, who subsumes any idea to set another person on a track, be it emotional or facts, as "Framing" [3, p. 137 ff.]. As an example, he makes a person estimate, how many liters of kerosene are needed for a jumbo jet: 500.000 or less? If one asks the same question, but gives a lower number, e.g. 5000, the estimations will be smaller, as we are set on a track for lower numbers. This also works in politics, where a preference for a politician is to be expressed. If one makes a person say: "I am against candidate X", and not "I am for Y", the person is less inclined to change his/her mind later than if he/she would have expressed it positively [3, p. 138]

Additionally, social scientists have determined that we accept inner responsibility for a behavior when we think we have chosen to perform it in the absence of strong outside pressures. [2]

Principle 26: Copying

Listening is one of the most important things in a negotiation [9, p. 86; 11]. It might be an idea to adapt one's language to the other party's, copying expressions, or even using the same slang or *argot* to signalize understanding and same provenience. Schranner even distinguishes listening from repeating what the other person has just said to reflect one's understanding [11]. He highlights the importance of making the other party finish speaking and of thus reflecting one's ability to listen carefully. By summing up what the other person has just said, we display the ability to *really* have listened.

Another well-known principle that might fit into the copying Principle in TRIZ, says that when we ask someone to do us a favor, we will be more successful if we provide a reason. "People simply like to have reasons for what they do." [2, p. 3], see also the following Principle 27 and example for that.

Principle 27: Dispose (Cheap Short-living Objects)

The examples given in [2, p. 3] suggest even pseudo-reasons to be successful, that only sound like reasons. It might not be of relevance, if the reason is logical or easy to understand. So *sounding* logical without being logical might be sufficient alone. Experiments have shown, that the question "Could I use the copying machine first?" works better, if we say: "Could I use the copying machine first, *because* I have to make copies?", even if the reason is not to be seen as a reason [2].

Principle 28: Replacement of Mechanical System (Mechanics Substitution)

The term "acoustical" in the explanation above makes thinking of not forgetting to use one's voice as an instrument to influence the counterpart. If the negotiation is led on a rational level, speaking slowly and calmly will always be considered as adequate.

Apart from increasing loudness or speed, a rise in stress-level can be reached by provocative sentences such as "Funny, that you have forgotton…." [9, p. 101], especially when one has found out, that the counterpart puts much strength on offering complete documents. Here, having analyzed one's counterpart according to his/her trigger points is a prerequisite. Signs as dry mouth or tensed-up musculature are signs for a risen stress-level that can be observed. This was immediately what came the author in mind, when of "thermal" replacement is spoken in the Principle, so it is considered in a very transferred sense here, but will again be taken up again in Principle 35 (Transformation of Properties / Parameter Changes). It surely does not mean to abet attack here, so one should be aware, that those "tools" can be come back like a boomerang.

Principle 29: Pneumatic or Hydraulic Constructions (Pneumatics and Hydraulics)

--- none --- Not even in a transferred sense.

Principle 30: Flexible Membranes or Thin Films (Flexible Shells and Thin Films)

One could refer to status symbols here and to authorities and titles [2], an aspect being taken up again under Principle 34, where such symbols are considered more deeply.

In some branches and professions, authority is displayed by buttons and badges, and/or uniforms, and other visible, sometimes expensive-looking clothes' accessories. In terms of negotiations, it might be of use to send a person in his/her proper uniform to imply power or in the same uniform outfit to show affiliation, an aspect that will be reconsidered in Principle 33.

Principle 31: Porous Material

In a transferred sense, one could refer to the numerously cited pauses that play an important role in any conversation. Pauses, be it gaps in conversation or in an agenda, help to concentrate more on the parts in-between. [9].

Principle 32: Changing the Color (Color Changes)

--- none --- Not even in a transferred sense.

Principle 33: Homogeneity

It is a basic element of any negotiation that different interests collide and therefore the other party does not tend to cooperate. The aim of any negotiation is find the best solution for oneself in the course of a conversation with the other party. Therefore, the other party is a partner during the course of the conversation. Consider the other party you are negotiating with as an equal partner; this is also suggested by experts, when the other party is a hostage taker or a bank-robber [9, p. 15].

Other sources claim the fact that "We like people who are similar to us. This fact seems to hold true whether the similarity is in the area of opinions, personality traits, background, or life-style." [2]. We could use that effect to send a person or a group of people to the negotiation, that are as similar as possible to the counterpart's characteristics or traits. This might apply on race, hobbies, profession or alike. This also refers to the social proof effect, named above under Principle 5: Consolidation (Merging).

Principle 34: Rejecting and Regenerating Parts (Discarding and Recovering)

When the strategy is clear and reflects the corridor, in which the negotiation can be evolved, the tactics constitute the different steps taken within that strategy. They might follow an S- and U-shaped way to reach the target area, meaning that making detours might also be in terms with the strategy. For that aspect, consider *Figure 2* again, depicted above.

A little far-fetched example for this principle of regeneration might be our tendency to obey to higher authorities. Once a title or a function is acquired, we tend to accept it for granted, even if the status symbol was acquired years ago. If your negotiation partner tends to display authority by name, rank or title, try to ask yourself, if this really is an assurance for his competence, know-how and alike. The main problem is here, that "... We are trained from birth that obedience to a proper authority is right and disobedience is wrong. ... Religious instruction contributes as well." [2]. This can also be seen in medicine, government and with all other types of authorities. Titles and clothes (e.g. business or club outfit, uniforms, white collars, ...) also might set us into a situation where we see us under constraint, even if we are not: "There are several kinds of symbols that can reliably trigger our compliance in the absence of the genuine substance of authority. Consequently, they are employed extensively by those compliance professionals who are in short of substance." [2, p. 165]. (See also Principle 30).

More close to this “Rejecting and Regenerating Parts” Principle of TRIZ might be the example tactic, that we can often see in commercials: "… A little tactic, compliance practitioners often use to assure us of their sincerity: They will seem to argue to a degree against their own interests. Correctly done, this can be a subtle effective device for proving their honesty. Perhaps they will mention a small shortcoming in their position or product... (e.g.: "L'Oreal, a bit more expensive and worth it"). By establishing their basic truthfulness on minor issues, the compliance professionals who use this ploy can then be more believable when stressing the important aspects of their argument." [2]. This approach is used also in restaurants, when a waiter suggests another, most often an even cheaper than the firstly chosen meal and thus displays expert knowledge ("Today, the ... is not as good as normal. May I suggest ... . It is excellent tonight.") in order to later increase the percentage of the charge that is given as tip. [2]. This is rejection of one issue to suggest another one, sometimes with making concessions for the negotiation partner, but for later achieving concessions for oneself.

Principle 35: Transformation of Properties (Parameter Changes)

Even if in the original meaning of this Principle, always physical condition is meant, it could be used in a transferred sense here: Stress is a frequent participant in any negotiation, it cannot be seen, but it can be influenced to higher or lower level. If you want to contribute to a constructive and rational atmosphere of the negotiation, you should talk little, but listen carefully. If talking, it should be in a calm and slow way, speak in a subjunctive form, avoid any fixations and pressure, and give not so many rational arguments; your counterpart will not appreciate them anyhow [9, p. 101].

The application of the principle could then be all the contrary, as depicted in Principle 28 (Replacement of Mechanical System / Mechanics Substitution): Speaking louder, rise the stress level by provocative sentences (e.g. "How could you forget such an important point?”), or by rejecting the possible achievements of the other party, especially if the other party is a perfectionist.

What you get is that the counterpart might try to oppose against you and might leave his formerly set strategy plan to convince you. It is important to say that this tactic is only for exception, as it might return like a boomerang, meaning that the negotiator should know what he does.

Principle 36: Phase Transition

--- none --- Not even in a transferred sense.

Principle 37: Thermal Expansion

"There is a principle in human perception, the contrast principle that affects the way we see the difference between two things that are presented one after another. Simply put, if the second item is fairly different from the first, we will tend to see it as more different than it actually is." [2]. If we put our hands in cold water first and in lukewarm water second, we will estimate the lukewarm water hotter than if we would have put our hand directly into it without first trying the cold water.

In negotiation terms, using this principle in a transferred sense, we could use that effect to make two offers, the first one to pave the way for the second that we are really interested in. This idea was analogously expressed under and to the author's opinion much better suited to Principle 25: Self-service, where estimations are made lower, when a lower anchor is suggested first.

Principle 38: Accelerated Oxidation (Strong Oxidants)

--- none --- Not even in a transferred sense.

Principle 39: Inert Environment (Inert Atmosphere)

It might be useful to take away anything from the negotiation space or room that is not needed for the discussion, but not more; this being a hint given by Schranner [9].

He also never gets tired to highlight that it might be useful to speak in a subjunctive form [9]. This might be seen in a transferred sense here, but it seems reasonable in order not to fixate oneself to one's own response and to stay flexible in terms of one's own acceptance: If you register acceptance or rejection on your counterparty's side, one gains information without giving any for free. Ask your counterpart, why he is frowning or if an alternative could be acceptable if it would be formulated differently. Here, one might also use the tactic of simulating not to understand. Ask your counterpart to explain more or to make you understand something he says.

Principle 40: Composite Materials

It is always difficult to negotiate just one item. Bring as many alternatives as possible into the negotiation. The more alternatives there are for one's self, the more power can be taken over. Bring as many alternatives for your offer as possible. This hint, often given by [9, 10, 11], is repeated here.

5 TRIZ Principles without specific Negotiation Tactics suggested

For some principles, it is hard to define an analogy in terms of negotiation and persuasion tactics and strategies based on the 3 given sources focused on. But these principles may also be used to lead a negotiation successfully, by using them in a highly transferred sense with much phantasy applied: Take Principle 35 (Change Properties) and think of understanding it such, that it means a change of the stress level in the room. This tactic could analogously be applied to Principle 32, 36 and 38, but this might be fetched from too far.

Also, Principle 37 (Thermal Expansion) is applied in a very transferred sense, by formulating a "cold" offer first, the following "lukewarm" offer will seem much warmer than it actually is. Admittedly, a little far-fetched, but the author claims to stay open for imaginative suggestions and analogies! But even with most phantasy and benevolence, the following principles, that are addressing highly physical aspects of problem solving and invention in the original TRIZ meaning, could *not* be used in terms of negotiation tactics and strategies:

- Principle 29: Pneumatic or Hydraulic Constructions (Pneumatics and Hydraulics)
- Principle 32: Changing the Color (Color Changes)
- Principle 36: Phase Transition
- Principle 38: Accelerated Oxidation (Strong Oxidants)

Maybe, later updates and the integration of more and other sources could provide ideas for these TRIZ Principles the author could not yet assign a suitable strategy or tactic to.

6 TRIZ Principles with many Negotiation Strategies and Tactics suggested

It finally comes out, that the most intensively suggested strategies and tactics for negotiation in the three given sources/authors could be assigned to:

- Principle 01: Segmentation
- Principle 08: Counterweight (Anti-weight)
- Principle 16: Partial or Excessive Action
- Principle 17: Transition into a New Dimension (Another Dimension)
- Principle 23: Feedback

Here, many different strategies and tactics could be enumerated. Especially Principle 17 (Transition to a New Dimension – Another Dimension) seems to be most promising for a fruitful communication and negotiation. Following are Principles 23 (Feedback) and 16 (Partial or Excessive Action), that subsumed a little less, but still many strategies and tactics highlighted by the chosen authors. Last, Principle 8 (Counterweight) and Principle 1 (Segmentation) united many suggestions of how to lead a successful negotiation. Remains the question, if these five principles are the golden keys of communication, bringing about compliance in a negotiation conflict.

7 Negotiation and Persuasion Tactics that could have been assigned to various TRIZ Principles

Other negotiation tactics could have been assigned to several principles. One such example is Cialdini's social proof effect, that was assigned to Principle 5 (Consolidation / Merging), but could as well fit under Principle 33 (Homogeneity), especially when shown as an attempt to put oneself onto the same level as the counterpart – or vice versa.

Schranner's principles of speaking up, speaking faster, rising the stress level by provoking sentences and alike were assigned to Principle 35 (Transformation of properties) and Principle 28 (Replacement of mechanical system / mechanics substitution). The ideas for rising the stress level by increased speech, also would have fitted under Principle 16 (Partial or Excessive Action) and 17 (Transition to a New Dimension).

Schranner's advice to check any information twice could have been assigned to more than two different principles. Apart from assigning it to Principle 17 (Transition to a new dimension), where the author has finally put it, it could have fitted to other TRIZ Principles as well, such as Principle 16 (Partial or Excessive Action), Principle 03 (Local Quality), Principle 08 (Counterweight / Anti-weight) and Principle 09 (Prior Counteraction / Preliminary Anti-action).

Schranner's suggestion to act the fool in certain situations is actually assigned to Principle 17 (Transition to a New Dimension / Another Dimension), but could also fit to Principle 16 (Partial or excessive Action). The strategy of ignorance allows you to ask more questions and make your other party speak more about oneself, which allows you to listen and learn.

Cialdini's principle of displayed authority (e.g. by ranks, titles) are now assigned to Principle 34 (Rejecting and Regenerating Parts – Discarding and Recovering), but could have also be displayed under Principle 30 (Flexible Membranes or Thin Films / Flexible Shells and Thin Films), especially when they come along with clothing, tissues or other worn accessories. Wearing a certain uniform (like the doctor's lab coat, the police officers cap, ...) or sign on tissue (e.g. a tattoo) surely more rises the membrane and film and shell effect, as Principle 30 is originally named after in a technical sense.

Cialdini's influencing principle of scarcity (consider losses instead of gains, as they are valued higher) could also be assigned to more than one principle. Here, it was assigned to Principle 16 (Partial or excessive action), but it could also be assigned to Principle 17 (Transition into a new Dimension) or even Principle 22 (Convert Harm into Benefit). In case you really do not know about details might give you a welcome opportunity to ask more questions.

Schulz von Thun's [12] four-sides model of communication heavily refers to the requirement of asking and giving feedback, Principle 17 (Transition to a new Dimension), in order to avoid misunderstandings. The model refers to numerous principles if considered more detailed.

Schranner's [11], Cialdini's [2] and Schulz von Thun's [12, 13, 14] principle of reciprocity (also referred to in [3]) is actually assigned to Principle 08 (Counterweight), but could also fit to Principle 22 (Convert Harm into Benefit). Obviously, the strategies and tactics named and repeated in numerous sources display their importance also by being able to be assigned to a number of Principles of TRIZ.

Altogether, there were not so many negotiation tactics and strategies given in the chosen sources that could have been assigned to more than two or three TRIZ Principles alike.

8 Conclusion and outlook

This work's state of the art is September 2016, which is why books that appeared after that period, are not considered. The author considered it difficult not to integrate the newest book of R. Cialdini on behavioral sciences, which focuses on the pre-phases of persuasion and therefore is about "pre-suasion".

The entire paper thus could be up-dated and enriched with more authors, more recent papers - or other (also older) sources, e.g. China's 36 strategies, (as done by [17]); here, merely three main approaches, M. Schranner, R. B. Cialdini and F. Schulz von Thun up to 2013 were focused on. It should be stated, that especially Cialdini and Schulz von Thun as psychology professors provide further proof by their own and other cited papers on empirical testing and (body) activity and other behavioral measurements.

As could be shown, the frequency of use of the 40 IPs is not uniform. As shown in chapter 5, some are rarely used – if at all – and others are used very often and seem to repeat themselves, as shown in chapter 6. The first group of IPs might thus be problem-specific and could be left out for communication issues, the latter group could be seen as real basic communication principles. This would also deliver and approach to reduce the 40 IPs to fewer moralities beginners could start with. The overlap between some of the principles has already been mentioned by [7, p. 268]. Approaches to group the principles and thus gain more overview had been suggested by [8], or [5], who suggested grouping for easier application within ASIT (Advanced Systematic Inventive Thinking).

Remember, the paper's intention merely was to highlight the strategies and tactics given by these three communication experts, NOT to invent own ideas. Nevertheless, it can be stated, that reading these hints with their relation to the 40 IPs of TRIZ, inspires to create own negotiation strategies and tactics. For example, IP 32: Changing the color (Color changes) makes think of different colors that are associated with different feelings and mental associations. This idea could be used for changing colors of slides and documents shown during the negotiation. Such ideas are very welcome, nevertheless it is not explicitly to be found in the referred three publications focused on here. If the 40 IPs now inspire to create more ideas oneself – *tant mieux!*

In general, the 40 IPs can be seen as very helpful to design and lead a negotiation, to bring about compliance and to resolve conflicting conversations to one's own success.

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The method of the design improving by using the TRIZ function analysis and the trimming

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Abstract This article is devoted to the design improving and the development by means of the TRIZ function analysis and the trimming. A new formal trimming method is presented in the paper. This one takes into account the importance of functions in the system, interactions between functions and relations between elements and functions. An addition change of the trimming paradigm is proposed. In the suggested approach the improvement of the system is completed by using the replacement of the function sets with other single function. As well, the suggested approach is illustrated by the industrial case study.

1 Introduction

The present paper is considered to the function-based method of the design improvement and the development. According Ullman, 75% of the product cost is defined on the conceptual stage [1]. It means this stage is extremely important in the product life-cycle. In this case, the usage of the systematic method on this stage is very useful for the design development and the improvement.

There are several systematic approaches, such as Axiomatic Design [2], USIT [3], TRIZ [4] etc. In this paper the TRIZ methodology is used for the development, because it is easy to understand, use formal and inventive tools and, as well, this methodology is widely used both in science and in industry [5–7].

TRIZ, in Russian - Theoria Resheniya Izobretatelskih Zadech, or The Theory of the Inventive Solving, is the inventive method proposed by the soviet inventor Genrih Alshuller (1926-1998) in 1956 [8]. He studied about 40000 patents and drew out the formal processes for some new ideas of the generation and the technical evolution trends. Such methods have 40 inventive principles, contradictions, ideality, and patterns of the evolution.

This paper is devoted to the modern TRIZ tools, such as, the Function analysis and the Trimming [9]. The last one is a formal method for the system development and the improvement, based in the system complexity reduction. Different types of this tool are used for the patent-around design

[10], the system improving [11] and to receive of a new design patterns [12]. The improved method of the trimming is used for the system improvement and the development in the formal manner in this paper. Meanwhile the function analysis is used as input to the Trimming.

Existed trimming methods use formal rules for the system step-by-step improving [10, 11, 13]. Functions are independent in these approaches and authors did not use the formal ranking index to define the function importance in the system. Unlike existed methods, the new one takes into account the relation between functions and elements. In this case the function analysis step is improved and a new operation “creation and analysis of the Function interaction matrix” is added before the trimming step. This improvement highlights the “function streamlines” in the system. It means the functions are grouped in the sets. This idea permits to automate the trimming algorithm.

The remainder of this paper is structured as follow: the section 2 is considered to the Method description, in the section 3 the industrial case study illustrates the presented method, and the finally conclusions and the further development are presented in the section 4.

2 Method description

The method presented in this paper is based in [14–16]. In contrast to other approaches [10, 11, 13], it takes into account the relation between functions and element, but also proposes the improvement of trimming algorithm. There are three main steps:

- The Function analysis
- The Creation and analysis of the Function interaction matrix
- The Trimming

The function model is created in the first step. This one defines relations between elements, their types and the rank of the each function. The process of the function analysis is based in previous works [12, 14, 15]. The formal index of the function importance (function rank) is calculated in this step. It is defined by, the number of links between the function carriers, the distance between the function carrier and the target element and finally of the duplicated functions number.

Interactions between functions are defined in the second step. Three types of interactions are distinguished there, such as the dependence, the independence and the similarity. Also, in this step the set of functions is highlights.

The improvement of the system is done in the trimming step. This step is based on three trimming rules [13] but takes into account the function rank, defined on the function analysis step.

The presented process may be used for different types of dynamic and static systems. In this case the different type of ranking may be used. In the presented paper only the static system is consider.

2.1 Function analysis

This step is based on [12, 14, 15], and consists of three main parts: the component analysis, the interaction analysis and the function analysis.

The first one is devoted to the system decomposition. It means the system is decomposed to the main elements, mostly to assemblies. Links between elements are established on the interaction analysis step. Finally, interactions between elements are defined as functions and the rank of the each function is defined on the function analysis step. In this case the ranking process takes to account the following formal indexes such as: the number of links for elements, numbers of duplicated functions and the distance between the function carrier and the target element.

The special software is used [17] in this step. This one creates the function model of the system and defines the rank of the functions by means of the CAD model of the system in the semi-automatic manner.

2.2 Function interaction matrix

The formal procedure of the interaction between functions is presented in this step. Meanwhile the functions interaction degree is not defined, their existence is only specified. There are three types of interactions, such as: the dependence (+), the independence (-) and the similarity (=). Functions are called dependent if they "create result" together. For example, it needs a nut and a bolt to fix plate. In this case, the functions "bolt hold nut" and "nut holds plate" are dependent. On other hand, functions are independent if they don't interact, e.g. for the fun system installed in the wall, functions "fun moves air" and "wall holds fun" are independent. Finally, similar functions have the equal action, e.g. "rivet holds plate" and "welding hold plate", are similar in many cases.

Functions of this table are also added in sets. The last ones include from two to infinity elements.

2.3 Trimming

The trimming is based on [13–15]. On this step the main difference is the distinction between independent, dependent and similar functions. Three formal rules are used for the independent functions. The same rules are used for depended and similar functions, but the trimming for these functions are completed in set. It mean the depended and similar functions set trims as one function.

Three formal rules are used in this case, such as:

- An object of the Function does not exist (rule A);

- An object of the Function performs the function itself (rule B);
- Another Engineering System Component performs the useful function of the Function Carrier (rule C).

3 Case study

The industrial case is presented in this chapter. This one is considered to the special tool for the flow meter assembling. This example is used by the firm TERMOTRONIC (Saint-Petersburg, Russia) in the manufacturing process. The presented mechanism is very complex; therefore this paper focuses only on the flow meter holding system. The step-by-step algorithm is presented below.

The holding system is presented in the Figure 1. This one is inspired with the linear actuator and is used to hold the flow meter in the vertical axe. Considering that the various flow meter models have the different tube diameters, this system must be adaptive. In this case, the system, based in the pinions, was used. A user rotated the handle, and this handle rotated the first pinion in the initial tool. Then the pinion rotated the driven pinion, and the last one moved the thread. In this process, the thread moves the holder in the horizontal axe. The frame in this system holds the holder.

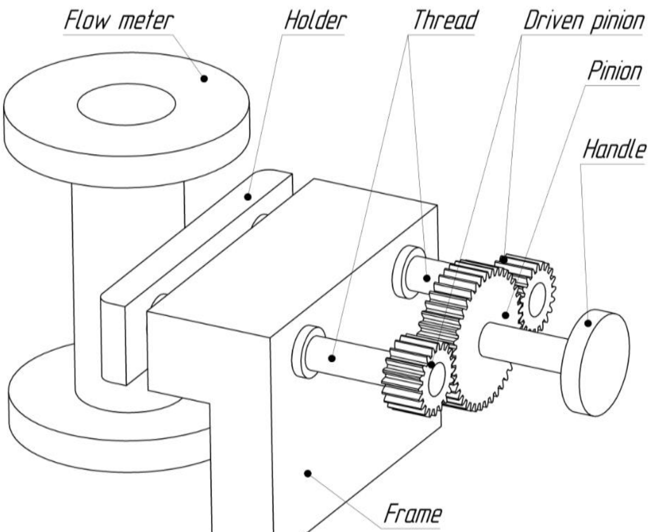

Figure 1 – Initial flow meter holding system

3.1 Function analysis of the holding system.

The first step of the suggested approach is the function analysis. This one is based on previous developments [12, 14, 15] and the Gen3 function analysis approach [13].

There are three parts on this step, such as: the component analysis, the interaction analysis and the function analysis. The first and second steps are accomplished by means of the special software [17] which uses the CAD model of the flow meter holding system.

The function model of the holding system is presented in the Figure 2.

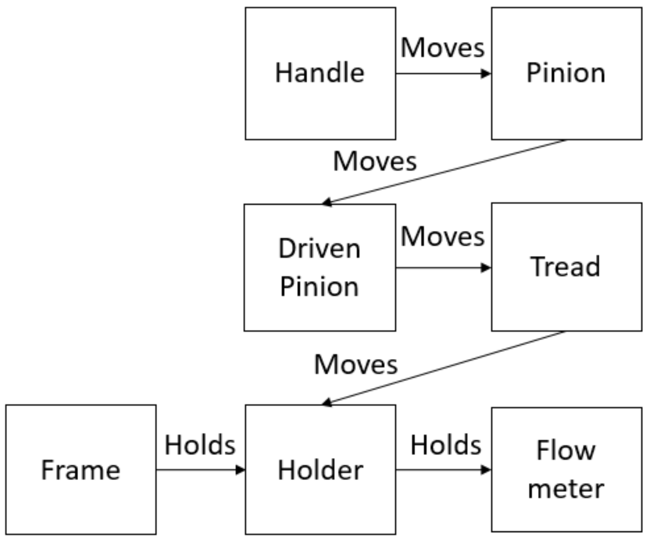

Figure 2 – Function model

3.2 System function interaction matrix

The interaction between functions and the interaction type are defined on this step. There are three types of the interaction in the suggested method: the dependence (+), the independence (-) and the similarity (=). In Table 1 independent and dependent functions are distinguished.

By means of this table it is possible to divide functions into two part, such as: the function "Frame holds Holder" and the set of five remaining functions. This one is named the set "Handle moves Holder".

Table 1 – Holding system function interaction table

	Handle moves Pinion	Pinion moves driven pinion	Driven pinion moves Tread	Tread moves Holder	Holder holds Flow meter	Frame holds Holder
Handle moves Pinion		+	+	+	+	-
Pinion moves Driven pinion	+		+	+	+	-
Driven pinion moves Tread	+	+		+	+	-
Tread moves Holder	-	+	-		+	-
Holder holds Flow meter	+	+	+	+		-
Frame holds Holder	-	-	-	-	-	

3.3 Trimming of the system

The system simplification is completed by means the trimming algorithm on this step. There set of functions "Handle moves Holder" and function carriers of this set are transformed to the system "Handle-Spring-Holder". It means the spring is added in the system and the functions set "Handle moves Holder" are trimmed by means the Rule C. As well, this system is self-adaptive. It means the spring holds the flow meter with different pipe diameter without using any action.

The function model of the improved system is presented in the Figure 3. The improved system is presented in the Figure 4.

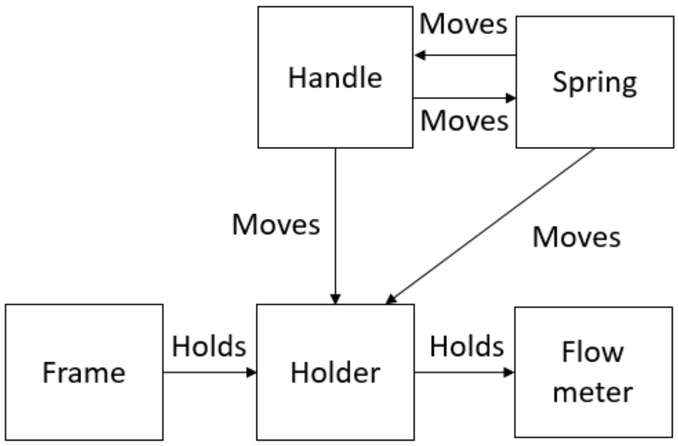

Figure 3 – Improved holding system

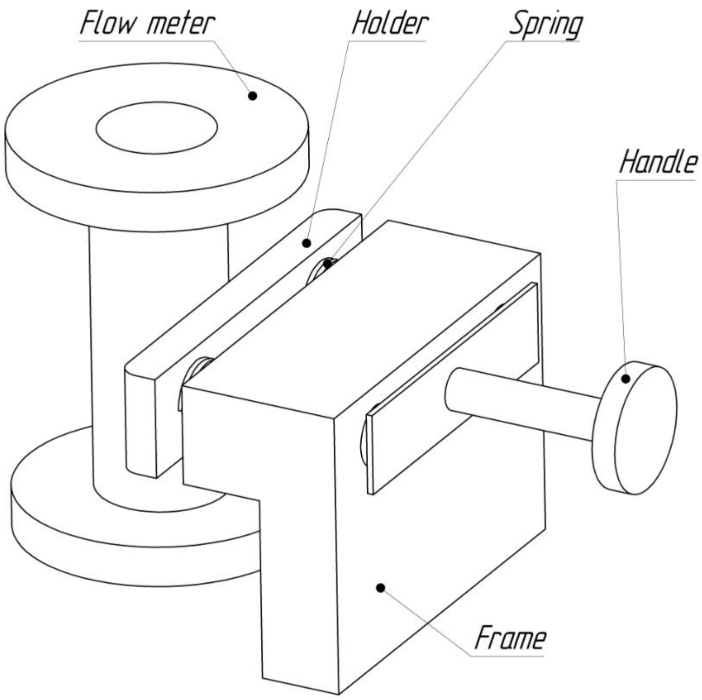

Figure 4 – Improved holding system

4 Conclusions and further development

The method, presented in this article, proposes the improvement of the trimming paradigm. The suggested method is clear, easy to use and to automate. This method maybe used for the design generation, the patent-around design, the design improving, and the development.

The further development will be going in three areas, such as, the verification of the presented approach, the introducing of the assessment system, based in complexity factor [18] and the including of this method in the CAD and the TRIZ collaboration software.

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The Study of Effectiveness of TRIZ Tools for Kaizen Activities in Japan and Developing Countries

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Abstract TRIZ has been generally recognized as an effective methodology for creating innovative technological systems. However, such a strong belief might give TRIZ practitioners excessive expectations or discourage its beginners from practicing TRIZ. Therefore, this paper intends to verify that the basic concept of TRIZ and its inventive principles are very useful for solving problems even in production sites and communities, by paying attention to Kaizen activities in the field of daily life of people as well. This paper touches upon not only "Kaizen activities" born in Japan, but also "Jugaad innovation," a kind of Indian type improvement activities. "Jugaad" is a colloquial Hindi word meaning an innovative solution, and "Jugaad innovation" means a unique product developed under the limited resources available in the communities. In fact, such improvement activities are widely seen not only in India but also in some of developing countries. This paper focuses on the several cases of "Kaizen (improvement)" and shows the results of case studies mainly from the standpoint of TRIZ's inventive principles and functional analysis, to illustrate that the TRIZ approach is basically effective for not only the Japanese-style Kaizen activity, which can be defined as "Japanese-style Grass-Root Innovation (Js-GRI)," but also "Developing-Country-style's (Dc-GRI)".

1 Background and Purpose of the Study

"Kaizen activities" of the Japanese manufacturing industry are acknowledged internationally and over the years, many cases providing values that make an impact on society have generated from the activities. The Toyota Production System (TPS) is well-known around the world, and the convenience stores (CVS) providing services with attention to details, which are unique to Japan, as well as the Japanese railway system, which boasts an accurate train operation system, may be regarded as typical examples of such cases. On the other hand, in developing countries, unique products and services that have sprung out of the needs of the community of common people including the poor, have come to be recognized by Japan and other industrialized countries through "Design Exhibition for the other 90%" [1] and other literatures [2,3]. As such, in this paper, cases of Japanese-style Grass Roots Innovation (Js-GRI) based on the Japanese Kaizen activities and Developing country-style Grass Roots Innovation (Dc-GRI) generated from the "field" of developing countries are analysed and the similarities and differences between the two are organized to demonstrate that TRIZ (inventive principle, in particular) is sufficiently effective in either of them. In other words, the paper intends to verify as much as possible that TRIZ is not only a complicated and profound methodology aimed at innovative resolution (mainly radical innovation) of issues in the R&D department, etc. but it also has aspects enabling easy utilization in the "field" of the life of common people.

2 Origin of Js-GRI and its Affinity with TRIZ

In considering the origin of Js-GRI, the author focuses on "the technology of karakuri dolls" uniquely developed in early Edo period (17th century) in Japan. There is a study done by Katayama and others [4] on the Japanese original "karakuri dolls' mechanism＝karakuri Technologies" in relation to the present Japan*ese* monozukuri (manufacturing). Japan Institute of Plant Maintenance (JIPM) has organized "Exhibition of Karakuri contraption & improvement" since 1993 [5,6]. These show karakuri technologies are considered as one of the means of "Kaizen mind" supporting the present Japanese monozukuri technologies. The basic concept of Kaizen mind" is "simplicity," "hand-making" and "low cost," which are relevant to today's environmental design and TRIZ's Inventive Principles No.16 and No.27 (See Table 1). The concept of main karakuri technologies has similarity with several inventive principles in TRIZ (See Table 1).

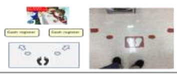
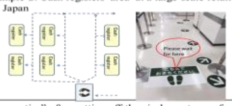
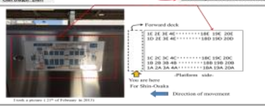
Table1. Relationship between karakuri technologies and inventive principles

Main "Karakuri Technologies"	Required Function	40 Inventive Principles in TRIZ
Utilization of gravity on the earth	Accumulate energy Absorb energy	Mainly, "Equipotentiality (No.12)"
Utilization of spring, flat spiral spring	Accumulate energy Absorb energy Cushion the shock	Mainly, "Equipotentiality (No.12) "
The principle of leverage	get bigger power	Mainly, "Anti-Weight (No.8)"
Utilization of cam Utilization of crankshaft	Change A (motion or power) into B (power or motion)	Mainly, "Curvature (No.14)"
Utilization of gear	Divide power Change the direction of A (axis of rotation etc.)	Mainly, Segmentation(No.1) Another Dimension(No.17)
"Kaizen Mind"	**40 Inventive Principles in TRIZ and so on**	
Low cost	Manly, "Cheap Short-living objects(No.27)	
Simplicity	Mainly, "Partial or excessive actions(No.16)	
Made by hand	" Made by hand" is not related with TRIZ thinking directly. However, "Made by hand" is one of Essentials of "Design Thinking(DT)". DT recommends you make prototype ASAP after idea generation.	

The background of their similarity seems to include some historical facts such as the concept of karakuri technology significantly influenced the Japanese robotics, which is one of the most advanced Japanese industries [8,9]. In other words, karakuri technologies have been handed down until today because of their wide applicability just like a fundamental principle of manufacturing. They, therefore, are presumed to have similarity with some inventive principles in TRIZ. Kaizen activities based on “Kaizen mind” have been implemented in Japanese enterprises (especially in manufacturing sector,) since its rapid economic growth period. As a result, ”Kaizen(=Js-GRI)” has become a common idea (See Fig.4) and it has helped activating workplaces of manufacturing. Some people today say Js-GRI is already getting outdated and do not highly regard it, but there is no doubt that it is still playing a significant role in the world [10]. As karakuri technologies, Kaizen mind, and Js-GRI are based on concepts similar to some of the inventive principles in TRIZ, the author believes, Js-GRI should introduce TRIZ more positively to get rid of its stereotyping and to further enhance such activities.

In recent years (2015～2016), the author conducted field studies on some cases of Kaizen (or Js-GRI) commonly seen in Japanese society and analysed their characteristics. Specifically, they included “Improvement of waiting system at the cashier in convenience stores/department stores,” “Notice board in the airport to call attention to check if any personal belonging is left behind,” “Human-centered design equipment in Shinkansen(bullet train) restroom,” and “Direction board on station platform showing Shinkansen seat numbers.” These cases were found to be related to some inventive principles not shown in Table 1. They are visually arranged in Table 2.

Table2. Relationship between Case examples of Kaizen (Js-GRI) and 40 Inventive Principles in TRIZ

Case examples of Kaizen (Js-GRI)	40 Inventive Principles in TRIZ
Case example 1 Forward area of the cash registers at a CVS in Japan)  Case example 2: Cash registers' area at a large-scale retail stores in Japan  	**Inventive principle 10: Prior action** Carry out required action (Introduce guests to cash register smoothly) in advance or at least in part
Case example 3: “The notice board for preventing lost properties” after getting off the airplane at one of Japanese domestic airports 	**Inventive principle 24 : Mediator** Use an intermediary object (Notice board to carry out an action to prevent lost properties)
Case example 4 Assiduities to various guests in the restroom at Tohoku-Shinkansen  	**Inventive principle 2::Extraction** **Inventive principle 11:Cushin in advance** **Inventive principle 16: Overdone action**
Case example 5 A direction board on a shinkansen platform at Shin-yokohama  	**Inventive principle 11:Cushin in advance** Direction board shows seat numbers of the shinkansen car for passengers Passengers will be able to find their seats easily.

In addition, the author analysed several other cases including “Washing room in Shinkansen,” “Seven-Eleven Café (self-service coffee vending machine),” “Taxi rear door automatic operation system,” “Tool to hook umbrella in train station restroom,” “Toilet sound blocker devise (Product name: Oto-hime),” and “Thin nozzle of mayonnaise plastic bottle.” Most of them were found to be relevant to the inventive principles shown in Table 2 (No. 10 and 11 in these cases).

In selecting these cases, the author asked 55 students (in their 20's who attended "Voluntary Seminar on Studying Japanese Monozukuri" organized by the author in 2015 and 2016) their opinions on improvement examples of their familiar equipment, products or services which were not seen in other countries (or not presumed to be found overseas from those who have never been abroad). Among the gathered majority opinions from those students, the author made the final selection of the cases so that the selected examples were not biased by their age and other factors. In the next chapter, some cases of improvement in developing countries (called Dc-GRI in this paper) are elaborated in relation to inventive principles in TRIZ.

3 Analysis of Cases and Six Principles of Dc-GRI from the TRIZ Viewpoint

The author would like to share three case studies of Dc-GRI that was created in developing countries. One of the cases is a case in India and the other two are in South African and in the Philippines. In India, Dc-GRI is often referred to as "Jugaad innovation", which means innovative solution in Hindi, but this concept is not specific to India [2]. Accordingly, in this paper, Dc-GRI is used as a collective name to GRI in developing countries, including India. Figures 1 shows a "non-electric refrigerator made by clay (India)", "Q Drum (South Africa)" and a "lantern for keeping mosquitos at a distance (Philippines)", respectively. The example C in Figure1 should be particularly noted as it is a product of hand-made Kaizen that the author discovered in a house at the edge of a village in the Philippines. The feature of this product is that it is made of a surplus scrap of Olyset Net, a product of Sumitomo Chemical, Japan, and scrap wood.

Figure1. Three case studies of Dc-GRI [1,4]

As these three cases have traces that the inventive principles of TRIZ, etc. were "intuitively utilized" in some way or other, they were analysed in detail as in Table 3. Based on the analysis result, it is assumed that not only the "karakuri technology", which is an origin of Js-GRI, but also Dc-GRI has an affinity with TRIZ.

Table3. Relationship between Dc-GRI's cases and TRIZ

Case examples about Dc-GRI	40 Inventive Principles in TRIZ	Required Function
Non-electric refrigerator made by clay(India)	N/Y, However, utilization of "heat of evaporation" like effects in TRIZ	remain fresh of food (without electricity)
Q Drum (South africa)	Mainly "Curvature(No14)"	Carry water easily
the lantern for avoid mosquitos (Philippines)	Mainly " Taking out(No2)" "Local quality(No3)"	keep mosquitos at a distance

Since Table 3 covered as few as three cases, similarities between the publicly released six principles of Jugaad innovation [2], which may be representative of Dc-GRI, namely, "Seek opportunity in adversity", "Do more with less", "Think and act flexibly", "Keep it simple", "Include the margin" and "Follow your heart" and the TRIZ methods, including the 40 inventive principles were organized in Table 4.

Table4. Similarity between "Jugaad Innovation" and TRIZ

Six principles of "Jugaad Innovation"(= Dc-GRI)	40 Inventive Principles and so on in TRIZ
Seek opportunity in adversity	Manly, "Convert harm into benefit (No.22)"
Do more with less	Manly, "Cheap Short-living objects(No.27)" Get involved with "Kaizen mind(Low-cost)" Utilization of limited resource >>Kaizen mind(Low-cost)
Think and act flexibly	"Elimination of psychological inertia (in TRIZ)"
Keep it simple	Mainly, "Partial or excessive actions(No.16)" Get involved with "Kaizen mind(Low-cost)" Utilization of limited resource >>Kaizen mind (Simple)
Include the margin	Unique standpoint
Follow your heart	Get involved with "Kaizen mind(Made by hand)"

As a result, it was found that three principles of the six principles of Jugaad innovation are obviously similar to the TRIZ inventive principles No. 16, 22 and 27. Also, the principle of "Think and act flexibly" is relevant to "Elimination of psychological inertia" proposed by G. S. Altshuller and as such, it is highly likely that the other inventive principles and techniques are also intuitively utilized as a means to practice this philosophy. In fact, in the examples in Table 3, No. 2, 3 and 14 are utilized and the non-electric refrigerator made by clay uses vaporization heat, which may be regarded as a principle of nature and the approach taken is similar to the effect-based approach. In this way, it became clear that Dc-GRI also has a strong affinity with TRIZ. As shown in Table 4, Dc-GRI is also relevant to "Kaizen mind" and "karakuri technology". The next chapter explains "Kaizen mind" in detail.

4 Similarities and Differences between Js-GRI and Dc-GRI

The philosophy of Kaizen activities (Js-GRI in this paper), according to a book written by Imai, a Kaizen pioneer researcher [10] and Japan H.R. Association's definition [11], can be summarized to" Change alternative," "Accumulate small changes," and "Utilization of Limited resource." There characteristics are relevant to Kaizen mind mentioned in Chapter 2, but "Accumulate small changes" is not confirmed in Kaizen mind. That means the most significant characteristic of Js-GRI, the Kaizen activities suited to the modern society, is continuity. On the other hand, three out of six principles of Dc-GRI (=Jugaad innovation) are highly relevant to Kaizen mind, and yet, the characteristic of "Accumulate small changes." is not found in Dc-GRI (See Fig.2).

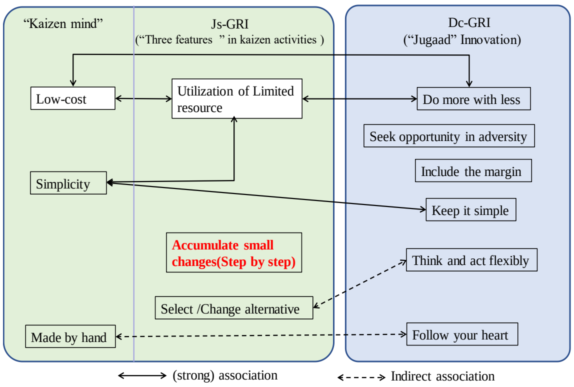


Figure2. Association chart showing the relationship between Js-GRI and Dc-GRI

Historically speaking, Js-GRI was established by integrating Kaizen mind into the Western-style management (especially Plan-Do-Check-Act), which has taken root in Japan after introducing QC during the economic growth period after the war. Js-GRI has evolved in its original way and contributed a lot for strengthening the actual manufacturing site capabilities in Japan. Taking such a background into account, there are three points to be noted here as illustrated in Fig. 2.

First, even now, Kaizen mind is the basis supporting Js-GRI, because being aware of the two characteristics of Kaizen mind, namely, Low-cost and Simplicity are necessary for realizing Utilization of limited resource in Js-GRI. Secondly, the six principles of Dc-GRI (Jugaad innovation) are associated with Kaizen mind. In particular, "Keep it simple" is identical with "Simplicity" in Kaizen mind and "Do more with less" are relevant to "Low cost" in Kaizen mind and "Utilization of Limited resource" in Js-GRI. From the considerations above, it can be concluded that Js-GRI and Dc-GRI have a significantly strong affinity, which implies the possibility of collaboration between the two GRIs. On the other hand, the third point is about the difference between Js-GRI and Dc-GRI. As was mentioned earlier, the concept of "Accumulate small changes" was not confirmed to have association with any of the six principles of Dc-GRI. In fact, an aspect of "problem-solution as an emergency escape" is strongly reflected on the philosophy of Jugaad innovation and even if it resulted in commercial product development, the "Think and act flexibility" principle seems to have a sporadic nature and is almost unlikely to lead to the concept of "Accumulate small changes" in Js-GRI. According to multiple experts who are well-versed with the cases of GRI that the author has met in India, there are few cases where the formal sector provides support to the GRIs in India that have developed commercial products and as such, in most cases, stable quality cannot be achieved [11]. This may demonstrate that Dc-GRI is deficient of "continuous Kaizen mind" directed to the maintenance of stable quality.

5 Expectation for TRIZ as a Mediator between Js-GRI and Dc-GRI

Js-GRI and Jugaad innovation (its six principles) which is regarded as symbolic Dc-GRI are found to have similarities and high affinity. It is also found, however, that Jugaad innovation is not practiced as well-organized and continuous activities. In fact, Jugaad was originated from individual ingenuities devised in Indian communities and not intended to be implemented in an organized manner in the first place. It is true, however, that some elements of Jugaad way of thinking are associated with Kaizen mind and Js-GRI. Considering the fact that Dc-GRI is expected to be implemented more in the companies there, the author believes that Jugaad way of thinking should be collaborated with the practice of PDCA in developing countries including India. On the other hand, there are cases of Js-GRI, in which implementation of PDCA is taken for granted, has become stereotyped and tends to attract less attention. It might be an interesting attempt to incorporate Jugaad concept into Js-GRI, but it might not be well accepted among the Japanese corporate people.

Table.5 Checklist of Inventive principles for GRI

Inventive Principles for GRI	Specific Directions for GRI
Segmentation	Divide the object (one object) into multiple parts independent of each other
Extraction	Extract the only necessary part or property
Local quality	Change the object or external environment (external effect) from a homogeneous structure to a heterogeneous structure.
Anti-Weight	Balance the weight by combining the weight of the object with another buoyant object.
Prior action	Carry out required action in advance or at least in part
Cushin in advance	Compensate for relatively low reliability of an object by countermeasures(pictographs) taken in advance
Equipotentially	Change the state of work so that we do not need to raise or lower the object.
Curvature	Change linear parts and flat surfaces to curved ones, or replace the shape of the cube with a spherical shape.
Overdone action	Try to be able to accomplish with somewhat more or less states trying to greatly simplify the problem, if it is difficult to get the desired effect 100%
Another Dimension	Remove the problem caused by moving the object linearly by two dimensional movement (along the plane). Likewise, if objects can be changed in three-dimensional space, there is a high possibility of eliminating problems occurring when moving an object on a plane.
Convert harm into benefit	Take advantage of harmful factors and environmental factors in order to obtain positive effects.
Mediator	Use an intermediary object to carry out an action
Cheap Short-living objects	Replace expensive target objects with aggregates of inexpensive objects so that you do not have to drop characteristics (such as lifespan and usability).

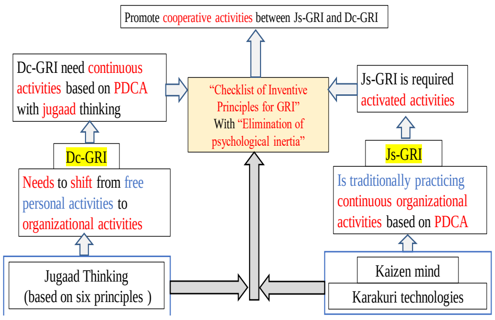


Figure.3 Collaboration between Js-GRI and Dc-GRI based on the checklist of inventive principles for GRI

What the author proposes here, therefore, considering the current situation of increasing collaborative business activities between developed and developing countries, is to utilize inventive principles in TRIZ as a mediator at the time of collaboration between Js-GRI and Dc-GRI, by making use of the proposed GRI inventive principle check list (as shown in Table 5) including the inventive principles which have affinity to either Js-GRI or Dc-GRI or both of them, hoping that this check list will be utilized in a continuous manner. Figure 3 explains this concept schematically.

6 Conclusion

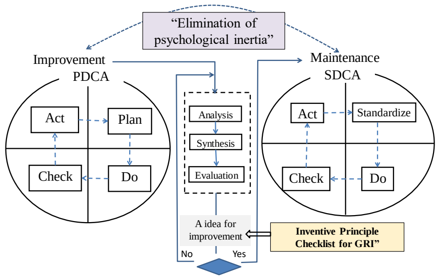


Figure.4 Continuous activities based on inventive principles for GRI

In the previous chapter, the use of "GRI inventive principle check list" was proposed for enhancing worksite Kaizen activities (GRI) at the time of promoting smooth and effective collaborations between developed countries like Japan and emerging countries including India, as a common tool for the both parties (Japan and India, for example.) For the continuous activities, however as was mentioned in Chapter 4, it is essential to implement the concept of PDCA (Plan-Do-Check-Act) as well as a set. The idea is explained in Figure 4.

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Trimming in the context of IT-services

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Abstract In an increasingly digital world IT-services are the corner stone of any credible strategy. This has led to large investments in developing new and adding features to old IT-services. Many companies emphasize time to market for new services and features. Getting new features into production is critical for staying ahead of competition and reacting to market changes and disruptions. This emphasis on speed often comes at a cost. Instead of investing time and effort into refactoring existing services new, features and services are often "glued" on top of existing solutions and processes. This in turn leads to increasingly complex services, IT-architecture, processes, etc. The increase in complexity leads to slower development times, increased development and maintenance costs and a worse user experience. TRIZ trimming questions have been successfully used together with functional models in traditional engineering domains to simplify systems. This article explores simplifying IT-services with trimming questions covering architecture, process and user interface. The article presents how the different aspects of IT-services can be modelled, so that the trimming questions can be effectively applied into practice and want changes can be made to the trimming questions to make them more effective. The key findings are that TRIZ trimming questions are an effective way of simplifying IT-services, but the aspects of IT-services that are simplified (architecture, user interface…) need to be modelled in a way that is suitable for the trimming questions. Small modifications to the trimming questions also make them easier to apply into practice.

1 Introduction

This article makes some assumptions about why simplification is important in the context of IT-services. These assumptions are commonly shared in the organizations the author has worked with, but there is no reason to assume they are universal so it is good to be explicit about them.

Speed: The speed of change has been increasing in most markets. Competitors are launching new services and features at an increasing pace. The competitors are also often different companies then they used to be. The new competitors can be startups, companies that are extending their service offering, or global organizations that are extending their reach to new geographical areas. To make the challenge even more difficult, the new companies are often lacking the baggage of old infrastructure (startups), or can afford to invest more in R&D (global organizations). Speed serves two functions: 1) it provides a first/early to market advantage, 2) and it enables reactivity to market disruptions.

Costs: Despite the increasing need to develop new services and features quickly to the market, few companies can afford significant increases in their R&D budget. There are multiple reasons for this, but probably the most important are decreasing profits and margins and the need be profitable on the short term. Many organizations are even forced to look at R&D as a source of cost savings. This puts organizations in an interesting dilemma. They need to be fast in delivering new services and functionality to customers

Sustainability: Providing new functionality to customers, while being cost effective is not only a short term need. It is likely to continue for the foreseeable future as well. This means that using sort term solutions that enable new functionality and cutting costs, but will limit the ability to offer new functionality in a cost effective way over the long term are not viable solutions.

User experience: Providing new functionality is not enough. The functionality needs to be provided in a way, which enables a high quality customer experience. This puts further pressure on the way services are developed. Not only does new functionality need to be added quickly and cost effectively, but it also needs to be done in a way that this is not achieved the cost of the user experience.

Even though many organizations buy into all the assumptions that were stated above they are struggling in applying them into practice. New functionality is taking longer to develop then expected, or needed. Costs are running over expectations or if costs are cut, they are having negative impacts to the development speed of new functionality. Many organizations are attempting to fix these issues by introducing Agile or Lean development practices [1]. While this often has a positive impact, the underlying issue of complexity (and its effects on speed and cost) in IT-services is not fully understood. Even when the issue of complexity is understood companies often lack a systematic approach to tackle it in a practical way.

This article aims provide insight why complexity is an important concept to understand, and how reducing complexity has been systematically approached in classical TRIZ, by a combination of functional analyses and the trimming tool.

This article will also introduce how a similar approach can be applied to different aspects of IT-services.

2 Complexity and its costs

Complexity is a word that is increasingly commonly used in the world of IT. Everyone has an intuitive grasp of the concept, but many struggle to formally define the concept. It has multiple definitions, and many of them can be useful in different situations. When it comes to communicating the costs of complexity and making the case for the value of simplifying, the author has used the definition by Joseph Tainter that complexity can be defined by the amount of parts, amount different types of parts and to what degree the parts are integrated together [1, page 6]. Whenever we add new and different parts to a system, and when those new parts are integrated with existing parts, the level of complexity in the system rises. A practical example of this in the context of IT-services would be adding new architectural components, user interface elements and processes that together add new functionality to the service. The implementation would increase the complexity of the system.

Increasing the complexity of the system does of course have benefits. Complexity has great utility in problem solving [1, page 7]. In practice this means we can solve problems related to the IT-service by increasing the complexity of the system. One example of this would be adding clustering to a service in order to decrease response times for the customer using the user interface. Another example would be adding integration to other IT-services to improve market positioning. These examples of increasing complexity have clear benefits. Unfortunately they have a cost as well. The cost of increasing complexity is “the amount of energy, labour, time, or money needed to create, maintain and replace a system” [1, page 7]. This means that increasing the complexity of a system has not only development costs, but also the investment and effort needed to maintain the system will be larger. These costs can add up over time to the point where the system is no longer sustainable.

If organizations make deliberate balancing choices between the cost of complexity and the benefits it brings this is not necessarily a problem. Unfortunately decision makers are not always aware of the full consequences of their actions [1, page4]. The consequences of adding complexity may not manifest themselves until years or decades later [1, page 5], which makes the situation even more challenging.

Another interesting phenomenon regarding complexity is the concept of diminishing return on increasing complexity. The high cost to benefit solutions are the once that implemented first and as they are exhausted the problems must be addressed with more costly and less effective solutions. This leads to a point “where further investments in complexity do not give proportionate return”. If “carried far enough this can lead to stagnation and ineffective problem solving” [1, page 9].

By being aware of complexity, and both the positive and negative consequences it brings organizations, we can hopefully make good decisions on when it is needed. This still leaves the issue that many organizations have accidentally arrived in a situation, where they have increased complexity without understanding the consequences. In the challenge of reducing unnecessary complexity a systematic approach to the different aspects of a system can make it a more approachable challenge.

3 Classical TRIZ trimming

TRIZ offers an interesting and practical approach to reducing complexity by simplifying a system with the Trimming tool. The approach is twofold [2, pages 383-390]:

1. Create a functional model of the system
2. Removing components from the system by using the trimming questions

The functional model is created by first identifying the components of the system and then identifying the functional relationships of the components. The relationships are drawn as arrows between the components and expressed as active verbs. It is important to identify which function is the "main useful function" of the system and also model the harmful functions (drawn as red arrows). Functions that are insufficient or excessive are also identified as part of the analyses. If the useful function is insufficient it is drawn with a dashed line and if it is excessive it is drawn as a double line [2, pages 104-107].

After the functional model is ready, we can start trimming the system by asking the seven trimming questions for all components of the system that are potential trimming candidates. The trimming questions are organized in a list, so that the questions on top of the list are more difficult to achieve, but will provide more value, if we can utilize them to trim the system [2, pages 383-385]. An additional consideration for trimming the system is that it should still adhere to the law of system completeness even after the trimming [2, page 387].

The trimming tool can also be applied to time based problems, e.g. situations where the system can be modelled as an ordered sequence of steps. In these situations the trimming tool can be applied in two ways: 1) to optimize individual steps of based on functional analyses and trimming, or 2) by using the trimming provocations to remove unnecessary steps in the process [2, pages 394-396].

In addition to classical technical systems the trimming tool can also be applied to business and management problems. The basic workflow is the same is it was for technical systems. [3, pages 438-441]. The questions are a based on the trimming questions for technical systems and interestingly a minor variation of the questions is proposed for time based systems [3, pages 439-441].

4 Trimming in the context of IT-services

4.1 Trimming the customer functionality of a IT-service

Trimming the customer functionality of the existing functionality and trimming proposed new future functionality is key area of focus to reduce complexity and decrease time to market for features. This is an area where IT-services can be different to mechanical systems. Just because a system has more functionality does not make it better. Good usability, quality and reliability are often far more important. The proposed methodology follow the twofold process: 1) model the system, 2) trim the system.

The modeling of the system can be done as by first describing the customer value that is being provided by the functional world tool/template. It contains customer value described in a 2by2 matrix with dimensions of me/we and tangible/intangible value. It is important to capture the intangible value aspects as well, because they are often the ones that drive customer behavior [4, pages 10-11]. Next the features of the service can be model with a table that contains the following pieces of information for each row (feature): 1) name of the feature, 2) customer value provided by the feature (linked to the functional world template for the service), 3) a list of other features, that the function is a mandatory enabler for.

This provides a similar model than the classical functional model, but has the following benefits: 1) the list can easily be sorted on the basis of how different features provide customer value, 2) customer value adding and supporting features are easily separable, 3) the list of functions a IT-system provided can be very long and it is not practical to visualize it in a single image in many cases 4) the people responsible for product management often have an existing list of the features provided by the service

After the customer value is modeled, and the features have been listed, we can proceed to trim the system. The TRIZ Trimming tool (the business version) is a good starting point for trimming questions. It is often practical to first try to trim the features that provide customer value, because if it is possible to trim some of them it often becomes easier to trim some of the features that enable customer value features. After a customer value feature is attempted it is time to try to trim the enabler features.

Trimming proposed functionality is a good way to reduce lead times for new releases and make sure the development efforts are focused on the most value adding features. It will also result in cost saving for unnecessary development efforts. In the case of refactoring already developed functionality to simplify the system the benefits are twofold: 1) The services is easier to learn and understand (which can add to the customer experience), 2) it is easier to add new functionality later (or change existing functionality) because it will effect less existing functionality. In this case it is wise to consider is the decrease of complexity worth the costs related to refactoring the service.

4.2 Trimming the user interface of a IT-service

Trimming the user interface is a close cousin to trimming the customer functionality. The difference is that customer functionality can be achieved with one or more user interface elements and the elements can be utilized in multiple functions. In practice this means that the reduction of customer functionality does not always lead to a simpler user interface, or that a simpler user interface does not necessarily lead to less customer functionality.

Again the trimming process has two main parts: modelling the system and trimming the system. A practical way to model the system is to take an existing visualization of the user interface as the starting point. In the case of a new service this can be the proposed wireframe diagrams, or in the case of an existing system take screenshots of the user interface. After this it is good to list all the user interface components of the view/screen and identify that appear on multiple different "screens"/views of the user interface.

Ones this is done the next step is to model the functions provided by the user interface elements. The functions the user interface elements provide can be categorized as: 1) functions that provide direct value to the customer, 2) functions that enable other user interface elements. An example of the first type is a chat screen that directly contributes customer value by enabling the customer to see chat messages. The navigation bar would be an example of a user interface element that provides supporting value (easier to find other elements), but not direct customer value. It is possible for a user interface element to provide both kinds of value.

If the user interface is relatively simple it is possible to add the functions on the visualization/image of the user interface and a customer symbol so that arrows can be added to the symbol to represent the functions that provide value directly to the customer. Other functions (enablers) can be drawn as relationships between the user interface elements. This type of visual model is very close to a classical functional model, but the minor difference is that the layout is the same as the user interface.

After the model is completed trimming can be done using the standard trimming questions. The benefits of trimming the user interface are: 1) a simplified customer experience, 2) reducing the time and costs to develop new user interfaces, 3) the simplified model makes it faster and cheaper to add new functionality later to the system.

4.3 Trimming the processes of IT-services

Many IT-services are operated with significant number of processes. Some of these process are general support processes like the ITIL incident management services, and some of them are custom processes designed for the specific service (like an online interview process for a digital recruitment service). Even the "standard" support process are very seldom completely by the book. Just to give an idea of the number of processes involved the often used ITIL V3 standard contains 26 processes [5]. And these are just standard service support processes.

The author proposes three different approaches to trimming processes: 1) trimming the process collection, 2) trimming steps from processes, 3) value stream analyses for complex systems.

The first approach is the process listing all the processes need for the IT-service currently and documenting the customer value and supporting value to other processes each of them provides. After this step the trimming questions are used to reduce the number of processes needed. This is a high level approach that can used to challenge many of the assumption behind the processes that can lead to significant reduction in complexity.

The second approach involves listing all the steps of an individual process and using the trimming questions to reduce the needed steps. It is described comprehensively in by Darrell Mann in HOSHI for business and management [2, pages 439-441].

The third approach (value stream analyses for complex processes) is a thorough method for analysing and improving complex processes. It involves looking and the process for multiple different viewpoints and using several Lean and TRIZ tools to generate improvement ideas. The down side of the approach is the amount of effort needed for the analyses [6].

Useful additions in the authors experience to trimming processes in the context of IT are: 1) can the service do it by its self (automation), 2) can the function be done by supporting self-organization?

The first questions is meant to provoke ideas related to automation and second is a way of questioning the need for traditional control (which is behind many of the ITIL processes) and proposing replacing it by enabling more self-organization by teams providing the services.

Trimming the processes of an IT-service can make it more cost effective, faster for the customer, easier to change (less moving parts) and more engaging for the employees who are providing the service.

4.4 Trimming the architecture of a IT-service

IT-architecture is a practice that is done on multiple different abstractions levels. When we are looking at IT-services from a trimming point of view enterprise architecture and system architecture are two of the more interesting perspectives.

Enterprise architecture is done on a high level, and its focus is understanding and defining the high level building blocks that are needed for the organization to achieve its purpose. In relation to IT-services, this means that an IT-service is often modeled as one such component. System level architecture on the other hand looks at the components that are required for an individual service. The building blocks in system level architecture can be things like databases and applications.

IT-architecture is often an established practice in organizations. This has the positive effect that, in many cases, there are visual representations of both enterprise and application architecture. These diagrams typically model all the components of the system and how they are connected to each other in terms of integrations, dependencies and information flow. This visual modelling is very close to functional modelling and offers a good starting point for utilizing the trimming questions.

A noteworthy addition to normal trimming is the emphasis on timing and difficulty of changing it later. Often architects have a tendency to err on the safe side. Meaning that both enterprise architecture and system architecture often have components that are not strictly speaking needed in the current situation, but have been added in anticipation of future needs like scaling or adding new types of functionality. It can enhance the trimming workshop to add the following questions to the list of trimming questions: 1) do we need it at the current moment, 2) how difficult would it be to add it later when it is actually needed?

4 Conclusions

Many organizations are struggling with complexity as consequence of trying to adjust to the needs of digitalization. This article offers some ideas how to approach reducing complexity in IT-services in a systematic way. This is an area with a lot of practical potential, but the suggestions made can't be considered as mature recommendations. Rather they are early exploration of ideas that come from the authors consulting experience with IT-services and TRIZ. There is a lot of room for improvement and inventing new tools to tackle the problem of complexity in IT-services. This paper aims to be an opening note on the topic and hopes to inspire new ideas, research and interest on the topic.

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TRIZ popularity, challenges and strategies to make it work in Finland

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Abstract Finnish government introduced new policies towards innovation in 2008 when the global financial crisis was growing. Finland has always been known as one of the top innovative countries worldwide. However, recent research shows that the output factors of innovation regarding manufacturing and high-tech do not work well in Finland. The Theory of Inventing Problem Solving (TRIZ) is one of the methods used in different industries to lead efforts towards radical innovations. Both primary and secondary data were deployed to realize the level of popularity of TRIZ in Finland. Companies' challenges for management of innovation (TRIZ in particular) were extracted and the possible strategies to make TRIZ favored in Finland were suggested. The research conducted through an online survey by participating R&D and innovation managers of Finnish companies. From the responses received, it was found out that many SMEs had no innovative activities and TRIZ was not a prominent method in large Finnish companies. Other innovation techniques including lean principles were of more popularity. The most important challenges for Finnish companies were the lack of motivation in employees and managers, the lack of basic knowledge about the method and the risk of information leakage by consultants. The most important strategies towards TRIZ dissemination were considered for different layers of the society. Finnish government and the big funders in innovation system should contribute to higher innovation outcome by assigning more budget to universities for innovation-related courses such as TRIZ in master's degree programmes. Joint TRIZ seminars, where companies participate in its basic courses were found out to be interesting for participants. In addition, top-level managers and trainers in both universities and industries, should have new strategies in order to motivate the participants of the course and make it work more effectively.

1 Introduction

In today's world, where the markets and industries experience tight and close competition, firms must pay special attention to their innovative activities in order to have a competitive advantage to their rivals [1-3]. Thus, it is crucial to make radical changes to innovation-related behaviours at all levels of the society, including national, organizational, educational and individual levels. Finland has known to be one of the top countries in the world as it pertains to innovation. However, the statistics were based on multifactor productivities and "often unrealistic assumptions" [4]. According to the most recent reports of Bloomberg in 2015 [5] and early 2016 [6], Finland was in the fourth and seventh places in the world considering the overall calculation of different indices. Although Finland ranks first in the European Union in R&D intensity and Tertiary efficiency (enrolments for higher education mostly in science and engineering according to Bloomberg (2016) definition [6]), it stays far behind the most competitive countries in Manufacturing and High-tech activities. Being the most innovative country in the world, South Korea has put a good deal of effort in increasing all factors and indices (apart from the Productivity where South Korea stands in the 39th place). This shows clearly that some strategies towards innovative activities should be changed in Finland. Now that the Finnish economy has been suffering from a financial crisis for years, it is time for innovative activities to mitigate the detrimental effects of the crisis and save more money and resources in favour of the country. Having said that, a jump from the 13th place to the 7th in patent activities in the last year is a good sign for Finnish innovation-related behaviours [5-6].

TRIZ is one of the methods used for innovation management, particularly at the front-end of innovation [7], which is the initial stage of New Product Development phase by means of generating systematic creative ideas leading towards value creation (see chapter 2 for more details). There are different conceptions about the popularity of TRIZ around the world. However, these conceptions come from different indices. Cavalluci's study [8] shows that TRIZ had been used widely over the past decades before the completion of his study. Ilevbare, et al. [9] believe that the popularity of TRIZ gaining a steady increase. Teplov, et al. [3] are also of the opinion that the popularity of TRIZ is growing in both academic environments (increasing number of scientific papers) and the industry. However, Abramov [10] notices that there are not many innovations developed through the implementation of TRIZ. His research also indicates that the number of TRIZ experts has decreased since 2013. Another interesting finding in Abramov's study is that 65% of TRIZ experts reside in South Korea whose government supports TRIZ dissemination in the country. This might be a ground for its first rank in innovation. Yet, more research is needed to prove this assumption.

Despite the increasing number of academic papers in TRIZ, the literature lacks information on the evaluation of the challenges and strategies to help its better implementation in Finland. A recent study by Elfvengren, et al. [7], however, shows that TRIZ is not very popular in well-known Finnish companies and only a few of their considered cases use TRIZ as an innovation method.

The objective of this paper is to demonstrate a big picture of the challenges of TRIZ deployment in Finland and what should be done in both short-term and long-term in order to propagate this method in Finnish society. Considering these objectives, the formulated research questions are as follows:

1. How popular is TRIZ in Finnish industries and education system?
2. What are the challenges of using innovation techniques and particularly TRIZ in Finnish industry and education system?
3. What strategies should be taken in decision-making to overcome the existing challenges of using innovation techniques and increasing the particularly of TRIZ in Finland?

The second chapter of this paper includes the literature review containing the previous research on Innovation Management, particularly on TRIZ and innovation system in Finland. In the third chapter, the methodology to gather data is discussed. The results of the research are presented in the fourth chapter of the paper. Then, in the fifth chapter, the results are discussed and compared with the previous studies. Finally, in the conclusion, the contribution to academia, limitations of the study, practical implications and possible future research are described.

2 Literature

Innovation Management defined by Weis [11] as a systematic management and control of innovation in an organization in the way to best benefit from ideation till a successful commercialization of a product or service. It consists of six stages including ideation, preliminary analysis, business case, product development, test and validation, and market launch. However, this process is not as easy as it might seem, because a lot of uncertainties are involved within the whole process and makes it quite complex and challenging [12].

Koen et al. [13] divides the innovation process into three different areas including Front-end of Innovation (FEI) which they call it Fuzzy Front End due to high degree of uncertainty, New Product Development (NPD) and Commercialization. They regard FEI as the most important phase for exploiting opportunities and making improvements to the innovation process. It is the period between the start of the ideation of a new product and the start of the product development process. Screening the ideas at this stage and selecting the right ones reduces the risk of investment in poor ideas [14]. There are many different tools and techniques for management of innovation in FEI stage including TRIZ [7].

Based on our research questions, the theoretical part of this paper is divided into two parts: Within the first sub-chapter, the literature on TRIZ, challenges of its application and strategies to make it work better are reviewed. The second part of the theoretical part is devoted to innovation system in Finland in different levels of the society including national, organizational, educational and individual. The Fig. 1 shows the theoretical framework of the study, where the focus of our study is on the intersection of TRIZ and Innovation system in Finland.

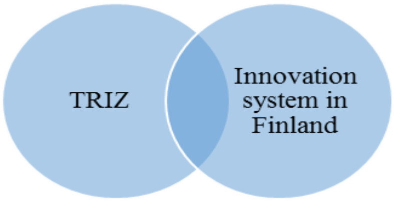

Fig. 1. Theoretical framework of the study

TRIZ

TRIZ is an acronym for *Teoriya Resheniya Izobretatelskikh Zadach* (in Russian: Теория решения изобретательских задач) which means the *Theory of Inventive Problem Solving*. TRIZ was developed by Genrich Altschuller [15], who discovered that different engineering and technological patents in the former Soviet Union had similar patterns in their evolution. He then developed the techniques and methods used in TRIZ and wrote papers on how to evolve new technologies systematically. TRIZ is taught in many universities and has been applied in more than 35 countries [9]. There exist many methods and techniques in TRIZ to make radical or incremental improvements to a product, technology, process, service or even in a business. These include but are not limited to, for example, Contradiction Matrix, Ideal Final Result and Trimming. In this paper, however, the main focus is on the application of TRIZ, its benefits, challenges in workshops and the strategies that help to better use TRIZ in the society.

The nature of this study is the evaluation of how TRIZ is deployed in Finnish society. Accordingly, there was a comprehensive longitudinal research conducted by Cavalluci [8] where the perceptions of TRIZ users and the way they deployed it in their organizations were considered in a global scale. This study had the advantage that the European TRIZ Association ETRIA was supporting it. Below, some of the main outcomes of the study regarding challenges can be found.

- TRIZ was deployed already not only in industrialized countries, but it was also used in all developing countries covered in the study.
- Surprisingly though, some 12% of the respondents were considering TRIZ as a software.
- Research-related activities had been increased for the past two decades before this study completed in 2009.
- TRIZ was included in the studies mainly in postgraduate level.
- The three top sectors where TRIZ was more popular was Automotive, Telecommunication and Electrical equipment, and Electronics.
- Most of the TRIZ-related activities were developed inside the organizations.

There are a lot of success stories in the application of TRIZ. For example, BAE systems noted that TRIZ contributed to their organization by improving problem solving skills in its degree of complexity and variety of problems solved, in addition to better teamwork and collaboration [16]. Ilevbare et al. study [9] represents that those who have applied TRIZ considered it as a tool that helped in better approach to problems, increase in idea numbers, higher speed in reaching the resolution, more effective teamwork, less expenditures in problem solving, providing competitive advantage and so on. From a more technical point of view, Spreafico & Russo [17] noticed that TRIZ has got advantages in quality improvement, less pollution of products, increase in productivity, energy saving and higher safety standards.

Previous studies show that one of the main challenges in TRIZ workshops implementation in companies and organizations is the lack of time for employees and managers to participate [8, 16, 18]. Another challenge that is mentioned in the literature of TRIZ is the resistance against grasping its material [8, 16, 19, 20]. Rantanen and Domb [18] believed that the suspicion on using TRIZ or another innovation techniques is considered as a challenge. In addition, they noticed that contradiction in the nature of TRIZ techniques with traditional project management systems and the Not-Invented-Here syndrome NIH (another type of resistance) prevents proper implementation of TRIZ. Among other challenges in TRIZ workshops, authors [1, 3, 9, 16, 19] noticed its complicated structure and flow of information, inappropriate approach to learners or non-professional trainers, lack of motivation and cross-cultural issues. The cross-cultural issues stem from the perceptions that TRIZ methods came from Russian culture which may be difficult to develop in Western countries. Furthermore, the method subjectivity and adaptation to management-related issues are different regarding the cultures.

There are different strategies in approaching systematic innovation and creativity (including TRIZ), their implementation and post-implementation activities. These strategies should be carefully taken into consideration as a part of change management in organizations [21]. Choi, et al. [22] notices that companies, especially in developing countries, should change their ethical climate in the way that avoid only short-term benefits and instead, they must lead their strategic decision-making towards long-term benefits such as customer satisfaction. It is suggested that organizations need innovative staff with high motivations and skills to make breakthrough and bring competitive advantage for them [23] and therefore, should be a dimension in Human Resource Management departments. For the staff to be motivated for innovation, a good support from risk-taking management is required as well. An appropriate training is not only a must for innovation purposes, it also increases the staff motivation to get involved in creativity-related activities. Two factors that lead organizations towards better achievements in innovation are *absorptive capacity* and *knowledge management capacities*. Increased absorptive capacity helps organizations to benefit in terms of innovation and learning process [4, 24, 25]. The term ‘Absorptive Capacity’ was first coined by Cohen & Levinthal [24] and they defined it as “*the ability of a firm* *to recognize the value of new, external information, assimilate it, and apply it to commercial ends".* It is essential that both employees and managers continuously familiarize themselves and learn new innovation and creativity techniques including TRIZ. This, in turn, affects the organization's performance and hence, more financial and non-financial benefits is expected. Yet, this is not sufficient for them to just get to know to the concepts at one juncture of time and stop developing skills further. Learning and innovation are continuous processes, which require careful consideration of firm's dynamic capabilities and knowledge capacities deeply investigated in the literature [26].

TRIZ education and training is of a paramount importance to notice, especially for those companies who use consultancy groups for TRIZ workshops in their organizations or universities. The question whether to use consultancy groups for training or develop TRIZ internally should be considered case by case in terms of costs, existing resistance in the organization against TRIZ (for example due to unsuccessful prior experiences), level of TRIZ difficulty to be taught and finally, time that could be allocated for workshops. Ilevbare, et al. [9] recommends to come up with a standard for TRIZ and make a global platform for the exchange of information regarding TRIZ easier.

Innovation system in Finland

According to the formulated research questions, innovation system in Finland is further considered in the theoretical part of this paper in national, organizational, educational and individual levels. There are, however, similarities when scrutinizing the elements of innovation system, since these elements are parts of the national system and cannot be taken into account as absolutely separate components. To better realize the Finnish innovation, the general structure of the innovation system, government's policies to support innovation, innovation and research support by government, education and research effectiveness in schools and universities, and the specific factors affecting innovation in Finland, Finnish companies and individuals (skills and motivation in particular) are investigated. The Fig. 2 represents a simple overview of the innovation system in Finland, where the relationship between the elements of the system are demonstrated. The model has got similarities with the innovation model of Triple Helix, developed by Etzkowitz and Leydesdorff [27] where the government, industry and university are the core players of innovation in a country. The difference is that individuals are also considered in this model and government's policies are the base for other players' activities. The model has also got similarities with the one presented by Boly, et al. [28] in its top-down approach. However, that model has the focus on firm innovation. In this model we concentrate on the big picture of innovation system in Finland.

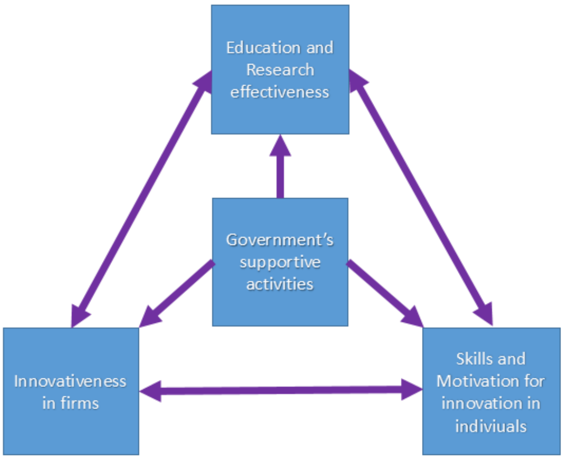

Fig. 2. Innovation system in Finland

In order to understand how the national innovation system in Finland works, we first clarify its main elements at macro level. A study by Woiceshyn and Eriksson [29] indicates that three organizations play the key role in funding innovation in Finland: The national Research and Innovation Council (RIC), the Finnish Technology and Innovation Funding Agency (TEKES) and the Finnish Innovation Fund (Sitra). The same study shows that these organizations contribute to Finnish innovation system by coordinating Finnish Ministry of Education and Ministry for Employment and Economy, providing initial investment funding for start-ups (Sitra) and funding research projects based on the collaboration between companies and universities (TEKES). Since 2014, TEKES has also taken the role of funding start-ups instead of Finnvera [30].

Innovation indices gap

There are various categories of indices to measure and evaluate innovation. Regardless of the indices used for measuring innovation, there is always input and output factors to determine the real innovation level. For instance, Jie, et al. [31] used R&D numbers, R&D funding and new developing projects as input and, number of patent applications and new products as output factors in their study on technological innovation efficiency evaluation in manufacturing industry in China. Adam [32] notices that even though the amount of expenditure on R&D activities in Finland is quite high (2.8 times the average in EU), the export of complicated engineering products and services is below the EU average. In this paper, we refer to Bloomberg's report in 2016 for the level of innovativeness worldwide, where 50 countries were investigated in the study. As mentioned before, Finland ranks the highest in European Union with almost 4% of GDP [32] considering the innovativeness factors of Research and Development intensity, and tertiary efficiency. However, the same report shows that Finland is not even among the top 10 countries as it pertains to Manufacturing value-added. To make matters worse, Finland stays in the 23rd and 26th places when it comes to High-tech density and Productivity factors. The statistics prove that despite the high ranks in input factors of innovation, the output indicators in Finland are low and far behind the most competitive countries such as South Korea, US and Germany.

There were different strategies in different junctures of time such as market liberalization and joining EU [29] Radical changes happened to the Finnish innovation system in 2008 when the government took new strategies. Blau [33] mentioned some of these strategies including tax reduction incentives, 'Demand Pull', where ideas are introduced to the market and users are a part of the innovation process, and attracting 'brains' from abroad. Recently, Finnish government has come up with new strategies, particularly in clean-tech and bio-economy that provides a unique environment and lots of green-field projects for innovation [30]. Another revision to the new strategy model regards the new funding system for universities and improvements to the quality and effectiveness of education and research in universities [30]. The very last strategy, however, faced difficulties in implementation in late 2015 because of economic crisis in Finland and the government decided to cut the universities budgets noticeably [34].

Finland, as mentioned before, has got one of the best education systems in the world [6]. There are, however criticism that universities are not effective enough in order to contribute to national, regional and industrial innovation system. For instance, a study by Montonen & Eriksson [35] demonstrates that Finland needs far more work to do to teach innovation in schools and universities and innovation should be based more on practice rather than teaching theories. They also suggest that the 'innovation practice' should be a continuous activity and it requires feedback from all the parties such as students, teachers and involved organizations. The continuity of innovation process has been emphasized not only in education, but also in organizations and companies, for instance in Bayhan, et al. [36] study.

After the division of the higher education system into universities and Polytechnics (also called Universities of Applied Science), enrollment for engineering and science and consequently attention to math's and natural sciences in schools increased and Finland is among the top countries in these fields [29]. On the other hand, a report from OECD [37] about Finnish innovation system, indicated that Finnish government was considering a jump to non-technical business areas and currently there is an emphasis on business fields such as social welfare [29]. This contradiction in strategic decision-making may have had detrimental effects on business atmosphere and employment rate in Finland.

Workplace innovation has become an attractive issue, especially in Europe since the start of the third millennium. Lorenz [38] believes that organizational innovation by national level policies in Nordic countries has been successful in terms of workplace innovation such as Value Creation (VC) programme in Norway, TEKES in Finland and VINNOVA in Sweden. A comprehensive quantitative research conducted in Finland by Kalmi and Kauhanen [39] based on some former studies, has got the following findings: First, differences in workplace innovations such as information sharing, self-managed teams and training result in positive outcomes for employees such as better job influence, higher salaries, risen job satisfaction. Training itself influences on increased job security and higher job intensity. Second, workplace innovation has got positive implication on employee performance and innovativeness. Third, employee participation in decision-making, high level of trust in Finnish society and high job security level have positive outcomes for workplace innovation.

Companies recruit employees that contribute to their level of innovativeness and competitiveness in the market. In order to be innovative, employees should be both motivated and skilled in thinking and creativity and, also be able to realize their ideas. As mentioned before, one of the main dimensions of being innovative for employees is to provide an appropriate and continuous trend of training in the organizations.

Studying in Finnish universities has its own privileges for students, especially for those enrolled in technical majors. For instance, students of engineering departments usually write their paid theses in collaboration with the Finnish industry. This strong tie is beneficial for them in gaining a unique experience before entering the labor market and provides a good opportunity in finding the right network for their future career. Another endowment of the Finnish society for individuals is the high level of trust in Finnish society that results in broader networks and collaborations [29, 39]

Based on the theoretical part provided in this sub-chapter, it seems that Finnish society, schools, universities and companies provide an appropriate atmosphere for individuals to contribute to innovation in different levels of the country. Especially, individual's motivation in being innovative seems to be high.

3 Methodology

The nature of the study required a descripto-explanatory research design and an interpretivism-realism research philosophy with an inductive approach to respond to the research questions. The research strategy to collect data was an online survey. There were three variants of questionnaires sent to the Finnish organizations and each organization were supposed to choose only one of the variants. The three different variants were if they had never used TRIZ in their organizations, if they used it at least once but they failed and they were not using it at the time they received the questionnaire, or if they were using TRIZ in their organizations. The questionnaires were distributed together by a short message in both Finnish and English as a guidance to choose the right questionnaire. In addition to the online survey, a short unstructured interview with an expert of teaching TRIZ in Finland was conducted.

In order to prepare the questionnaire, prior studies regarding TRIZ, other innovation techniques and also innovation system in Finland (the references cited in the theoretical part of this paper) were used. In contrast to the usual approach by questionnaires used for quantitative analysis, due to the research objectives these questionnaires included mainly questions concerning companies' behaviors towards innovation and TRIZ. However, some questions were provided by a Likert scale of 1-10 in order to make an assessment of the degree of challenges and strategies affecting the companies' innovative activities. Before sending the questionnaires to the Finnish companies, a pilot study conducted on a Russian company that was using TRIZ for their production as a strong tool for innovation. This was a base to double-check whether the questions were prepared appropriately and with true assumptions. The response from the Russian company proved that the questions were prepared successfully. Due to the restrictions on the paper length, the questionnaires and the interview of transcript could not be appended.

The study was cross-sectional, where the data was collected from the companies only at one juncture of time. For sampling, the first decision was not to limit the population by sector, industry, business model and so on and the goal was to collect as much data from Finnish society and business on innovation techniques (and particularly TRIZ) as possible. The Finnish journal of Talouselämä 500 [40] was used in order to prepare the list of Finnish organizations. At the first stage, the questionnaires were sent to 403 Finnish companies through email, contact details of which were collected through their official websites. Immediately, it was found out that we failed to contact 38 companies, because the email addresses were not updated. Therefore, the real number of recipients of the emails changed to 365. At this stage, we received 54 responses from small Finnish companies (the response rate of 14,7%) indicating that they had no innovative activities. This was the ground for reconsidering the first stage and within the second stage, the decision was that the focus should be more on the medium sized and large companies. The author contacted 67 R&D and Innovation Management departments through their emails and LinkedIn pages. At this stage, 10 participants filled out the questionnaires (the response rate of 14,9%). We also received a response from a large and famous Finnish company mentioning that they were not willing to reveal such information. The total response rate of the survey considering all the responses we received was 17,8%. Due to confidentiality of the data, the companies' names cannot be published.

4 Results

From the responses received, no company answered to the second questionnaire (a company that used TRIZ but then failed). The responses could be divided into two categories:

1. Those who were not using any innovation techniques in their companies or those whose innovation technique was not TRIZ, would be in the first category. This category consists of eight companies named A-H.
2. The second category includes those companies that were using TRIZ for their innovative activities. The second category comprises two companies named I and J.

First category

In the first category, companies were from very different sectors and industries including international trade, production, energy sector, packaging, industrial services and media. The respondents from management departments were aged from 35 to 62. All the respondents were from Finland and had higher education degrees in different fields. Three respondents said that they heard about TRIZ before the research. Five said that they use other innovation techniques, including Design for Six Sigma (DFSS) and KAIZEN. The Table 1 demonstrates a brief introduction to the respondents.

The respondents were then supposed to give their answers to the questions regarding the challenges TRIZ might have for them to be deployed in their companies, their perception on how beneficial TRIZ is and the strategies to make it work better. There was only one manager (C) who had not known about TRIZ before the survey and did not respond the questions. All other respondents who had no prior knowledge of TRIZ gave their opinions about the challenges, benefits and strategies regarding TRIZ.

As it pertains to challenges, it can be seen that four of the respondents (A, B, D and and E) who did not know about TRIZ in advance, answered to the questions whereas only one of the respondents who had heard of TRIZ before the research (F) filled out the questionnaire in an acceptable way. While considering the challenges these companies had for their innovation-based activities and their perception of TRIZ, two companies believed that their activities were so hectic that their employees and managers had no time for innovation-related discussions. Although only three managers had an idea of TRIZ, four managers considered TRIZ as an unnecessary method for innovations (including only two of those heard about TRIZ before). Three respondents said that TRIZ is a non-practical tool (including only one of the respondents who knew TRIZ in advance). Five respondents believed that the employees and managers' motivation for innovation was not high enough to be willing to participate in innovation or TRIZ discussions. Three respondents were of the opinion that their employees were not ready for innovation workshops and need basic introductions first. Two believed that there exist better methods and techniques (rather than TRIZ) for innovation. Four companies complained about the leakage of information in innovation discussions and one of the respondents said that TRIZ is not a suitable tool neither for hybrid offers nor for Finland in general. Further details of the responses can be seen in the Table 2.

Regarding the respondents' perception on how they can benefit from innovation and creativity techniques in TRIZ, it was found out that the majority of companies believed that TRIZ can provide them with competitive advantages, more effective idea generation, saving money and resources, better systematic thinking and problem solving and suitable for decreasing lead time. Two were of the opinion that they can benefit by more patents. Three mentioned TRIZ as a method for better teamwork and organization performance. Two thought that prediction of the future of technology and market would be easier by using TRIZ. And, only one believed that TRIZ helps to detect contradictions faster. The Table 3 represents the respondents' perception on benefits from TRIZ in details (the positive perception is marked by an X).

Finally, the strategies to better implement TRIZ techniques would be investigated. The majority of the respondents believed that more budget is required for universities and professionals to better train students and employees for innovation workshops. The Table 4 depicts how the respondents assumed the required strategies for better implementation of innovation techniques. As can be seen, most respondents assumed that joint workshops are useful for their activities. Four thought that motivation should increase in employees and managers for further innovation workshops. However, their opinions about whether to deploy professional consultants or develop workshops internally were quite diverse. We were also interested in knowing whether they would be willing to implement TRIZ workshops in future. Only two said (F and G) that they would like to use TRIZ in their companies in future.

The strength of the managers' perception on companies' challenges and recommended strategies were examined by a Likert scale. The aim of this triangulation was to give more value to the results. However, since the number of participants were low and there were missing values in the responses received (respondents' answers were quite subjective and thus, missing values could not be replaced by quantitative techniques), calculation of the mean value for different factors did not make much sense.

Table 1. General information of the first category respondents

Firm	Industry	Age	Nationality	Experience (years)	Education	Knew TRIZ before	Other methods
A	Trade	61	Finland	8	eMBA, TUT (Finland)	No	No
B	Energy	62	Finland	30	M.SC. in Technology	No	Yes
C	Packaging	49	Finland	20	M.SC., UTU (Finland)	No	Yes
D	Industrial Services	47	Finland	3	M.SC., University of Surrey	No	DFSS, KAIZEN
E	Production	35	Finland	10	M.SC. in Technology	No	Yes
F	Hybrid offers	39	Finland	9	PhD, Eastern Finland	Yes	No
G	Hybrid offers	54	Finland	5	PhD, Helsinki University (Finland)	Yes	DFSS
H	Media	55	Finland	33	B.SC. Helsinki Polytechnic	Yes	No

Table 2. Challenges of TRIZ

	Hectic activities of the company	TRIZ is not a necessary method	TRIZ is not practical	There exist better tools rather than TRIZ	Lack of motivation in employees	Employees need basic knowledge of TRIZ	Leakage of information is a challenge	TRIZ does not work for us	TRIZ does not work in this industry	TRIZ does not work in Finland
A		3			6	5		8		
B		8	7	8	4	3	8	4		
C										
D							8			
E	8	6	3		2		2			
F	10	8	1	6	4	5	2	4	4	1
G					5					
H										

1 strongly disagree
10 strongly agree

Table 3. TRIZ benefits

	Competitive advantage	Idea generation	patent	Money and resources saving	Systematic thinking and problem solving	Lead-time decrease	Future prediction of market and technology	Better teamwork	Detection of contradictions
A	X	X		X	X	X	X	X	
B	X	X		X		X	X		
C									
D	X				X	X		X	
E	X	X	X	X	X				
F	X	X	X	X	X				
G	X			X	X	X		X	X
H	X	X	X	X	X	X		X	X

Table 4. Strategies to better implement TRIZ

Company	More budget required	Increasing motivation	Skilled trainers and consultants	Internal development by R&D	Joint TRIZ workshops	Considering TRIZ workshops in future
A	1		6			
B	6	8	4	8	7	
C						
D		8			9	
E	8	9		9	2	
F	7				4	Yes
G	7			7	7	Yes
H	7	9	8	9	9	

1 strongly disagree
10 strongly agree

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Second category

In this category, those companies that used TRIZ for innovation-related purposes are investigated in more depth. The companies are among the largest Multinational Enterprises (hybrid offers of products and services) and have a noticeable number of patents per year.

Both respondents were from Finland, aged 27 and 48. Both had got a master's degree in science, but their work experience were obviously very different. Both mentioned that their companies got to know to TRIZ by the same consultant (they mentioned the name of the same consultant in the questionnaire) and also they had been developing it internally in their companies after the training. Both mentioned that they got their interest to further develop TRIZ in their companies internally after a seminar about TRIZ by the same. None of the respondents said that TRIZ workshops were used regularly in their company.

Company I believed that the only challenge they had been experiencing (from the list of challenges) for application of TRIZ was the hectic activity of the company and lack of time for employees and managers for those workshops and discussions. Company J however, had more challenges with TRIZ. The strongest challenges they had were the lack of motivation in employees, problems with readiness of the employees for TRIZ workshops and the risk of information leakage. The respondent from company J also thought that TRIZ might not work further in their organization or even in that particular industry that they were active in Finland. They added that there were several tools for innovation that employees and managers sometimes felt frustrated by their variety and made it difficult for any new innovation technique in their organization to be deployed. Finally, they said that in order to keep TRIZ in their company active, more efforts and stamina were required.

As it pertains to the benefits TRIZ had or might have for them in the future, both companies had a positive perspective of TRIZ in future. Both companies believe that they would have competitive advantages through proper deployment of TRIZ. Both agreed that they would have higher rate of idea generation, more patents registration, more effective systematic thinking and creativity, predicting the future of technology and market, better performance of the organization, better teamwork and faster detection of contradictions in future. None of the respondents mentioned that they had benefited or they might benefit from decreasing lead-time. Company J said that the motivation and work satisfaction were better in their company after TRIZ workshops. Both companies marked that TRIZ was a strong method for innovation for them.

The companies had also quite similar ideas regarding the required strategies towards better application of TRIZ both in their companies and generally in Finland. Both were of the opinion that:

1. More budget is required for them to further apply TRIZ in their companies
2. More budget should be allocated to universities for training the students of technical departments
3. More motivation is required for employees from managers

4. Customized TRIZ training is necessary for each company based on their activities
5. R&D departments should be responsible for TRIZ workshops after the required training in long-term
6. Joint TRIZ workshops are helpful in terms of atmosphere, information exchange and learning process.

Company J mentioned that some real life case examples and success stories were quite important to motivate the employees and managers to be willing to deploy TRIZ workshops regularly in their companies.

Interview

The interviewee, who had a long experience in teaching TRIZ in Finland, briefly mentioned that TRIZ cannot be considered a popular method for innovation in Finland. Yet, He was of the opinion that the horizon of TRIZ in Finland could be brighter than before.

"I conducted first TRIZ courses in Finland in 1985 and 1986. Small TRIZ activities have been here about 30 years. Today, when TRIZ has got much stronger, big activities may begin. We have been in first part of the S-Curve long time. Perhaps we soon will be in the growth part of the curve."

4 Discussion

We respond to the research questions based on the information received from the participants and from the interview. We compare the results with prior studies and discuss the respondents' answers in more details. Finally, we briefly analyze the robustness of the research by means of validity, reliability and generalizability.

As it pertains to the RQ1, it was understood that the majority of companies did not even hear about TRIZ and its position in innovation. This can be explained by many reasons including the responses received from small Finnish companies (concerning that the share of SMEs in Finnish society are quite high [41]), low response rate at the second stage, the secondary data from previous study [7] and the unstructured interview with the expert in teaching TRIZ in Finland. It is believed that overall, TRIZ is not a popular innovation and creativity method in Finnish industries. Although there might be some large companies that use TRIZ workshops and just did not have the desire to reveal the information to the authors, it can be assumed that most of the Finnish companies have not even heard about it. As it pertains to the education system, it was figured out that TRIZ is not a popular course in Finnish universities. By the time this study was carried out, there were only two research units in Finnish universities who were interested in TRIZ. This study, thus, confirms the literature and the secondary data used to conduct this research in that TRIZ is not a popular method for innovation management in Finnish industries and education system.

Considering the RQ2, this study confirms the literature regarding the possible challenges that one Finnish firm or individual might have while deploying innovation workshops and discussions (particularly TRIZ). The most important challenges found in Finnish companies were the lack of motivation in employees and managers, the risk of information leakage (by consultants, for instance), lack of the required basic skills for TRIZ workshops in employees and management assumption on that TRIZ is neither a practical nor a necessary method for innovation. These are obvious challenges that could be seen in all companies investigated. However, in some cases, one might argue that this resistance and inertia against a new method could be based on no reason and just the natural reaction of human being against change. For instance, the respondent from company B believes that TRIZ is a significantly unnecessary tool, non-practical and worse than many other methods, but the respondent had not even heard about TRIZ before answering the questions. To make matters worse, it was then marked by company B that many benefits and strategies are involved in its deployment and there is an obvious contradiction in the answers. There was only one company (C) who had no idea of TRIZ and did not provide any further details about its challenges, benefits and improving strategies which can be considered an acceptable reaction.

According to our data, the possible strategies to make TRIZ work in Finnish industries and education system (response to the RQ3), would be provision of more budget for Finnish industries and education system, increasing managers and employees' motivation, hiring experienced consultants and trainers for implementation of TRIZ workshops, assigning more time and hiring skilled employees in R&D departments for innovation by TRIZ method and organizing joint TRIZ workshops. Taking a look at the column about those who had heard about TRIZ before (see Table 1), it is understood that only those with PhD degree heard about it. The application of TRIZ in the second category including managers with M.SC. level of education does not necessarily mean that they first heard of TRIZ while they were studying. Especially, it is more likely that they got to know to TRIZ through the consulting sessions they had with the same trainer. The interesting point about this information is that TRIZ is not applied in any of the companies managed by those who knew TRIZ in advance. One was not willing to consider TRIZ in future, which shows the resistance against the tool. The other two considered TRIZ quite beneficial and commented on possible strategies. It is also likely that they did not have the required authority to to implement the tool. Therefore, manager's authority and risk-taking attitude on making such decisions should be taken into account as well. Finnish companies complained about the lack of budget for workshops. It is also understood that companies were willing to develop the method internally because of the risk of information leakage, but they needed the basic principles to ignite the procedure. The main key to this is to overcome the natural resistance against the method. The results of the second category shows that TRIZ was perceived as a strong method of innovation for those who implemented it. One solution would be regular TRIZ seminars supported by the big funders of the innovation system in Finland. This could be also an approach for companies and individuals to make a wider network and possible joint projects in future. Companies can participate and get to know to the method at the initial stage. After the initial stage, they can first implement the workshops together with consultants in their companies for their own specific needs in short-term and then deploy the method regularly in their R&D departments internally. From the education perspective, it is believed that universities should allocate more courses related to innovation and creativity techniques. The idea of including TRIZ in master's degree programmes is to eliminate the abovementioned seminars and workshops at basic level or to minimize the required time and resources for training. This training would be very sensitive and skilled trainers are required for this purpose, because if the primary training course is not interesting, then the subsequent trials could be of less value. Universities need more budget for innovation-related courses and it seems to be essential to pay a significant attention to the issue.

The basic idea of this paper was to disseminate innovation and creativity techniques and particularly TRIZ in Finnish society. Regardless of how useful it can be for a company in its application and outcomes, this method could be necessary for individuals. According to the Table 3 (especially, those who knew TRIZ), and the information provided from the participants in the second category, the managers' perception on TRIZ benefits included higher rate of idea generation, higher creativity in staff, more systematic thinking, better teamwork and more work satisfaction. These could increase the productivity of individuals and organization performance and consequently, the GDP of Finland.

Research robustness

Evaluating the robustness of the research seems to be challenging and might remain subjective. There are many missing values in the dataset and many questions and answers were related to the managers and interviewee's perception on TRIZ challenges, benefits and the popularizing strategies. Nevertheless, validity, reliability and generalizability of the study could be briefly analysed.

The answer to whether the research was reliable or not can be misleading. Some experts believe that reliability test in qualitative research could be irrelevant and misleading [42-43]. In our research, the research was cross-sectional and the test results on the same participants were not observed over time, hence test-retest analysis of reliability is not applicable. Conducting internal consistency test by means of Cronbach's alpha could be misleading, because there are many missing values in the dataset which cannot be replaced (because the values could be quite subjective). As can be seen in Tables 2 and 4, evaluating the Cronbach's alpha by calculating the average of the data in each row and variance on the factors in each column can be biased with the presence of many missing values (which cannot be replaced because of subjectivity).

Assessing the validity of the research could also be subjective, because the nature of the study is qualitative and evaluating whether the questions really measured the intended factor could remain subjective. However, it is still possible to analyse the validity by different validity criteria. The content validity, which evaluates the extent to which the respondents answered to what they were supposed to answer could be considered acceptable. Providing three different variants of the questionnaires (only relevant questions based on the prior studies by experts in TRIZ within each variant considering the challenges, benefits and strategies), the response to our pilot study and sampling strategies for choosing only innovation and R&D managers of large Finnish companies increased the content validity of the research. Due to the restrictions on the length paper and that we could not append the questionnaires, the analysis of construct validity could be quite subjective. Yet, from our point of view, the questions provided in the questionnaires (measuring tools) could be perceived as means of assessing what we were exactly looking for on manager's perceptions on TRIZ.

Based on the responses received from small companies, the overall low response rate and the results of the interview it is understood that the response to the RQ1 (TRIZ is not popular in Finnish industries and educations system) could be generalized for the Finnish society. The types of challenges, benefits and strategies presented in the Tables 2, 3 and 4 could be generalized to the Finnish industry, hence the response to the RQ2 and RQ3 could also be generalized to the Finnish industry. However, because of the low response rate and invalid information provided by some of the companies, more factors concerning challenges, benefits and strategies could have been discovered. The degree of the challenges and strategies could not be generalized.

5 Conclusion

Innovation-related issues have been paid significant attentions In Finland. Yet, there were very few prior empirical studies about the application of TRIZ and other innovation techniques in Finland in depth. This paper contributes to the fields of innovation management and systematic creativity (TRIZ in particular) by studying the application of TRIZ in Finnish industries and education system.

The research and the methodology used had limitations. Firstly, the duration of the research was limited to the summer time in 2016. A longer research could have provided higher response rate, especially that many managers were unavailable during the summer time. Secondly, the nature of the research, email and the questionnaires sent to the participants and fear of information leakage might have been reasons for them to avoid responding. Thirdly, contacting the participants through email and LinkedIn by the first author (only in English at the second stage) might have been a barrier. Fourthly, the lack of proficiency in Finnish language was a barrier to the first author of the paper. For instance, finding out a comprehensive information regarding the industry, sector or precise information about the companies' activities through their official websites was not possible. Finally, the improper design of the small Finnish companies' websites was a barrier to access the contact information of all 500 companies in the journal of Talouselämä.

The content of this paper could be a sign for the technical departments of Finnish universities to revise the curriculum in master's degree programmes regarding innovation. From the practical point of view, the Finnish Ministry of Education and Culture, TEKES and other funders of innovation system in Finland could assign the required budget to universities in order to teach TRIZ and other innovation techniques to students of technical universities. Besides, more budget is required for implementing joint TRIZ seminars for professionals in industries by skilled trainers of the field. Individuals in Finland and other countries can also benefit from this paper by orientating themselves towards more innovative and creative mindset. Finally yet importantly, since the lack of motivation is one of the reasons behind the unsuccessfulness of TRIZ in Finland, the roots of this problem (including possible unsuccessful attempts and stories or low quality of training and consulting) should be found out.

From the academic point of view, this paper could be a base for further research in innovation management in Finland and in countries experiencing the same difficulties with the output factors of innovation indices. To understand the extent to which the companies that use TRIZ or their own innovation techniques are successful, more quantitative research is required. Also, some other researches could be carried out to realize the diffusion of other systematic creativity techniques in Finland.

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TRIZ to resolve socio-technical contradictions within the product usage integration in design

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Abstract Actually, product usage is done very late after the prototyping step in the design process. In these last steps, use integration can cause contradictions between product performance and the respect of European directives and standards for product use. For instance, to fulfil the function "to cut" designers could propose many technical solutions like cutter, saw, laser, etc. As each technical solution is based on one type of energy (cutter is based on mechanical energy; saw is based on elctro-mechanical energy; laser is based on thermic energy, etc.) this must be taken into account. Moreover, cutter has a cutting edge and laser have a high temperature, for safety reasons, user must not have access to these cutting edge or to high temperature area. Therefore, designers propose some protection equipment that may decrease visibility and accessibility. In our article in TRIZ FUTURE 2015, we proposed a method to identify the socio-technical contradictions engendered by the product usage integration in the early steps of the design process. In this paper, we propose systematic method based on TRIZ to help designers to resolve these socio-technical contradictions. Our proposition enables designers to find out the potential problems before prototyping step that may occur during the product usage phase and to resolve them thanks to TRIZ.

1 Introduction

Product design has usually been based on the consideration of product function and structure. Designers rarely pay much attention to the behavior which derives from the function and structure. In [13], Gero defines the product or the system behavior, by behavioral variables describing the attributes that are derived or expected from the structural variables. Moreover, the structural variables describe the components of the product and their relationships. In this study the product behavior is considered from the technical point of view but the use of a product or a system is hardly taken into account in the final stages of design [1]. Many works are published on how to integrate user in design process using Reality virtual after the detail design stage where CAD model is already generated [14; 15; 16; 17; 18;]. At this stage, the costs of the modifications or design errors are usually very expensive and they may make the product (system) more complex [2]. It is commonly considered that the majority of the product cost is committed by the end of the design [3; 4].

To take use into account from design phase, designer has to answer the following additional questions early:

- What is the task that the system has to do to fulfil an automated function?
- What is the task that user has do to fulfil a manual function?
- What, how, for how much time is the interaction between the user and the system?
- How to characterize this interaction by defining the place, the duration, and the nature of the task carried out respectively by the user and the system?
- How to maximize the system global performance by minimizing the influence of user experience on the global system performance 7?

To answer all these questions, the designer applies standards voluntary; and stays free to choose any technical solution that provides compliance with the directive requirements [8]. He often uses compromise to answer partially all requirements. However, designer confronts with many contradictions to solve. We cannot detail the method because it is already in review for publishing in a scientific journal.

2 Objective

Using TRIZ [7] to solve contradictions resulting from use integration in early design phase is very useful. In [5] Sun presented the progress in the field of methods, and research development for integrating use into innovative design process. He discussed taking into account the user in engineering innovative design process and explaining why carrying out a socio-technical analysis hardly works on changing the design results. He illustrated how TRIZ can help effectively, designer to identify socio-technical contradictions. This type of contradiction is defined as every contradiction resulting from product or system interaction with its user to improve the global performance. However, Sun did not propose how TRIZ can help to solve this type of contradictions.

In this paper, we choose TRIZ theory's 9 laws of evolution to solve socio-technical contradiction to show its capacity to solve such contradiction. Where many scientific studies such as [10] evaluated the effectiveness of TRIZ compared to other methods of innovation. This same study shows the applicability of TRIZ in different cases: as in space applications where strong technical contradictions exist.

In the following paragraphs, we explore the laws of evolution of TRIZ theory in product innovation based on use integration in design process. After analyzing laws of evolution interpretation in use field, we use STEPS, a software based on TRIZ to solve socio-technical contradictions.

The TRIZ evolution laws are generally interpreted from a purely technical point of view. The socio-technical (practice) is considered late when solving problems and implicitly considered constraints.

3. Interpretation of laws of evolution for resolution of socio-technical contradictions

3.1 Increasing the degree of ideality of the system

This law approaches the Functional Analysis and Value Analysis, at least qualitatively, because these analyses help to define the character of the functions and to optimize them, especially eliminating of useless functions. Quantitatively, the ideality can be defined by the system performance and its efficiency. From use point of view, to facilitate the completion of task by a machine without stopping it or without using safety measures, increase the performance of overall system (the machine and its user). We note that, without sacrificing reliability and safety, this trend minimizes constrains in systems design and maximizes gains in usage. Thus, the first target value becomes the ergonomic efficiency measured by the mastered and intended use.

3.2 The completeness of the parts of the system

Any function requires to master, transform and transmit energy. Consequently, the evolution of a part is accompanied by an adjustment of other parts of the system. The user is part of the overall system and plays a role as other technical parts of the system in mastering, transforming and transmitting energy safely and in ergonomic conditions.

3.3 Energy conductivity of the system

A technical system must allow free passage of energy through all its components. The user can take the role of the motor that supplies power to the other components. He can also be considered as an energy converter, when the need to use another form of energy is required. For example, the user provides energy to transfer a workpiece between two machines in the same production cell.

3.4 Harmonizing the rhythms of parts of the system

A system only works if all its parties act in perfect synchronization where the frequencies and intervals actions are linked together harmoniously. The dynamic phenomena in the behavioral level as defined by Sun 1 and Gero [11] (user/machine interaction) translate into effects on performance, by impacts "global system" and thus failure modes or accidents. For example, the production rate of a machine must respect the capacity of the user and his capability.

3.5 Uneven development of parts of a system

The development of a system over time depends on the technological progress in S-curve of each subsystem and each technology used in the overall system to which user belongs. To increase the system performance, the most mediocre party is strongly encouraged to be improved. So improving the technical parts is limited to the user's ability to do his functions or tasks. For example, it is generally considered that old users are less effective when using computers compared to new generations. This shows that: keep moving forward in the technical part without accompany the user does not ensure optimal performance of the system. For example, Smartphones are used at least than 15% of their functions. In spite of all functions offered in these systems, the user does not use them all because of its level of maturity to use the data processing.

3.6 Transition to a super-system

This law concerns the further development of a system within a larger system which is the overall system (system and user) to improve its performance. Typically, this principle is applied by Dependability (RAMS) to greatly reduce the probability of the event of failure by implementing redundancy but also by complementarity between the technical system and its user [12]. For example, consider the driver, the car and the road to improve performance transport system.

3.7 Transition from macro to micro level

This law is the opposite process of the precedent one. It is a way to improve efficiency of the system during its development in going from macro to micro level. This law matches the principle of intrinsic prevention proposed by the standards of safety and ergonomics [19]. It is necessary to find the solution at micro-level. That means, to eliminate the component that causes a problem to the other parties and limits their performance. For example, a hazard defined by a hazardous area requires safety measurements. These safety measurements limit the accessibility of the user. This law calls for eliminating the hazard in the system to allow user to go through all necessary areas to enhance system productivity and consequently its performance.

3.8 Increasing the flexibility

To increase efficiency, rigid systems must become dynamic, i.e they must evolve towards a structure flexible, changeable and quickly to an operating system that adapts to changes in their environment. From socio-technical point of view the flexibility of global system increase by integrating user experience and flexibility to fulfill function and to increase global performance. User is known as most flexible part of system thank to his polyvalence.

3.9 Increasing the S-Field involvement

To increase system supervision, the reduction of human involvement with increasing automation is very visible in the current systems. This law aims to eliminate or decrease user role to reach auto-supervision level. Technical systems tend to operate increasingly in "closed loop" and therefore to be more controlled and regulated. This allows first to reduce the need for human intervention, and secondly to ensure the functioning of the system in various situations. This leads to the need to identify and control all system performance situations but also variances of these situations. All feedbacks show that automation systems have good performance when all usage conditions are fulfilled. However, when some failures or accidents happen, those systems become completely uncontrollable.

The limitation of these laws, from socio-technical point of view, is the difficulty to define the ideality of overall system (user and system) and to quantify the degree of its development in a timely manner (i.e. it must position itself among other systems that are supposed to illustrate a technological evolution or use).

We believe that the success of the approach is based on a gradual introduction and balanced by the socio-technological maturity of these ideas. For implementing a solution based on TRIZ, the condition for success is the maturation and prior scientific assessment of detected solutions to justify objectively in a trade-off.

These analyses of the evolution laws allow us to understand how we can integrate the user in finding superior performance for our product and system.

In the following sections, we show how TRIZ can solve socio-technical contradictions. So, we take the example the proposed by Sun, 5.

4. Solving socio-technical contradictions using TRIZ

In [5] Sun used TRIZ to identify socio-technical contradictions of a simple product the Binder clip (Figure 5). It is used for binding sheets of paper together and for preventing a book to be automatically closed. The method allows to identify in so simple product three contradictions:

The first one is a physical contradiction: the clip has to apply an enough force on papers to fix them. The clamping force must be high to tighten the papers but it must be as small as possible to easily open the clip by every user which can be a young girl in the primary school. So, for this contradiction to fix better the paper the force must be high and in the same time it has to be small to able user to open the clip.

The second contradiction is also a physical contradiction. When the user wants to fix more papers sheets the clip has to be large enough to tighten the all papers. In this case clip has a zone in which user can pinch his finger and heart himself. So Clip has to be large to fix more paper but also he has to be narrow to prevent user to put his finger in the dangerous zone.

The third physical contradiction appears when user use clip to fix a book open. If the book is very thick, clip will be very light to prevent book closing. Also, here there is a physical contradiction; clip has to be heavy to keep thick book opened and have to be light to be easy to use.

One of the added values of this paper is to develop a socio-technical analysis using STEPS to identify and solve socio-technical contradictions. So, we propose a method in 5 stages:

1- Problems and partial solutions graph

Here, we first identify problems (green rounded rectangles) and known partial solutions (orange shaped rectangles) and the cause-effect relationships between them. These problems and partial solutions are presented in figure 1.

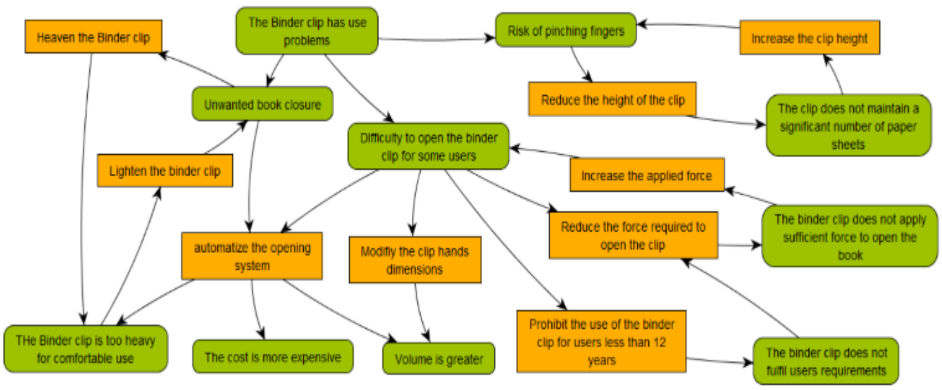
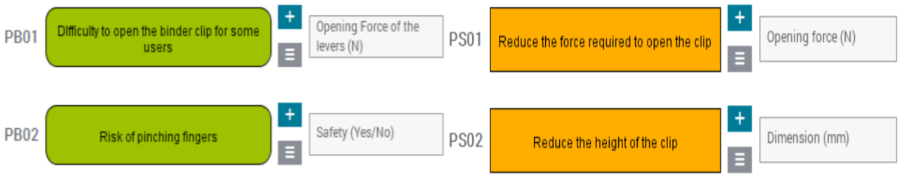


Fig. 1. Problems & partial solutions graph

2- Problems and partial solutions parameters

In this stage, we characterize each problem by Evaluation Parameter (EP) and each partial solution by Action Parameter (PA). An Evaluation Parameter is a measure of the importance of the associated problem. In Figure 2, we show the EP “Open force of the binder” of the problem "Difficulty to open the binder clip for some users". And also the problem "Risk of pinching fingers" is characterized by the EP

"Safety". An AP describes how its associated Partial Solution can overcome a related problem or improve the product performance regarding this problem. We



show the partial solution, "Reduce the force to open the clip" characterized by the AP "Opening force". We repeat this step for all problems and action parameters.

Fig. 2 Problems and Partial solutions parametrization

3- Analysis of poly-contradictions

At this stage, we identify different socio-technical contradictions. Here we outline the procedure for solving such contradictions by treating one of them: The Opening force contradiction. In figure 3, we see that when the force to open Binder clip is high the user has to apply a high pressure (not desired) and when this force is law the pressure exercised on paper is law (not desired).

Fig. 3 Opening force contradiction

4- Methods for resolution of contradictions

We focus on this socio-technical contradiction that must be resolved taking into account the 8 laws of evolutions one of TRIZ tools to solve physical contradictions. In Figure 4. So we show, as example, the use of law Energy Conductibility.

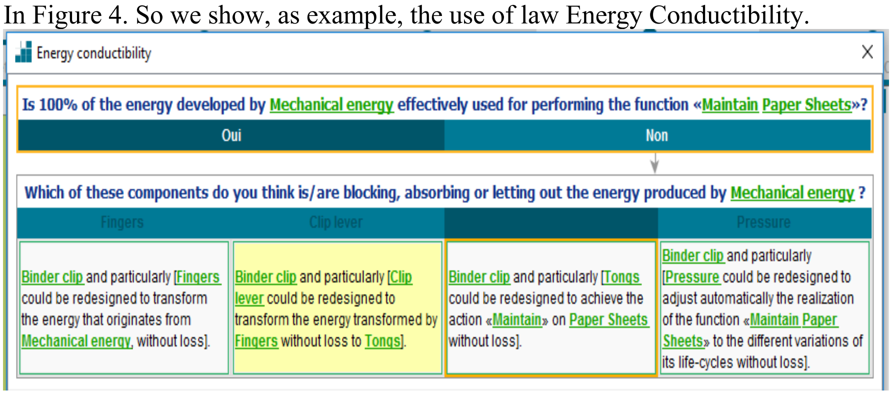


Fig. 4 Opening force Track

5- Conceptual solution generation

The law Energy Conductibility guides us towards the solution proposed in Figure 5 where we show the different forces and dimensional parameters that concern the binder clip operation and sketch of possible solution.

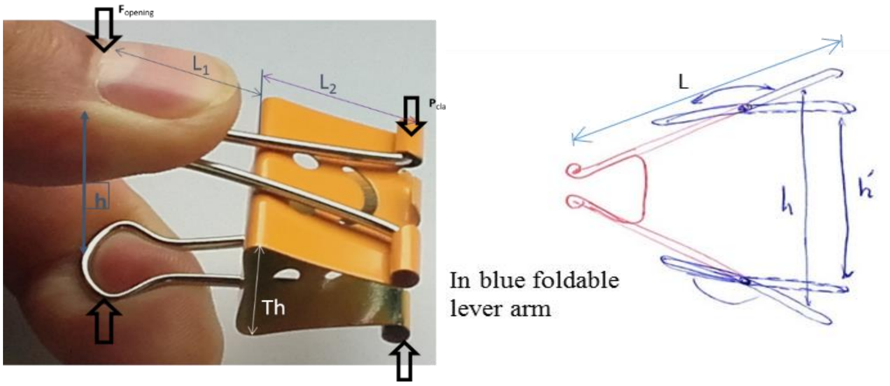


Fig. 5 the parameter taken into account to solve contradiction open force.

5 Conclusions and future work

The case study presented above shows how the laws of evolution of TRIZ and its inventive principles can be used to solve contradiction caused by the usage integration in the design phase. To illustrate, we limited ourselves to solve a socio-technical contradiction of the opening force of the binder clip. This helps identify at the earliest at the design stage the socio-technical contradictions associated with the use and leads to innovative solutions concepts to improve the use of products. The STEPS software we used in the study provides a structured process that facilitates a systematic convergence to solutions concepts. In this paper, we show how TRIZ can be used to solve socio-technical contradictions. The proposed approach takes account a count of the user and the constraints related to use of the product. In future studies, such an approach could be extended to analyze and solve the constraints of ergonomics [19].

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