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TOWARDS EVALUATION OF SOLUTION CONCEPTS IN INVENTIVE DESIGN

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Abstract: *Inventive design is a new approach to innovative product design generally based on the understanding of the initial problem, transform the problem into the form of a contradiction, and solve this latter by taking into account inventive principles and patents databases. In the end of the problem-solving process, several solution concepts that solve the initial problem are identified. These solution concepts resulting from the inventive design process using TRIZ (theory of inventive problem solving) tools are generally described in a declarative and simplified manner. In innovative product development process, the difficulty of choosing the suitable solution concept is generally faced. This paper presents a general idea for future research program to pro-pose a systematic method to evaluate solution concepts in conceptual stage of the design process so help the designers to choose an appropriate solution among others.*

Key words: *Solution Concept Evaluation, Inventive Design, TRIZ, Conceptual Design*

1. INTRODUCTION

Selecting an appropriate solution needs a deep analysis of design requirements and generating eligible solution concepts (SCs). These solution concepts are then evaluated by using different methods. The evaluation of solution concepts is an important part of concept generation in design process because of its effect on all following steps in terms of performance, quality, maintainability, cost, safety, etc., of the selected solution concept for development. than competitors. According to Bakerjian, R [1] by the time a product has been decided only about 8% of the total product budget has been spent. But by that point, the design has determined 80% of the lifetime cost of the product ,also shown in (Fig.1) by[2]. The design determines the manufacturability, and that determines a significant part of the introduction and production cost, the 80% of the product. Once this cost is locked in, the failure of a selected solution concept for development can barely be compensated at next phases of advance design and development by resulting to long time of redesign and rework expense without any solution and disadvantages of delay in commercialization of product. Cost effective works programs should initiate right from ate start of product design, because of its effects at later stages.

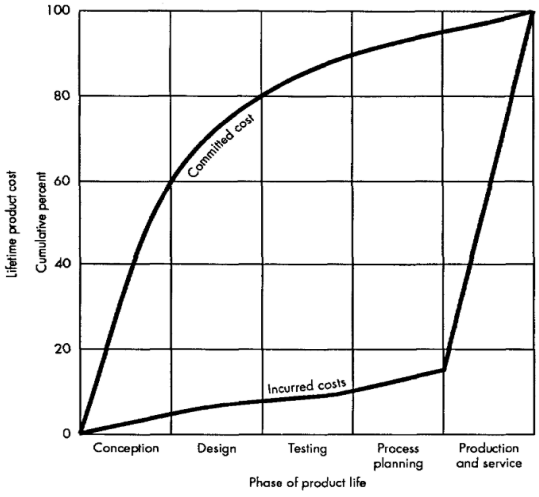

Fig. 1. Product Cost vs Time [2]

One of the toughest, critical and complex problems in inventive design process is the evaluation of best solution concept following

manufacture etc. [3]. Selecting the best concept to develop depends on designer ability and experience. Therefore, for the same problem, we can have many concepts and many criteria and select different "best-concept".

We are presenting a general idea for future research program in order to develop a method for evaluation of solution concepts in inventive design.

Keeping the aim of this research, a framework preferably a modern tool will be developed which will integrate designer, modern tools of solution concept generation like Inventive Design Method IDM and simulation software for evaluation as shown as a general idea in (Fig. 3). The modern TRIZ tools like IDM generate solution concepts using different TRIZ methods. With the help of our propose tool the designer will also take participation in the evaluation of generated solution concepts which can be analyzed using simulation software for visual representation of solution concepts before the embodiment design phase.

The section 2 of this paper presents background of TRIZ and inventive design method IDM, along with some introduction of solution concept, solution concept generation methods in inventive design and need for evaluation of solution concepts. Then in section 3, a general overview of the proposed method for evaluation of SC in ID is presented. Conclusion and future directions are presented in section 4.

2. RESEARCH BACKGROUND

2.1 Solution Concept in Inventive Design and Evaluation

According to Isaksson O. [4] despite their importance, there is not much attention to breakthrough technologies in engineering design. One of the reasons could be generally due to the unexplored link between engineering design and innovation. Several attempts have been made to define inventive design by both scientific and artistic terms. Inventive design is a thought-provoking engineering activity associated to all areas of human life. It follows the laws of science, fulfill the requirements for realization of a solution concept and needs professional integrity and responsibility [5]. It is an attempt to possible realization of concepts by meeting particular constraints [6]. Inventive design is acquisition of knowledge and capitalization [7]. Inventiveness here is in terms of invention which means "the action of creating or designing (something that has not existed before), typically a process or device" [8]. T. Chikatham one of the authors [6] compared inventive design and routine design as given in table 1: In Inventive Design, the contradicted features of a situation or problem by TRIZ tools is highlighted and these contradictions are then considered as a key source to solve problem.

Table 1

Inventive Design vs Routine Design [6]

Routine Design	Inventive Design
Manage what is known	Discover what is unknown
Optimization of existing data for best result	Moving further ahead from the optimized result of existing data
Accept compromise as a potential solution	Refuse compromise as a possible solution

With reference to the inventive design techniques like TRIZ (theory of inventive problem solving) where ideas are defined more properly than conventional terms of creative activities. Creativity has been considered as an integral part of design used for exploring creative ideas for solving problems as well as developing innovative products [9]. After going through properly defined process, creative idea is called "Solution concept" [10].

The first article on TRIZ was by Genrich Altshuller in 1956 [11]. Its application has been observed in various fields like technic, management, sociology, education and marketing [12].During 80s Altshuller work developed into a set of tools to carryout systematic creativity called TRIZ "Theory of inventive problem solving" and in 90s to OTSM "General theory of strong thinking" and ZhSTL "Lifetime strategy for creative person"[11]. With the passage of time due to widespread lectures and seminars of TRIZ by Altshuller and his team thereby new additions to TRIZ occurred: such as ARIZ inventive problem-solving algorithm developed during 1965 to 1985 [13]. Knowing TRIZ methodologies and to

use them will provide solution opportunities for one of the key problems in management of innovation processes that is the development of current technologies and analysis regarding the potential directions of their evolution [14]. Since 2000s TRIZ became research attraction especially for those who wants to publish their research results in scientific journals or other related forums. These publications as a result gave rise to organized data in order to understand TRIZ and its extension as IDM (Inventive Design Method). A concept of any product is a predicted representation of the shape of product, its working principles and technology. It is a well explained definition of product characteristics that indicates how the product will satisfy the customer requirements. Generally, a concept is considered as a sketch or 2D/3D model following a detail description [15]. The success of any product depends on the selection of best concept. Success here means the commercialization of a quality product. With reference to inventive design solution concepts, the arrival of TRIZ and its extension to IDM has been considered as a systematic methodology to produce set of solution concepts as compared to earlier unstructured methods [16].

A solution concept should be described in a concrete way using a description template. The description template for solution concept characterizes into five categories [17]:

1) an abstract of idea describing the general properties, all the relevant performing functions, extra note, merits/demerits.
2) A complete explanation of problem model (in which contradiction contain action parameter and evaluation parameter or SU-field model) and solution model (using tools like inventive principle, inventive standard, physical effect database).
3) Possible outcomes, trends and developments from the outcomes of related projects in term of hypothesizes and laws of technical systems evolution.
4) Keeping the objective of the project point out all the inacceptable conditions.
5) A sketch of the solution concept, which is synthesized by model of solution and hypothesis of solution concept. After the solution concepts are identified and ranked using Pugh's matrix by the inventive design methodology. The next step is the solution concept evaluation to select the appropriate solution concept to develop.

The evaluation phase of solution concept is the key challenge for the designers, as well as the customers. Particularly in solution concept selection phase qualitative methods are used to evaluate the generated solution concepts. Although, to facilitate the inventive design solution concepts evaluation steps, there are many methodologies used by designers and customers [18][19] [20]. However, these methodologies are generally described in a qualitative, declarative man-ner, which does not allow to choose the best solution concept neither to have a shareable formal or visual representation between partners of the project, like [21] gives principally relative judgements. Pahl & Beitz [22] use multicriteria methods to differentiate technical and economical values.

In inventive design the process stops after ranking of solution concepts and final selection of solution concept to develop depends on research and development (R&D) department or the top management of company. That is why, the absence of a confident model does not allow evaluation and compare competing concepts thereby making a challenge for researchers and designers to develop a confident model for evaluation of solution concepts in inventive. This research is continuation of an accepted research article in process of publication named state of the art for evaluation of solution concepts in inventive design [23]. (Fig. 2) shows the steps of IDM highlighting the need of solution concept evaluation model presented in the above-mentioned state of the art.

There are different methods exists regarding the testing of new product reliability, but these are not directly considered as evaluation methods, rather as validation methods. Some of important ones from these methods are Failure Mode and Effect Analysis (FMEA) and Fault-Tree Analysis (FTA) [24].

Given a review of prominent evaluation methods used in literature. Most commonly use method is Pugh's matrix [25]. Pugh's matrix uses a qualitative evaluation scale and compare solution concepts in a matrix format against a

number of performance criteria. Another similar method is numerical concept weighting by Ullman [26].

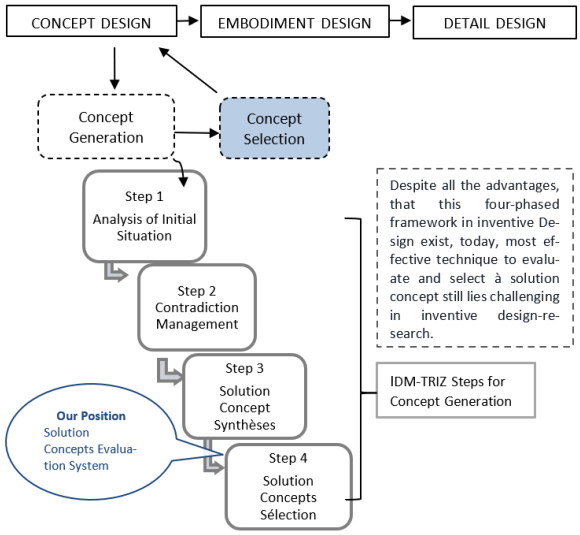

Fig. 2. Status of this research Proposed Model in the first phase of Design Process and in last step of IDM-TRIZ

According to Otto and Wood [27] solution concept selection is a process initi-ates with the identification of the criteria by which the solution concepts are evaluated. Multi criteria decision-making MCDM techniques like the Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) etc. that uses hierarchically related performance metrics. The common technique for these methods is to assign a value for each performance metric, weight the value by the importance of the metric, and then aggregate the weighted scores to con-vert multiple metrics into a single metric.

The selection of the concept is done by some method of evaluation that can be purely intuitive or based on some evaluation criteria or experiments. Honkala et al. [28] compared methods of evaluation and concluded that since different methods use different algorithms for ranking of solution concepts, the results may vary depending of the method used to make the selection. However, all the methods produce feasible solution concepts. As discussed above these methods are necessary since usually not all of the concepts can be prototyped. In this re-search, the focus is to make way to use modern simulation and virtual prototyping tools like CAD prototype mentioned [29] for evaluation and make use of a framework for integration of different solution concepts generation methods in-stead of using a single method. That is why, the absence of a confident model does not allow evaluation and compare competing concepts thereby making a challenge for researchers and designers to develop a confident model for evaluation of inventive design solution concepts. (Fig.2) illustrates position of this re-search in the steps of Design Process and in steps of IDM-TRIZ.

2.2 Concept Generation Methods in Inventive Design

In this section, related research development in the field of concept generation and how inventive design method use tools to develop solution concepts are de-scribed. A detail explanation of IDM work is given in [30].

With reference to inventive design solution concepts generation methods, the arrival of TRIZ and its extension to IDM has been considered as a systematic methodology to produce set of solution concepts as compared to earlier unstructured methods [16]. Several conventional, intuitive, discursive and automated solution concept generation methods have been created to help exploration of the solution concepts. Prominent inventive solution concept generation methods are categorized in two main types: Intuitive and logical [31]. Intuitive methods are based on provoking human mind creative thought techniques like the prominent methods of brainstorming [32], Gallery Method, Delphi Method [22] and Lateral Thinking [27] etc.

Logical method based on experience and scientific principles uses step-by-step problem synthesis to get close to feasible solution concepts. TRIZ, structured inventive thinking SIT [33] and Taguchi [34] are prominent logical methods for solution concept generation.

Modern tools usage for solution concept generation in inventive design has been increased in last two decades. An example of such tool is the TRIZ based Inventive Design Method by INSA Strasbourg with software tool like STEPS [35].

3 PROPOSED EVALUATION METHOD

Solution concepts are generated in conceptual design phase of design process. The conceptual design step starts with the description of the product to be designed and includes the steps of concept generation and concept evaluation. It is a well explained definition of product characteristics that how the product will satisfy the voice of customer. Based on the most relevant and latest research articles considered in the state of the art [23], we clearly identify the research gap regarding evaluation of inventive design solution concepts. More clearly stating that there is not any certain tool, model etc., for evaluation of solution concepts in inventive design to suggest a specific solution in the solution concept building phase or solution evaluation phase.

Selection of best solution concept is important as the embodiment design step is purely based on the selection of solution concept. During the design process also often there appears contradictions in some criteria. Therefore, once the solution concepts are decided. It is now important to have a model to select the best, optimize solution for implementation etc. Generally, evaluation methods for solution concepts are developed by using intuitive or logical techniques such as: Mind-Mapping, Forward steps, Morphological chart, Synectic thinking, Brainstorming, Taguchi, TRIZ/SIT [36].

Keeping in consideration the discussed methods and research gap from mentioned state of the art, it is easy to mention that in all the solution concept generation methods like IDM-TRIZ generate only list of solution concepts, and the final selection of SC to de develop depends on R&D department or top management of the company. Also, existing solution concepts generation tools follow only a single concept generation method like IDM follow TRIZ. The main work of this research is to propose a methodology and modern tool to integrate designer, concept generation tools and simulation tools at concept generation phase in order to give a visual representation of the solution concepts helping in evaluation of a solution concept to select best concept for development.

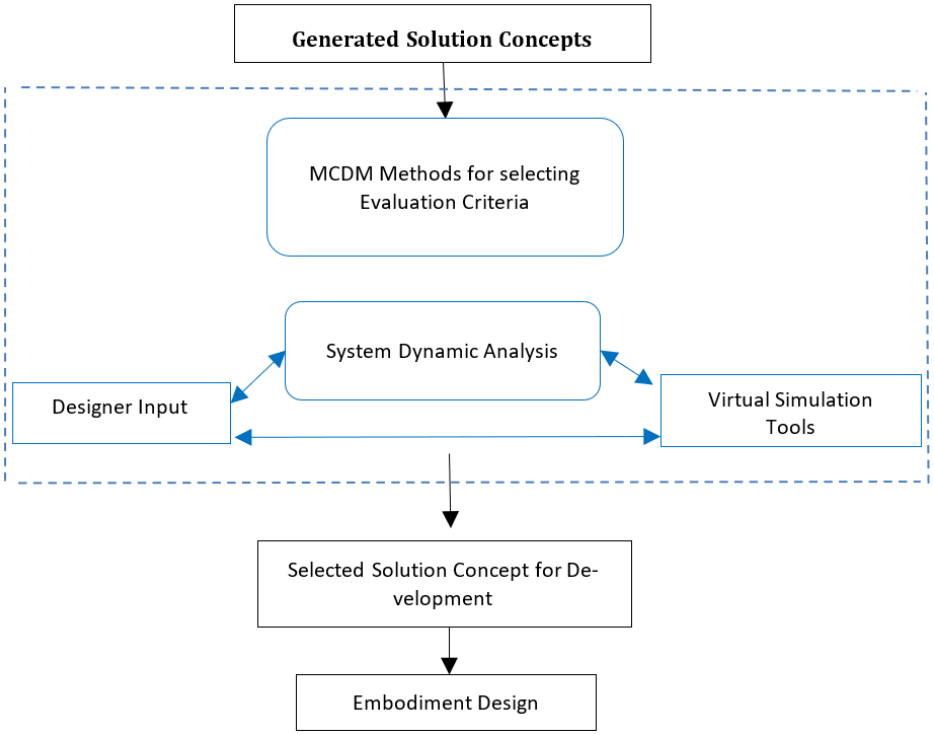

Fig. 3. Propose Framework for Evaluation of SCs in Inventive Design

In proposing general overview of a solution concepts evaluation method, we took inspiration from the Inventive Design Method developed in [18] for generation of solution concepts in inventive design. This research will be an addition to the previous research work of TRIZ extension as Inventive Design Method IDM that generates solution concepts for inventive design. The general proposal of this research is to make a framework for evaluation of solution concepts in inventive design.

As the conventional solution concepts are represented in description or numerical outputs which is not reliable, so this evaluation will be done by integrating solution concepts with modern tools of visual simulation for 2D or 3D sketch to consider designer inputs like whether the solution concept is acceptable or not with quickly assessment of concepts.

The designer interaction with solution concept generation tools will be done following some heuristics and the designer inputs will be use to search the best solution concepts. The general view of proposed framework is shown in (Fig. 3).

The integration of these various synthesis tools into a particular framework of solution concepts evaluation, which can provide an automatic evaluation and visual representation of solution concepts, is still missing which is focus of this research in future.

4. CONCLUSION

Evaluation in inventive design process provides a way to find the value, usefulness, or strength of a solution concept design with respect to a given objective. The purpose of the general proposed model is to future develop a framework for evaluation of solution concepts in conceptual design phase of design process, which will be able to integrate between designer, solution concept generation tools and simulation tools for evaluation and visual representation of solution concepts in inventive design.

The validation and applications of develop method will be illustrated through case studies so that the objective of the research is achieved i.e. to help designers in companies to choose an appropriate solution concept among others.

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Evaluarea soluțiilor de concept în proiectarea inventivă

Rezumat: Proiectarea inventivă este o nouă abordare a proiectării inovatoare a produselor, în general bazată pe înțelegerea problemei inițiale, transformă problema în forma unei contradicții, pe care o

rezolvă luând în considerare principiile inventive și bazele de date de brevete. În finalul procesului de rezolvare a problemelor, sunt identificate mai multe concepte de soluții care rezolvă problema inițială. Aceste concepte de soluții care rezultă din procesul de proiectare inventivă folosind instrumentele TRIZ (teoria rezolvării inventive a problemelor) sunt descrise în general într-un mod declarativ și simplificat. În procesul inovator de dezvoltare a produselor, dificultatea de a alege conceptul de soluție adecvată este în general confruntată. Această lucrare prezintă o idee generală pentru viitorul program de cercetare pentru a propune o metodă sistematică de evaluare a conceptelor soluției în etapa conceptuală a procesului de proiectare, astfel încât să ajute proiectanții să aleagă o soluție adecvată.

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