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Muhammed Irshad Yehya, Amadou Coulibaly, Hicham Chibane, Remy Houssin. Solution Concept Modeling and Evaluation Based on Function-Structure and Behavior Approach in the Context of Inventive Design. Creative Solutions for a Sustainable Development: 21st International TRIZ Future Conference, TFC 2021, Bolzano, Italy, September 22–24, 2021, Sep 2021, Bolzano, Italy. pp.456-464, 10.1007/978-3-030-86614-3_36 . hal-03412226

HAL Id: hal-03412226

<https://hal.science/hal-03412226v1>

Submitted on 2 Nov 2021

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Solution Concept Modeling and Evaluation Based on Function- Structure and Behavior Approach in the Context of Inventive Design

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Abstract. With the advancement in technology, market competition and globalization, innovative design processes are attracting researchers and designers more. There are many innovative methods upon which designers mainly depend on the initial phase of innovative concept generation. However, literature shows that these techniques have some research gaps in terms of the final evaluation and selection of best solution concept. In this study, we identify three scientific questions for evaluation method of solution concepts resulting from the TRIZ based inventive design method, first, how to define a solution concept, then a Function-Structure-Behavior approach for modeling solution concept. The proposed model is based on object-oriented modeling formalism. Then in future, using this solution concept modeling we will identify, analyze and classify evaluation criterion to evaluate solution concepts.

Keywords: Inventive Design, Solution Concept Modeling, Function-Behavior-Structure Approach

1 Introduction

Concept generation can be seen as a matter of generating, developing and communicating ideas, where ‘idea’ is understood as a basic element of thought [1] while solution concept (SC) is the final form of an idea that can be either visual, concrete or abstract. The evaluation and selection SC 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 SC for development [2].

The inventive design method IDM is a problem solving tool derived from the theory of inventive problem solving (TRIZ) with the intention to assist the engineers in inventive design process [3][4][5]. The TRIZ based IDM is 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. At the end of the problem-solving process, several SCs that solve the initial problem are identified [6][7][8]. After the generation of SCs the evaluation and selection phase is most

important phase as failure of a selected SC for development can barely be compensated at next phases of advance design and development by resulting into long time of redesign and rework expense without any solution and disadvantages of delay in commercialization of product than competitors [9].

Literature shows in various evaluation methods, mostly qualitative, the evaluation is done by identifying criterion from design requirements dominated by voice of customers and experience of decision maker [10][11][12]. Many researchers have developed different methods, to evaluate and select the more suitable SCs, including identifying evaluation criteria from concept of ideality [13], using functional ideal model and the algorithm [14] and by comparing Problem Model and SCs [15]. Recently Thongchai [8] used Design of Experiments (DOE) method to evaluate SCs from concept of feasibility. Besides this, selection of best SC is not easy, since the IDM provides a list of SCs and no further input to go for the selection of best SC to develop [16][2] resulting the final selection of SC depends on the R&D department or the top management of the 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 SCs in IDM. So, there is a need for an evaluation framework for SCs generate in IDM [16].

In our case of SCs, the evaluation step will be focusing on criterion related to TRIZ parameters. Keeping the evaluation research gap in view [16], in this study as a first step of SCs evaluation, we deal with the following scientific questions:

- Define what is a SC in a more general context?
- How SC could be represented?
- Define evaluation criterion?

In our case, we are mainly focused on IDM which is based on TRIZ theory. The generated SCs not only contain functional data, but also very likely to have data of behavioral and structural domains. So, we propose a FSB (Function Structure Behavior) SC modeling based on object-oriented modeling formalism. Further this modeling will be used to identify evaluation criterion using TRIZ parameters. Because of the importance of function, behavior and structure, there have been countless definitions, descriptions, and discussions on them in the research community. The Function Behavior Structure FBS approach initially proposed by [17][18][19] forms part of the research area in functional, behavioral and structural modeling, a general idea is shown in Fig 1. The FBS ontology is a design ontology that describes all designed things, or artefacts, irrespective of the specific discipline of designing. The propose method is different from others in TRIZ but not a novelty regarding Function-Behavior-Structure theory using in TRIZ as some researches have already used FBS and TRIZ by rewriting TRIZ principles based on FBS[20], using FBS for device functions clarification [21] or using FBS for TRIZ contradiction definitions [21].

This paper is structured as follows. Section 1 introduces SC and highlights the importance of evaluation and indicates the scientific questions. Section 2 presents our general work on SC modeling, highlights our position in IDM phases, and shows using FBS for SC modeling. Section 3 shows classification of TRIZ parameters with respect to function, structure and behavior domains. Finally, the conclusions and future perspectives were represented in the last section.

2 Solution Concept Modeling Using FSB

In proposing SC modeling, this research will be an addition to the previous research work of TRIZ-IDM that generates SCs for inventive design process[8]. The IDM is subdivided into four main steps shown in Fig 1: initial situation analysis, contradiction formulation, SC generation, and SC selection or evaluation [6].

In our research first how, we define a SC: A SC can be considered as a virtual product describes by words only, sketches only with no words, or a combination of words and sketches. It is just an idea which is not really realized in terms of product, but we can say that this SC has to full fill some functions. So, SC has already a functional dimension. Keeping this in view, in the case of IDM, SCs already consist of functions. SC modeling is a critical foundation for evaluation of SC. As we are mostly concerned with the TRIZ tools developed SC which is very near to product design concepts so for SC modeling we can use the product design concept modeling approaches such as Function Structure Behavior FSB approaches.

2.1 Function Behavior Structure Approach

There are many ways adopted in literature to model design concepts. The structural modeling of concept, named function structure [22] which defines all functions and relationships between functions and the relationships are defined by flow (material, signal and energy). This kind of model can be constructed based on the function tree [23]. Following this idea many structured methods developed consisting Function-Behavior-Structure (FBS) [24], Structure-Behavior-Function (SBF) and Function-Behavior-State (FBS) [25]. Following these different new methods [26] also proposed like “configuration flow graph (CFG). One of our author proposed and developed product modeling approach for behavior performance of product maintainability [27].

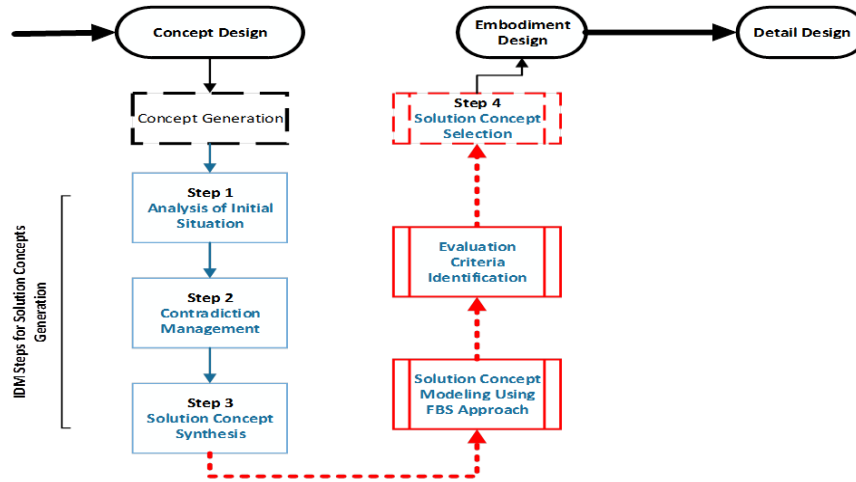


Fig. 1. Propose General Framework for Evaluation of SCs in IDM.

The FBS ontology is a design ontology that describes all designed things, or artefacts, irrespective of the specific discipline of designing. Its three fundamental constructs i.e., Function (F), Behavior (B) and Structure (S) are defined as follows:

- **Function dimension:**

Function is the explanation of the SC i.e., what the SC is for. This model deals with the conversion of the requirements into functions that the SC has to realize. Through Functional Analysis related functional specifications are identified. This diagram is helpful to explain the SCs main functions and the constraints to fulfill, etc., as it is used for related things in product design [28] .

- **Structure dimension:**

The structure part describes the different components of SC and states their geometry, topology, dimensions, and other physical properties. Using functional specifications and matching functions with parts or sub-assemblies the structural model is derived.

The structural view is similar to physical model [29]. This structural view represents SC information with a description of the physical realization of SC and is strongly related to the physical parameters.

- **Behavior dimension:**

In other words, like behavior is like consumption of inputs (stimuli) and production of outputs (responses). In conventional design engineering, the inputs and outputs that form behavior are flows of either mass, energy, or information. The SC behavior is like the degree and extent of response of a SC to stimulus.

The SCs generated in IDM already consists of functional dimension, further then these SCs may have a structure and then it may have some behavior. In terms of behavior what can be considered, like if you have the structure and the function then you may have different behavioral domains like efficiency, performance etc. And then what we really need to do is to define criteria with respect to these domains, that may allow us to distinguish between different SCs to evaluate. Satisfying functional requirements is one of the primary SC requirements. To achieve this, the behavior and structure of the SC often needs to be explored. Function, behavior and Structure the most fundamental and dominant concepts. Therefore, this research focuses on the Function, Behavior and Structure dimensions in SC modeling. A generic schematic of how our SC modeling is concerned with FBS dimensions shown in Fig 2.

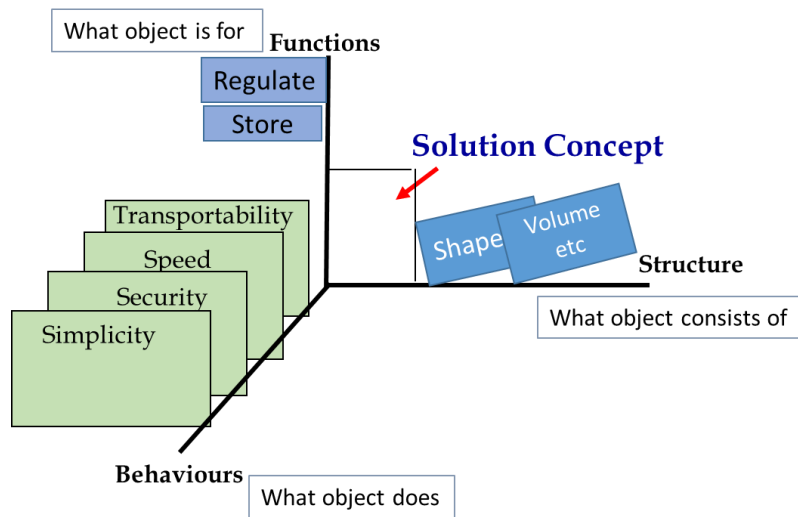


Fig. 2. Solution Concepts FBS modeling with focus on TRIZ Parameters.

2.2 Application of FBS for-SC Modeling

The general proposal of this research is to model SC making way for its evaluation. The Fig 1 also shows the position of our contribution to IDM in the first phase of innovative product design process indicated after step 3 i.e., solution concept synthesis. As stated in literature that with the four main steps, IDM develops a list of SCs and rank them using Pugh's matrix and there is no further input from IDM for modeling and selection of SC. This lack is encouraging our research to go for development of an evaluation method of SC. The output of SC modeling with FSB domains will be helpful in identifying the evaluation criteria of SCs. This last step is done by focusing on TRIZ process parameters.

The general implementation of proposed model for evaluation of SCs generate in IDM is shown in Fig 1. The SC modeling will be helpful to identify criteria for evaluation of SCs by focusing on TRIZ parameters.

The FBS representation of SC deals with the already generated SCs from IDM. So, the generated SC already has function(s). Then main step to follow is the collection of information to predict how a SC will behave and what kind of properties it will show in a particular context. Analysis and simulation are activities that are characteristics for this step. Analysis mainly focuses on estimation of the required behavior for SC and simulation to identify potential limitations or disadvantages. To be able to define the function, behavior and structure of a SC, we propose to use the TRIZ parameters.

3 TRIZ Parameters Considering FBS Perspective

Generally, a traditional TRIZ contradiction matrix consists of 39 improving and worsening parameters. In our study, we are using the extended parameters [30] consist of 48 parameters. Following these parameters, suggests different kinds of solutions to a technical or socio-technical problem, that, according to our opinion, they can be extended thinking the parameters in terms of function, behavior, structure of a SC. Characterizing the TRIZ parameters based on FBS makes the user aware if he is acting on the function, on the behavior or on the structure of the SC. By analyzing the parameters with the FBS approach, we can see that most part of parameters can be extended to structure and behavioral directions which could be used as criteria. In Table 1 we characterized and classified TRIZ parameters in the three defined dimensions: function, structure and behavior.

As a next we need to define a set of parameters to describe the SC function, behavior and structure parameters in terms of TRIZ parameters. So, we propose to future generate a set of related criteria for evaluation focusing on TRIZ parameters. This means we need to present the SC in terms of FBS model and by use of TRIZ parameters to identify relevant domain parameters of SC. Once the parameters are defined, we use it to define evaluation criteria and by using multicriteria decision methods the best SC to be identified depending upon the situation given. As the current research is in process so the details of how criteria identification from TRIZ parameters table is not mentioned here.

Table 1. TRIZ Parameters and their classification in terms of Function, Behavior and Structure.

Sr.	Parameters	FBS Domain
1	Weight of Moving Object	Structure
2	Weight of Stationary Object	Structure
3	Length/Angle of Moving Object	Structure
4	Length/Angle of Stationary Object	Structure
5	Area of Moving Object	Structure
6	Area of Stationary Object	Physical Parameters
7	Volume of Moving Object	Structure
8	Volume of Stationary Object	Structure
9	Shape	Structure
10	Amount of Substance	Structure
11	Amount of Information	Structure
12	Duration of Action of Moving Object	Behavior

13	Duration of Action of Stationary Object		Behavior
14	Speed		Behavior
15	Force/Torque		Behavior
16	Energy Used by Moving Object		Behavior
17	Energy Used by Stationary Object		Behavior
18	Power	Performance related	Behavior
19	Stress/Pressure	Parameters	Behavior
20	Strength		Behavior
21	Stability		Behavior
22	Temperature		Behavior
23	Illumination Intensity		Behavior
24	Function Efficiency		Function
25	Loss of Substance		Behavior
26	Loss of Time		Behavior
27	Loss of Energy		Behavior
28	Loss of Information	Efficiency related	Behavior
29	Noise	Parameters	Behavior
30	Harmful Emissions		Behavior
31	Other Harmful Effects Generated by System		Behavior
32	Adaptability/Versatility		Behavior
33	Compatibility/Connectability		Behavior
34	Transportability		Behavior
35	Trainability/Operability/ Controllability		Behavior
36	Reliability/Robustness	ility (Reliability, Durability related	Behavior
37	Reparability	Parameters)	Behavior
38	Security		Behavior
39	Safety/Vulnerability		Behavior
40	Aesthetics/Appearance		Behavior
41	Other Harmful Effects Acting on System		Behavior
42	Manufacturability		Behavior
43	Manufacture Precision/Consistency		Behavior
44	Automation	Manufacture/	Behavior
45	Productivity	Cost Parameters	Behavior
46	System Complexity		Structure
47	Control Complexity		Structure
48	Ability to Detect/Measure	Measurement	Behavior
49	Measurement Precision	Parameters	Behavior

4 Conclusion and Future Perspective

This paper presents an approach to undertake in future, application of TRIZ parameters and brings some new insight into the SC modeling and FSB approach. It makes the idea that designer can evaluate the performance of a SC in each specific domain by defining

criteria, from TRIZ parameters. The general proposed SC modeling approach focuses on giving the SC a functional, behavioral and structural dimensions. The research is in process and after the completion of the model, this will help in identifying various evaluation criteria of SCs from different dimensions of FSB and in different domains of application.

In future, work illustrating the detail steps showing the applicability of TRIZ parameter tables for criterion and feasibility of our proposed model with case study for evaluation of SC will be done. Also, we work to refine our analyses and classification of TRIZ parameters in terms of FSB approach (Table 1). We have another challenge which is how to extract evaluation criteria from TRIZ inventive parameters in function of domain in which SC will be developed.

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