The Importance of Preparing Customized TRIZ Matrix to Accelerate the Innovation for Design Buildings

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Abstract. This paper shows that the Lack of TRIZ implementation in the Construction industry is significant. Establishing specialized contradiction matrices extracted from TRIZ could help the designer solve further innovative proto-types than standard TRIZ. In this trend, some of the principles are more serviceable and more meaningful than the other principles that persuade us to recommend and highlight this research gap. Numerous papers have been written about TRIZ, but a restricted number of these essays are about the construction industry; especially in architecture and building manufacturing. The suggestion is that presenting a detailed methodology for invention in the construction industry's architectural field is remarkable. This paper focuses on several papers' literature reviews that helped us find our research gaps and research problem. Utilizing TRIZ can escalate the construction process's technical innovations. The utility of TRIZ directly in the building design process is not easy. In some fields, researchers extracted Eca-Triz from the original TRIZ, but Eca-Triz is not practical in the building design process [1]. So, establishing a customized contradiction matrix that has been extracted from the original TRIZ for building design is essential and valuable as a future work. Construction experts do not utilize formal or systematic design approaches in most cases. This circumstance results in several drawbacks (for a typical case, it is time consuming to discover an innovative and suitable solution). A systematic innovation approach could suggest to avoid such minuses that came out of TRIZ.

Keywords: TRIZ · Customized matrix · Design building · Innovation · Architecture

1 Introduction

TRIZ is the Theory of Inventive Problem Solving, a creative and innovative approach to problem-solving, which means problems can be solved by applying new ideas based on data and logic. [2]. Briefly, when an innovator wants to resolve a problem, he must procure an innovative approach to improve an element that will worsen another parameter. In other words, the inventor's innovatory solution has to endeavor to diminish or eliminate

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the worsening trend in another factor while improving one factor. Altshuller had several books, seminars, and articles, but he is famous because of his TRIZ contradiction matrix [3]. Since 2000, There has been much research in different fields utilizing TRIZ to find inventive solutions. Based on SCOPUS, the percentage of papers in the construction field that includes the word TRIZ is about two percent out of all TRIZ papers in all fields. Therefore, the lack of innovation in the construction industry is obvious. Various articles have been investigated with the keyword TRIZ, but the primary challenge is that when the search has limited to the words: construction engineering, architectural engineering, and building among TRIZ articles, the quantity of articles dramatically decreases. Furthermore, this limited collection of articles has either done joint work between QFD and TRIZ or presented examples of the usefulness of TRIZ. However, none of them has done straightforwardly preparing a special matrix for architectural engineering. Number 4 article is the only paper that worked on a multi-piece wall panel [4], which also did not work on specialized matrix. Rather, he has studied the exportable building that contains a segmented wall panel with the combined QFD and TRIZ methods, which also has differences from our proposed research. When numerous keywords have been examined, many articles have been founded, which have been supposed similar to current research in a glance, but the contrasts have been evidenced when the article's text has been read. Intact, there are a few papers like papers [5, 6], but they have not done a customized TRIZ contradiction matrix. The building and construction industry falls behind some other sectors (such as computers, IT, software, electronics, mechanical engineering, automotive industry, etc.) [2, 7–11]. Innovation can be explained as "the successful exploitation of new ideas" [2, 9]. The modern building industry is eager to use inventive design rather than traditional approaches to be more flexible and competitive in the novel construction market. The significance of building industry organizations' innovations is tremendous. Construction innovations can be appointed as a fourth dimension (4D) in the time ahead, parallel with the standard dimensions of time, cost, and quality. So, these companies could profit from market economy changes [12]. Observing the research mentioned above proved the significance of current research.

2 Literature Review

2.1 Lack of TRIZ Implementation in the Construction Industry

TRIZ has not been used vastly in developing new techniques or production in the industry. In other words, the lack of persistent and factual utility of TRIZ, an innovative approach to producing new products and designs, compared to its innate potential is significant [13–16]. Since 2000, There has been much research in different fields utilizing TRIZ to find inventive solutions.

Superior building artifacts must be innovative to be appointed as formidable on the market in performance, time, and cost-effectiveness. Furthermore, in a survey, 100% of respondents judged that innovation is pivotal for construction [17]. There are innumerable surveys, research, and literature regarding innovation in building or structure, and approximately all of them announce that innovations are essential in the construction field. Nevertheless, the question is how someone can become innovative. Utilizing TRIZ can escalate the construction process's technical innovations [18].

Construction experts do not utilize formal or systematic design approaches in most cases. This circumstance results in several drawbacks (for a typical case, it is time consuming to discover an innovative and suitable solution). A systematic innovation approach has suggested avoiding such minuses extracted from TRIZ. The procedure has 5 principles entitled "pillars": contradiction, resources, function, interfaces, and ideality [19].

2.2 Some Case Studies that Utilized TRIZ in the Construction Industry

The need for preparing specialized hypothesis for organizing innovation enhancement in the civil engineering field is obvious. Innovation is an essential side of the enrichment of construction techniques, but most procedures are based on the trial-and-error method. The Utility of TRIZ in discovering innovative solutions in Construction has been done in some subjects like tunnel construction [20, 21]. There are assorted articles in various construction fields, such as TRIZ in Evolution of Construction Techniques and Technologies [22–24], TRIZ in the Design of Construction Materials and New Structures [25–27], TRIZ in Value Engineering, and Construction Project Management [28–30]. However, a minimal number of them are relevant to our prospective research that I will particularly focus on them in the following chapters. Likewise, the innovation platform has been formulated by considering construction patents, and it gave more opportunities for obtaining inventive solutions in some sectors of this field [31].

Several design theories such as C-K theory, Coupled Design Process, Axiomatic Design, General Design Theory, Infused Design, and TRIZ are available.

Most of the theories are limited, which leads to inflexibility in the design process except for TRIZ and CK theory. TRIZ has principles for problem-solving and has special utility for our project. So, I choose TRIZ for our project. Ck theory is also an innovative design method, but it is needed knowledge and concept, and its knowledge is expanded during the design process. However, because CK theory could not solve our problem, we use TRIZ principles to solve our problem step by step.

None of them except TRIZ has compared 40,000 inventions to produce a matrix such as a TRIZ contradiction Matrix.

TRIZ has forty inventive principles extracted from 40000 inventions and should lead to solutions, especially in our case studies.

2.2.1 Case Study 1: The Implementation of the Theory of Inventive Problem-Solving in Architecture

In this article, TRIZ has been utilized for constructing a building more accessible for individuals with disabilities. A tool developed by Kishinev School of Moldova, the Innovation Situation Questionnaire (IQS), has been used to subdivide the problem into subproblems. The Problem Formulation Process (PFP) and inventive principles (MIP) tools have also been used with the contradiction matrix to find possible inventive solutions. Ultimately, the novel TRIZ contradiction Matrix was utilized to obtain solutions [32].

Table 1. Summarized Contradiction Matrix [32].

study					
FEATURE TO IMPROVE		UNDESIRED RESULT			
		...	PR-13 STABILITY OF THE COMPOSITION	...	PR-39
...	...				
PR-36	COMPLEXITY OF OBJECT		**IP-2, IP-22, IP-17, IP-19**		
...	...				
PR-39	...				

As it has been illustrated in Table 1, the principles IP-22 (convert harm into benefit), IP-2 (extraction), IP-19 (periodic action), and IP-17 (moving to a new dimension) have been extracted from the Contradiction matrix TRIZ. From the aforementioned principles, two of them (IP-22, IP-17) guide to results.

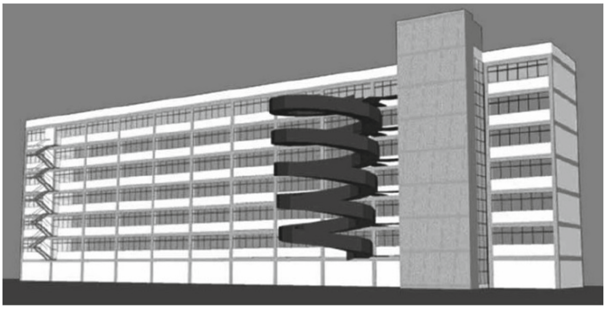


Fig. 1. TRIZ, IP – 17 application in the footbridges [32].

In Fig. 1, by inspiration from Principle IP-17, Spiral forms has been suggested for footbridge ramp [32].

2.2.2 Case Study 2: Development of an Exportable Modular Building System by Integrating Quality Function Deployment and TRIZ Method

The purpose of this article is to examine Quality function deployment and the use of the TRIZ technique in the manufacturing business. These solutions are exceptionally efficient in reducing costs and enhancing quality. In contrast to the regular manufacturing process, manufacturing and exportable modular construction systems include several concurrent subprocesses. Therefore, there is a limit to the efficiency attained if one of these approaches is used straight to product development. To solve this issue, the authors propose a novel technique that combines TRIZ with the deployment of quality functions. According to the findings of a case study, it is feasible to lower the volume of an exportable modular construction system compatible with ISO container shipping by 48% and the weight of structural steel by 30 percent by using the new approach [4].

Table 10. Solution Derivation for F01-02

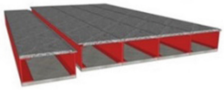
Level 2 function	Form outside the module	
Level 3 functions	F01-2-A column, F01-2-B beam, F01-2-C Floor panel, F01-2-D Wall panel	
Solution derivation using contradiction matrix	"Principle 1: Segmentation": All components need not be delivered as a unit module. The building can be segmented into modules and non-modules. Components other than the modules are manufactured as columns, beams, floor panels, and wall panels. Modular units are offset stacked, with non-module components installed between modules. "Principle 31: Porous materials": Segmented components are loaded into other modules and delivered to the site. A modular unit is used as the porous material.	
	Segmentation of floor and wall panels	Load components inside other modules
	 Segmented floor panels  Segmented wall panels	 Loading segmented components into other porous modules
Design factors	Design span between modules for site installation of panels shorter than 5 m. The size of panels is determined considering the possibility of loading inside the modules.	

Fig. 2. Segmented wall panels [4].

As it has been illustrated in Fig. 2, On page 540 (JAABE vol. 16 no. 3 September 2017) in [4], the author (Seri Oh et al.) have used segmented wall panels for the Exportable Modular Building System, but it is just for transportable building design, and it is not what exactly we are going to do.

In Kiatake, M. and J.R.D. Petreche article, these following future works is mentioned:

"1 - Case studies of MIP applications to completely new design projects;
2 - Case studies of other TRIZ tools with experimentation in the Architectural design field;
3 - Studies on the interface of the TRIZ methodology and multi-criteria decision-aid methods;
4 - Development of architectural knowledge databases and design of computational support tools;
5 - Creation of a structure of the TRIZ theory concepts for application in architectural design education" [32].

These are the research gaps in TRIZ theory, precisely in the building and architecture industry, which shows our research problem and research gap. It is a worthwhile idea to adapt TRIZ to the conservative field of study like Construction and do some investigations to verify its performance.

In this context, TRIZ would be applicable more straightforwardly in the construction industry. To support this proposition, we can declare some comparable case studies have been done in papers [33–37] in other fields such as Redesign Service, Process Engineering, Quality Improvement, Related Context, and Electric Energy Storage Systems.

2.2.3 Case Study 3, 4

In a thesis, the author gives a number of examples demonstrating the effectiveness of TRIZ in underground constructions. The majority of case studies have been derived from real-world circumstances, and it has been shown that TRIZ methodologies aid in achieving creative conceptual outcomes. On the basis of TRIZ, a design framework for the technological innovation platform has been suggested by using patent knowledge in constructing projects. Some of the TRIZ concepts have not been used at all, whilst others have been used repeatedly [20].

After 3 years, the same author justified the advantage of TRIZ and its serviceableness in the Construction tunnel industry. Moreover, he did not consider the most suggestive principles in a customized new contradiction matrix to accelerate tunnel construction innovation by this methodology [20, 21] (Table 2).

Table 2. Contradiction matrix sample [21].

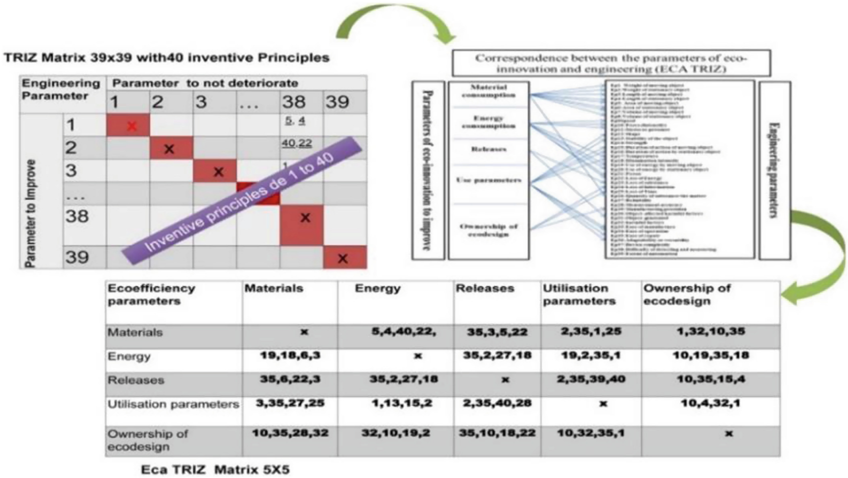
Parameter to be improved	Engineering Parameters	Parameter that is getting worse: 27 Reliability	28 Accuracy of Measurement	29 Accuracy of Manufacturing	30 Harmful factors acting on object from outside	31 Harmful factors developed by an object
23	Loss of Substance			35, 10, 24, 31		
24	Loss of Information					
25	Waste of Time	10, 30, 4	24, 34, 28, 32	24, 26, 28, 18	35, 18, 34	35, 22, 18, 39
26	Amount of Substance			33, 30		
27	Reliability	Physical Contradiction		11, 32, 1		
28	Accuracy of Measurement		Physical Contradiction	-		
Resolution Principles		23) Feedback 24) Intermediary 25) Self-service		26) Copying 27) Inexpensive short-lived objects 28) Mechanics substitution		

2.2.4 Case Study 5

Eca TRIZ has been suggested as a methodology to resolve some contradictions in eco-design. This methodology aims to aid small and medium-sized enterprises (SMEs) in developing products that will enable them to reach their eco-innovative goal. A qualitative matrix will enable the prioritization of all environmental impacts. Implementing the creative TRIZ principles on an individual basis will aid the researcher in selecting eco-innovative solutions. Based on an original contradiction matrix, a unique technique called

Ecatriz (ecology-friendly approach TRIZ) has been developed. It has been studied in various situations, including the "24 h of Innovation" competition and eco-innovative patents [1] (Table 3).

Table 3. The approach to obtaining the Ecatriz matrix [1].



Ecoefficiency parameters	Materials	Energy	Releases	Utilisation parameters	Ownership of ecodesign
Materials	×	5,4,40,22,	35,3,5,22	2,35,1,25	1,32,10,35
Energy	19,18,6,3	×	35,2,27,18	19,2,35,1	10,19,35,18
Releases	35,6,22,3	35,2,27,18	×	2,35,39,40	10,35,15,4
Utilisation parameters	3,35,27,25	1,13,15,2	2,35,40,28	×	10,4,32,1
Ownership of ecodesign	10,35,28,32	32,10,19,2	35,10,18,22	10,32,35,1	×

Based on these researches, we found that producing the customized contradiction matrix as the methodology in the architectural building design process with moveable walls would be a fascinating research gap that we can fill and add value to this field in the future.

3 Result

Previous surveys have concentrated on the efficacy of TRIZ in design various construction industries slightly and not on How to operate TRIZ to consider better the different customer needs base on considering customer elections by utilizing various architectural plans in the same apartment. TRIZ is one of the essential tools in the innovative design process. Especially for decreasing the cycles of design that is required to finalizing the architectural plan design process.

In other words, there are so many varied architectural plans that can be drawn for a unique apartment. How could we suggest an approach or tool that can provide different plans faster during the life cycle without wasting too much budget and time in renovating the apartment based on the new tenant's preferences? Consequently, this will diminish the price of the nonessential renovation of a building for interchanging its plan. The specialize matrix that could extracted from TRIZ could help the designers to accelerate the process of innovation in their design process.

4 Conclusion

Using TRIZ matrix in the building design process, the first challenge is that the plans produced right now by computer programs like Revit cannot consider all the needs of costumers perfectly. Moreover, when the property owner wants to rent out one apartment to a tenant. There are several choices for a tenant. Some tenants prefer a one-bedroom apartment rather than two bedrooms. Some others prefer to rent out two bedrooms or a studio without a bedroom, thinking about the problems and their possible solutions through the contradiction matrix Altshuler is significant. The main objective is to prepare and fulfill table by its 7 steps and prepare a specific contradiction Matrix extracted from the original TRIZ contradiction Matrix to accelerate the design process with more inventive solutions in the upcoming paper.

5 Future Works

As a future work, we will fulfill Customized Matrix and choose the most repetitive and relevant TRIZ principles to put in every part of this Matrix. Therefore, we hope that the work will become more specific, and fascinating results will be achieved by completing the specific contradiction matrix extracted from the original TRIZ matrix for building design process.

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