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Applicability of TRIZ to In-Situ Construction Techniques

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Abstract. "TRIZ" is the (Russian) acronym for the "Theory of Inventive Problem Solving" which was developed by the Soviet engineer and researcher Genrich Saulovich Altshuller. TRIZ is a methodology for problem-solving and forecasting in innovation, based on logic and data. In the study the applicability of TRIZ method to in-situ construction techniques of architectural components is investigated. There are three main factors affecting the productivity of a construction: quality, cost and time. In this context, improving the quality of the construction technique for wood joint fixing is defined as a problem to be tackled. The defined problem is solved with TRIZ method considering "construction time" and "strength" criteria. For assessment of the method, construction process observation and compressive strength tests are carried out. In the context of the study, it is seen that the TRIZ method is applicable to in-situ construction techniques of architectural components.

Keywords: quality, productivity, TRIZ, in-situ construction techniques, construction process, architectural components.

1. Introduction

Construction is a process with the main inputs such as project, funding, information, management, knowledge, environmental factors, materials, tools and labour force and the "building" as its output. For centuries a limited number of "traditional" construction techniques refined through "trial and error" have been used for erecting buildings. In the last century a large number of new construction techniques emerged caused by new building materials, developments in technology and the increasing need for buildings caused by population growth and changing requirements [1]. Today industrialized construction techniques or traditional construction techniques or combinations of both are used in "building", according to specific conditions of each project. The construction process together with the design process plays a paramount role in achieving the required level of "quality" of the building. Quality in construction can be described as the totality of a building's attributes that enable it to perform a stated task or to fulfill a given need satisfactorily for an acceptable period of time [2]. In the context of the construction process, quality derives from [2].

- Reliability of organization, procedures and skills of builder to interpret the design, organizing required resources and provide the end product in accordance with design and specification, and at contracted price
- Labour force of appropriate skills
- Products of specified quality.

Research work is indicating that lack of quality in terms of building failures are originating to a certain percent from the construction process [3]. From this point of view, improving or rationalizing construction techniques is needed in order to avoid building failures. A study was conducted for determining innovation models for improving quality in the construction process. Papinniemi's model [4], TRIZ [5] and its derivatives P-TRIZ [6] and ARIZ [7] are models which can be used in improving construction quality. Among those models TRIZ has the highest potential to be adapted successfully into the field of construction process.

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2. TRIZ (Theory of Inventive Problem Solving)

TRIZ, the Russian acronym for "Theory of Inventive Problem Solving", is a methodology for problem-solving and forecasting in innovation, based on logic and data. TRIZ was developed by Genrich Altshuller by analyzing more than three million patent documents between 1946 and 1985. The fundamental view is that almost all "inventions" are repetitions of previous discoveries already made in the same or other fields and that problems can be reduced to contradictions between elements [8, 5]. Altshuller has defined the method in the light of these paradigms with following steps:

- Identification of the problem
- Comparing and matching the problem with the general TRIZ problems
- Finding the general TRIZ solution that is related to the problem
- Development of ideal solutions related to problem.

As a result of patent examination, 39 "technical contradictions" of the problem were determined, giving rise to conflict (between improving feature and worsening feature) [8]. The problem is analysed into its basic, abstract constituents according to a list of those 39 parameters are given in Table 1.

Table 1. 39 Technical Contradictions and 40 Inventive Principles of TRIZ.

technical contradictions			
1	weight of moving object	21	power
2	weight of stationary object	22	loss of energy
3	length of moving object	23	loss of substance
4	length of stationary object	24	loss of information
5	area of moving object	25	loss of time
6	area of stationary object	26	quantity of substance
7	volume of moving object	27	reliability
8	volume of stationary object	28	measurement accuracy
9	speed	29	manufacturing precission
10	force (intensity)	30	object-affected harmful
11	stress or pressure	31	object-generated harmful
12	shape	32	easy of manufacture
13	stability of the object	33	ease of operation
14	strength	34	ease of repair
15	durability of moving object	35	adaptability or versatility
16	durability of non moving object	36	device complexity
17	temperature	37	difficulty of detecting
18	illumination intensity	38	extent of automation
19	use of energy by moving	39	productiviy
20	use of energy by stationary		

inventive principles			
1	segmentation	21	skipping
2	taking out	22	convert harm into benefit
3	local quality	23	feedback
4	asymmetry	24	intermediary
5	merging	25	self-service
6	universality	26	copying
7	nested doll	27	cheap short living objects
8	anti-weight	28	mechanics substitution
9	prior counteraction	29	pneumatics and hydraulics
10	preliminary action	30	flexible shells and thin films
11	beforehand cushioning	31	porous materials
12	equipotentiality	32	colour changes
13	the other way round	33	homogeneity
14	spheroidality-curvature	34	discarding and recovering
15	dynamics	35	parameter changes
16	partial or excessive actions	36	phase transition
17	another dimension	37	thermal expansion
18	mechanical vibration	38	strong oxidants
19	periodic action	39	inert atmosphere
20	countinuity of useful action	40	composite materials

Table 2. Part of Contradiction Matrix.

worsening feature → improving feature ↓			technical contradictions														
			Weight of moving object	Weight of stationary object	Length of moving object	Length of stationary object	Area of moving object	Area of stationary object	Volume of moving object	Volume of stationary object	Speed	Force (intensity)	Stress or pressure	Shape	Stability of the object	Strength	Durability of moving object
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
technical contradictions	1	Weight of moving object	+	-	15,8 29,34	-	29 17	-	29,2 40,28	-	2,8 15,38	8,10 18,37	10 36	10 14	1,35 19,39	28 27	5,34 31,35
	2	Weight of stationary obj.	-	+	-	10,1 29,35	-	35 30	-	5,35 14,2	-	8,10 19,35	13 29	13, 10,	26 39,1	28,2 10,27	-
	3	Length of moving object	8,15 29,34	-	+	-	15 17,4	-	7,17 4,35	-	13,4 8	17 10,4	1,8 35	1,8 10,29	1,8 15,34	8,35 29,34	19
	4	Length of stationary obj.	-	35 28	-	+	-	17,7 10,40	-	35,8 2,14	-	28 10	1,14 35	13 14	39 37,35	15 14	-
	5	Area of moving object	2,17 29,4	-	14 15	-	+	-	7,14 17,4	-	29 30,4	19 30	10 15	5,34 29,4	11,2 13,39	3,15 40,14	6,3
	6	Area of stationary obj.	-	30,2 14,18	-	26,7 9,39	-	+	-	-	-	1,18 35,36	10 15	-	2,38	40	-
	7	Volume of moving object	2,26 29,40	-	1,7 4,35	-	1,7 4,17	-	+	-	29,4 38,34	15 35	6,35 36,37	1,15 29,4	28 10,1	9,14 15,7	6 35,4
	8	Volume of stationary obj.	-	35 10	19 14	35,8 2,14	-	-	-	+	-	2,18 37	24 35	7,2 35	34 28	9,14 17,15	-
	9	Speed	2,28 13,38	-	13 14,8	-	29 30,34	-	7,29 34	-	+	13 28	6,18 38,40	35 15	28 33,1	8,3 26,14	3,19 35,5
	10	Force (intensity)	8,1 37,18	18 13,1	17 19,9	28 10	19 10,15	1,18 36,37	15,9 12,37	2,36 18,37	13 28	+	18 21,11	10 35	35 10,21	35,10	19,2

inventive principles

On the other hand 40 inventive principles of problem solving have been identified [8]. The 40 "principles of problem solving" are the most accessible "tool" of TRIZ is given Table 1. A set of solution alternatives are determined with the help of the "contradiction matrix" is seen in Table 2. Each matrix cell points to principles that have been most frequently used in patents in order to resolve the contradiction [8]. Up to this stage TRIZ steps are very systematically. However, the method is lacking a decision-making step for selecting the "best" solution from the set of solution alternatives.

3. Applicability of TRIZ In-Situ Construction Techniques

TRIZ is used in every field of engineering such as chemical [9] etc. TRIZ is also applied to other fields such as education [10] etc. When it comes to the construction industry, two examples of the application of TRIZ can be highlighted. 40 inventive principles of TRIZ were adapted to architecture [11] and Teplitskiy, has generated examples for construction by using 40 inventive principles of TRIZ [12]. Although TRIZ was adapted into the fields of architecture and construction, it is rarely used in the in-situ construction process of architectural components. A research study is set to investigate the applicability of TRIZ to in-situ construction techniques for improving construction quality. The preliminary study of the research work comprises the evaluation of the applicability of TRIZ in the construction process, through an analysis of a problem and experimental assessment of the solution alternatives. TRIZ method consists the following steps: definition of construction work, identification of the problem, determination of technical contradictions, and determination of solution proposals.

As the TRIZ method has not a decision-making module, the fifth step; "evaluation of solution alternatives" is generated in using the "benefit-value" analysis method [13]. The application with steps listed above is outlined below.

3.1. Definition of Construction Work

In the study construction work consisting of the fixing of two wooden boards is selected for analysis and evaluation. Two wooden boards, 24x8x2,2 cm in size, are fixed together using nails or screws.

3.2. Identification of Problem

The objective is defined as; "increasing the construction speed" of mechanical fixing of two wooden boards, without affecting product quality.

3.3. Determination of Technical Contradictions

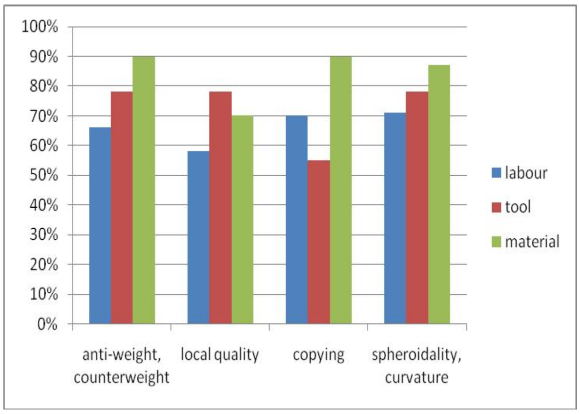
In increasing construction speed, the "quality" of construction should not be adversely affected. In this case "construction quality" is defined with the criterion "strength of joint". TRIZ's improving feature is "velocity" (9th technical parameter) and worsening feature is **"**strength" (14th technical parameter) are seen in Table 1.

3.4. Determination of Solution Proposals

Solution alternatives were determined using the TRIZ contradiction matrix. When crossing the 9th parameter on the-y axis with the 14th parameter on the x-axis, the following principles (8th principle: anti-weight, counterweight, 3rd principle: local quality, 26th principle: copying and 14th principle: spheroidality, curvature) are offered on the contradiction matrix which is the hatched area in Table 2:

3.5. Evaluation of Solution Alternatives

In the evaluation process solutions derived from the TRIZ contradiction matrix are compared in order to determine the "best" solution. The four solution alternatives (anti-weight, counterweight, local quality, copying and spheroidality-curvature) are evaluated in the context of construction inputs namely, labour force, tools and materials. The relative importance of those evaluation criteria is determined according to "specialist's judgment". Each criterion is divided into sub-criterias and coefficients are given. Some of sub-criterias of labour criteria are physical power, experience/education level etc., sub-criterias of tool criteria are frequency of usage, difficulty of usage etc., sub-criterias of material are application easiness, necessity of energy usage etc. In the "Benefit-Value" analysis the Churchmann&Ackoff approach is used in weighting and ranking of evaluation criteria. Results of the evaluation using the Churchmann&Ackoff approach are given in Figure 1. All four solutions are suitable for solving the problem. According to weights of the evaluation criteria, expressed in percentages, the solutions are ranked as follows:



1th solution alternative: spheroidality, curvature, 79% (14th principle).
2nd solution alternative: anti-weight, counterweight, 78% (8th principle).
3 th solution alternative: copying, 72% (26th principle).
4 th solution alternative: local quality, 67% (3th principle).

Figure 1. Comparison of solutions in the context of the construction inputs.

4. Results Evaluating the Applicability of TRIZ to In-Situ Construction Techniques

For the evaluation of the applicability of TRIZ to in-situ construction techniques the process of the defined construction works are observed and the product quality is determined experimentally. The first and second solution alternatives, with very close evaluation values, were examined. In fulfilling the 8th principle (anti-weight, counterweight) of TRIZ, the following construction activities were done (Figure 2). Firstly, before mechanical fixing, wood panels were glued together. Then, five nails were driven against rotation. Finally, nails were driven angled.

In fulfilling the 14th principle (spheroidality, curvature) of TRIZ, the following construction activities were carried out (Figure 2). Firstly, before mechanical fixing, wood panels were glued together. Then, holes for guiding, were drilled. Finally, five screws were driven into the guiding holes, against rotation.

Total construction time for the 8th principle and the 14th principle was 60 seconds and 160 seconds respectively. For determining the quality for both of the constructions a compressive strength test was conducted (Figure 3). Results of the tests indicated that the construction fixed with nails resisted to a maximum load of 11,050N whereas the construction fixed with screws resisted to a maximum load of 12,550N.

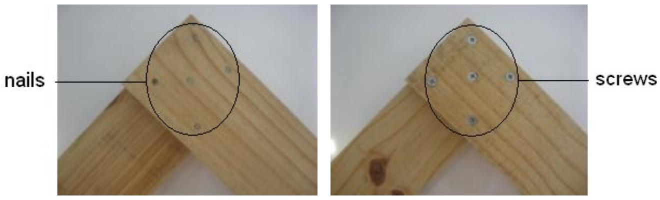


Figure 2. Fixing with five nails (left), fixing with five screws (right).

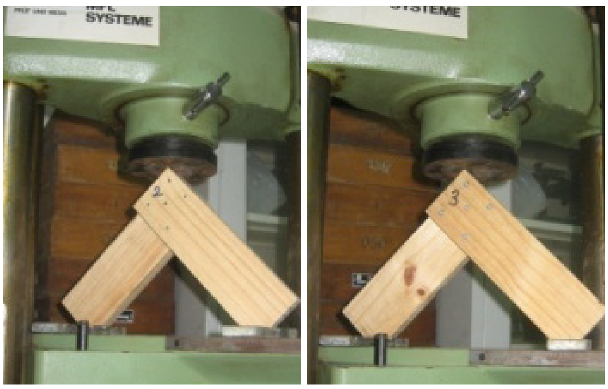


Figure 3. Compressive strength test for the construction fixed with five nails (left) and fixed with five screws (right).

In evaluating the solution alternatives, the “Benefit-Value” analysis is conducted by using “different weighted value criterias” and “different weighted sub-objectives”. A ranking scale is developed, ranging from 1 (moderate) to 3 (very good) for judging the “benefit” from the measured values of the sub-objective;

"construction time" and "compressive strength". Designated "sub-objective values" are given in Table 3. In this case the "weight value" of the sub-objective; "construction time" and "compressive strength" is weighted by percentage to be 40% and 60% respectively. In multiplying the "sub-objective values (B)" with "sub-objective weight value (D)", results from the total "Benefit-Value (FD)" analysis are obtained (FD=BxG) [13] and (Table 4). According the evaluation, it can be concluded that the 1th solution alternative (14th principle) is the ideal solution.

Table 3. Designated "sub-objective values" of the measured values for the 1th solution alternative (14thprinciple) and the 2nd solution alternative (8th principle).

solution alternative	14th. principle	8th. principle
construction time	160 sec.	60 sec.
"sub-obj." value	2	3
comp. strength	12,550N	11,050N
"sub-obj." value	3	2

Table 4. Evaluation of solution alternatives.

solution alternative	14th. principle	8th. principle
comp. strength	3x0,60	2x0,60
application time	2x0,40	3x0,40
total value	2,60	2,40
% value	0,86	0,80

5. Conclusion

In the study the applicability of TRIZ method to in-situ construction techniques of architectural components, for improving construction quality at the same time construction productivity, is investigated. In this context, improving the quality of the construction technique for wood joint fixing is defined as a problem to be tackled. The defined problem is solved with TRIZ method considering "construction time" and "strength" criteria. For assessment of the method, construction process observation and compressive strength tests are carried out. In the context of the study, it is seen that the TRIZ method is applicable to in-situ construction techniques of architectural components. The findings of the study are not be generalised, as they are related to a specific case study. Further research work is ongoing to obtain data which will lead to generalised conclusions.

6. References

[1] S. Emmitt. *Architectural Technology*, Blackwell Science, Oxford, UK, 2002.

[2] G. Atkinson. *Construction Quality and Quality Standards,* 1th ed., Chapman & Hall, UK, 1995.

[3] F. Baytop. *Wright and Wrong in Construction,* YEM Print, Istanbul, 2001 (in Turkish).

[4] J. Papinniemi. Creating a Model of Process Innovation for Reengineering of Business and Manufacturing, *Int. Journal of Production Economics.,* 60-61, p.95-101, 1999.

[5] K. Barry., E. Domb., M. S. Slocum. TRIZ - What Is TRIZ? *The TRIZ Journal (Online), 2010.* Available at: http://www.triz-journal.com/ archives/what_is_triz/

[6] H. Smith. P-TRIZ Formulation, Part 1 and Part 2, March, 2006, Available at: www.bptrends.com

[7] V. Fey., E. Rivin. Innovation on Demand: New Product Development Using TRIZ, Cambridge University Press, UK, 2005.

[8] G. Altshuller. *Creativity as an Exact Science*, Gordon & Breach Publishers, New York, 1984.

[9] J. Hipple. 40 Inventive Principles with Examples for Chemical Engineering, *The TRIZ Journal (Online),* June, 2005. Available at: http://www.trizjournal.com/archives/2005/06/index.htm

[10] D. G. Marsh., F. H. Waters., T. D. Marsh. 40 Inventive Principles with Applications in Education, *The TRIZ Journal (Online),* April, 2004, Available at: http://www.trizjournal.com/archives/2004/04/04/index.htm

[11] D. Mann., C. O. Cathain. 40 Inventive (Architecture) Principles with Examples, *The TRIZ Journal (Online),* July, 2001, Available at: http://www.trizjournal.com/archives/2001/07/b/index.htm

[12] A. Teplitskiy., R. Kourmaev. Application of 40 Inventive Principles in Construction, *The TRIZ Journal (Online),* May, 2005. Available at: http://www.trizjournal.com/archives/2005/05/b/index.htm

[13] M. Tapan. *Benefit-Value Analysis As a Tool for Evaluation in Architecture*, ITU Print, Istanbul, 1980 (in Turkish).