TRIZ-DR MODEL FOR DISPUTE RESOLUTION IN CONSTRUCTION INDUSTRY

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ABSTRACT

Conflicts and disputes are inevitable in the construction industry. This is due to the complex nature and the involvement of so many parties along the contractual chain, adversarial relationships, uneven risk allocation and uneven bargaining power. Different formal and informal Dispute Resolution (DR) strategies are currently being practiced in construction industry aimed at resolving disputes as effective as possible. But the major drawback of these strategies is the lack of innovativeness generated within their processes. In this background, significance of an inventive dispute resolution approach is emphasised.

As an inventive problem solving tool, TRIZ methodology has become famous in various fields such as Engineering, Manufacturing and Information Technology. TRIZ is primarily about solving technical and physical problems, but is now being used in solving many problems or situations. Hence, this study aims to develop TRIZ-DR model to resolve disputes in construction industry.

Accordingly, a mixed methods research approach was followed to achieve the research aim. A comprehensive literature review followed by semi structured interviews with seven subject matter experts were used to investigate the common construction disputes, existing dispute resolution strategies and their drawbacks, applicability of TRIZ based approach for construction dispute resolution and implantation procedure. The collected data were then analysed using code based content analysis and statistical mode in developing the TRIZ-DR model. The four phase model is a systematic procedure of abstracting problem, relating to TRIZ-DR matrix, interpretation, suggesting a solution, checking the feasibility of the solution and implementation to be followed at each phase. Therefore, this research offers a TRIZ-DR model to enhance inventiveness in construction dispute resolution, hence providing an effective dispute resolving mechanism.

Keywords: *Dispute Resolution; Inventive Problem Solving; TRIZ Methodology; TRIZ-DR (TRIZ-Dispute Resolution) Model.*

1. INTRODUCTION

Construction projects are often criticised for its intrinsically hazardous and complicated process. Complex construction can often result in complex disputes, which predominantly arise from the difficulty and magnitude of the work, multiple prime contracting parties, poorly prepared or executed contract documents, inadequate planning, financial issues, and communication problems (Harmon, 2003). Therefore, it is necessary and useful to avoidable from necessary claims; and also to minimize disputes arising from unresolved conflict and claims in construction projects (Kumaraswamy, 1997) since the success of a project depends on the way an organization approaches problems and disputes (Danuri *et al.*, 2012).

As Cheung and Suen (2002) stated due to differences in perception and frequency of conflicting goals among partners to a project, disputes in the construction project environment are inevitable. If construction disputes are not resolved in a timely manner, they tend to drag on and escalate causing project delays, lead to claims, require litigation proceedings for resolution, and ultimately destroy business relationships (Cheung and Suen, 2002).

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There is a growing awareness in the construction industry to adopt dispute resolution techniques that can reduce the risk of disputes occurring and may prevent disputes escalating into costly formal resolution procedures (Danuri *et al.*, 2012). The importance of inventive systematic approach for dispute resolution is highlighted in this background. As a systematic inventive problem solving tool, TRIZ methodology allows finding innovative solutions to the disputes by identifying with precision the root cause of the problems (Cabrera and Li, 2014). Identifying the zones of conflict before applying the tools of TRIZ helps practitioners understand the conflict better, simplifies problem solving and can lead directly to a solution (Domb, 2015). The overall aim of TRIZ has been to construct a problem definition and solving process that enhances innovation and incremental improvement of final outcome (Stratton and Mann, 2003).

The paper stucture begins with an introduction to the study and followed by a literature review on common construction disputes and TRIZ method in section 2. Section 3 presents the research methodology and section 4 presents the TRIZ-DR model developed for dispute resolution. The final section summarises conclusions derived from the research findings and present recommendations.

2. LITERATURE REVIEW

2.1. CONSTRUCTION DISPUTES

The "Disputes may arise from different perceptions as to the legitimacy and/or the quantum of the claim" (Kumaraswamy, 1997). Construction disputes are the major hindrance for the performance of construction industry (De Alwis *et al.*, 2016). Further to the authors, it is still difficult to eliminate disputes in construction projects although the number of attempts have taken to avoid disputes while serving its own purposes.

Though the nature of disputes may vary, some disputes are common in every project irrespective of its nature. According to Assaf *et al.* (1995) contractual dispute is the most common dispute in the construction industry. Furthermore, Cheung and Yeung (1998) stated that time delays and contractual disputes has a huge impact on the construction industry. In addition, Wall (1998) mentioned that delayed payments and erroneous documents even have become vital there.

Relationship between contractor-subcontractor and contractor-employer cause for critical disputes in a construction project (Cheung and Yeung, 1998). Kumaraswamy (1997) identified human relationships as one of the most vulnerable elements which results in construction disputes. The disagreements due to quantity evaluations also laid the foundation for serious construction disputes in the construction industry (Kumaraswamy,1997). Employer has a great responsibility of facilitating funds for the construction and if not it ultimately results a dispute (Fenn *et al.*, 1997). All above facts supported that delayed payments and unwanted interference by the employer result in construction disputes.

Further to the authors, the different types of disputes can be; Contractual disputes, Management related disputes; Time Delays; Material delivery delays; Delayed Payments; Construction defects; Document errors; Contractor – Subcontractor relationship; Contractor - Employer relationship; Quantity measurement and evaluation; Termination; Lack of communication; Contractor's poor financial control; Employer interference; Frequent and late changes to design and the External factors such as Market, Political and Weather. Resolving above stated disputes in an effective manner is crucial to enhance the efficiency of construction project outcome.

2.2. DISPUTE RESOLUTION

Construction industry is characterized to be antagonistic and confrontational. Hence, disputes have become increasingly common in the construction industry. Chong and Zin (2012) stated that disputes should be resolved in the earliest possible stages of dispute resolution. Cui (2014) further reviewed that if any dispute which is not resolved promptly, then it may escalate, and ultimately require litigation proceedings, which can be extremely costly for the parties concerned.

Cheung *et al.* (2000) highlighted that dispute resolution in construction industry is crucial and topical as there is a growing concern. Considering the increasing complexity of construction projects and the economic environments within which they are being procured, there is a need to obtain an enriched understanding of the underlying conditions that contribute to disputes (Cui, 2014).

Disputes can be resolved through various mechanisms and it is not being true to say that all disputes are resolved by court proceedings or in other formal or informal settings involving Alternative Dispute Resolution methods (ADR) (Chong and Zin, 2012). Type of dispute resolution strategy can be identified by considering their efficiency in terms of time and money according to the nature and complexity of the dispute.

It can be identified that there are pros and cons to every dispute resolution method practiced and selection of an appropriate dispute resolution method is vital as every project is likely to have disagreements (Chong and Zin, 2012). Usually litigation involves a lengthy process, capacious documentation, procedural and adversarial in nature (Merna and Bower, 1997). Thereby ADR explored the context and cost and time saving have been realised (Chon and Zin, 2012). However, Danuri *et al*. (2012) mentioned that ADR would not be successful if the parties did not have mutual respect and understanding between the parties and ADR will not bring the desired outcome if either side did not have the genuine desire to resolve the dispute by a simple method. ADR will be inappropriate where one party does not want a settlement and it may also be in the commercial interests of a party to delay a hearing (Harmon, 2003). Obviously, if the disputing parties are not willing to settle, going through ADR process would just be a waste of time.

In this scenario, the importance of establishing an inventive problem solving approach which can address above stated shortcomings is highlighted.

2.3. TRIZ METHODOLOGY

TRIZ (a Russian abbreviation for the Theory of Solving Inventive Problems) was originated by the Russian Scientist and Engineer Genrich Altshuller (Sohn, 2013). As defined by Livotov (2008) “TRIZ is an inventive and technical problem solving tool which improves a single part or characteristic of the system without impairing other parts or characteristic of the system or adjacent systems”. Altshuller proved that inventive problems can be tackled through a systematic approach (Souchkov, 2013). He started his work by studying thousands of patents, looking for commonalties, repetitive patterns and principles of inventive thought. After investigating approximately 400,000 patent descriptions, Altshuller found that newly discovered physical principles were used in only 0.3% of all patented solutions (Souchkov, 2013). In addition, it appeared that a great number of inventions complied with a relatively small number of basic solution patterns (Domb, 2015). The author further codified, documented and published his findings which attracted number of Scientists, Engineers, and inventors (Stratton *et al.,* 2000). Together the research continued, eventually resulting in the screening of more than two million patents and from which numerous analytical and knowledge based tools for solving inventive problems were developed.

According to Savransky (2000), following four specific features can be identified in TRIZ methodology; human oriented, knowledge based, systematic and inventive problem solving. The basic idea in TRIZ is that systems evolve in similar ways, and by reducing any situation and problem to a physical level, standard solutions and problem solving techniques extracted from different fields can be applied (Yan *et al.,* 2014). As Vignesh and Natarajan (2013) stated, the process of solving a problem using TRIZ includes, 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 and development of ideal solutions related to problem.

Based on above process, TRIZ can be approached under three main steps (Yan *et al*., 2014).

- The “formulation” phase - where the expert uses different tools to express the problem in the form of a contradiction network or another model.
- Abstract solution finding phase - where access to different knowledge bases is made to get one or more solution models. TRIZ users need to be capable of choosing the accurate abstract solution according to the current abstract problem.
- The “interpretation” phase - where these solution models are incorporated with the help of the scientific-engineering effects, knowledge base, to get one or more solutions to be implemented in the real world.

TRIZ methodology is mainly used in technical problem solving but it can be effectively used for non-technical problems (Savransky, 2000). Although it has shown effectiveness when applied to domestic industries, especially manufacturing, there are no cases of it being applied to the field of construction (Sohn, 2013).

2.4. *REVIEW ON THE APPROPRIATENESS OF TRIZ BASED APPROACH FOR CONSTRUCTION DISPUTE RESOLUTION*

Construction industry deals with complex nature which ultimately results in number of disputes due to different views of parties. Existing dispute resolution strategies generally aim at conventional problem solving methods as often complex contexts are extremely simplified, alternatives ignored, constraints avoided, risk not evaluated correctly and resources, knowledge and potentials not utilized for the best problem solving at the right time (Livotov, 2008). In this scenario, TRIZ provides a great advantage over other problem solving tools as it is a faster and more effective problem solving and innovation processing tool (Domb, 2015).

In contrast to the common "trial and error" problem solving methods such as brainstorming, morphological analysis etc. used in dispute resolution process, TRIZ only relies on the unbiased laws of evolution of technical systems and therefore enables a focused search for possible solutions (Livotov, 2008). The difficulty of existing dispute resolution strategies is that too much information has to be browsed and there is no guarantee of moving in a right direction. TRIZ organizes translation of the specific problem into abstract problem and then proposes to use a generic principle or a pattern, which is relevant to the type of the problem (Souchkov, 2013).

TRIZ evolutionary criteria such as adaptability, controllability and periodic occurrences complete the systematic approach to the problem which is highly applicable to construction industry (Livotov, 2008). Also it reduces the generic risk of missing an important solution to a specific problem as it provides a broad range of generic patterns of inventive solutions (Souchkov, 2013). It is a completely open approach that amplifies individual creativity, rather than limiting exploration to a narrow solution space in the way that traditional methods do. Furthermore, it is not necessary to be highly experienced in the use of TRIZ in order to generate creative results (Catháin and Mann, 2013). Therefore, from a new perspective, Cui (2014) proposed a TRIZ theory perspective on construction conflict resolution.

Through different TRIZ methodologies, there are "40 Inventive Principles" which has been successfully used in number of other fields rather than other methods as an innovative problem solving approach. Hence, "40 Inventive Principles" method was used in constructing TRIZ-DR model under this study. Each principle in the collection recommends a number of directions for solving a particular type of an inventive problem which is very much applicable in respect with construction dispute resolution. As 40 inventive principles were mainly developed regarding engineering applications, some principles were identified as non-related in resolving construction disputes due to their high technical nature. Through a desk study, 23 inventive principles were identified which can be applicable in construction dispute resolution as shown in Table 1. Therefore, the aforementioned findings were used in developing the study findings which are explained in next sections.

Table 1 : Interpretation of TRIZ Inventive Principles

TRIZ inventive principle	Meaning
1. Segmentation	Divide an object into independent parts
2. Extraction	Remove or separate a needless part from an object, or extract and utilize the necessary part
3.Local quality	Place each part of the object under conditions most favourable for its operation
4.Asymmetry	Replace a symmetrical form with an asymmetrical form of the object
5.Merging	Combine in space or in time homogeneous objects or objects destined for contiguous operations
6.Universality	Have the object perform multiple functions, eliminating the need for other objects
7.Nested doll	Placing one object inside another
8.Preliminary action	(Prior counter-action)
9.Beforehand cushioning	Compensate relatively low reliability of an object with countermeasures taken in advance
10.Equipotentially	Change the condition of the work so an object doesn't need to be raised, lowered, rotated, etc.
11.Dynamics	Make characteristics of an object, or outside environment, adjusting for optimal performance or operation for different internal or external conditions
12.Another dimension	Remove problems by moving an object in a line by two-dimensional movement
13.Continuity of useful action	Carry out an action without breaks - all parts of an object should constantly operate at full capacity
14.Intermediary	Use an intermediary object to transfer or carry out an action

15.Self Service	Make an object serve itself by performing auxiliary helpful functions, Use waste resources, energy, or substances.
16.Copying	Use simple and inexpensive copy instead of an object, which is complex, expensive, fragile or inconvenient to operate
17.Cheap short living objects	Replace an expensive object by a collection of inexpensive ones
18.Porous materials	Make an object porous or use additional porous elements.
19.Color changes	Change the colour of an object or its surroundings; change the degree of transparency of an object or its surroundings, etc.
20.Homogeneity	Make objects interact with a primary object having the same properties or ones close to its behaviour
21.Discarding and Recovering	Regenerating materials and parts after they has completed its function or become useless.
22.Phase transition	Use effects, which are relieved during phase transition.
23.Composite materials	Replace a homogeneous material with a combination of materials

Source: (Cui, 2014)

3. Research Methodology

Research design is a logical blueprint which can be explicit or implicit (Yin, 2013). The design of this research includes, literature survey, expert opinion survey and data analysis. Background study and a comprehensive literature review were carried out in order to identify the different concepts practiced in TRIZ methodology and to identify the benefits of TRIZ over the other DR strategies. This research was then subjected to a mix method research approach using in-depth interviews with subject matter experts by considering the nature of the study. Thereby, semi structured interviews with seven subject matter experts were carried out in gathering details in determining the adaptation and application of TRIZ-DR model to construction dispute resolution. The interviews were conducted until the data saturation is reached, among the subject matter experts who belong to consultant, contractor and client organizations. Manual code based content analysis was used to analyse the qualitative data and statistical mode was used in analysing the quantitative data gathered in this study. The findings of data analysis were assisted in discovering the urge of TRIZ methodology in construction dispute resolution and developing the TRIZ-DR model ultimately.

4. Research Findings and Discussion

4.1. Commonly Used Dispute Resolution Strategies and their Drawbacks

As the first step of this study, semi structured interviews were carried out with subject matter experts to identify existing dispute resolution strategies and their drawbacks. Gathered data were analysed using manual code based content analysis. Respondents categorised commonly used dispute resolution strategies into two methods; informal dispute resolution methods and formal dispute resolution methods. Under informal dispute resolution methods, they have stated that negotiations and mediations are mostly used by parties as first choice of dispute resolution process, whereas amicable settlement is least used. Adjudication is the most commonly used formal dispute resolution strategy and as the final step of dispute resolution, litigation is also practiced in resolving construction disputes when parties are not satisfied with ADR methods.

However, most of the dispute resolution strategies take considerable amount of time to come up with a solution such as litigation and arbitration generally undergo more than one year to reach a solution. High cost is also another major drawback of existing dispute resolution methods such as adjudication, arbitration and litigation. Sometimes, cost occurred for arbitration process can be more than 20% of contract sum of the project. Furthermore, lack of expertise knowledge may cause to unsuccessful outcomes in dispute resolution methods and lack of enforceability and legality of informal dispute resolution methods is another drawback as parties often tend to seek solution, which can be enforced by law. Hence, drawbacks of existing dispute resolution strategies can be summarised as lack of innovativeness, high cost and time involvement and limited knowledge, which urge the need of an innovative DR solution to eliminate the associated drawbacks.

4.2. *TRIZ-DR MODEL FOR CONSTRUCTION DISPUTE RESOLUTION*

During the next step of the study, the sixteen common construction disputes identified through literature review (refer Section 2.1) were assessed by the subject matter experts according to their impact and frequency of occurrence in a construction project using three point likert scale: High (3), Medium (2) and Low (1). The gathered data were analysed using the statistical mode. Accordingly, common construction disputes based on their occurrence are presented in Table 2. The highlighted construction disputes were eliminated as they have low impact and low occurrence, and hence 11 out of 17 disputes were considered as common construction disputes in the industry

Table 2: Impact and Occurrence Analysis of Construction Disputes

No.	Dispute	
1	Contractual disputes	High impact / High occurrence
2	Time Delays	
3	Delay in approvals	
4	Document errors	High impact / Medium occurrence
5	Delayed Payments	
6	Frequent and late changes to design	
7	Management related disputes	Medium impact / Medium occurrence
8	Material delivery delays	
9	Construction defects	
10	External factors (Market, Political, Weather)	
11	Quantity measurement and evaluation	
12	Contractor – Subcontractor relationship	Low impact / Low occurrence
13	Contractor Employer relationship	
14	Termination	
15	Lack of communication	
16	Contractor’s poor financial control	
17	Employer interference	

Subsequently, twenty three TRIZ inventive principles identified during the literature survey were assessed by the subject matter experts according to their importance and level of applicability as per their experience. Three point likert scale, i.e. High (3), Medium (2) and Low (1), was used in data collection and statistical mode was calculated in data analysis. The research findings are summarised in Table 3.

Table 3: Importance and Applicability Analysis of TRIZ Tools

No.	TRIZ tool	
1	Segmentation	Highly important / Highly applicable
2	Extraction	
3	Nested doll	Highly important / Medium applicable
4	Intermediary	
5	Homogeneity	
6	Local quality	Medium importance / Medium applicable
7	Merging	
8	Universality	
9	Preliminary action	
10	Equipotentiality	
11	Dynamics	
12	Continuity of useful action	
13	Copying	
14	Composite materials	
15	Another dimension	Medium importance / Low applicable
16	Beforehand cushioning	
17	Discarding and recovering	
18	Phase transitions	Low important / Low applicable
19	Self-service	
20	Cheap short living objects	
21	Porous materials	
22	Asymmetry	
23	Color Changes	

Therefore, TRIZ tools with Medium importance / Low applicable and Low important / Low applicable were eliminated from the group as all respondents agreed their applicability in resolving construction disputes is negligible. Subsequently, the respondents were requested to assess the level of applicability of fourteen (14) TRIZ tools in resolving eleven (11) common construction disputes identified in Table 2. The findings are presented in TRIZ-DR Matrix in Figure 1. "H" signifies highly applicable TRIZ tools in resolving particular dispute whereas "M" and "L" denotes moderately applicable and least applicable TRIZ tools in resolving particular dispute respectively. The study finally developed TRIZ-DR model incorporating TRIZ-DR matrix as presented in Figure 1. The implementation process of the model is discussed below.

PHASE 1

The construction dispute should be identified and defined in this phase of TRIZ-DR model. The nature of the dispute should be clearly identified and contractual background should be examined prior to using TRIZ-DR matrix. Dispute identification leads to analyse technical conflict of the scenario. TRIZ-DR model mainly focuses on solving most common and frequently occurred construction disputes hence identification of dispute category of the selected dispute is essential in this phase.

PHASE 2

After identifying the nature and extent of the dispute, it should be analysed with TRIZ matrix to identify most appropriate TRIZ tools which can be used in solving specific dispute. After identifying the category of the specific dispute, it can be identified the TRIZ tools which are more applicable in resolving such dispute using TRIZ-DR matrix.

Example: If the dispute is about a global claim, as per the nature of the dispute it is fallen within the contractual dispute category. As per TRIZ-DR matrix, TRIZ tools of Segmentation, Extraction, Merging, Universality, Nested doll, Preliminary action and Continuity of useful action have the higher applicability in resolving this type of construction disputes. So those tools can be clearly identified as the most appropriate TRIZ tools to be applied in this scenario.

PHASE 3

This is the most important phase of the TRIZ approach where inventive solutions are derived to the specific dispute interpreting basic TRIZ solutions. Experience and overall knowledge about the dispute is vital in this phase for the practitioner to generate innovative solutions. The above example stated in Phase 2 can be analysed as following in this phase.

Example: After identification of the most appropriate TRIZ tools using TRIZ-DR matrix, interpretation for each and every basic solution should be done to come up with solution for the dispute. As per 1st TRIZ tool, Segmentation defines breaking and object into independent parts. This is the basic solution provided by TRIZ inventive principles. Interpretation of this basic solution to the specific dispute is generally based on the experience and skill of the practitioner. The interpretation of Segmentation tool to generate solution above dispute can be discussed as follows.

Segmentation tools generally define breaking an object into identifiable independent parts to simplify the process. When applying this basic solution to contractual dispute regarding global claim it can be identified that global claim is presented as mix of each and every event occurred within the construction project which may or may not be resulted in delaying the project. So identification of events which have had impact on delaying the project is crucial.

As suggested by Segmentation tool, breaking the global claim into identifiable independent parts simplifies the evaluation of global claim. For this scenario "cause and effect analysis" can be performed in order to identify delay events. The solution of breaking global claim into independent parts as cause and effect of each event is derived through the basic solution of TRIZ segmentation tool.

After interpreting and deriving a solution for the specific dispute through TRIZ approach, it should be assessed on technical grounds whether it can be practically applied to the scenario. In this phase it should be identified whether the solution is derived within contractual limitations of the project and if not whether parties are mutually agreed to implement the solution which is out of contractual grounds. Hence, the feasibility of the suggested solution is evaluated during this phase 3. If the solution is not feasible, the dispute should be assessed through TRIZ-DR matrix again to identify other appropriate solutions to the specific dispute.

PHASE 01

PROBLEM IDENTIFICATION

ABSTRACTING PROBLEM
Define the dispute
Define the scope

PHASE 02

ABSTRACT SOLUTION FINDING

TRIZ-DR MATRIX

DISPUTE \ TRIZ-TOOL	Segmentation	Extraction	Local Quality	Merging	Universality	Nested Doll	Preliminary Action	Equipotentiality	Dynamics	Continuity of useful action	Intermediary	Copying	Homogeneity	Composite Materials
Contractual Disputes	H	H	M	H	H	H	H	L	L	H	H	H	M	L
Time Delays	H	H	H	H	H	H	L	L	L	H	L	L	L	L
Delay in Approvals	H	H	H	H	H	L	H	H	L	H	H	H	M	L
Document Errors	H	H	H	H	H	L	H	H	H	H	H	L	M	H
Delayed Payments	H	H	L	H	L	L	H	H	M	H	L	M	L	L
Frequent and Late Changes to Design	H	M	M	M	L	H	L	M	M	H	M	M	L	M
Management related Disputes	H	M	M	H	L	M	H	M	L	L	M	L	H	H
Material Delivery Delays	H	H	L	H	H	L	H	M	M	H	H	H	L	L
Construction Defects	M	L	H	L	L	L	L	M	L	L	L	L	M	L
External Factors (Market, Political, Weather)	H	L	H	H	M	M	L	L	L	H	L	L	H	L
Quantity measurement and evaluation	M	M	M	H	M	H	M	L	L	M	M	H	L	L

NOT FEASIBLE

PHASE 03

SPECIFIC SOLUTION FINDING

INTERPRETATION OF SOLUTION
AND
EVALUATION OF THE FEASIBILITY OF SUGGESTED SOLUTION

FEASIBLE

PHASE 04

IMPLEMENTATION

IMPLEMENTATION OF THE FINAL SOLUTION

Figure 1: TRIZ-DR Model

PHASE 4

If the solution is deemed to be practical, it should be implemented with immediate effect to resolve the existing dispute.

5. CONCLUSIONS

Construction is a complex process that requires the coordinated effort of a temporarily assembled multiple-member organization of many discrete groups. As each group is having different goals and needs, and each expecting to maximise its own benefits, it is inevitable that disputes may arise. Many researches revealed that identifying the causes and early settlement of the dispute is crucial as if not solved in timely manner disputes may tend to drag on and cause project failures.

There are many dispute resolution strategies currently practiced in the construction industry. Applicability of each existing dispute resolution strategy is governed by the nature and extent of the dispute. The main drawbacks of existing dispute resolution strategies can be identified as high cost and time involvement, limited innovation and limited application of inventive solutions. There is a growing awareness in the construction industry to adapt an innovative dispute resolution strategy which can address above issues effectively. As a systematic inventive tool, TRIZ methodology can be used to generate innovative ideas through identifying root cause of the dispute. An overall process of TRIZ methodology enables to systematically define and solve any given dispute in an effective manner. As to addressing drawbacks of existing dispute resolution strategies, this research presents the novel TRIZ-DR model for construction dispute resolution. .

This novel TRIZ-DR model is applicable in resolving any construction dispute despite the nature and background of the dispute. The model is bound around four main phases such as problem identification, abstract solution finding, specific solution finding and implementation. Further it shows the synergy between TRIZ inventive principles and common construction disputes through generated TRIZ-DR matrix. In transforming the TRIZ-DR model to practitioners' language, the step by step procedure; abstracting problem, relating to TRIZ-DR matrix, interpretation, suggesting a solution, checking the feasibility of the solution and implementation to be followed at each phase is also specifically incorporated within the model itself. Hence, the novel model facilitates a systematic dispute resolution procedure for effective dispute resolution in construction industry.

6. REFERENCES

Assaf, S., Khalil, M., and Hamzi, M. 1995. Causes of delay in large building construction projects. *Journal of Management in Engineering*, 11(2), 45-50.

Cabrera, R., and Li, G. 2014. A lean-TRIZ approach for improving the perfomance of construction projects. *In: conference proceedings IGLC-22 Norway*, June 2014. 883-894. Oslo: Norway.

Catháin, C., and Mann, D. 2013. Construction innovation using TRIZ. 296-306. Available from http://www.irbnet.de/daten/iconda/CIB15607.pdf [Accessed 20 June 2015].

Cheung, S.O., and Suen, H. C. H. 2002. A multi-attribute utility model for dispute resolution strategy selection. *Construction Management and Economics*, 20(7), 557-568.

Cheung, S., Tam, C., and Harris, F. 2000. Project dispute resolution satisfaction Classification through neural network. *Journal of Management in Engineering*, 16(1), 70-79.

Cheung, S. and Yeung, Y. 1998. The effectiveness of the Dispute Resolution Advisor system: a critical appraisal. *International Journal of Project Management*, 16(6), 367-374.

Chong, H., and Zin, R. 2012. Selection of dispute resolution methods: factor analysis Approach. *Engineering, Construction and Architectural Management*, 19(4), 428 – 443

Cui, H. (2014). Exploring Conflict Resolution Methods for Construction Projects: A TRIZ Theory Perspective. In: *ICCREM 2014*, China 27-28 September 2014. USA: ASCE press, 791-796.

Danuri, M.S.M., Ishan, Z.M., Mustaffa, N.E. and Jaafar, M.S., 2012. A revisit on the current practice of dispute resolution and ADR in the Malaysian construction industry. *Journal of Design and Built Environment*, 10(1), 1-13

De Alwis, I., Abeynayake, M. and Francis, M. 2016. Dispute avoidance model for Sri Lankan construction industry. In: *5th World Construction Symposium 2016: Greening Environment, Eco Innovations and Entrepreneurship*, July 2016. University of Moratuwa: Sri Lanka, 162-173.

Domb, E. 2015. Find the Zones of Conflict – Identify the Problem. *The TRIZ Journal*. Available from http://www.triz-journal.com/innovation-methods/innovation-triz-theory-inventive-problemsolving/find-zones-conflict-identify-problem/ [15th August 2015]

Fenn, P., Lowe, D., and Speck, C. 1997. Conflict and dispute in construction. *Construction Management and Economics*, 15(6), 513-518.

Harmon, K. M. J. 2003. Resolution of construction disputes: A review of current methodologies. *Leadership and management in engineering*, 3(4), 187-202.

Kumaraswamy, M.M.1997. Conflicts, claims and disputes in construction. *Engineering, Construction and Architectural Management,* 4(2), 95 – 111.

Livotov, P. 2008. *TRIZ and Innovation Management*. Innovator. 08/2008 ISSN 1866-4180. European TRIZ Association ETRIA

Merna, A., and Bower, D. 1997. *Dispute Resolution in Construction and Infrastructure Projects.* 1st ed. Hong Kong: Asia Law and Practice Publishing Ltd.

Savransky, S. D. 2000. *Introduction to TRIZ Methodology of Inventive Problem Solving*. Florida: CRC Press LLC.

Stratton, R., and Mann, D. 2003. Systematic innovation and the underlying principles behind TRIZ and TOC. *Journal of Materials Processing Technology,* 139(2003), 120–126.

Stratton, R., Mann, D. and Otterson, P., 2000. The Theory of Inventive Problem Solving (TRIZ) and Systematic Innovation-a Missing Link in Engineering Education? *TRIZ Journal*. [online] Available from http://www.researchgate.net/publication/228901791_The_theory_of_inventive_problem_solving(TRIZ)and_systematic_innovationa_missing_link_in_engineering_education [Accessed 25 September 2015]

Sohn, M. S. 2013. *Application of TRIZ for creative phase in design-VE. SAVE.* [online] Available from http://www.value-eng.org/knowledge_bank/attachments/200443.pdf [Accessed 12 August 2015]

Souchkov, V. 2013. Accelerate Innovation with TRIZ. *TRIZ Journal.* [online] Available from http://www.xtriz.com/publications/AccelerateInnovationWithTRIZ.pdf [Accessed 25 August 2015]

Vignesh, K., and Natarajan, U. 2013. Introduction to TRIZ concept. In: *National Conference on Emerging Trends in Mechanical Engineering 2013,* India 09 November. India, 203-207.

Wall, C. (1998). The dispute resolution adviser in the construction industry, in *Construction Conflict Management and Resolution*, Fenn, P., and Gameson, R. (eds). London, 25-27 September 1998. London: Spon, 328-339.

Yan, W., Merk, C., Cavallucci, D., and Collet, P. 2014. An ontology-based approach for inventive problem solving. *Engineering Applications of Artificial Intelligence*, 27(1), 175-190.