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Recent Trends in Problem Solving through TRIZ: A Review

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ABSTRACT: With the latest advances in technology along with the human advancements, a hard-hitting contest exists between various organizations and the top management. At this stage, the Research and Development (R & D) and Marketing of products are more important. As a result, the multinational enterprises should rely on both the innovations and marketing strategies of products for higher competency. TRIZ is a premier disruptive technology for innovation that can be used all through numerous industries and sciences. Essentials of TRIZ can be successfully used by a wide range of people -- from children to adults. The genesis of TRIZ is derived from empirical data, patents. This paper introduces the concept of ideality and an overview over the literature of TRIZ aiming to benefit the production industries in India.

KEYWORDS: TRIZ, Productivity, Innovation, inventive

I. INTRODUCTION

TRIZ is a Russian acronym that indicates, "Theory of Inventive Problem Solving". In 1946, Genrich Altshuller, the creator of TRIZ, was a patent assessor at the Russian naval patent office at the young age of 20. He supposed that there is a definite model in the way innovations take place in technical systems. He started a study of 200,000 patents to look for the basic principles and patterns in the world's most innovative patents. He bring into being that each of the most creative patents primarily solved an creative problem. Altshuller defined inventive problems as those which contain conflicting requirements, which he called, contradiction. Further he bring into being that the same primary solutions were used over and over again, often separated by many years. He reasoned that if last inventors had the knowledge of earlier solutions their task would have been simpler. He, therefore, set about extract, compile, and organize such knowledge. The collated patent database and subsequent analysis revealed a natural pattern of innovation that can help solve parallel technological problems. This study was continued, by Altshuller and his student, over the past 50 years and has yielded a structured approach to definition and recognition of innovative problems, a set of problem solving tools, and a enormous knowledge database, which can help solve current technical problems in an innovative way. He amorphous 39 basic properties and 40 principles for solving problems containing contradiction in any two-of-39 properties. This he gave in the form of a contradiction table of size 39 x 39 with each cell giving up to 4 principles (and examples from patent data base), that may be used to eliminate the contradiction.

List of the 39 Features

1. Weight of moving object 2 Weight of stationary object 3. Length of moving object 4.Length of stationary object 5.Area of moving object 6 .Area of stationary object 7 .Volume of moving object 8. Volume of stationary object 9. Speed 10. Force 11. Stress or pressure 12. Shape 13. Stability of the object's composition 14. Strength 15. Duration of action by a moving object 16. Duration of action by a stationary object 17. Temperature 18. Illumination intensity 19. Use of energy by moving object 20. Use of energy by stationary object 21. Power 22. Loss of Energy 23. Loss of

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substance 24. Loss of Information 25. Loss of Time 26. Quantity of substance/the matter 27. Reliability 28. Measurement accuracy 29. Manufacturing precision 30. External harm affects the object 31. Object-generated harmful factors 32. Ease of manufacture 33. Ease of operation 34. Ease of repair 35. Adaptability or versatility 36. Device complexity 37. Difficulty of detecting and measuring 38. Extent of automation 39. Productivity

List of the 40 Principles

Principle 1. Segmentation Principle 2. Taking out Principle 3. Local quality Principle 4. Asymmetry Principle 5. Merging Principle 6. Universality Principle 7. "Nested doll" Principle 8. Anti-weight Principle 9. Preliminary anti-action Principle 10. Preliminary action Principle 11. Beforehand cushioning Principle 12. Equipotentiality Principle 13. 'The other way round Principle 14. Spheroidicity - Curvature Principle 15. Dynamics Principle 16. Partial or excessive actions Principle 17. Another dimension Principle 18. Mechanical vibration Principle 19. Periodic action Principle 20. Continuity of useful action Principle 21. Skipping Principle 22. "Blessing in disguise" or "Turn Lemons into Lemonade" Principle 23. Feedback Principle 24. 'Intermediary' Principle 25. Self-service Principle 26. Copying Principle 27. Cheap short living objects Principle 28. Mechanics substitution Principle 29. Pneumatics and hydraulics Principle 30. Flexible shells and thin films Principle 31. Porous materials Principle 32. Colour changes Principle 33. Homogeneity Principle 34. Discarding and recovering Principle 35. Parameter changes Principle 36. Phase transitions Principle 37. Thermal expansion Principle 38. Strong oxidants Principle 39. Inert atmosphere Principle 40. Composite materials

Objectives and fundamental concepts from innovation, some aspects of lean enterprise management are likely to cause discrepancies within an organization that is striving for product innovations. The goal of lean philosophy is to design and manufacture products of high quality and low cost in an efficient manner through eliminating all muda, the Japanese term for waste[55], which range from overproduction and unnecessary transportation to wastes of motion and correction[56]. Innovation is the commercialization of newly designed and implemented products or processes [57]. An important part of building innovative culture in an organization is to preserve uncertainty [57], encourage risk-taking experimentations on new ideas, and allow enough freedom to promote creativity among all individuals within an organization.TRIZ consists of knowledge these repeating patterns of problems-solutions and patterns of scientific development, and methods of using scientific property, and applying the general TRIZ patterns to the specific condition that confronts the developer. Figure 1 describes this process graphically

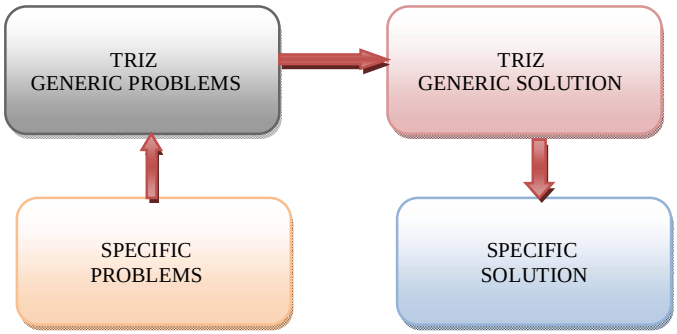

Fig. 1 *The General Model For TRIZ Problem Solving*

Altshuller's work on problem classification and the discovery that there are only a very small number of Inventive Principles available to the engineer is already profoundly changing the systematic innovation picture. That there are only these small number of principles has, for example, meant their systemisation in software form has been relatively easy. The emergence of a number of commercial packages built around TRIZ ideas *[56]* is therefore not surprising.

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II. LITERATURE REVIEW

This paper studies issues relate to documentation and classifications of innovations and generally have an experimental origin. 40 inventive principles (classes) of TRIZ -one of the less widely used modernization tools- have been the basis of the study for documentation and classification of innovations in procurement and supply chain management of the company. Classification (assigning innovations into 40 classes and development of analogies) has been performed by expert judgment based on analysis for re-applicability. Resulting framework based on 40 innovative principles then has been mapped against elements of company's procurement and SCM system to check applicability and soundness of innovative patterns. Results show a good potential for speeding up innovation in SCM with use of TRIZ systematic approach. In the last section some difficulties of TRIZ [1]

Traditional QFD planning method compromises contradictions between engineering uniqueness to achieve higher customer satisfaction. However, this compromise exchange cannot get rid of the contradictions existing among the engineering characteristics which limited the overall customer satisfaction. QFD (Quality function deployment) integrated with TRIZ (the Russian acronym of the Theory of Inventive Problem Solving) becomes hot research recently for TRIZ can be used to solve contradictions between engineering uniqueness which construct the roof of HOQ (House of quality). But, the traditional QFD planning approach is not suitable for QFD integrated with TRIZ for that TRIZ requires emphasizing the contradictions between engineering characteristics at problem definition stage instead of compromising exchange. So, a new planning approach based on QFD/TRIZ integration is proposed in this paper, which based on the consideration of the correlation matrix of engineering uniqueness and customer satisfaction on the basis of cost. The application indicated that higher customer satisfaction can be met and the contradictions between the characteristic parameters are eliminated.[2]

Further study describes the database and the web-based interactive system that we have designed and written for maintaining and enhancing it. Any given biological function needs simultaneously to be coordinated at many levels of organisation – from cell organelle to organism population and ecological unit.[3]

This paper is to study the significance of safety in the workplace, and propose innovative problem-solving methods for engineers, using the theory of TRIZ. Through studying 10 specific Inventive Principles, it demonstrates how TRIZ can be used to create innovative ideas, to minimize and reduce safety hazards in the workplace, especially in construction and manufacturing industries, and TRISolver 2.2, as an innovative problem-solving software is introduced and applied in this process. IT is realized that TRIZ can be a powerful tool to tackle difficult problems within a wide range to enhance workplace safety [4]

TRIZ and Six Sigma integration as an innovative method has been researched by many domestic and foreign scholars. The article analyzed the groundwork and structure of TRIZ and DMAIC integration, focuses on the integrated of TRIZ and DMAIC. On the basis of the analysis at home and overseas, the article anticipated the management, organizational innovation and applied research in different industries which based on integrated of TRIZ and DMAIC. Inventive problems from many domains are usually problems we are not able to solve. This problem insolvability is often due to the imperfect or un- matched representation model of the problem that does not correspond to the given problem. In this paper, we set up two problem solving theories for the solution less problems: Constraint Satisfaction Problem (CSP) and dialectical based methods and models (TRIZ). It is a tentative analysis of both theories in order to compare grounding approach and tools of both theories. Their potential complementarities will be defined in further objective to improve problem solving tactic for the inventive problems by matching the CSP and TRIZ solving principles [6].

TRIZ (Theory and Innovative Problem Solving) methodology is one of the most valuable scientific method, used by managers or inventors. In this study, TRIZ methodology was described in detail with creativity and innovation concepts and TRIZ was presented in comparison with other creative techniques. In the last part, a sample about TRIZ application has been expressed. [7]

TRIZ, theory of solving inventive problems, is a powerful inventive tool for systematically generating innovative ideas and resourceful solutions. TRIZ proved itself for solving scientific and technological problems, and much effort has been concentrated in extending TRIZ to other fields, especially no-technological. Several TRIZ tools are considered to be equally effective in addressing no-technological problems. A good example is the 40 Inventive Principles which were applied in many areas, such as marketing and management. In this paper, we make a critical analysis of these

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translations by carrying out a case study of the most important marketing problem, and highlight some of the errors made by translators and especially general sources of errors when applying a badly translated principle. [8]

The study reports on a proscribed workshop experiment to test a structured method – TRIZ (the theory of inventive problem solving) – for enhancing eco-innovation, particularly in the early stages of team design. The quantitative and qualitative data suggest that TRIZ tools are not best suited to the team design activities at the earliest stages of innovation. The teams' outputs did include interesting new technology developments. The information provided to designers in early-stage workshops plays a bigger role than expected in innovation. [9]
TRIZ action on a problem-solving situation undoubtedly leads to an inventive solution, often satisfying the initial technological requirements imposed by the company. Nevertheless, when observing the arrival of TRIZ for the past ten years in highly industrialised countries, we have witnessed how incredibly difficult its progress in corporate strategies has been. The paradox lies in the sense that while successful actions are there and properly trained people are ever more numerous, there still remains (ever stronger) obstacles to TRIZ penetration in these organisations. This paper aims to provide the reader with the results of an analysis of blocking factors through the state-of-the-art knowledge found in the human sciences and their link with several realities found in TRIZ and its arrival in an organisation. [10]

This study combines the Russian Theory of Inventive Problem Solving (TRIZ) and the fuzzy analytical hierarchy process (AHP) for designing the automated manufacturing systems. This study applied the contradiction matrix table, 40 innovative principles, and 39 engineering parameters to compromise the trade-off between design contradictions and engineering parameters. The design engineers can acquire more reasonable solutions and motivation through the proposed approach. However, due to vagueness and uncertainty in the decision maker's judgment, a fuzzy AHP is employed as a decision support tool that can sufficiently represent qualitative and subjective assessments under the multiple criteria decision making environment In short, the objectives of this research are to use TRIZ to propose the automated design alternatives under the inventive design consideration, and to use a fuzzy AHP to evaluate and select the best feasible alternative under several criteria. [11]
TRIZ is a problem-solving process that seeks to resolve design and engineering contradictions rather than compromise presentation and parameters. It focuses on defining a best system, tapping unclear resources, and taking advantage of patterns of invention common to frequent industries and technologies that can be used in a large fashion [12]
Inventive problems from many domains are usually problems we are not able to solve. This problem insolvability is often due to the incomplete or un- matched representation model of the problem that does not correspond to the given problem. In this paper, we introduce two problem solving theories for the solution less problems: Constraint Satisfaction Problem (CSP) and dialectical based methods and models (TRIZ). It is an exploratory analysis of both theories in order to compare grounding approach and tools of both theories. Their potential complementarities will be defined in further objective to improve problem solving strategy for the inventive problems by matching the CSP and TRIZ solving principles [13]
TRIZ is a problem-solving process that seeks to resolve design and engineering contradictions rather than compromise performance and parameters. It focuses on defining an ideal system, tapping unobvious resources, and taking advantage of patterns of invention common to numerous industries and technologies that can be used in a broad fashion [14]

This article follows on from a first paper examining the application of TRIZ to the improvement of the performance and maintenance of a yogurt bottling plant. In this part, we examine how a novel perception mapping tool was used in conjunction with TRIZ to examine and handle the constraints and human issues associated with the problem. As is often the case, the constraints dictated by these people issues can very easily come to dominate a problem setting. Traditional TRIZ is not normally very effective in dealing with such situations. As such, it is our hope that the new perception mapping tool offers a source of help to problem solvers operating in such environments [15]
The purpose of the research carried out was to identify ways in which tools and methodologies from Theory of Inventive Problem-Solving (TRIZ) might be used in Design for Environment (DFE) approaches. The aim was to develop an integrated methodology for environmentally superior product design at the conceptual stage of the product design phase. The paper commences with a review of the TRIZ methodology itself, followed by a discussion of the

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DFE strategies. A TRIZ approach to DFE is proposed as a new methodology and the paper concludes with a case study using the new TRIZ to DFE approach. [16]

Cleaner Production is a planned approach to minimize industrial waste and emissions by increasing the efficiency of the use of resources and force. It is propagated especially by UNIDO and UNEP as an approach to identify preventive measures to cut on waste and emissions from industrial activities. Case studies conducted by the authors in the last 10 years demonstrate, that in a number of cases water consumption per production unit of industries from the surface treatment sector, from food processing and from the textile industry could be reduced by 30-90%, auxiliary materials consumption could be reduced by 30-50%, and energy consumption of processes could be reduced by 15-25%. All these measures were actually economically helpful for the companies, most of these measures paid back in less than one year [1]. The standard approach to apply Cleaner Production originates from chemical engineering. It follows the steps of: Drawing a process flow sheet - collecting input/output data - doing mass and energy balances - identify sources for waste and emissions - set priorities - identify options. In the process of option generation one generally relies on expert knowledge or on checklists which are available in different manuals or in the best available technology reference (BREF) notes.11The BREF-notes are documents developed by the European Commission to support companies and the relevant authorities in the process of upgrading their technology to best practice standards, as required by the IPPC directive (Integrated Pollution Prevention and Control; Directive 2008/1/EC). They state best practice regarding pollution prevention for most industrial sectors. This approach is strong with teams with an (chemical) engineering background. The authors wanted to develop a standard approach for option identification especially for teams with little formal engineering background or teams which have to go beyond their professional experience by using elements of the so-called TRIZ method (Theory of inventive problem solving, or originally Russian: "{A figure is presented}" (Teoria reschenija isobretatjelskich sadatsch)). TRIZ offers very strong tools for growing process improvement options on a standard level without specific technological knowledge about the process which shall be improved. The authors have found from their research that especially the concept of the Ideal Final Result and the Laws of Evolution form a conceptual framework which can aid effectively in the identification of improvement options in a systematic way. [17]

TRIZ action on a problem-solving situation certainly leads to an inventive solution, often satisfying the initial technological requirements imposed by the company. On the other hand, when observing the arrival of TRIZ for the past ten years in highly industrialised countries, we have witnessed how extremely difficult its progress in corporate strategies has been. This paper aims to provide the reader with the results of an analysis of blocking factors through the state-of-the-art knowledge found in the human sciences and their link with several realities found in TRIZ and its arrival in an organization [18].

When observing the arrival of TRIZ for the past ten years in highly industrialised countries, we have witnessed how incredibly difficult its progress in corporate strategies has been. The paradox lies in the sense that while successful actions are there and properly trained people are ever more numerous, there still remains (ever stronger) obstacles to TRIZ penetration in these organisations. This paper aims to provide the reader with the results of an analysis of blocking factors through the state-of-the-art knowledge found in the human sciences and their link with several realities found in TRIZ and its arrival in an organisation. [19]

The studies issues relate to documentation and classifications of innovations and generally have an experimental origin. First, SCM Innovations applied by Petrochemical Industries Development Management Company (PIDMCo.) in last seven years have been extracted. 40 inventive principles (classes) of TRIZ -one of the less widely used innovation tools- have been the basis of the study for documentation and classification of innovations in procurement and supply chain management of the company. Classification (assigning innovations into 40 classes and development of analogies) has been performed by expert judgment based on analysis for re-applicability. Resulting framework based on 40 innovative principles then has been mapped against elements of company's procurement and SCM system to check applicability and validity of innovative patterns. Results show a good potential for speeding up innovation in SCM with use of TRIZ systematic approach. In the last section some difficulties of TRIZ application in SCM are discussed. [20]

TRIZ (theory of inventive problem solving) is a widely used problem solving method, most readily applicable to physical domains. To complement ongoing software process improvement activities, TRIZ and an associated software tool Tech Optimizer were used to model the software development process, to assess whether this could provide new

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approaches on process development. The study concludes that the method and functions provided by the Tech Optimizer tool do show promise in the area of SPI with immediate returns identifying process improvement priorities and scope for new approaches to process design. [21]

The paper aims to answer some of the questions sought by the design community at large and to provide some directions for scholars and practitioners on how TRIZ techniques can be applied during various stages of the design process. The CBD framework is based on a systems-view that integrates core principles coming from traditional engineering design with fundamental concepts as they are used in cognitive psychology and other fields related to cognition (e.g., problem solving, creativity, and learning theory). The paper provides the details of the proposed cognition-based classification scheme for TRIZ techniques. This is illustrated with the help of the CBD framework. The classification scheme is based on three components: (1) the stage of the design process in which TRIZ techniques are applied and the primary cognitive function supported by the technique; (2) the cognitive level required for mastery of the technique; and (3) the cognitive style simulated through the technique. The aim of this classification scheme is to help design practitioners and TRIZ students make better choices about the techniques they will use, based on the challenges of the given design opportunity, rather than choosing only those techniques they are familiar with. Recommendations are given for making use of the new classification scheme and guidelines for future research. That research can also identify potential loopholes in the problem solving process and techniques, as they are currently available to the designer. [22]

TRIZ has been applied to a wide range of problems. The work reported here shows that the method can generate innovative Construction solutions while reducing risk. The authors applied the method retrospectively to the design of a complex part of the facade of a recently-completed building, showing how use of TRIZ could lead to a simpler and more robust solution. The method was introduced on an ad-hoc basis to a number of postgraduate architecture students, with a limited amount of tutoring. In most cases TRIZ produced great enthusiasm and creative output on the part of the students, who applied TRIZ to a variety of tasks, including planning, detailed design and facade design. One of the most powerful notions in TRIZ is the concept of Idealist. Imagining designs which gives us all of the 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. [23]

To promote the efficiency of design work, this thesis provides a renovated application tactics for theory of innovative problem solving (TRIZ) which emphasize on differences existed in design needs and targets. Its main feature is based on one characteristic in application of TRIZ in practical design where different TRIZ tools may have different instructive effects on the problems belonging to different design types. In other words, the designers can choose the most suitable tool from toolkit of TRIZ to solve a certain design problem, the provided tactic with a workflow is able to help designers locate the promising TRIZ tools in accordance with design problems. The workflow contains several steps: Firstly, analyse the cognitive process of designers; secondly, propose an application method which is based on ontology to analyse innovative design problems; thirdly, utilize a mapping method between design problems' targets and needs with certain TRIZ tools to help designers locate the suitable tools to solve design problems. Presenting two sample design examples to verify the practicability of optimized method proposed in last part of article. [24]

Theory of Inventive Problem Solving (TRIZ) has powerful tools that can be used to solve contradiction problems in technical or non-technical systems. The most common tool used in TRIZ is 40 inventive principles (IPs). The purpose of this paper is to interpret this IPs from a service prospective. The data was collected from many resources found in the literature. A case study was conducted to prove the feasibility of interpretative IPs. The outcome of this study enhanced the usability of the 40 IPs by including new synonyms for some principles, comprehensive descriptions, and providing suggestions and examples for each principle. The interpretative principles focused on a service process used to fulfil customer demands. An Interpretation of TRIZ tool such as the 40 IPs in a service related context improves the understanding of these principles by researchers or service designers. [25]

A methodology of integration of patterns or lines of technology evolution in TRIZ parlance is presented, which is also known as TRIZ technology forecasting, as input to the QFD process to design a new product. For this purpose, TRIZ technology forecasting, one of the TRIZ major tools, is discussed and some benefits compared to the traditional

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forecasting techniques are highlighted. Then a methodology to integrate TRIZ technology forecasting and QFD process is highlighted. [26]
The literature focuses on the application of the Theory of Inventive Problem Solving (TRIZ) to diverter Remote Handling (RH) issues in Fusion Advanced Studies Torus (FAST), a satellite tokomak acting as a test bed for the study and the development of innovative technologies oriented to ITER and DEMO programs. The objective of this study consists in generating concepts or solutions able to overcome design and technical weak points in the current maintenance procedure. Two different concepts are designed with the help of parametric CAD software, CATIA V5, using a top-down modelling approach; kinematic simulations of the remote handling system are performed using Digital Mock-Up (DMU) capabilities of the software. The evaluation of the concepts is carried out involving a group of experts in a participative design approach using virtual reality, classifying the concepts with the help of the Analytical Hierarchy Process (AHP).[27]

The technical problems are very complex in nature requiring many parameters to be considered. TRIZ methodology suggests sequential consideration of parameters, mostly as technical contradiction pairs, yielding a lengthy process. In this paper, we present an improvement to the typical TRIZ methodology, where an algorithm is presented to systematically reduce the considered parameters into a manageable set. We compare the typical TRIZ methodology to the proposed improved approach using a case study of a robotic hand exoskeleton design problem. Our results show the improved efficiency in the TRIZ implementation process. [28]

This literature presents research that advocates process, methods and new technology for performance related robustness improvements in product development. Rapid advances in technology in recent years have set new demands on product development. As a consequence, an increasing variety of products are built on heterogeneous technologies. Specialists from different engineering disciplines must cooperate to a greater extent than before in order to understand the products. Increased cooperation and heterogeneous technologies in products set high demands on rapid product development models in order to deliver products of high quality in short lead time, at low cost. One of the most important tasks in robust design is to select an appropriate system output response. The quality of this selection will greatly affect the effectiveness of the robust design project. Currently, this selection process is more like art than science. By using TRIZ Design principle, several new approaches to enhance robust design are developed. These approaches enable us to select the appropriate system output response in a systematic fashion. The approach developed in this paper was successfully applied and verified in two case studies in two different major automotive companies. This research consists of theory development, mainly in the field of engineering design, TRIZ and CAE. The research in the papers provides: (1) An approach to problem solving by combining design object analysis with TRIZ and FEA; (2) Two case studies carried out with the researcher actively taking part in practical problem solving.[29]

The concept of the TRIZ evolutionary approach to be implemented in the field of education. Traditionally, TRIZ was considered a teaching tool for solving nonstandard problems and tasks (using TRIZ tools). At super system level, the TRIZ didactics system deals with teaching creative imagination, specifically in the area of TRIZ known as Development of Creative Imagination (DCI). Finally, at the highest level TRIZ didactics can be applied for realization of the TRIZ evolutionary approach in the field of education. But it is necessary to learn TRIZ tools and DCI at first to use this concept. The concept realization is based on TRIZ evolutional maps [30]
This article is focused on literature review in the area of TRIZ application in building industry. TRIZ is the Russian acronym for the Theory of Inventive Problem Solving which can be presented as a methodology for problem-solving, ideas-generating and forecasting in innovation, based on logic and data. The theory has been widely used in many fields since early 2000s when innovation became an integral part of the modern World The paper is organized in the following order: introduction into the topic, the principle of obtaining the dataset for the review, Short description of TRIZ and its possible application in construction, discussion of demand of innovation in building industry and the main body consisting of TRIZ in Development of Construction Techniques and Technologies, TRIZ in Design of New Structures and Construction Materials and TRIZ in Construction Project Management and Value Engineering. The work ends with conclusion, suggestion for future work and acknowledgment. Overall, 28 scientific works regarding application of TRIZ in building industry were discovered and reviewed in this paper. The study reveals that TRIZ

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usage in construction is still quite limited. The further research will adapt classic TRIZ tools for construction engineering and management and provide a number of specific case studies [31]

Using a non-equivalent pretest-posttest design to evaluate a 6-week educational program, we explored the effect of the Theory of Inventive Problem Solving (Teoriya Resheniya Izobretatelskikh Zadatchin [Russian], TRIZ) on the creativity Creative processes and creative products were the dependent variables in this study. Using scores of previous design works as covariates, this study used multivariate analysis of covariance (MANCOVA) to analyse the effects of TRIZ on students' creative processes and creative products. We found that TRIZ has a strongly positive effect on a student's ability to analyse problems, and to generate, select, and execute a strategy. TRIZ also increased the creativity with which students designed products, including their ability to develop and implement novel ideas. Based on these results, suggestions for teaching practices and future studies are proposed. [32]
Overcrowding that happens in places like concerts, stadiums or pilgrimage locations might sometimes cause injury or loss of life. Maintaining the safety of crowd in these places is therefore very important. In addition, increasing the performance of the buildings and structures has always been an important concern. Most of the previous work focused on using new devices and methods for monitoring and management of the crowd but they rarely focus on a comprehensive and structured approach with the purpose of increasing efficiency and safety. In this paper, we explore a Russian “Theory of Inventive Problem Solving", TRIZ, to see whether its principles can help us to solve or improve overcrowding issues. More specifically we find the contradictions that arise in the context of crowd management and we observe which of the categorical solutions suggested by TRIZ might possibly be useful for our problem. Increasing the crowd capacity in a relatively small area, which leads to overcrowding, is one of the common contradictions in crowd management. TRIZ has been suggested as a good method for solving problems which involve contradiction and thus, chosen for this purpose. [33]
The paper shows that more similarities than differences exist between TRIZ methods and classical design methods. The solution principles of abstraction and concretion are discussed in detail and are formalized mathematically. As an example, the methodical analogies of the conflict modelling and the preparation of similarity ratios for dimensioning are pointed out. TRIZ methods are integrated in a typical model of a systematically design process. For selected working steps of the design process, the author describes alternative suitable design methods. Further, the article includes the experiences of the author concerning conflict and contradiction modelling and presents a simple manageable software tool to support the conflict modelling. A complex case study from automotive industry shows the harmonized use of TRIZ and classical design methods[34]

This paper surveys Theory of Inventive Problem Solving (TRIZ) integration into other creativity tools, methods and philosophies using a literature review of publications from 1995 to 2006. After explaining the motivation of the integrations, a categorical analysis is carried out on how TRIZ has been integrated with these tools based on publications of combining TRIZ with design problem-solving tools. The applications of the integrations in different industries are summarised, and possible future directions are presented. This paper can satisfy the needs of researchers and practitioners for easy reference of TRIZ and problem-solving tools, and hence promote the future development of TRIZ. [35]
Theory of Inventive Problem Solving (TRIZ)" has been developed and systematized since 1946 in ex- USSR and has become known to the western countries after the end of the Cold War as a new methodology for technological innovation. It is based on the philosophy: "Improvements, innovations, and evolutions of technologies share some common aspects across their fields and their eras. Thus, by extracting such shared essences out of a large number of excellent cases, and by making them easy to retrieve after classification, we may reuse them for facilitating new development of technologies. Especially, excellent cases of technology innovation can be understood in a number of patterns of breaking through the contradictions in the problem; such patterns provide us hints for our own creative innovation." The followings have already been established as a methodology system and applied in real practice: (a) Trends of evolution of technical systems (b) Inverted database of science and technology which are retrievable from technical goals to various candidates of technical means (c) 40 "Principles of Invention" (d) "Contradiction Solving Matrix": corresponding to each element of a problem matrix of 39 improving aspects versus 39 worsening aspects, top four most-frequently-used Principles of Invention are quoted on the basis of an elaborate analysis of world patents.

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Recently in USA, the TRIZ methodology has been implemented in software tools and rapidly become known to industries. In Japan, TRIZ has been introduced and promoted in a significant scale since last year. The present paper describes an overview of TRIZ and points out the possible large impact of TRIZ on the future of world's technologies, industries, and education. It discusses how to introduce TRIZ to the practice of industries, and also discusses the necessity of introducing the TRIZ philosophy in education [36]

When TRIZ is introduced into an organization setting, it invariably encounters a host of processes and tools already in place. These can include enterprise tools such as Six Sigma, Design for Six Sigma (DFSS), QFD and Lean Manufacturing. It is fairly easy to combine TRIZ problem-solving and technological forecasting with these processes and tools, because most of these enterprise tools are problem-identifying processes that couple easily with the strong problem-solving capabilities of TRIZ. What is more difficult is to integrate TRIZ thinking with other psychologically based creativity and assessment tools. Users and trainers for these various tools tend to be very protective about each process and do not spend sufficient time thinking about ways to integrate the best of all tools. Organizations also frequently use psychological assessment tools to assist employees in career development, but they are seldom used in a proactive way to improve group problem-solving. These assessments can be used proactively within the use and implementation of TRIZ. This paper will review suggested ways to effectively integrate TRIZ innovation and problem-solving principles with these other tools. [37]

The friction stir welding (FSW) method has significantly increased the quality of a weld. However, FSW has a slightly short research and application progress. The related applied experiences are not prevalent. Therefore, FSW has a lack of reference information on related welding applied design, such as fixture, joining, and integrated design. This article intends to combine innovative design methods in the application of FSW design. Additionally, this article establishes the applied design mode of FSW through case analysis to assist engineers or design personnel who are not familiar with the FSW process. This will help to decrease trial and error or failure risks in the welding process of fixture design. Encountered welding difficulties are thus solved after being guided by the theory of inventive problem solving (TRIZ) design method. By combining traditional TRIZ design methods, this article also refers to other TRIZ methods proposed by some scholars because work will often encounter various engineering challenges. This article hopes to provide welding design personnel with innovative design ideas under research and for practical application. [38]

Teoriya Resheniya Izobretatelskikh Zadatch, and which, translated, mean Theory of the Solution of Inventive Problems. Today, TRIZ is commonly used to refer to the Theory of Inventive Problem Solving, a slight variation of the literal translation. TRIZ is one of the most comprehensive systematic innovation and creativity methodology available to mankind; it was invented by Enrich Saulovich Altshuller. Sooner or later and preferably sooner, almost everyone who seriously studies TRIZ, begin getting intrigued about its history. History is often regarded as ‘His-story’, ‘his’ being a representative term for mankind. However, today the connotation of “his” is used in a broader sense, with it being significant of anything or any phenomenon that has a story connected to it. So, what is so important about history? After all, it has already happened. There is nothing we can do to change it-hence, what is the big deal? Actually, a vital part of a successful future is the understanding the successes and failures of the past. History is not just chronicles about dead people. It is the DNA of the world today. This article is by no means a comprehensive digest of TRIZ his-story, but rather it focuses on the most significant millstones in the 3 eras of TRIZ evolution. The authors strived to give a fairly good representation of particularly significant events, individuals and achievements of TRIZ evolution. [39]

This paper considers the development of TRIZ Technical System ontology with the aim of facilitating the indexing of knowledge contained within available resources in a way that will make it accessible and useful to a user undertaking a design engineering task. The function of the developed ontology is evaluated using a case study, in which a patent is classified using the defined scheme. The quantitative nature of the classification structure developed to support this procedure offers a mechanism that may be further developed and integrated into research aiming to support the computerisation of the knowledge elicitation and representation process. The ontology developed to enable the classification methodology will support the integration of design by analogy procedures and enable effective information retrieval via the TRIZ based approach [40]

QFD (Quality Function Deployment) has been used to reflect the needs of customers in products, while TRIZ (a Russian acronym for Theory of Inventive Problem Solving) was developed to assist engineers in finding innovative solutions to technical problems in product development processes. However, no method has been proposed to integrate QFD with TRIZ effectively. This report describes a new method, named the Innovative Product Development Process

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(IPDP), which systematically integrates QFD with TRIZ and enables the effective and systematic creation of technical innovation for new products. In IPDP, the target products' functions and mechanisms are deployed in parallel into hierarchical structures, and the mechanism that most requires technical innovation is specified from an analysis of customers' needs by calculating a mechanism weight. Then, the technical problems to be solved are defined by considering the relationship between the specified mechanism and corresponding functions or quality characteristics, and technical innovation is executed by applying TRIZ. The effectiveness of IPDP was confirmed by applying it to the technical innovation of a washing machine. [41]

The method, however, needs enhancements in the safety considerations at the earlier stage of conceptual design. This paper presents a hybridized TRIZ methodology with the work of Pal and Beitz, Systematic Design Approach (SDA) through an effective modelling. This modelling helps in critical problem solving in conceptual design of aircraft parts. The process is applied to a case study of selected aircraft components with a proposal of a systematic and creative methodology in the conceptual designing process. The implications of this study will help aircraft designers to optimize the aircraft parts design in an effective and creative way.[42]

To help maintenance engineers, the chair Maintenance Engineering at the University of Twenty has set up a list of 37 guidelines. However, these guidelines only state the goal that should be achieved, but do not define the actions that should be taken to solve maintenance-related problems during the design phase. TRIZ is a product and process innovation method that uses various tools that propose paths to possible innovations and solutions. As such, TRIZ promises it could be a useful addition to the existing set of 37 maintenance guidelines. In this research the compatibility of TRIZ and maintenance guidelines is explored using a 3 stage research plan. Firstly, applicable guidelines are linked to TRIZ methods. In a second step these links are grouped and generalized so not every maintenance guideline also needs a unique TRIZ strategy. Finally a roadmap is presented that helps during Design for Maintenance activities in solving maintenance problems with the support of TRIZ tools. [43]

This study proposes a framework combining the evolutionary trends developed by the Theory of Inventive Problem Solving, or Teriyaki Reshniya Izobretatelskikh Zadatch (TRIZ) in Russian, with the visualization technique of text mining to systematically identify technology trends from patent documents. As technological information in patent documents is stored almost entirely in text format, the text mining method allows R&D personnel to efficiently identify technology trends and effectively conduct R&D planning. Utilizing text mining method on patents of magnetic random access memory (MRAM) systems and the underlying principles of TRIZ evolutionary trends, this study shows that MRAM includes 10 important technology trends. These trends have almost reached the evolutionary limit phase defined by TRIZ, which means that MRAM is fast becoming a mature technology. Therefore, for businesses that intend to acquire MRAM technology they do not possess, a wise R&D plan may be licensing the technology, buying the technology from others, or participating in a joint venture rather than using in-house R&D. [44] The objective is to explore TRIZ tool as a tool that could be helpful during Lean implementation, in particular, during the continuous improvement process efforts. Attending to the already published papers regarding Lean and TRIZ, at least since 2004, this synergy is viable and sustainable. This paper presents TRIZ principles and discusses their relation with Lean Production principles. Additionally, presents some TRIZ tools and explain how they can be useful in the context of the methodology in development to be applied in Textile and Clothing Industry. [45]

Automatic patent classification facilitates searching for previous patent documents. For TRIZ users, they would like to search for patents based on the solutions (TRIZ Inventive Principles) to the Contradictions addressed in the patents, which is different from traditional searching for prior arts based on the application fields of the inventions. For this purpose, a TRIZ-based patent classification expert system is needed. To facilitate automatic classification of patent documents according to Inventive Principles (IPs) for TRIZ users, we analyse the original 40 IPs proposed by Altshuller. Seven IPs are defined as Obscure IPs, the other 33 as Distinct IPs. Furthermore, two kinds of similarity among the Distinct IPs are defined: text similarity and meaning similarity. Then the 40 IPs are grouped into 22 new classes. Automatic classification based on 674 patent documents associated with these 22 new classes is tested and analysed, with two issues of multi-label classification and class imbalance addressed [46]

In this study, we attempt to extend the Lean Six Sigma approach to a broader application in the service industry and integrate TRIZ methodology to enhance the traditional techniques of Lean Six Sigma. Theoria Resheneyva Isobretatelskehuh Zadach (TRIZ) is an effective method for analysing customer needs and developing innovative solutions to meet those needs. A sample problem of the banking service is used to demonstrate how TRIZ can be

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applied to a real-world problem while in a Lean Six Sigma DMAIC process. The results show that the application of Lean Six Sigma methodology with TRIZ performs effectively in the improvement of banking services. Service operations now comprise more than 80% of the GDP in the United States and are rapidly growing around the world. The cost to maintain and service an application is typically more than the initial purchase price. The revenue growth potential of improving the speed and quality of service often overshadows the cost reduction opportunities. The Lean Six Sigma approach is a popular methodology to improve the business opportunities in customer satisfaction, cost and process speed for manufacturing. In this study, we attempt to extend the Lean Six Sigma approach to a broader application in the service industry and integrate TRIZ methodology to enhance the traditional techniques of Lean Six Sigma. Theoria Resheneyva Isobretatelskehuh Zadach (TRIZ) is an effective method for analysing customer needs and developing innovative solutions to meet those needs. A sample problem of the banking service is used to demonstrate how TRIZ can be applied to a real-world problem while in a Lean Six Sigma DMAIC process. The results show that the application of Lean Six Sigma methodology with TRIZ performs effectively in the improvement of banking services. [47]

Complex organizational processes are subject to many dynamic attractors and influence factors. They generate a multitude of obstacles in the framework of process improvement. Application of traditional tools of process improvement cannot lead to significant evolution of process maturity and capability. Even the use of TRIZ-related tools has limitations in defining an ideal solution because in complex adaptive nonlinear systems optimality cannot be achieved. Therefore, an enhanced way of applying TRIZ for process improvement projects is considered in this paper. The proposed algorithm identifies the pool of obstacles and applies TRIZ in relation with each obstacle. Afterwards, a strategy is considered to handle a long list of inventive principles for generating and ordering appropriate improvement projects. The proposed algorithm is successfully tested in the case of a company dealing with software development services. Results demonstrates the concept effectiveness and reveals that active improvement of complex processes requires a well-scheduled implementation of a well-directed package of interrelated and convergent improvement projects.[48]

This paper is devoted to the practical use of TRIZ the in high-tech industry based upon the authors' considerable experience. There are three main aspects related to this methodology in the framework of a high-tech business: research, development and practical utilization. These areas are analysed through problems of company employee training, in-house consulting and the problem solving processes. The research problems of TRIZ methodology and its operation in real practical conditions are investigated. Some methods are proposed for adaptation of methodology structure and applied tools for different kinds of projects. The comparative assessment is presented with regards to the application of different TRIZ tools (Contradictions, Inventive Principles, Standard Solutions, ARIZ, and trig-oriented software) in research, engineering and manufacturing projects. The distinctive features of logical algorithms applied in industrial R&D projects and for solving manufacturing problems are demonstrated as well. The operation of developed logical algorithm for problem solving is presented through examples of industry cases studies with schemes and pictures of proposed solutions. [49]

This study enhanced and refined the previous grouping of the 40 IPs under five service redesign approaches (SRA): self-service, direct service, pre-service, bundled service and physical service. The methodology used to group these principles was by mapping between the principles hints, which have been developed to interpret the TRIZ principles in service context, and each characteristic of the SRA. A comparison between TRIZ contradiction matrix and proposed grouping for a problem case study has been conducted, and it has demonstrated and verified the feasibility of grouping of the 40 principles according to the SRA. [50]

The purpose of this paper is to explore the efficacy of 40 inventive principles of TRIZ for developing researchers' innovative capabilities and to evaluate the extent of application of “40 inventive principles” by inventors in the Research Centre of Intelligent and Signal Processing (a successful research centre that is producing new products in the field of signal processing and medical engineering).Design/methodology/approach – A range of relevant literature is explored initially. A questionnaire about 40 inventive principles of TRIZ was developed based on literature review. Finally, a data analysis including descriptive statistics, correlation and regression analysis was designed by using SPSS software. Findings – The results showed that about 71 percent of the researchers have employed TRIZ above the average in their innovative products. Also these studied researchers used TRIZ principles unintentionally. Therefore, if this research centre and similar institutes want to make full use of their [51]

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The use of some ideation tools can assist in this endeavour. The effective utilization of certain tools can even impact the long-term development of problem solving ability. This study investigates how different tools of TRIZ can be helpful for problem finding. This paper considers the following: 1) what functionality is required in a problem solving tool to ensure effective problem finding? 2) Which tools of TRIZ can assist problem finding?; and 3) How does the use of these TRIZ tools enhance the process of problem finding? The tools explored in this paper are: Situation Analysis, Substance - Field Analysis, Method of the Ideal Result, ARIZ, OTSM and IDM-TRIZ. Discussions are also made as to why these tools of TRIZ offer benefit for problem finding. The results from this paper have implications on the design of training programs in TRIZ for both educational and professional settings. [52]

QFD (Quality Function Deployment) and TRIZ (a Russian acronym for Theory of Inventive Problem Solving) have been each one separately and thoroughly studied by authors. However, integrating both techniques QFD and TRIZ effectively for technology innovation and new product development (NPD) process remains still less explored. Using QFD and TRIZ, for new product design, is one of the best ways to meet the challenge of satisfying customers' inconstant demands and then to thrive in business. In this article we tend to describe a process which systematically integrates QFD with TRIZ and enable the effective and systematic creation of technology innovation for new products. Finally, the Balanced Scorecard (BSC) was introduced to demonstrate the practicality and efficiency of that integration. [53]

TRIZ (the theory of inventive problem solving) has been promoted by several enthusiasts as a systematic methodology or toolkit that provides a logical approach to developing creativity for innovation and inventive problem solving. The methodology, which emerged from Russia in the 1960s, has spread to over 35 countries across the world. It is now being taught in several universities and it has been applied by a number of global organisations who have found it particularly useful for spurring new product development. However, while its popularity and attractiveness appear to be on a steady increase, there are practical issues which make the use of TRIZ in practice particularly challenging. These practical difficulties have largely been neglected by TRIZ literature. This paper takes a step away from conventional TRIZ literature, by exploring not just the benefits associated with TRIZ knowledge, but the challenges associated with its acquisition and application based on practical experience. Through a survey, first-hand information is collected from people who have tried (successfully and unsuccessfully) to understand and apply the methodology. The challenges recorded cut across a number of issues, ranging from the complex nature of the methodology to underlying organisational and cultural issues which hinder its understanding and application. Another contribution of this paper, potentially useful for TRIZ beginners, is the indication of what tools among the several contained in the TRIZ toolkit would be most useful to learn first, based on their observed degree of usage by the survey respondents. [54]

III. AIMS AND OBJECTIVE

The aims and objectives of this study are listed as follows:

- To introduce present TRIZ
- To submit applications in the production industries in India

IV. CONCLUSION

From the above mention literature , it is no doubt that TRIZ is not only an influential but also flexible to all classes of engineering complications of a system. However, it is vital that this theory should be sustained and systematized by other methodologies. Therefore, a systematic innovation model must be developed, in which, more objective tools shall be functional to refine this theory. In correspondence to the purposes of this study, such a systematic innovation model could be useful in the conceptual, design, and construction phases of the construction life for better design or more fiscal substitutes. Furthermore, it could be applied to ―Value Engineering (VE) as well.

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