

The Contribution of TRIZ Integration with Others Design Tools In the Engineering Design Process

Solomani Coulibaly

Assistant Professor, Department of Industrial Engineering, National School of Engineering.– Abderhamane Baba Touré
(ENI-ABT), Bamako, Mali

ABSTRACT: Since its introduction in the beginning of 1990s in the western countries, TRIZ is considered as a very effective tool in the early design process. Consequently, it is no stop growing; developing new approaches (e.g. Ideation-TRIZ, OSTM-TRIZ, TRIZ+, etc.) testifies that. In parallel to the new approaches, researchers find that TRIZ is very complementary to others design tools and methods. That is why many authors proposed an integrated form of TRIZ with others design tools and methods in the engineering design process. The present article carried out a survey in order to disclose an updated situation of TRIZ integration with others design tools and methods. For that, more than hundred relevant articles published in the last seven years (2010-2016) in TRIZ journal, ETRIA TRIZ Future Conference, inderscience and springer have been collected. The goal is to disclose how TRIZ contributes, by its integration, to the effectiveness of design tools and methods in the engineering design process. The findings of this study show that more 17 articles, that integrate TRIZ and others design tools and methods, were published per year. More than twenty tools or methods were integrated with TRIZ, but only five (QFD, AD, DFSS, AHP and TOC) are the most used. Only two (Matrix of Contradiction and The 40 Inventive Principles) of TRIZ tools are most preferred by authors. Then, manufacturing is the favorite field of application. And finally, steps three and four are the steps where TRIZ integration contributes the more.

KEYWORDS: TRIZ, TRIZ integration, design tools and methods, engineering design process

I. INTRODUCTION

In today's economy the globalization of business and markets, the changing nature of world trade regulations and business operations, and the impact of information technology on business have fundamentally changed the economy and having a profound effect on engineering practice. With the maturing markets and the eye of the customer becoming more and more selective in choosing products, business must continue to provide products to their respective markets that give a feeling of satisfaction to their customers. Due to the dynamic character of customer's expectations, technology and competition existing products in the market will have a limited lifetime and either needs to be significantly improved upon or simply replaced. To face this challenge methods and creativities tools can be a strategic alternative. Many creativity tools, methods and philosophies have been developed in the literature [1], but new tools continue to grow. Among these tools there is TRIZ. TRIZ, the Russian acronym that stand for "Theory of Inventive Problems Solving"[2], is very appreciating in design process. It is an experimental science based on the analysis of over millions of invention patents that is very powerful for generating new ideas to solve an innovative problem. Since its development TRIZ has been introduced in many smalls and mediums enterprises or industries [3]. Moreover, many researchers find that TRIZ is very complementary to others design tools and methods. In the literature, the integrated forms with others tools have been proposed by several authors: Quality Function Deployment (QFD) by Liu and Cheng [4], Axiomatic Design (AD) by Borgianni and Matt[5], Design for Six Sigma (DSS) by Wang et al [6], Theory of Constraints (TOC) by Huang et al [7], etc.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 1, January 2017

The present paper explores the implementations and practices of TRIZ integration with others design tools, methods and philosophies in the organizations. A survey was carried out, from database of the last seven years in order to examine how TRIZ integration with others problem solving tools and methods can contribute to make effective the engineering design process. The findings of this research revealed some amazing results, even if some where our understanding of TRIZ integration with others problem solving tools implementation were strengthened.

II. RELATED WORK

In the early years which followed its growing, there was a true passion for the researchers to make help TRIZ (or vice versa) by other design problem-solving tools throughout the design process of their product or service. The literature review done by Hua et al [8] about TRIZ and its integration with others design tools shows how much practitioners were excited by this tool. But in these last five years the batch of tool which arouses the interest for TRIZ integration is decreasing. This new trend identified five design tools and methods that have been frequently integrated with TRIZ. These five tools are: Axiomatic Design (AD), Analytic Hierarchy Process (AHP), Design for Six Sigma (DSS), Quality Function Deployment (QFD) and Theory of Constraints (TOC).

A. TRIZ IN BRIEF

TRIZ is the Russian acronym of *Theory of Inventive Problems Solving*. It is a theory resulting from the researches completed by G. S. Altshuller, a patent expert in Russian navy. It is an experimental science based on the analysis of over millions of invention patents classified in 5 categories (table 1), from the apparent solution to the discovery one, according to the levels of inventiveness [9] and [10]. Table 1 explains that, an invention can be as well a minor improvement of an existing product that required only little time to be found, as a discovery resulting from very long research. TRIZ is considered to be a powerful tool for obtaining inventions located between levels 2 and 4 of this classification.

Table 1: Levels of inventiveness

Level	Degree of inventiveness	% of solutions	Source of knowledge	Approximate of solutions to consider
1	Apparent solution	32%	Personal knowledge	10
2	Minor improvement	45%	Knowledge within company	100
3	Major improvement	18%	Knowledge within the industry	1,000
4	New concept	4%	Knowledge outside the industry	100,000
5	Discovery	1%	All that is knowable	1,000,000

Three main findings emerged from his analysis:

- Problems and solutions were repeated across industries and sciences
- Patterns of technical evolution were repeated across industries and sciences
- Innovations used scientific effects outside the field where they were developed

From these findings a structured methodology have been developed aiming to help designers to:

- develop new generation products,
- resolve difficult problems, and
- identify and treat failures of products.

The development of TRIZ leads to many tools and concepts that designers can use, according to their problems, throughout the design process. Among the tools there are: Contradictions matrix, Su-Field analysis and Standard solutions, Scientific and Technical Effects, Trends of evolution of technological systems, Algorithm for Inventive Problem Solving (ARIZ), etc.

From the literature it appears that, TRIZ is not an exact science, but a well-structured methodology for creative problem solving based on a set of tools established from the findings of statistical research of patents and other sources of technical information. The main aim is to develop a well-established process for solving inventive problem from

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 1, January 2017

different innovations in the past. Figure 1 shows that most of the problem-solving methods are based on trial and error approach. Yet, TRIZ proposes that, to solve a given problem, designers have always to find a generic problem, then use a TRIZ appropriate tool to generate the generic solutions, and finally interpret these generic solutions to choose and develop the specific one [11].

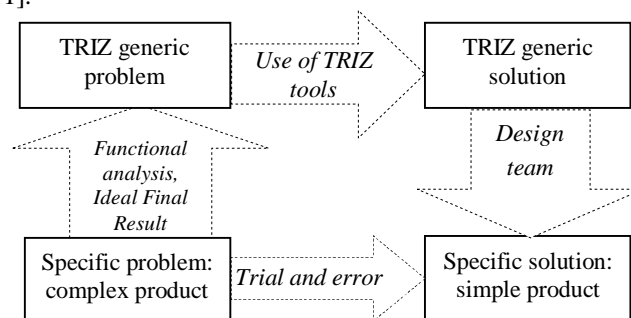


Figure 1 : The TRIZ problem solving process

B. AXIOMATIC DESIGN (AD)

Axiomatic Design (AD) is a design approach proposed by Professor Nam P. Suh in the end-1970s. He defines an axiom as obviousness or fundamental truth for which, there is neither any counterexample nor exception. Axiomatic Design is based on three main concepts: design as process of mapping; laws of design in the form of axioms and the matrix of design representing the functional dependences. According to Suh, design follows an iterative and sequential advance between "what one seeks to achieve" and "How to achieve it"[12]. Design process is divided into four fields: the customer field, the functional field, the physical field and the field of the process. The transition from a field to another one is called process of mapping.

Two design axioms have been identified. Independence axiom maintains the independence of the function requirements and information axiom minimizes the information content of the design. Some of the corollaries and theorems resulting from these axioms are very comparable of TRIZ principles.

C. ANALYTIC HIERARCHY PROCESS (AHP)

AHP was developed by Thomas Saaty[13] at the beginning of 1970's. It is one of the most powerful analysis methods to solve complex problems. AHP method represents a problem of decision by a hierarchical structure reflecting the interactions between different elements of the problem, then compares by duos elements of the hierarchy, and finally determines the priorities of the actions. As to fill a gap, AHP appears on the list of tools accompanying TRIZ only these last years. Nevertheless, both tools are very suitable, insofar as TRIZ is known for its wealth for new ideas generation, while AHP is very strong in hierarchizing the collected ideas.

D. DESIGN FOR SIX SIGMA (DFSS)

Developed by Motorola in the mid-1980s, DFSS methodology offers techniques and tools to drastically improve business processes while reducing both the conceptual and operational types of vulnerabilities of designed entities[14]. Process production-oriented at the beginning; the method seeks the absolute regularity. Indeed, variability causes customer's dissatisfaction. Customers are expecting a certain quality, according to a specific standard, in each product. Not be able to guarantee the totality of the production by respecting this standard is particularly expensive for companies. To face this challenge DFSS proposes to release these entities at the Six Sigma quality levels in all their requirements, that is, to does not authorize more than 3.4 defects per million for designed entities.

E. QUALITY FUNCTION DEPLOYMENT (QFD)

Quality function deployment (QFD) was firstly introduced by Japanese Professors Shigeru Mizuno and Yoji Akao in the end-1960s. In a total quality approach, they sought to make sure that the "Voice of Customer" was deployed

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 1, January 2017

throughout the full process of designed entities. According to Akao[15], QFD is a method for developing a design quality aimed at satisfying the consumer and then translating the consumers' demands into design targets and major quality assurance points to be used throughout the production stage. They also see QFD as converting consumers' demands into "quality characteristics" and developing a design quality for the finished product, by systematically deploying the relationships between the demands and the characteristics, starting with the quality of each functional component and extending the deployment to the quality of each part and process.

The most common approach, promoted in U.S.A., is the so-called American Supplier Institute Four Phase Model [16] (figure 2). This figure shows the steps of quality deployment along the engineering design process. It uses three series of coupled matrices and a chart for planning production requirements to translate customer needs through several stages into manufacturing equipment settings.

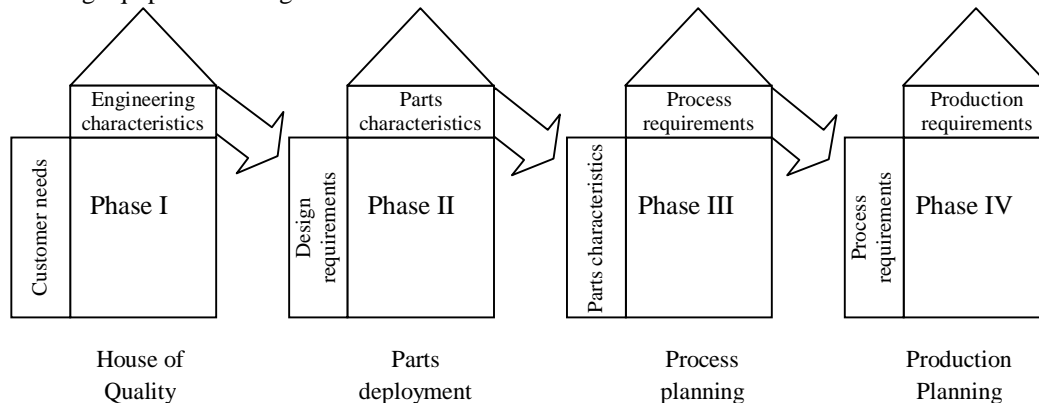


Figure 2: QFD Four Phase Model

F. THEORY OF CONSTRAINTS (TOC)

Theory of constraints (TOC) was developed by Goldratt[17] in 1984. Often described as a continuous improvement methodology, often as management philosophy, TOC seeks to help managers achieving a goal by identifying the constraints that prevent or limit the achievement of this goal. In an organization, managers can accomplish a fixed goal through analyzing of the underlying cause and effect dependency and variation of the system in question.

TOC is composed of two main components. The first one is a philosophy, which supports TOC working principles. It is composed of five steps for on-going improvement (figure 3), the drum-buffer-rope (DBR) scheduling methodology, and the buffer management information system. This philosophy suggests that the main constraint in most organizations may not be physical, but in fact managerial-policy related. To address the policy constraints and effectively implement the process of on-going improvement, Goldratt developed a generic approach called the Thinking Process (TP). This is the second component of TOC. The TP prescribes a set of five tools in the form of cause-and-effect diagrams. It starts to identify core problems by using a tool called Current Reality Tree (CRT). Dettmer [18] defined a CRT as a logical structure that depicts the state of reality as it currently exists in a given system. Once a core problem has been identified, the next step is therefore to search for a plausible solution to the core problem. This requires other tools such as Contradiction Resolution Diagram (CRD) also known as Evaporating Cloud (EC) and Future Reality Tree (FRT). Experts believe that it is the TP which will ultimately have the most lasting impact on business.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 1, January 2017

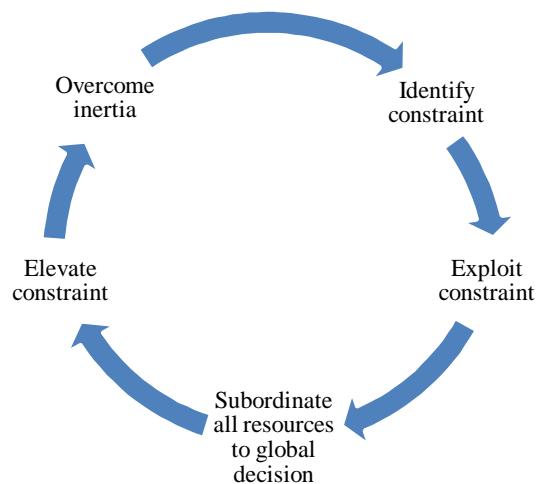


Figure 3: TOC process of on-going improvement

III. MATERIAL AND METHODS

TRIZ, since its emergence, is always growing. Consequently, new approaches are developing (e.g. Ideation-TRIZ, OSTM-TRIZ, TRIZ+, etc.). In spite of this growth, the tendency is rather to integrate it into other design tools. In order to disclose an updated situation of TRIZ integration with others design tools and methods, the present study was carried out. It is a survey oriented and based on how TRIZ contributes, by its integration, to the evolution of design tools and methods. For that, more than hundred relevant articles published in the last seven years (2010-2016) in TRIZ journal, ETRIA TRIZ Future Conference, Inderscience and Springer have been collected. The collected articles were compiled, analyzed to determine what is the contribution of TRIZ in the practice of designed entities, which fields are the most used, what are the most used tools, what are the tools that need more TRIZ.

IV. RESULTS

A. DISTRIBUTION OF PUBLISHED PAPERS IN THE TIME

To conduct this study we have collected 117 relevant articles that proposed an integration of TRIZ with other design tools or methods. La majority of the published articles put forward the synergies between TRIZ and just one tool, while some authors proposed it with two or more, such as [19]. The figure 4 shows how many papers have been published per year, from 2010 to 2016. A first analysis of this figure shows that an average of 17 articles, which treat the possibility of integrating TRIZ with other tools, was published per year. Without taking account TRIZ single papers, this number illustrates how much time this tool interests the researchers.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 1, January 2017

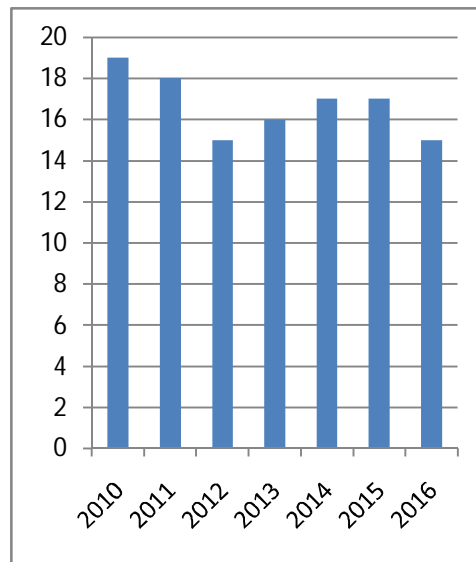


Figure 4: Distribution of published papers in the time

B. THE MAINS TOOLS INTEGRATED WITH TRIZ

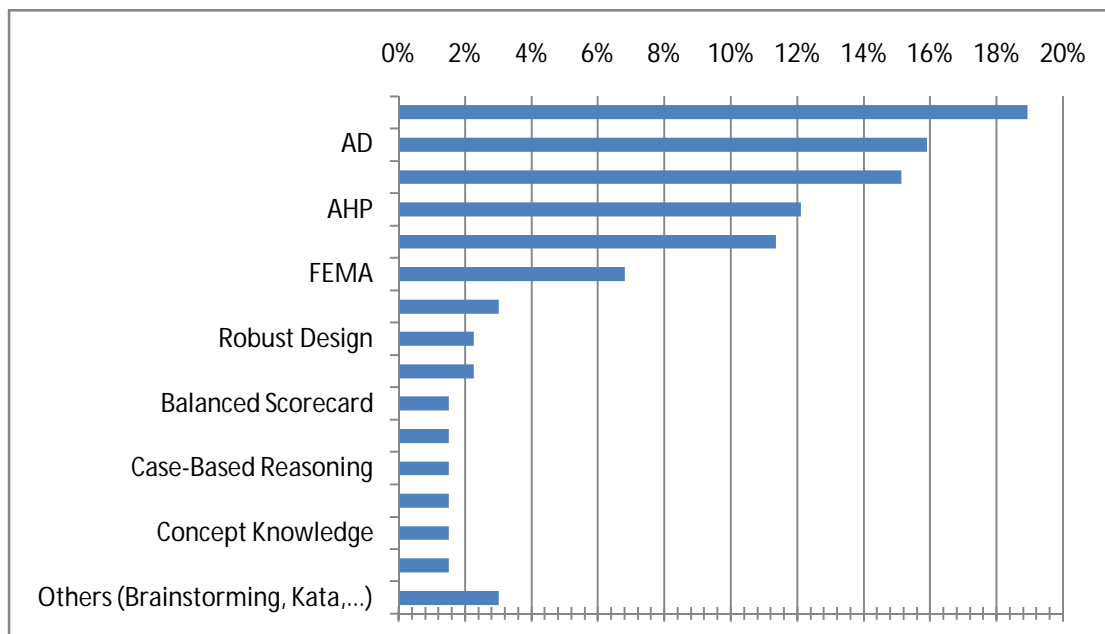


Figure 5: TRIZ integration with others design tools

Since its introduction, TRIZ has much especially inspired the researchers for its capacity to help others tools to be more efficient. It is besides this passion which explains the high number of publication which proposes its integration with others design tools and methods. Figure 5 shows the percentages of the different tools or methods that have been integrated with TRIZ among the selected articles. It indicates the mains preferred tools that are suitable for TRIZ. One of the remarkable facts is the appearance of AHP (Analytic Hierarchy Process) in the top four while such was not the

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 1, January 2017

case in the similar studies like [20] or [21]. More than twenty tools or methods that were integrated with TRIZ are indexed in the literature. The present study shows that only five of them are preferred by the researchers: they are QFD, AD, DFSS, AHP and FEMA that were introduced at the beginning of this article. The top five cumulates more than 73% of published articles. Among the top five, around 19% of the published articles put forward QFD with TRIZ, what is corresponding to the same tendency released by similar studies previously made, such as [20] or [21].

C. THE PREFERRED TOOLS OF TRIZ

During its integration with others design tools or methods; authors have to make a choice between several tools of TRIZ. Each tool has a certain advantage and some favorite fields. The analysis of the different TRIZ tools used by the authors in the articles allowed us to sketch the figure 6. It indicates the percentages of TRIZ tools used throughout the collected papers. The results show that two of the several tools are more preferred by authors: they are Matrix of Contradiction and The 40 Inventive Principles. More than 50% of the examined articles used these two tools. The opposite would have been astonishing knowing that TRIZ holds its notoriety by the effectiveness of these two tools to help engineers solving their design process problems.

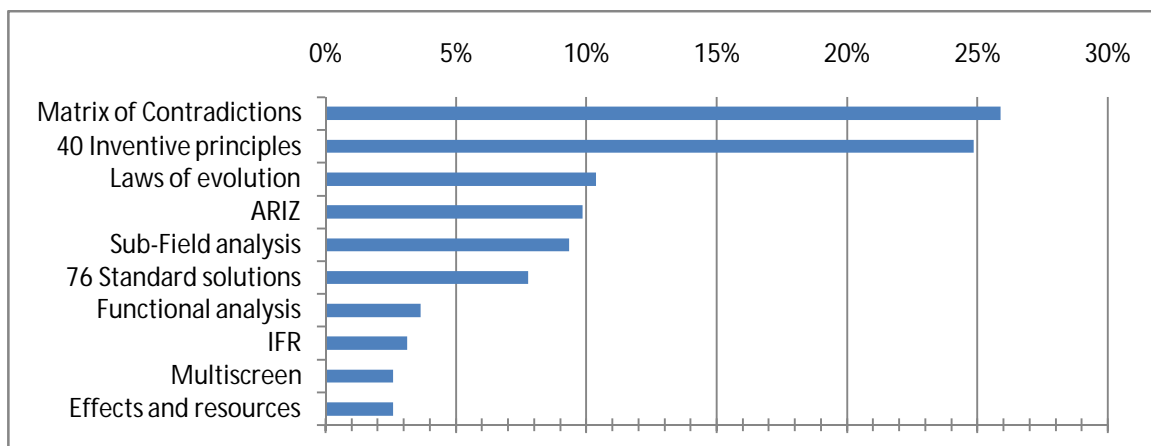


Figure 6: TRIZ tools contribution with others tools

D. MAINS APPLICATIONS FIELDS

The selected articles cover technical fields as multiple as varied. A meticulous analysis allowed us to identify, classify and sketch the Figure 7. It indicates the percentages of the mains applications fields of TRIZ integration with others design tools and methods. Even if the selected one is partial, we think that the chosen sample is highly representative. By considering the different technical fields covered by the collected articles we note that 78% of studies are made in the field of manufacturing product, transportation and services. From the top three fields manufacturing covers 47%. This reinforces our understanding of TRIZ key practices and how it helps engineers in their design process.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 1, January 2017

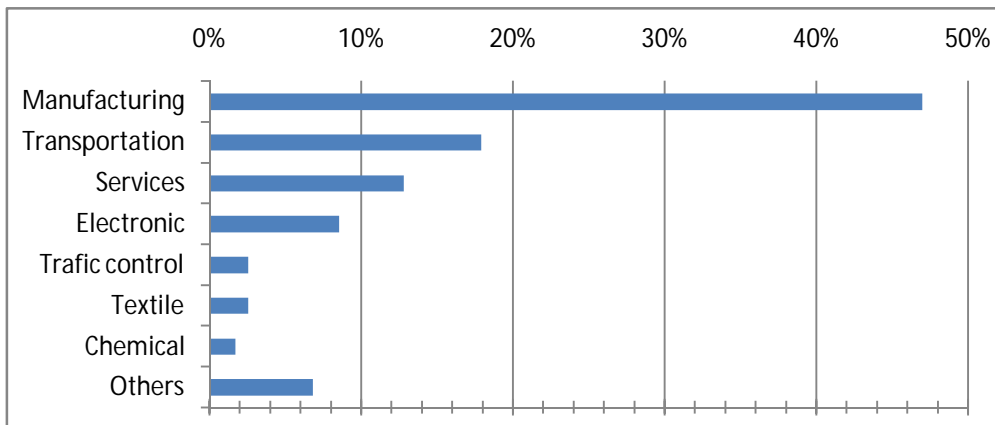


Figure 7: Application fields of TRIZ integration

E. THE CONTRIBUTION OF TRIZ INTEGRATION IN THE DESIGN PROCESS

The stages of engineering design process differ according to authors, but the following steps are common in most of the proposed processes.

- Step 1: Identify the need or problem
- Step 2 : Research the need or problem
- Step 3: Develop possible solution
- Step 4: Choose the best solution possible
- Step 5: Construct a prototype
- Step 6: Test and evaluate the solution(s)
- Step 7: Communicate the solution(s)

The table2summarizes all the reviewed articles in which TRIZ has been integrated with others tools or methods. By observing this table, we can see that QFD and DFSS are the two tools which better integrate TRIZ. Globally, itshows how much TRIZ integration contributes to make the others design tools efficient throughout the engineering design process, especially in the steps four and five. Here, we can see that QDF and DFSS are the two tools the more adapted Each tool taken individually has its strengths and weaknesses, but it remains obvious that TRIZ integration basically reinforces the assets of these design tools and methods in their favorite fields.

V. DISCUSSION

A. DISCUSSION

Even if we think that the sample used is validly representative, the present work remains that remains a survey. It is the photography of the state of the art represented at a given time. Consequently, the results are susceptible to be discussed if method is changed. Moreover, we found in the literature that some of the proposed approaches are so complicated, like the one of Yang and Chen [22] that they need a high background for new comer to be implemented. Is it necessary to have so trained humans' resources to perform a well-structured engineering design process? We don't think so.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 1, January 2017

Table 2: The contribution of TRIZ integration in the design process

TRIZ with	Engineering design process steps						
	Identify	Research	Develop	Best	Prototype	Evaluate	Communicate
QDF	x	x	x	x		x	
AD		x	x	x			
DFSS	x	x	x	x		x	
AHP			x	x	x		
TOC			x	x			
FMEA			x	x			
DFMA			x	x			
Robust design			x	x	x		
SWOT			x	x		x	
BSC			x	x			
KANSEI			x	x			
CBR			x	x			
Env. Analysis			x	x	x		
C-K			x	x			
PAHL-BEITZ	x	x	x	x			
Others		x	x	x	x		

B. LIMITATIONS

The main limitations of this work are considered in two ways. Firstly, the examined papers have been limited from 2010 to 2016, so that we fail to take account those published before. Even if we think that the sample is validly representative, it would allow more robust results if the overall published integration was considered. Secondly, non-English papers have not been included. It is sure that the integrations of TRIZ with others design tools and methods have been published in others languages.

VI. CONCLUSIONS

The present study examined more than hundred papers which put forward TRIZ integration with others design tools and methods. We have classified them according to many criteria, in order to show how TRIZ integration can help engineers in their design entities processes. We particularly focused on the way to detect: what are the most popular tools or methods that are suitable for TRIZ, what are the most preferred tools by authors, what are the favorite fields of TRIZ integration and what is the contribution of TRIZ integrated in the engineering design process. The findings of this study are in the same alignment to those previously made, but with different approaches. However, the AHP approach makes its appearance in the top five tools preferred by authors, which was not the case in preceding studies.

In order to improve the present study, future development regarding others aspect that have not been taking account in this work can be explored, by considering database of others websites. We believe that this would give more robust results.

REFERENCES

- [1] DeboisF., GroffA. and ChenevierE., "La Boîte à outils de la créativité", Dunod- 2ème édition, 2016.
- [2] AltshullerG.S., "And Suddenly the Inventor Appeared", Worcester, MA: Technical Innovation Center, 1996.
- [3] BoldriniJ.-C., "L'accompagnement méthodologique des projets d'innovation en PMI. Le cas de TRIZ", XIVème Conférence de l'Association Internationale de Management Stratégique, Pays de la Loire, Angers, 6-9 juin 2005.
- [4] LiuH. T, ChengH. S, "An improved grey quality function deployment approach using the grey TRIZ technique", Computers & Industrial Engineering, Vol. 92, pp. 57-71, 2016
- [5] BorgianniY., MattD. T., "Applications of TRIZ and Axiomatic Design: A Comparison to Deduce Best Practices in Industry", Procedia CIRP, Vol. 39, pp. 91-96, 2016.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 1, January 2017

- [6] WangF. K., YehC.T. and ChuT. P., "Using the design for Six Sigma approach with TRIZ for new product development", Computers & Industrial Engineering, Vol. 98, pp. 522-530, 2016.
- [7] Huang, S., Liu, X. and Ai, H. "Research on application of process model for product concept creative design based on TRIZ and TOC", International Journal on Interactive Design and Manufacturing, pp.1-10, 2016.
- [8] HuaZ. S., YangJ., CoulibalyS. and ZhangB., "Integration TRIZ with problem-solving tools: a literature review from 1995 to 2006", Int. J. Business Innovation and Research, Vol. 1, Nos. 1/2, 2006.
- [9] Altshuller G.S., "Creativity as an exact science", Gordon and Breach, New York, 1988.
- [10] Altshuller G.S., "The innovation algorithm: TRIZ, systematic innovation, and technical creativity", Worcester, Massachusetts, 1999.
- [11] Coulibaly, S., "Setting up a successful TRIZ project", Engineering Management Journal, vol. 15, no. 2, p. 14, 2005.
- [12] SuhN. P., "Axiomatic Design: Advances and Applications", Oxford University Press, New York, 2001.
- [13] Saaty T.L. "The Analytic Hierarchy Process", New York, McGraw-Hill, 1980.
- [14] Yang K. and El-HaikB., "Design for Six Sigma, New York, McGraw-Hill, 2003.
- [15] Akao Y., "Quality Function Deployment: Integrating Customer Requirements into Product Design", Productivity Press, Cambridge, MA, 1990.
- [16] Hauser J.R.; and Clausing D. (), "The house of quality", Harvard Business Review, Vol. 66, Issue 3, pp. 63-73, 1988.
- [17] Goldratt E.M. and Cox, J., "The Goal: An Ongoing Improvement Process", Gower, Aldershot, 1984.
- [18] Dettmer H.W., "Goldratt's Theory of Constraints: A System Approach to Continuous Improvement". ASQC Quality Press, 1997.
- [19] 18S. Vinodh, V. Kamala, K. Jayakrishna, "Integration of ECQFD, TRIZ, and AHP for innovative and sustainable product development", Applied Mathematical Modelling, Vol. 38, Issues 11-12, pp 2758-2770, 2014.
- [20] Spreafic. and RussoD., "TRIZ industrial case studies: a critical survey", Procedia CIRP 39,pp. 51 - 56.2016
- [21] CavallucciD., "World Wide status of TRIZ perceptions and uses a survey of results," 2009.
- [22] YangC. J. and ChenJ. L., "Forecasting the design of eco-products by integrating TRIZ evolution patterns with CBR and Simple LCA methods", Expert Systems with Applications, Vol. 39, pp. 2884-2892, 2012.