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Design-To-Cost Framework in Product Design Using Inventive Problem Solving Technique (TRIZ)

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Abstract: The research carried out to identify ways in which tools and methodologies from Theory of Inventive Problem-Solving (TRIZ) to solving gaps within the Design-To-Cost (DTC) strategy in product concept development. The aim was to develop an implementation framework for DTC improving product cost and at the same time increase the product innovation. The research paper reviews TRIZ methodology that has potential to be applied for cost reduction initiatives, followed by a discussion of the DTC strategies that commonly practiced in the various industries. The proposed new DTC implementation framework with TRIZ tools is developed and the research paper concludes with a case study using the new DTC Framework.

Keywords: Design-to-Cost, Cost Reduction Strategy, Inventive Problem Solving Technique, TRIZ Tools.

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INTRODUCTION

Market liberalization and global competition push companies to change the way they run the business. Automotive companies have to juggle between meeting the customer requirement, time-to-market and most importantly the investment cost, the main risk in product development project [1], [2].

Some firms adopting DTC strategy to provide solutions to these challenges. The DTC strategy always has been combining with target costing as the foundation of cost management in product development project. The DTC provide opportunity of early involvement for engineers or designers to create product that meet the target cost which have been derived from target selling price and target profit. DTC is a method of 'Management by Objective', step by step design uses the information of difference [3]. However, in real situation, a lot of product development projects have been dragged backward or delaying the time-to-market, resulting in huge negative impact to the organization goals. Some DTC ideas have contradiction parameters between low-cost product design and quality performances, conveniently trade-off has been used on conflicting requirements and accepted as the solution to the design. The trade-off analysis will provide solution that needs an amount of sacrifice in customer satisfaction to achieve a certain amount of cost saving, this will negatively impact the product competitive performance and hence product innovation.

The analysis on DTC framework done by Williamson [4] pointed out that to apply the strategy without strong justification brings failure to the cost reduction effort. Trade- off in design constraints, will hinder the effort to explore the ideas towards more cost reduction and halt the product innovation growth. Trade-off in DTC may change the direction of product development [5], thus drastically affect the project goals.

This paper presents the application of TRIZ tools in DTC implementation to resolve conflicting parameters in product concept design and development without any trade-off.

2.0 Literature Review

2.1 Design-To-Cost implementation

In facing today's turbulent market environment, companies are compelled to integrate and synchronize product design, process planning and cost estimating activities rather than following sequential planning procedures. Product and process modifications are more expensive at the later stage of product development cycle. The objective of concurrent cost information is to optimize the product design with respect to balancing the trades-off between cost and performance requirements before the prototype is built. The identification of cost and performance sensitive parameters to forecast the system's competitiveness is still being developed.

DTC methodology evaluates the cost and performance of a design solution in a top down approach, i.e. the evaluation of a system design instead of a single component design. New technologies can alter the component manufacturing as well as its assembly methods without changing the entire system. Taking this into account, competing system designs have to be compared at the system level. As a result, the cost model has to evaluate and aggregate costs from lower to upper system levels. One way that companies can regain control over their costs is through systematically classify and identify product costs. Using a systematic approach to perform cost reduction not only yields cost improvement but provides decision-makers with the trades-off involved in achieving these reductions [5].

The strength of DTC is the capability to define a measurable design parameters against performance, to bridge the communication gap between designers and others in product cost reduction, the capability to improve total cost including product and the processes and focusing on idea generation to reduce product cost. DTC also poses some weaknesses, such as resorting to trades-off to quickly solve any issue of unmet target cost, low innovation in product design, not improving deficiencies in critical areas or any harmful functions, indirect implication such as delaying the project time-to-market and impact the development cost [6].

DTC concept has a long history of use in the U.S. Department of Defence for evaluating new weapons system. This directive defines DTC as “a management concept when vigorous cost goals are established during development, and the control of systems costs (acquisition, operating and support). Practical trade-offs are often made between operational capability, performance, cost, and schedule. Non-defense related industries also apply this concept to their major procurement decisions. However, often in both defence and private sectors the cost goals are not achieved due to lack of proper planning and control of management tasks at different stages of the product life-cycle.

Table 1: Literatures on DTC applications in the industries

Research focus & Author (year)
Aerospace and aeronautic engineering
[3] Esaki & Yamaguchi (1979), [7] Kaufmann (2008), [8] Valerdi (2005), [9] Boyd (1982), [10] Dean (1990), [6] Tyson et.al (1989), [11] Schwint (1975), [21] Dean & Unal (1991), [25] Gosselin (1999)
Automotive and vehicle
[12] Sippel & Schelkle (2009), [13] Monden, Lee (1993), [29] Monde, Hamada (1991), [20] Tani et al. (1996), Taylor (1997), [14] Carr & Ng (1995), [22] Rösler (1996), [15] Lee & Monden (1996), [16] Hurley & Scyder (1987), [17] Favato & Mills (2007) Tereko (2002), [18] Feil et al. (2004)
Electronic, Software engineering and Others
[4]Williamson (1994), [31]Woods et al. (2012), [19] Wichita (1979), [20]Esaki (1991), [5] Cleark (1988), [22] Geiger & Dilts (1996), [30] Gilb (2011)

Table 1 show that the application of DTC started in the military and aviation sector later expand to non military industries. It also shows that the more case studies using target costing and design to cost is the automotive industries. Adopting DTC and target costing is significant to the automotive industry due to the level of product complexity that needs to be managed, similarly with the aeronautic and aviation industries. Free Trades Agreement create competitive environment for the manufacturer to increase their market sales and generating higher profit by producing low product cost with better quality [20][23].

In a manufacturing environment, the tools used in DTC strategy to generate ideas and in problem solving process are limited and not systematically structured [11].

Current knowledge of DTC Framework

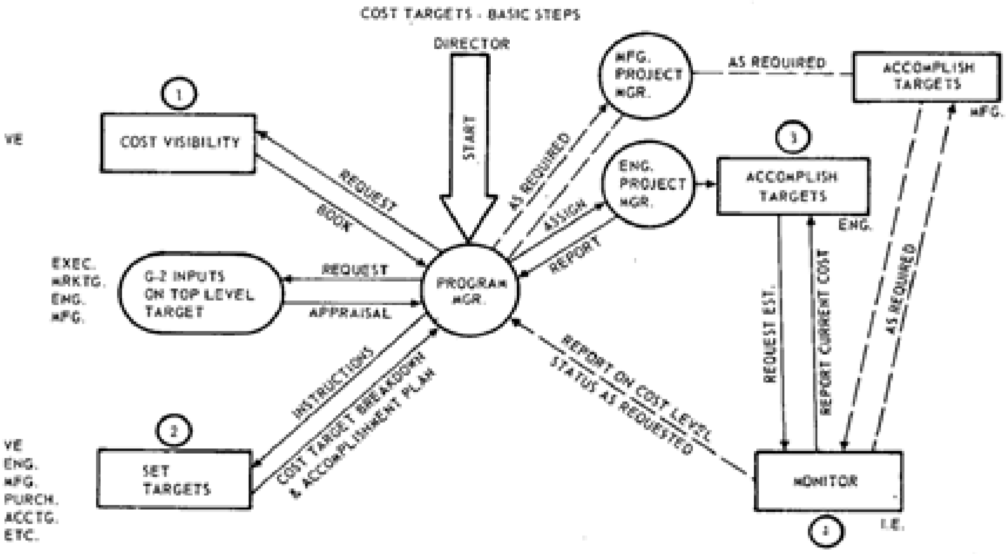

Figure 1 : DTC implementation framework by Steinmetz [22]

According to Steinmetz, Figure1, to gain effectiveness in implementing DTC is by early involvement of product and concept design, therefore a clear direction and procedure are required to successfully implement [24]. The author proposed that the framework need to have operating procedure in phases. The DTC implementation framework consists of 4 main phases which communicated with the program manager.

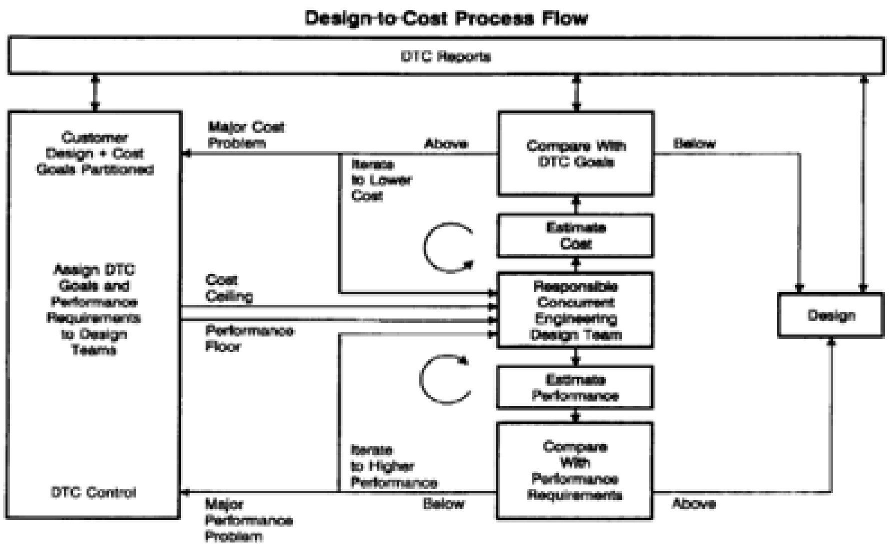

Figure 2: DTC implementation framework by Williamson [2]

Similar point highlighted by Williamson [4] that DTC need to start as early as possible in order to identify the opportunity to make improvement easier and maximize the cost reduction and other benefit, as shown in Figure 2.

INTEGRATION OF TRIZ INTO DTC STRATEGY

TRIZ, a Russian phrase "teorija rezhenija izobretatelskih zadach", means the "theory of inventive problem solving" [25]. It was developed by Genrich Altshuller (a Russian scientist and engineer, 1926-1998), who studied about 400,000 technology patents1, and from them drew out certain regularities and basic patterns which governed the process of solving engineering problems, creating new ideas and innovation. This provided an understanding for the creation of a systematic process for invention of new systems and the refinement of existing ones.

Implementing the concept of DTC in the product design, is essentially decision-making exercises. Earlier analytical tools were unable to secure the issue of uncertainty in decision making process. The main issue is that the effect of decreasing one or more key factors, simultaneously increasing one or more other key factors in design projects [26]. The emphasis on 'trade-off' solutions in traditional problem solving practice often means that designers are rarely explicitly aware that conflicts exist. Therefore it can be conclude that the need of new approach is critical in decision-making activities, which eliminate the dependability of trade-off concept.

Engineering Contradiction principle in TRIZ is the need for problem solvers to actively seek out the conflicts and contradictions inherent in all systems. The following TRIZ methodology is trying to 'eliminate' those contradictions rather than to accept them. By solving contradiction and strive towards 'Ideality' without any trade-off. Therefore, TRIZ have the capability to provide the opportunity to complement the significant weakness in adopting DTC concept in product design, even though there are constraints for TRIZ tools be used in cost improvement activities [27]. There is also time/cost trade-off or contradiction for innovation, when development time is shortened, cost is increased. The core of innovation is to find difficult problems, such as the problems with contradictions, and to solve them quickly. TRIZ is expected to provide solutions for the restriction of innovation and technology improvement experienced in implementing DTC in product design and development, such as upgrading value of design [28]. Designers who adopted TRIZ will increase the speed of product development and reduce the cost at same time.

TRIZ method has begun to be integrated with a number of established and emerging problem definition and problem solving tools and strategies. This integration of TRIZ have been achieved with other concepts such as Quality Function Deployment (QFD), Failure Mode Effect Analysis (FMEA), Value Stream Mapping (VSM), Value Engineering (VE), Theory of Constraint (TOC), Taguchi, Design For Manufacturing Assembly (DFMA), Six Sigma and other established new integration concept [29].

Based from the summary in Table 2, the main TRIZ tools that are suitable for DTC are product & component analysis, function analysis and trimming. Then from the trimming activity, a problem is normally created to solve function problem or contradiction problems between parameters. The DTC ideas that are generated from TRIZ tools need to be reviewed and evaluated. In evaluation phase, the idea will be rated based on two contradicted criteria, 'Ease of implementation' and 'High potential cost saving'. Using the Contradiction Matrix, both parameters associated with the criteria provide general solution to solve those contradictions.

Table 2: Literatures on DTC-TRIZ integration & applications

No	Authors & Year of publication	DTC gaps	Cost reduction using TRIZ	Integration of TRIZ
1	[31] Ikovenko & Bradley, 2004	Customer focus	Trimming	Integration Success
2	[32] Mann & Domb, 2007	Trade-off	Contradiction	Harmful factor
3	[45] Sawaguchi, 2002	Brainstorming	Automotive	High value idea
4	[33] Stratton et al.,2007	-	Trimming	Engineering Needs
5	[34] Domb & Kling, 2006	Challenges	-	-
6	[35] Domb, 2005	-	Potential	Manufacturing success
7	[36] Isaka, 2012	Design competitive	Trimming	Simplification
8	[37] Mann, 2004	-	Cost Matrix	-
9	[46] Martin, 2010	Complement	Waste reduction	Lean and TOC
10	[32] Mann &Domb, 2007	-	Function mapping	Customization
11	[38] Cho et al.,2004	-	Trimming	-

In summary, the gap in the research is lacking in the innovative solution for DTC Strategy, this can be solved by integrating TRIZ tools in the implementation framework that is able to provide better results not just in reducing cost but also improve product innovation.

IMPLEMENTATION FRAMEWORK OF DTC FOR PRODUCT CONCEPT DESIGN STAGE USING TRIZ TOOLS

The proposed framework as shown below is a part of product design and development process. The DTC implementation process is conducted in main four phases, prioritization of DTC system, idea generation, idea evaluation and the implementation ideas and off-line idea exploration.

Figure 3 shows the proposed implementation framework of DTC phases consist of main activities and TRIZ tools that need to be used in the processes. The most important data established initially is the target cost, and this will be the foundation of overall DTC deliverables and goals. Starting with the first phase, the product concept designs are analyzed through product analysis and components analysis.

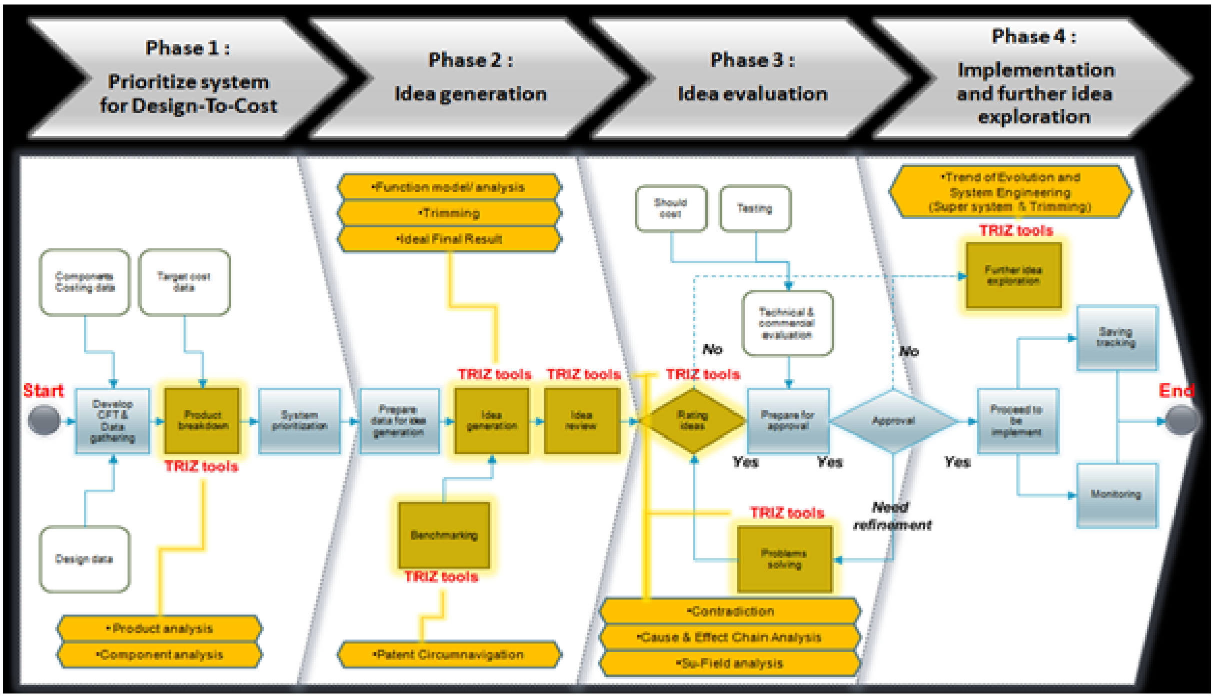

Figure 3 : Conceptual DTC strategy with TRIZ

Figure 4 shows the breakdown of the product analysis and components analysis. It provide clear identification of system that hold the biggest cost of a product. Each breakdown level are analyzed using Pareto analysis. Those components that carry high cost are the primary focus to DTC idea generation. In the second phase, the focus on sub-system for DTC which needs to go through function analysis whereby the function model is created. As the establishment of function model, the components, object and functions provide clear pictures to carry out trimming activity.

Trimming have three types of approaches, the first approach is that function carrier can be trimmed if we remove the object of its useful function [39]. Approach stated that the function carrier can be trimmed if the object of function performs the useful function itself. This approach provides ideal solution to DTC, where the object can provide function itself using available resources of the system, surrounding environment and free or inexpensive resources. The final approach said that the function carrier can be trimmed if another component performs its useful function.

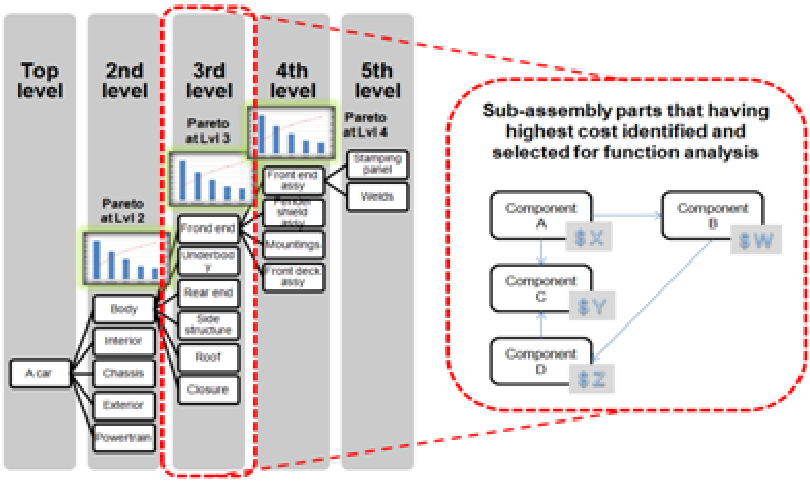

Figure 4 : Product analysis and Function analysis

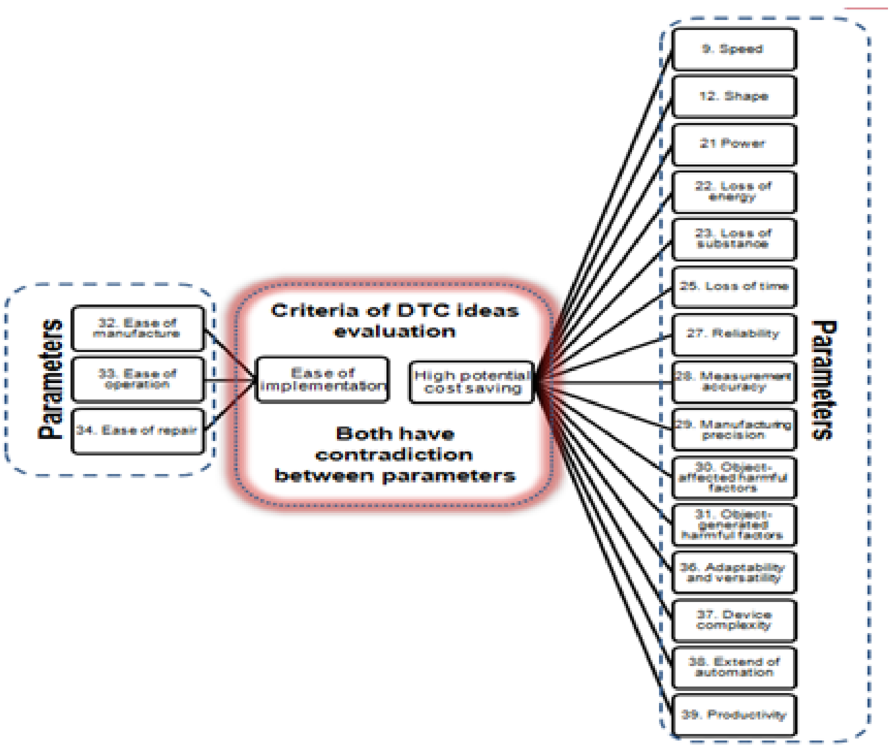

Figure 5 : Criteria of DTC idea evaluation parameters

In phase three, the ideas generated are rated on two criteria, 'ease to implement' and 'high potential of cost saving, as shows in Figure 5. Both play an important role to make sure the idea reduce part cost and feasible to be implemented on the product without affecting the project time line, this able to synergize the design and manufacturing [40]. Both criteria have their own parameters that are conflicting to each other, therefore the need of contradiction matrix and inventive principals' helps to solve the problem. In this phase, the evaluations also include feedback from the testing activity. The testing activity sometime highlight problems with undiscovered root cause, therefore the use of cause-effect chain analysis is required to investigate the root cause of problems that need to be solved. Later the ideas will go through final approval to proceed to the next phase.

In the final phase, the approved ideas will be implemented into the final design and the cost saving will be include in the financial monitoring system. Furthermore, the ideas that are not selected will be analyzed to increase the value of cost saving with TRIZ tools called Trend of Engineering System Evolution, as shows in Figure 6. The two type of trend focusing on the increase of cost saving value are Trend of Transition to the Super-system and Trend of increasing the degree of Trimming.

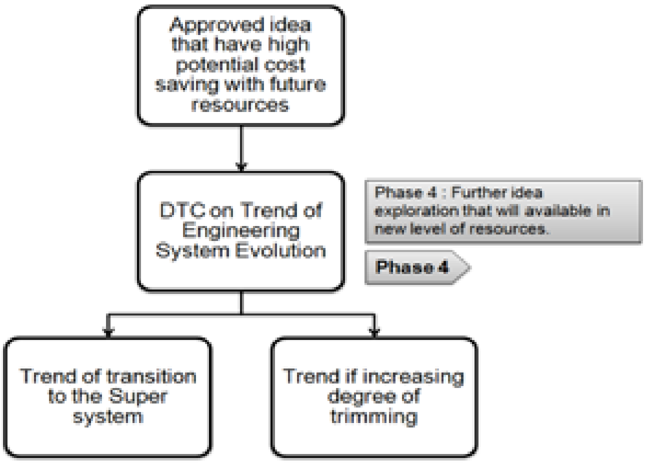

Figure 6 : DTC- with Trend of Engineering System Evolution

TFramework validation is important to confirm whether it is fit to a purpose. The most important thing in carry out validation is the context of validation process is carried out. The contextual factors that likely to impact the validation process are time, cost and geographical condition. The framework validations have several methods and approaches.

The approach includes reviewing research literature on related DTC and TRIZ tools application, seeking input from expert panel, undertaking empirical research, under taking survey research, conducting pilot projects and conducting case studies. In this study, the validation approach used is conducting on case studies.

The case studies approach is used in implementing DTC practices in Vehicle Cost Reduction program in an automotive company. The project has been closed contact with the DTC activity in product design and development project for new model. The intention of these case studies is to get a firmer idea of the importance of various implementation practices and the usability of framework.

RESEARCH METHOD

Literature review was performed to understand the current state with respect to Design-to-Cost and the application of TRIZ in automotive industries. Applications of strategy and tools in relevant industries we also studied. There is still research gap in applying Design-to-Cost with TRIZ methods in automotive industries. This study explores the implementation of Design-to-Cost and TRIZ in product design and concept development without using trade-off. The next step is developing the framework that represents the building block of the TRIZ-DTC components based on the researcher experience and knowledge. The framework components are organized to ensure that they are based on sound theory. Later, the TRIZ-VCR (Vehicle Cost Reduction) methodology is developed, consist of activities, principles, tools and important component that can be used to implement Design-to-Cost with TRIZ.

The Case Studies technique adopted demonstrates that the proposed framework results in cost reduction thus giving a positive impact to the organization. Several case studies were conducted in the VCR department of an automotive firm to demonstrate the usefulness and correctness of the Design-to-Cost with TRIZ framework. Lastly, the researcher developed recommendation for immediate future research that can help advance the theory and application of Design-to-Cost and TRIZ in other industries.

CASE STUDY

The extensive utilization of TRIZ tools and solutions in Korean automotive manufacturing showed outstanding performance in product design and market share worldwide [41]. Using TRIZ tools and solutions in Design-To-Cost (DTC) expect to produce better product design by solving contradiction and generated innovative solution. This provides opportunities to achieved better product cost and thus enhancing survival in automotive globalization market through innovation.

In the automotive industries, material usage is critical to the product design. The product design will determine the sufficient amount of material required. In this study sheet metal is selected as the focus for the DTC project. This selection is base on the material cost and the quantity of usage to manufacture a component based from metal sheet. The process of producing component from sheet metal require a lot of energy and resources such as large stamping machine and high logistic activities from process to another with more than 200 metal parts with various type of sizes and weights and also many level of assemblies processes.

DTC expires to improve the productivity by maximizing the utilization of sheet metal to produce stamping parts. This approach highlighted the engineering contradiction parameters between' Productivity' and 'Area of stationary object'. The idea generation activity utilized contradiction matrix to generated solution for this DTC activity. There are four solutions that can be extracted from the TRIZ contradiction matrix, i.e. #7- Nesting, #10-Prior Action, #15-Dynamicity/ Optimization & #17- Moving to a new dimension.

Assessing on engineering perspective, the current design of blank sheet metal of "pane side outer", there is possibility that the concept of #7-Nesting is applicable for this DTC activity. Figure 7 shows that blank sheet design that can incorporate other blanking sheet for other parts.

Based from types of material and sizes of the blank sheet metal, the engineering principles found that there are similar components that have used the same type of material or lower grade but most importantly the components must have the same material thickness, as shown in Figure 7. It is feasible to implement this in the concept design of panel side outer blanking sheet metal, and hence this provides an opportunity to engineers to expedite the concept into the product design.

One of the cost strategies of DTC is to look into the feasibility of component cost impact on product cost. The parameters of cost improvement are productivity, material usage, energy consumptions, logistic cost, and manpower cost against the investment cost in providing tooling to the engineers to implement the proposed ideas. From the cost analysis done by the procurement engineers, the return of investment are positive, the estimated data highlighted that the return of investment is within two months subjected to the stability in production volume.

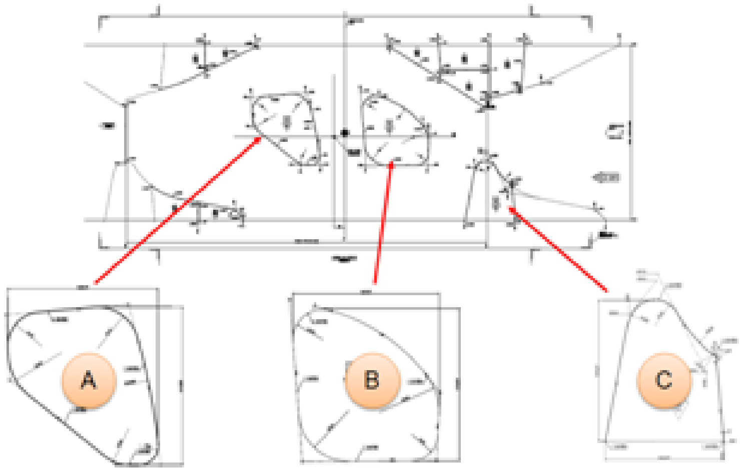

Figure 7: Feasibility study of TRIZ solution into blank sheet metal of side panel outer structure.

Based on both analysis of engineering and costing, the idea is feasible and proceed for implementation. The un-used sheet metal from the stamping process of panel side outer, owned by company A, will be sent to company B, C and D who will invest in tooling of stamping die to process other smaller stamping components, as shown in Figure 8.

The outcomes of this DTC project saves huge raw material, energy and resource consumptions in producing the same components. There are also indirect benefits, like cost saving on logistic. The ultimate goal is also achieved through productivity improvement of more than 15%.

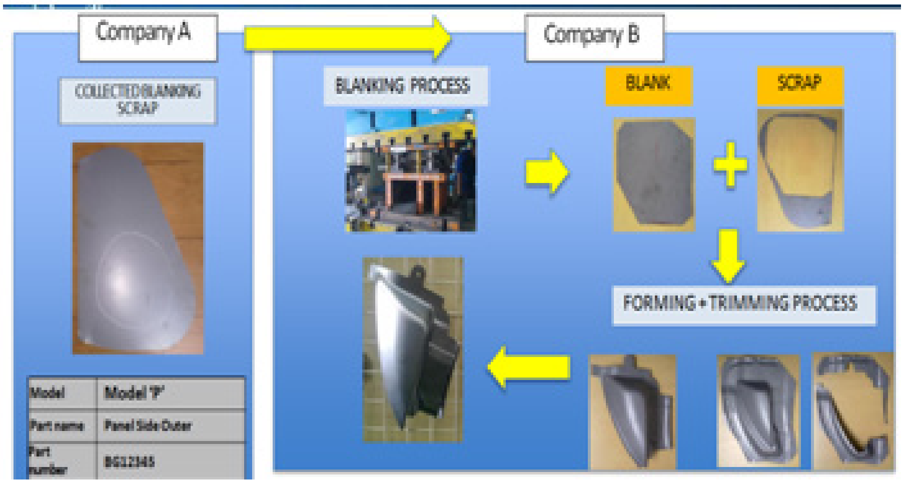

Figure 8: The utilization of "un-used" sheet metal (scrap) for other components.

CONCLUSION

The aim of this study was to demonstrate a proposed framework of DTC implementation with TRIZ tools application. A case study method was used to find out whether the DTC implementation with TRIZ tools could provide successful cost reduction in product costing. With a case study presented above, the results were positive. One of the main contributions is by introducing TRIZ tools in DTC, the idea generated have managed to solve contradiction parameters that constraint the exploration of potential cost saving in a product design and development. The most critical TRIZ tools that are able to enhance the potential of cost reduction in product design are 1) function analysis and 2) trimming. The researchers believe that the cost reduction can be achieved and this case study also contributes to higher level of innovation in product development.

The TRIZ applications, using contradiction matrix, in this stamping DTC case study suit the problems. The established solutions provide guidelines for future product development and concept design, and it shows that the DTC become more effective and introduce higher product innovation. Therefore, in future research, the proposed framework could be tested and applied in other automotive products or even other types of industries in order to further refine and eliminate any weakness that the framework might still have.

REFERENCES

[1] E. Domb, "The Ideal Final Result: Tutorial", TRIZ Journal, 1997.

[2] D. Mann and E. Domb, "40 Inventive (Business) Principles With Examples", TRIZ Journal, 1999.

[3] M. Esaki and T. Yamagichi, "New Thinking And Procedure of Design-To-Cost", SAVE Conference Proceedings, 1979, 199 -227.

[4] B. Williamson, “Design To Cost Lessons Learn”, SAVE Conference Proceedings, 1994.

[5] R.D. Clark, “A Design-To- Cost (DTC) Program Model and Value Engineering”, MVF Conference Proceedings, 1988, 79–83.

[6] K.W. Tyson et al., “ACQUIRING MAJOR SYSTEM: COST AND SCHEDUL TRENDS AND ACQUISITION INITIATIVE EFFECTIVENESS”, Institute For Defense Analyses, 1989, IDA paper P-2201, Chapter 9.

[7] M. Kaufmann, “Cost / Weight Optimization of Aircraft Structures”, Thesis, KTH Engineering Science, 2008.

[8] R. Valerdi, “Cost Metrics for Unmanned Aerial Vehicles”, American Institute of Aeronautics and Astronautics, 2004,1–6.

[9] W.B. Cleaveland, “VALUE ENGINEERING”, SAVE Conference Proceedings, 1982, 169–173.

[10] E.B. Dean, “The Design-To-Cost Manifold by Design-To-Cost Design-For-Cost”, International Academy of Astronautics Symposium, 1990, 1–13.

[11] W.Schwint, “Creative Design To Cost”, SAVE Conference Proceedings, 1975, 89-95.

[12] H. Sippel and E. Schelkle, “Design – To – Cost in Engineering”, 2009.

[13] Y. Monden and J. Lee,. “How a Japanese auto maker reduces costs.”, Management Accounting, Accounting, Management, and Inform Global, 1993, 22-26.

[14] C. Carr and J. Ng, “Total Cost control: Nissan and its U.K. supplier partnership” Management Accounting Research, 1995, 6, 347-365.

[15] J. Y. Lee and Y. Monden, “An International Comparison of Manufacturing-Friendly Cost Management Systems.”, The International Journal of Accounting,1996, Vol. 31, No. 2, pp. 197-212

[16] P.J. Hurley and L. E. Snyder, “LHTEC - MEETING THE LHX COST CHALLENGE”, SAVE Conference Proceedings, 1987, 171-177.

[17] G. Favato and R. Mills, “Identifying best practices in cost management.” Henley Manager Update, 2007,18(3): 43–53.

[18] P. Feil et al. “Japanese Target Costing: A Historical Perspective.” International Journal of Strategic Cost Management, 2004, 10–19.

[19] W. L. Wichita, 1975. "Application of Value Engineering To Design-To-Cost Contracts." SAVE Conference Proceedings, 315–318.

[20] M. Esaki, "Best TQM Tool: New Thinking and Its Procedures For Design To Customers Needs and Design To Cost" SAVE Conference Proceedings, 1991, 158–166.

[21] E. B. Dean and R. Unal, "Elements of Designing For Cost', Save Conference Proceeding, 1991, 1-7.

[22] T.S. Geiger and D. M. Dilts, "Automated design-to-cost: integrating costing into the design decision." Computer-Aided Design, 1996, Vol. 28, No. 6/7, pp. 423-438.

[23] E. B. Dean and R. Unal, "Elements of Designing For Cost', Save Conference Proceeding, 1991, 1-7.

[24] J.R.Steinmetz, "How To Start Something….With DTC" SANE conference Proceedings, 1978, 3–7.

[25] K. Rantanen, and E. Domb, "Simplified TRIZ." CRC Press. Boca Raton, FL USA, 2002, Chapter 5.

[26] P.A. Sandborn, and M. Vertal. "Analyzing Packaging Trade-Offs During System Design", IEEE DESIGN & TEST OF COMPUTERS, 1998, 10–19.

[27] E. Domb and T.J. Kling, "How to Reduce Cost in Product and Process Using TRIZ", TRIZ Journal, 2006.

[28] C.Y. Lo and Larry Jung Hsing Lee. "Valuing up Design Chain by VA / VE and TRIZ", TRIZ Journal, 2001.

[29] R.Stratton, and D. Mann, "From trade-off to innovation- the underlysing principles of TRIZ and TOC applied. System Innovation and the underlying principles behind TRIZ and TOC applied to Manufacturing", TRIZ journal, 2000.

[30] D. Justel, R. Vidal, and M. Chiner, "TRIZ applied to innovate in Design for Disassembly", 13th CIRP INTERNATIONAL CONFERENCE ON LIFE CYCLE ENGINEERING, PROCEEDINGS OF LCE, 2006, 377–382.

[31] S. Ikovenko, Sergei, and Bradley, "TRIZ as a Lean Thinking Tool", 2004 ETRIA TRIZ Future Conference, TRIZ Journal, 2004.

[32] D.Mann, and E. Domb, "Using TRIZ To Overcome Mass Customization Contradictions", TRIZ Journal, 2001.

[33] R. Stratton, D Mann and P. Otterson, "The Theory of Inventive Problem Solving (TRIZ) and Systematic Innovation-a Missing Link in Engineering Education?", TRIZ Journal, 2000.

[34] E. Domb and T. J. Kling, "How to Reduce Cost in Product and Process Using TRIZ" TRIZ Journal, 2006.

[35] E. Domb, "HOW TO DEAL WITH COST-RELATED ISSUES IN TRIZ" TRIZ Journal, 2005.

[36] Y. Isaka, "Eighth TRIZ Symposium in Japan , 2012 – Redesign by Reducing the number of parts through TRIZ : Break Away from Existing Designs and Enhance Competitive on Cost", Japan TRIZ Symposium, 2012, 1–13.

[37] D.Mann, "Hands-On Systematic Innovation for Business and Management", IFR Press, Clevedon, UK, 2004.

[38] Y.H.Cho, J.S.Kim and J.Y. Lee. "Innovation In the Material Cost of the 8mm Camcorder Using Triz.", TRIZCON 2004 Conference Proceedings, 2004 1–17.

[39] D.D. Sheu and C. T. Hou., "TRIZ-based problem solving for process-machine improvements: Slit-valve Innovative redesign", Proceedings of the 41st International Conference on Computers & Industrial Engineering, 2011, 1036–1044.

[40] J.D.Bolton, "Add Value to Manufactured Products with DFMA Labor Overhead Part Costs", SAVE Conference Proceedings, 2006, 1-8.

[41] K.Y. Ju, "THE FUNCTION MODELING METHOD FOR NEW PRODUCT", TRIZ Journal, 2010.

[42] Y. Monden and K. Hamada, "Target Costing and Kaizen Costing in Japanese Automobile Companies", Journal of Management Accounting Research, 1991, 16-34.

[43] T.Gilb, "Estimation: A Paradigm Shift Toward Dynamic Design-to-Cost and Radical Management", ASQ, SQP, 2011, Vol. 13, 25-38.

[44] M. Woods, L. Taylor and C.C. Fang, "Electronics: A case study of economic value added in target costing", Management Accounting Research, 2012, 1-17.

[45] M. Sawaguchi,"VE at the Planning / Development Stages of New Product utilization TRIZ Techniques", The 34th VE National Convention Proceedings, 2002, p 70.

[46] A. Martin, "TRIZ Theory of Constraints and Lean", TRIZ Journal, 2010.