Integrating TRIZ and AHP: A MPV's Utility Compartment Improvement Design Concepts

M. U. Rosli, M. K. A. Ariffin, S. M. Sapuan, and S. Sulaiman

***Abstract*—This study sets up a systematic product design model that assists decision makers or design engineers to improved current design through idea generation method of Theory of Inventive Problem Solving (TRIZ) and utilizing analytical hierarchy process (AHP) performing the selection of best generated idea. In addition, the proposed framework is analyzed and evaluated by a case study of utility compartment of MPV. There were 5 types of improved design triggered by TRIZ principles approach and ranked based on selected criteria by utilizing Expert Choice software. Employing the proposed integrated methods on new product development or product redesign may raise the concept design efficiency as well as avoiding the cost waste during the product design and development processes. In addition, this study also means to investigate the strengths of TRIZ and AHP integration.**

***Index Terms*—Analytical hierarchy process, TRIZ, conceptual design.**

I. Introduction

The rivalry among the product manufacturers is becoming more intensely, the transformation of customer product preferences is speeding up, promoting enterprises continuously introduce new product or improving current product in term of innovation and high quality. At this moment of transportation industry, a car has become more than just a means of transportation and having car is not a luxury but also a necessity of life. For many people, especially with longer commutes will spend two hours or more per day in their car doing boring routine driving tasks on their way to work and back every day. To make this time more valuable and safely driving, it is important to provide good user experiences inside the automobile and the manufacturer must fulfill the user needs.

II. TRIZ

Theory of Inventive Problem Solving "TRIZ" acronym in Russian was developed by Genrich Altshuller and his colleagues, and currently being broadly developed and practiced throughout any field. [1]. By utilizing the knowledge base built from the analyses of just about millions of patents which is mostly on technical design, this approach solves technical problems and presents innovative product design. It is believe that the creativity for innovation is a structured systematic method, not just try and error as illustrated in Fig. 1. In TRIZ, there are a few tools including the contradiction matrix, 40 inventive principles, laws of evolution, scientific effects and Algorithm of inventive solving (ARIZ) and substance-field analysis modeling. The TRIZ approach has been employed to various design problem-solving such as hydraulic cylinder improvement, energy efficient notebook computer and energy-saving products [2]-[4]. Several solutions in TRIZ method highlighted on contradictions or trade-offs in identifying innovative solutions which arose if an improvement in one characteristic resulted in degradation of another characteristic. Typically, designers attempted to compromise or reach the balances which do not really solve the problem instead. But in TRIZ, there was no compromising approach but rather completely solve the contradiction arises. The 39×39 contradiction matrix as shown partially in Fig. 2 provides designers 40 inventive principles to answer a problem that involved a particular contradiction.

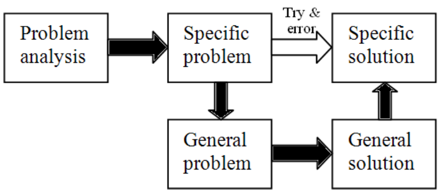

Fig. 1. TRIZ problem solving process.

Worsening Feature → / Improving Feature ↓	Weight of moving object	Weight of stationary object	Length of moving object	Length of stationary object	Area of moving object	Area of stationary object
	1	2	3	4	5	6
Weight of moving object	+	-	15, 8, 29,34	-	29, 17,	-
Weight of stationary object	-	+	-	10, 1, 29, 35	-	35, 30,
Length of moving object	8, 15, 29, 34	-	+	-	15, 17, 4	-
Length of stationary object		35, 28,	-	+	-	17, 7, 10, 40
Area of moving object	2, 17, 29, 4	-	14, 15,	-	+	-
Area of stationary object	-	30, 2, 14, 18	-	26, 7, 9, 39	-	+

Fig. 2. Partial of Contradiction matrix.

III. Analytical Hierarchy Process (AHP)

AHP is one of the most accepted methods commonly used in industry to aid in multi-criteria alternatives selection developed by Saaty [5]. One of the key strengths of AHP is the use of pairwise comparisons to obtain precise ratio scale priorities, instead of the long-established approaches of 'assigning' weights. This process judges against the relative importance, performance or likelihood of two elements with respect to another element in the upper level. A nine-point scale is used to conduct the pair-wise comparisons for each

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level with respect to the goal of the best alternative selection and represents as equally important, moderately more preferred, strongly more preferred, very strongly more preferred, and extremely more preferred to the others. Generally, basic steps of AHP namely decomposition, comparative judgment and synthesis. Sapuan et al. presented eight steps of AHP in material selection case study [6]. The advantages of AHP over other multi criteria methods are its ability to check inconsistencies, intuitive appeal to the decision makers and its flexibility. In the application of AHP, the decision makers are assigning the judgements based on their own experience and knowledge with respect to the upper parent component in the hierarchy. The outcome is the set of weight which represents their contributions or the priorities. Decision situations which the AHP can be applied include the evaluation, priority and ranking, benefit–cost analysis, planning and development, allocations, and decision-making. A. Kengpol et al. applied AHP as a decision tool for the selection of advanced technology in order to accomplish rapid product development [7] and M.I. Al Khalil utilized AHP approach to pick the most appropriate project delivery method [8]. The judgement of pairwise result is incomplete if consistency analysis is not done. The consistency ratio (CR) is used to estimate the consistency of the judgments of the participants. The CR is defined as [9]

$$CR = CI/RI$$

where CI is called the consistency index which is defined as

$$CI = \frac{\lambda_{max} - n}{(n-1)}$$

A CR of 0.10 or less is considered acceptable, otherwise it is considered inconsistent and the decision maker is allowed to change the preferences. Judgments should be revised and improved in order to obtain a consistent matrix.

IV. The Proposed Approach

In this paper, a systematic product design approach of TRIZ and AHP was applied as an integrated methodology for design improvement. By converting up the complex design problem into a contradiction matrix, TRIZ might provide various design suggestions and AHP will be utilized as a selection method for the ideas generated by TRIZ approach. The integrated approach is displayed in Fig. 3 comprises of the following steps.

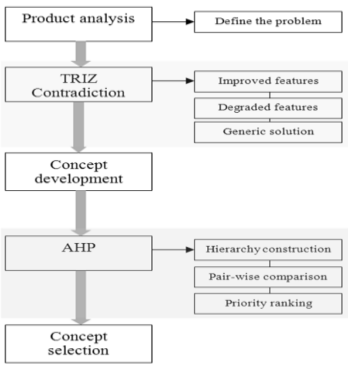

Fig. 3. Proposed approach framework.

Step 1: Product analysis

The elements of design that required to be improved and criteria for evaluation were defined.

Step 2: Construct the Contradiction Matrix and propose the related inventive principles

The engineering parameter was constructed and related inventive principles will be proposed. The suggested inventive principles were then may be adopted to stimulate redesign ideas.

Step 3: Concept development

Several improvement ideas based on the input of suggested principles from the previous step might be proposed and illustrated by sketching approach.

Step 4: Construct the hierarchy of AHP and perform judgments of pairwise comparison

Pairwise comparison construction and judgment were performed by utilizing Expert Choice software. The judgments were decided based on the author's experience and knowledge by using the relative scale of pairwise comparison. The priority vector of the judgment represented the importance of each attributes.

Step 5: Develop all priority ranking

Additional calculation of the overall priority vector to pick the best design concept must be performed after the consistency calculation for all levels was concluded.

Step 6: Find the final evaluation and select the best design

Finally, weight vectors for the each levels of hierarchy were evaluated using the methodology given in the ranking. The final priority results were ranked based on their weights.

V. The Case Study

In order to validate the applicability of the proposed product design model, a case study of MPV's utility compartment as portrayed in Fig. 4 was conducted.

Fig. 4. Current MPV's utility compartment.

Step 1: Product analysis and defining the problem

With the major aim to optimize the value in term of the functionality, ergonomics and quality of the compartment and at the same time, keeping the passenger in convenience as well as the compartment is easy for operation and manufacturability. The new compartment should have ability to store big items and organize small items as well. From the observation, there's no cup holder for front passenger. Hence, instead of making another slot in the current dashboard for cup holder, it's an advantage if the compartment can serve the function of cup holder.

Step 2: Idea generation of TRIZ contradiction principles

The specific objectives of multifunction for the utility compartment was generalized into 39's TRIZ features as

(#39- productivity, #36-device complexity) since that in TRIZ definition, ‘productivity’ and ‘complexity’ means the number of useful (value adding) functions or perform by a system per unit time. Conversely, multiple functions might caused the degrading of simplicity of application (#33-ease of operation) and difficult to manufacture (#32-ease of manufacturing) as shown in Table I. From the contradiction matrix, several solution principles were suggested as shown in Table I.

TABLE I: TRIZ CONTRADICTION AND GENERIC SOLUTION

Improving Feature	Degraded Feature	Solution Principle	Project ideas
#39 Productivity	#33 Ease of operation	Segmentation	-Adjustable partition
		Nested Doll	-Little compartment in current compartment -Retractable type door -Drawer concept compartment
	#32 Ease of manufacture	Take out	- Little compartment in current compartment
		Intermediary	-Convertible door to cup holder/laptop table
		Change parameters	-Retractable type door
#36 Complexity		Other way around	-Upside-down door

Step 3: Concept generation

After scrutinizing the project ideas triggered by TRIZ generic solution method, there were five new proposed compartment designs as depicted in Fig. 5 with brief description in Table II.

Step 4: AHP

A four level hierarchy decision process was constructed with a goal to select the best proposed design to improve MPV’s utility compartment design. A survey has been done in order to determine the weight of main and sub-criteria which is based on customer’s preference when buying a MPV. Expert Choice software was utilized for AHP method. The pairwise judgments were based on concept’s illustration and description as well as author’s design experiences. The rest of the steps were covered in AHP method.

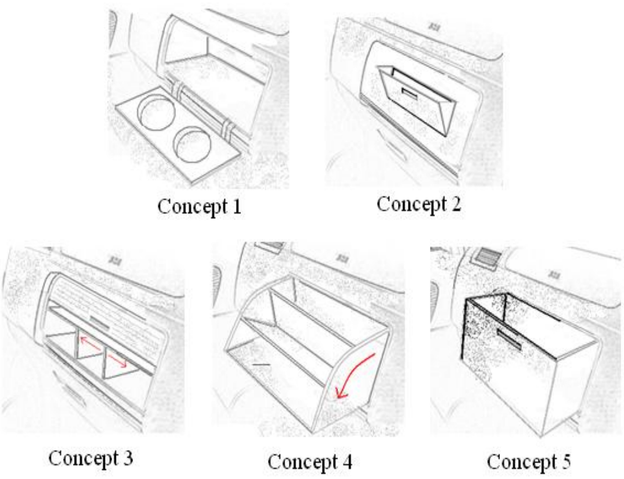

Fig. 5. Alternatives design of new compartment.

TABLE II: DESCRIPTION OF EACH CONCEPT

Concept	Brief description
1	The door of compartment serves the function as the cup holder and table as well. Based on ‘intermediary’ and ‘other way round’ principles
2	Mini pocket compartment to store small items such as coins and pens. Based on ‘take out’ and ‘nested doll’ principles.
3	Sliding type of the door and flexible partition inside to store big or small items. Based on ‘segmentation’ and ‘nested doll’ principles.
4	File drawer type compartment with flexible partition inside. Based on ‘segmentation’ and ‘other way round’ principles.
5	Drawer type compartment to store big items. Based on ‘nested doll’ and ‘take out’ principles.

VI. RESULT AND DISCUSSION

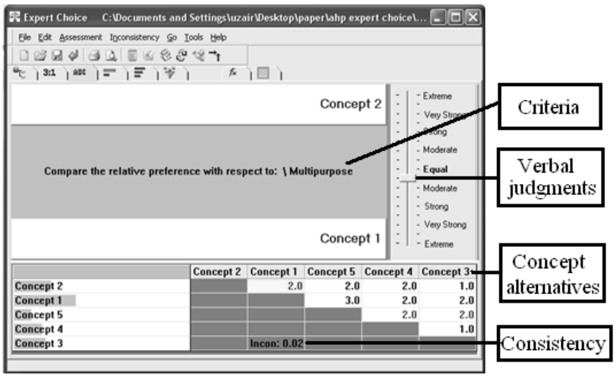

Fig. 6. Pairwise comparison with respect to the sub-criteria.

The results of AHP method utilizing Expert Choice software were shown in Fig. 6 and Fig. 7. Based on the alternatives of concept results, it was clear that Concept 1 of converting the compartment’s door as a table and cup holder ranked first with 0.245 (24.5%) and the last rank was Concept 4 (file drawer concept) with 0.171 (17.1%). The results of Concept 2 (pocket drawer concept), Concept 3 (partition compartment concept) and Concept 5 (box drawer concept) are 0.210, 0.201 and 0.173 respectively.

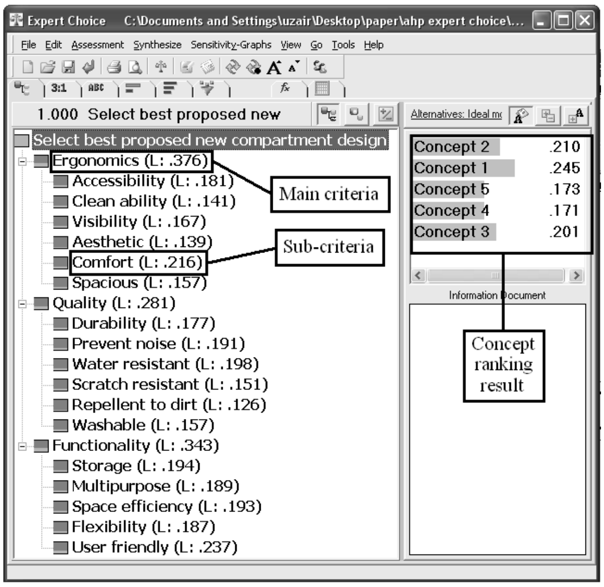

Fig. 7. Relative weight for main factors, sub-factors and ranking of concept alternatives.

In order to ensure the result achieved meets the objectives, if the result of analysis were not satisfied with some reason such as lack of information and inadequate model structure, the designer could perform the comparison again. When all the concepts had been evaluated and received their scores from AHP, based on compatibility of each concept, the author was decided that the promising and innovative concepts of Concept 1 and Concept 3 were chosen to take further. The combination ended up with a totally new improvised concept of compartment. This new concept of improvement shown in Fig. 8 was considered to be more innovative with convertible table/cup holder type door and the compartment also could easily be cleaned as well. Moreover, if larger storage volume is needed, the partition inside could be moved with the invention of flexible segmented partition.

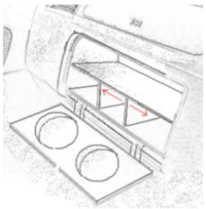

Fig. 8. Sketch of final design.

VII. Conclusion

The problem solving and decision making process has become essential in the industry. The conventional ‘try and error’ brainstorming processes of problem solving becomes more structured and organized since the innovation of TRIZ method. Meanwhile, AHP played an effective role as decision making tool in order to select the most appropriate decision. It was believed that the concept improvement framework not only provided evidence that the integrated AHP or TRIZ are better than the stand-alone method, but also aided the researchers and decision makers in applying the integrated AHP and TRIZ effectively. The study case revealed that the concept combination generated from TRIZ’s principles of intermediary, segmented, other way around and take out can give the most ideal proposed design for compartment improvement. This integration served an ideal framework as a foundation step for product improvement. It needed further steps to cover until final implementation such as design specification, cost and manufacturing processes. Further studies will focus on integrating the developed framework into a computer-assisted design support system for product improvement design.

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