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Synergizing TRIZ And Design Thinking: A Novel Approach for Enhanced Design in Product Development

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ABSTRACT

This study presents an innovative methodology that incorporates TRIZ (Theory of Inventive Problem Solving) principles into the Design Thinking (DT) framework to improve idea generation and design development in product engineering. The study uses a conceptual redesign case study of an electric vehicle (EV) strut bar to demonstrate the synergistic potential of combining TRIZ's structured problem-solving tools with DT's human-centered approach. The framework aligns TRIZ's inventive principles, such as curvature modification and engineering contradiction resolution, with DT's iterative stages, allowing for a seamless transition from user needs to technically optimized solutions. To evaluate and select the most viable conceptual designs, the Analytic Hierarchy Process (AHP) was used, considering key criteria such as material, patent compliance, and cost efficiency. The findings show that using biocomposites instead of traditional materials can result in significant weight savings without sacrificing structural performance, especially when guided by TRIZ-based design strategies. The proposed TRIZ-DT hybrid model not only improves creative ideation, but it also establishes a systematic path for translating abstract concepts into feasible engineering solutions. This integrated methodology provides useful insights into sustainable product innovation, particularly in the context of lightweight automotive structures. The study advocates for broader use of the TRIZ-DT synergy in complex design environments, emphasizing its ability to accelerate innovation in early-stage product development.

Keywords: TRIZ; design thinking; electric vehicle strut bar; lightweight biocomposites; Analytichal Hierarchy Process (AHP).

INTRODUCTION

In the dynamic landscape of product development, the search for innovative solutions to complex design challenges has led to the investigation of synergies between established methodologies. This study investigates the incorporation of TRIZ (Theory of Inventive Problem Solving) principles within the framework of the Design Thinking Method (DT), with a particular emphasis on optimizing the idea generation process (Rantanen & Domb 2008). The systematic problem-solving tools and inventive principles inherent in TRIZ have the potential to significantly benefit DT, which is known for its user-centric ethos (Azlan et al. 2023; Paxie & Carthy 2015).

This research seeks to understand how the collaboration of TRIZ and DT can improve the conceptualization phase, providing a more structured and innovative approach to addressing complex design problems (Deimel 2011; Smirnov 2020). The integration aims not only to increase creativity, but also to provide a methodical path for transforming ideas into tangible, well-defined product proposals (Hentschel & Czinki 2013). The seamless transition from ideation to real solutions by aligning conceptualization with product specifications is of particular interest, and this is where TRIZ's contribution shines through (Wu et al. 2020).

The investigation objective extends to the use of TRIZ in developing concept designs based on product specifications, resulting in a comprehensive strategy that has the potential to revolutionize the traditional product development process (Brown et al. 2009. This study aims to shed light on the effectiveness of this integrated methodology through insightful case examples and practical experiences (Chang & Chen 2004). As a comprehensive guide, it is poised to provide valuable insights to designers, engineers, and innovators looking to improve the creativity and systematic precision of their product development processes (Dorst & Cross 2001; Gundes 2016).

The incorporation of TRIZ principles into the Design Thinking framework for optimizing idea generation in product development is a novel intersection in the realm of innovation methodologies (Savransky 2000). A thorough examination of existing literature is required to comprehend the depth and significance of this combination.

An in-depth examination of TRIZ principles, elucidating their origins, theoretical support, and practical applications in inventive problem-solving as key components (Rutitsky 2010). This section aims to provide a solid understanding of TRIZ's systematic approach to tackling complex problems, laying the groundwork for its potential integration with design thinking.

The problem can be correlated with one or more conceptual solutions in its conceptual state. Following that, the identified conceptual solution can be translated into a concrete, factual resolution to the original problem. This methodology distinguishes itself by providing an outline of the TRIZ problem-solving process (Savransky, 2000). This distinguishes TRIZ from other traditional problem-solving approaches that seek direct, specific solutions to concrete problems as shown in Figure 1.

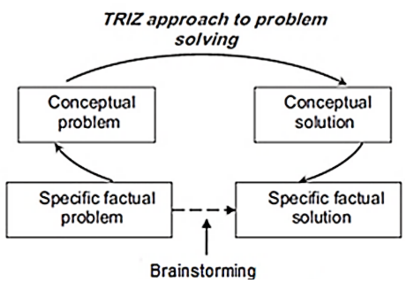

FIGURE 1. TRIZ systematic approach to problem solving (Savransky 2000).

TRIZ holds a significant edge over alternative problem-solving and innovation methods. While approaches like brainstorming, mind mapping, lateral thinking, morphological analysis, and others excel at recognizing or uncovering problems and their root causes, they often fall short in providing concrete solutions (Park et al. 2013). In contrast, TRIZ not only identifies problems but also furnishes direct solutions, instilling confidence that it has explored most, if not all, potential new solutions to the problem (Yiow et al. 2022). At the foundation of TRIZ is a collection of conceptual solutions to technical challenges, including inventive principles, technological evolution trends, and standard TRIZ solutions (Gadd 2011).

Analytical tools and psychological operators can be directly applied and easily adapted for non-technical applications. Knowledge-based tools, on the other hand, require a process of abstraction and generalization to move away from their technology-centric origins. Various iterations of the 40 inventive principles, for example, demonstrate this need for adaptation (Zlotin et al. 2005).

Simultaneously, a critical assessment of design thinking principles is required (Kaulio 1998; Robert et al. 2016). This section investigates design thinking's fundamental ideas, stressing its emphasis on empathy, ideation, and experimentation, with a focus on its user-centric philosophy (Aparna et. al. 2021). Understanding design thinking in isolation is required to determine how TRIZ principles could augment and complement their existing approaches (Glen 2015).

Prior research into the intersection of TRIZ and design thinking provides valuable insights into the evolution of this interdisciplinary approach (Chybowska 2019). However, there are significant challenges as well as opportunities for groundbreaking innovation in New Product Development (Floren et al. 2018; Adiyanto et al. 2023). Analyzing existing literature for successes, challenges, and gaps enables a critical synthesis of current knowledge and lays the groundwork for future research (Sheng 2023).

A review of literature on structured concept generation in product development is appropriate because the research focuses on improving the idea generation process (Liu 2020). Examining existing practices and methodologies in this domain helps to lay the groundwork for understanding the context in which the integrated TRIZ and design thinking approach seeks to make an impact.

Finally, the survey of literature broadens its investigation into the broader terrain of the imperative for innovation in product creation (Florén et al. 2018). It identifies the substantial obstacles that traditional methods face and emphasizes the growing demand for alternatives that not only foster creativity but also provide a systematic path from idea generation to real consequences (Sheu & Chiu 2017). This comprehensive analysis of literature tries to synthesize current knowledge, identify information gaps, and build a contextual framework for appreciating the incorporation of TRIZ principles into the design thinking paradigm (Mansor et al. 2014; Altshuller 2002). This effort lays the groundwork for a more in-depth analysis of the practical applications of this integration in product development.

METHODOLOGY

At the intersection of TRIZ principles and the design thinking paradigm lies a theoretical framework that illuminates the synergies and implications of this unique amalgamation. The framework is designed to elucidate the underlying principles, methodologies, and potential transformative effects that arise from integrating TRIZ within the design thinking process.

TRIZ PRINCIPLES DESIGN THINKING METHODOLOGY

The theoretical framework is built around a thorough examination of TRIZ principles, which includes a rigorous dissection of its key ideas, imaginative problem-solving methods, and theoretical foundations. This investigation is critical for comprehending how TRIZ integrates information from diverse fields and applies it to inventive processes, showing its potential influence inside the design thinking framework (Lee 2018).

At the same time, Figure 2 illustrated the theoretical framework delves into the Design Thinking technique, breaking it down into steps such as empathy, ideation, prototyping, and testing. The framework gives a baseline understanding against which the integration of TRIZ concepts may be evaluated by explaining the core features of Design Thinking. This research also identifies important points in the DT process where synergy with TRIZ is the most powerful in ideation.

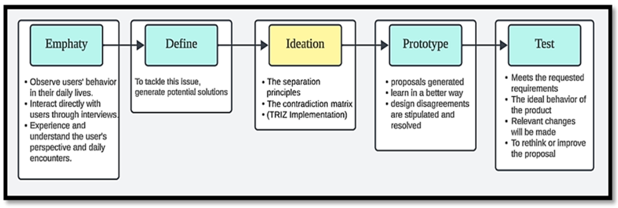

FIGURE 2. Synergizing TRIZ principle into Design Thinking Process

RATIONALE FOR INTEGRATION IDEATION

The theoretical framework elucidates the justification for introducing TRIZ into Design Thinking by investigating how TRIZ's systematic problem-solving methodology matches with and strengthens Design Thinking's user-centric philosophy (Uribe & Kaminski 2023). This part digs into the theoretical foundations that go beyond the individual contributions, with the goal of revealing the synergistic effects that emerge from the convergence of these techniques. Table 1 illustrates the benefits of each strategy as well as their complementarity.

TABLE 1. The Benefits Complementary of Design Thinking and TRIZ (García-Manilla, 2023)

Criteria	DT	TRIZ	DT + TRIZ
Identify customer requirement	Yes	No	Yes
Simulate an innovative issue	No	Yes	Yes
Provide solutions to the problem (problem solving)	No	Yes	Yes
Provide a framework for design	Yes	No	Yes
Submit the proposed solution for review	Yes	Yes	Yes
Considers the potential evolution of a product in the future	No	Yes	Yes
Users with no design experience can utilize it.	No	Yes	Yes
Provides significance to the products being designed	Yes	No	Yes
Prototypes for testing offered solutions	Yes	No	Yes

As shown in the table, both techniques complement one another in addressing certain weaknesses. Design Thinking (DT) enhances TRIZ by determining user requirements and preferences for whom the design is meant. It facilitates the design process, allowing people with no design experience to participate and develop things with added value and importance. DT, on the other hand, uses TRIZ to discover, characterize, and model problems, providing an efficient toolkit for precise problem resolution (Li, et al. 2022). Given the existing circumstances, a research gap becomes apparent concerning the application of TRIZ within Design Thinking (DT), despite the availability of numerous design tools. Notably, there is a dearth of studies focusing on the integration of TRIZ and DT, particularly within the realm of automotive components, especially structural elements in Electric Vehicles (EVs). This integration represents a robust approach to problem-solving, offering a valuable resource for users seeking to enhance or innovate in design processes.

This synergy focuses thought and creative efforts on developing successful solutions. The complementarity of both methods results in a framework that is both extremely technical and humanistic. This framework is ideal for creating new products that correspond to user criteria via a specified process. This collaborative approach is distinguished by the efficient directing of thought and inventiveness (García-Manilla 2023).

The framework includes an assessment of how this integration affects the idea creation process. The framework attempts to provide insights into how TRIZ's systematic problem-solving tools contribute to promoting creativity and structuring the ideation phase within the design thinking model through an analysis of prospective changes. It allows designers and engineers to balance innovative problem-solving, user empathy, and quantitative analysis when selecting optimal product design concepts, which is especially useful in the context of lightweight, high-performance automotive parts compared to the other researcher which focuses on the other sector (Idral 2025). He explained that the combination of Design Thinking and TRIZ had never been used in engineering, especially in the automotive industry.

SEAMLESS TRANSITION TO REAL SOLUTIONS

The theoretical framework goes on to investigate how integration promotes a smooth transition from ideation to real solutions by connecting conceptualization with product specifications. This entails investigating how TRIZ principles bridge the gap between creative idea generation and the practicalities of product development, so giving a methodical pathway for transforming ideas into tangible proposals. The theoretical framework provides a comprehensive lens through which the integration of TRIZ concepts inside design thinking can be understood by synthesizing these components. It serves as the intellectual foundation for the ensuing empirical investigations, directing research into how this hybrid technique emerges in real-world product development settings. Both Design Thinking and TRIZ contain characteristics that, when properly implemented, could complement one another, as outlined in Table 2, opening the door to further investigation of the collaborative use of both techniques.

TABLE 2. Complementary Characteristic Design Thinking and TRIZ

Criteria	DT characteristic	TRIZ characteristic
variation	Project & design activities	Patent Analysis
Approach	Customer	Technical Centered
Expected Result	Target Audience	Technology
Problem statement	Quantity & qualitative observe	Technical insufficiencies
Process driven	Empathy	Analysis and effect
Process based	Creativity	Knowledge & tools
Target outcome	Desirable solution	Best technical solution
Human involvement	Multidisciplinary	Specialist
Abilities	Creativity	Analytical
Background	General	Technical

CASE STUDY

The actual research study focused on the conceptual design and product development of a strut bar for electric cars. Strut bars are primarily designed to reduce chassis flexes during dynamic movements. Torsional flex can occur when a vehicle experiences lateral forces while navigating corners, resulting in imprecise handling and reduced stability. A well-designed strut bar helps distribute these forces, reducing chassis deformation and increasing overall rigidity. Strut bars help improve handling and stability by reducing chassis flexes (Farag, 2008) (Adam, 2025).

INCORPORATING TRIZ INTO DESIGN THINKING

To demonstrate the integration of Design Thinking and TRIZ, the process began with DT as the primary domain for problem solving (Jupp, et al. 2013). This approach helped to develop the Product Design Specification, which included qualitative data gathered from professionals and experts about how important the Strut Bar system (Mironenko, et al. 2018). Table 3 summarizes a prior study on the electric vehicle BMW model i3.

TABLE 3. Electric Vehicle Specification (Electric Vehicle BMW i3)

Body	Unit	Metric
Weight, unladen, to DIN / EU	kg	1270 / 1345
Max permissible weight / load	kg / kg	1710 / 440
Max axle load, front / rear kg /	kg	770 / 965
Axle load distribution (unladen)	% f / r	48 / 52

Using the information presented in the preceding table, combined with insights gained from an expert interview, it became necessary to assess the impact of using or not using a strut bar on the chassis stability of the vehicle structure. Furthermore, such factors play an important role in increasing the longevity of the suspension system (Jelti, et al. 2023; Patil, 2019).

The following phase is to determine that the primary issue is the need for the system to acquire new functions that meet the demands of users. Qualitative data plays an important role in defining the problem because it represents customer feedback, which is necessary for developing innovative solutions. The feedback emphasizes the importance of product simplification and weight reduction, which aligns with the current emphasis on weight reduction in electric vehicles (EVs) while maintaining the strut bar's fundamental function (Mansor, et al. 2023). Considering this context, it is imperative to improve the current design. The approach to this improvement is guided by the TRIZ method within the Ideation Section, which takes advantage of the Engineering Contradiction principles of typical engineering system outcomes (Sheu & Lee, 2011). Figure 3 below shows the current product of EV strut bar which is divided into two sides (left and right).

FIGURE. 3. Electric Vehicle strut bar (front side)

ADDRESSING IDEATION CRITERIA WITH TRIZ TOOLS

A pertinent tool in addressing this situation is Engineering Contradiction (EC), particularly relevant due to its applicability in the automotive structure and analysis study. Following data collection, any design changes or improvements must maintain the strut bar's fundamental function. In these scenarios, improving one parameter may influence other impact parameters, exacerbating the situation (Sharaf et al. 2020). Figure 4 portrays the strut bar as an aspect interacting with the vehicle structure as an object, focusing on its importance in shaping conceptual improvement outcomes.

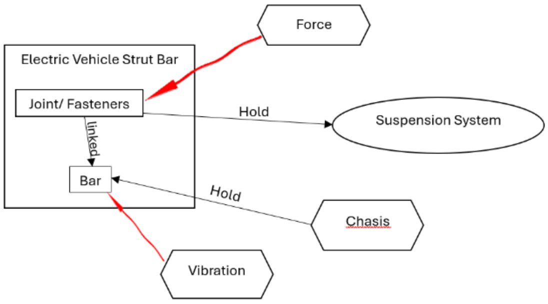

FIGURE 4. Function Model for EV Strut Bar

As shown in Figure 4, the interaction between strut bar and suspension is to connect between the EV chassis with the suspension main hard point. When substituting the existing EV strut bar material (steel) with bio-composite materials to gain the advantage of lightweight, the existing function performance decreases due to the lower structural strength of the bio-composites compared to steel (Mansor, et al. 2015). This interaction and situation are modeled using dotted lines to showcase the insufficient function that the strut bar carries. Hence, the next process is to seek for ideal solution to address this insufficient function by the strut bar while maintaining the desired positive lightweight attribute when using bio-composite materials.

SYSTEM PARAMETER AND CONTRADICTION MATRIX

Using the engineering contradiction normal statement, "If the weight is reduced, then the part will be simplified, but the strength of the product may be reduced". Based on this statement includes 39 systems parameters, Parameters for Improvement: Weight of stationary object (parameter #2) and the worsening parameter: Strength (Parameter #14). A similar study was also conducted using the same contradiction matrix and method by Kamarudin et al. (2016) and Ishak et al. (2018).

Following the contradiction matrix step, the suggested inventive principles are improving parameter #12 versus worsening parameter #14, resulting in suggested inventive principles #30 (flexible shell and thin films), #14 (curvature), #10 (preliminary action (prior action - "Do it in advance")), and #40 (composite materials). This condition is illustrated based on Table 4.

The contradiction matrix suggests four solutions, but after considering the type of product and the capability of the improvement, only two inventive principles #14 were chosen: curvature, which adjusts the shape of parts. The inherent contradiction is addressed by implementing design modifications, allowing for the development of a lightweight biocomposite component capable of effectively supporting structural loads.

TABLE 4. Extract of Contradiction Matrix

	Worsening Feature → / Improving Feature	Strength
		14
12	Shape	30,14, 10,40

The second one was #40: composite materials, which were replaced with lightweight materials. However, #40 was not included in this study because the primary goal was to discover and improve and show new designs. The material replacement and change can be done and analyzed using structural analysis such as Finite Element Analysis (FEA) for validation (Omar et al. 2025).

CONCEPTUAL DESIGN DEVELOPMENT

(PRODUCT DESIGN SPECIFICATION)

The composite strut bar is an automotive component designed to reinforce the chassis of a vehicle by connecting the strut towers, improving handling and stability by reducing chassis flex. It utilizes composite materials for lightweight construction and high stiffness (Mansor et al. 2024).

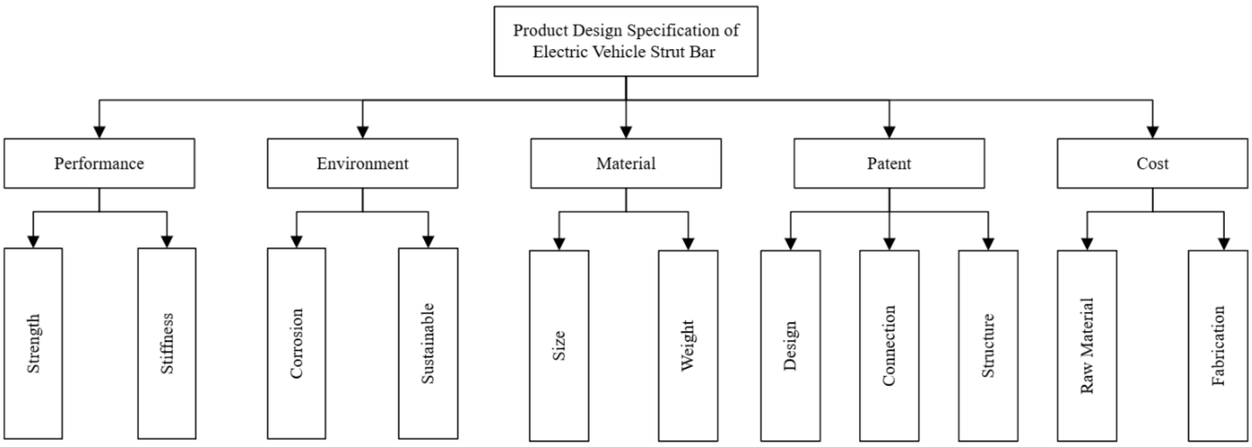

FIGURE 5. Electric Vehicle Strut Bar Product Design Specification

Figure 5 shows the Product Design Specification (PDS) for the EV strut bar component, which guides the selection process. The concept design is selected after considering five main elements and their sub-criteria from the comprehensive PDS document: performance, environment, material, patent, and cost. The decision criteria used in the AHP analysis are based on electric vehicle strut bar product design specifications (PDSs) as shown in Table 5.

TABLE 5. Product Design Specification Element

PDS Elements	Definition	Sub-criteria	Reference
Material	Compatible with standard vehicle models, with adjustable options for different car models	Size: The brackets are made of 4mm to 5mm steel plates, while the hollow steel tubes and oval tubes are of 1.2mm to 1.6mm thickness	Chong, H Performance Motorsport sdn bhd. Ultra Racing
	Significantly lighter than traditional metal strut bars to minimize additional load on the vehicle.	Weight: Steel max 1.5 kg Aluminium 700 g	Chong, H Performance Motorsport sdn bhd.

continue ...

... cont.

Patent	Ensure compliance with relevant automotive safety standards and regulations, considering any specific requirements for composite materials.	Strut Tower connection	US 7,328,909 B2 US 10703418 B2
		Strut Bar design	US 7,513515 B1 US 9,381,949 B2
		Structure	US 8,128,160 B2 US 10,144,456 B1
Cost	Although raw materials may initially be more expensive, explore opportunities for cost-effective manufacturing and mass production to reduce unit costs over time.	Raw material	
		Fabrication	

The Product Design Specification serves as a foundational document that delineates the critical elements essential to the product development process. In this study, five primary elements performance, environment, materials, patents, and costs have been identified as pivotal in guiding the design process. Nevertheless, during the conceptual design phase, emphasis is placed solely on three key elements: materials, patents, and costs. These elements are selected for their significant impact on the feasibility and practicality of early-stage design iterations. Furthermore, these elements are systematically expanded into evaluation criteria, which are subsequently employed in the selection of the optimal conceptual design through the Analytical Hierarchy Process (AHP). This approach ensures a structured and rigorous methodology in aligning the design process with strategic objectives (Al-Hubaishi et al. 2024).

DEVELOPMENT OF AHP HIERARCHICAL FRAMEWORKS

The initial step in applying the Analytical Hierarchy Process (AHP) method within this project involves constructing an AHP hierarchical framework. This framework systematically illustrates the relationship between the project's overarching goal or objective and the associated criteria and alternatives (HO, 2008; Ranmale & Ahuja, 2022). The fundamental structure of the AHP can be conceptualized as a tree-like diagram, comprising multiple tiers or levels. At the apex, designated as Level 1, the project's goal or objective is explicitly defined. Level 2 delineates the criteria or factors influencing the achievement of the stated goal. At the subsequent tier, Level 3, the framework identifies and specifies a set of alternatives or potential solutions aligned with the criteria to fulfill the goal.

While this standard three-tier hierarchical structure can be extended, for instance, by incorporating a level dedicated to sub-criteria—expanding the hierarchy for extensive evaluations can significantly increase analysis time and introduce complexities.

In this project, a four-level AHP framework has been developed, informed by the product design specification (PDS) elements identified in earlier phases. At Level 1, the project's objective is established: selecting the most suitable conceptual design for the electric vehicle strut bar component. Level 2 and Level 3 encompass the main criteria (Material, Patent, and Cost) and their respective sub-criteria (Size, Weight, Connection, Design, Structure, Raw Material, and Fabrication) pertinent to the conceptual design.

Finally, at Level 4, four conceptual design candidates are identified as potential solutions for component design. Connecting lines within the hierarchical framework visually represent the relationships and dependencies among these elements. Figure 6 illustrates the complete hierarchical framework for this decision problem, while Table 1 provides a detailed description of the decision criteria employed in the AHP analysis, based on the product design specifications (PDS) for the electric vehicle strut bar.

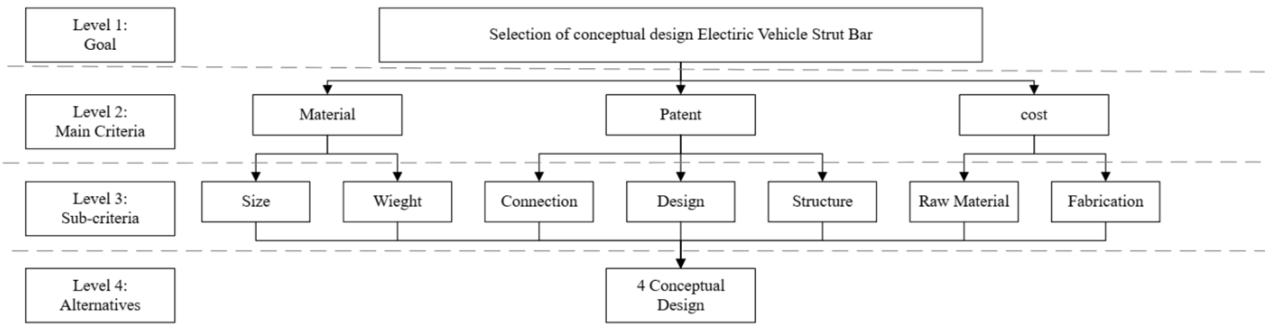

FIGURE 6. AHP Hierarchy framework for conceptual design selection for electric vehicle strut bar

RESULT AND DISCUSSION

FRAMEWORK FOR SMOOTH TRANSITION FROM IDEATION TO SOLUTION

Following the identification of the primary solution during the ideation phase of problem solving the next step was to create a comprehensive concept design. Adhering to inventive principle #14, which advocates form optimization, the component's shape was modified to achieve a more fitting and lightweight configuration while retaining its inherent functionality.

A variety of rigorous processes were used to generate the concept design, including morphological chart and the use of design matrix. These methodologies made it easier to thoroughly investigate potential design variations, considering a variety of parameters and constraints (Haniffah et al. 2025). This detailed case study focuses on presenting the 4 concepts design, which was carefully designed in accordance with inventive engineering principles. The selection and refinement of this design were guided by careful application of inventive principles, ensuring that the resulting concept not only met the prescribed criteria but also embodied a synergy of innovation and functional optimization.

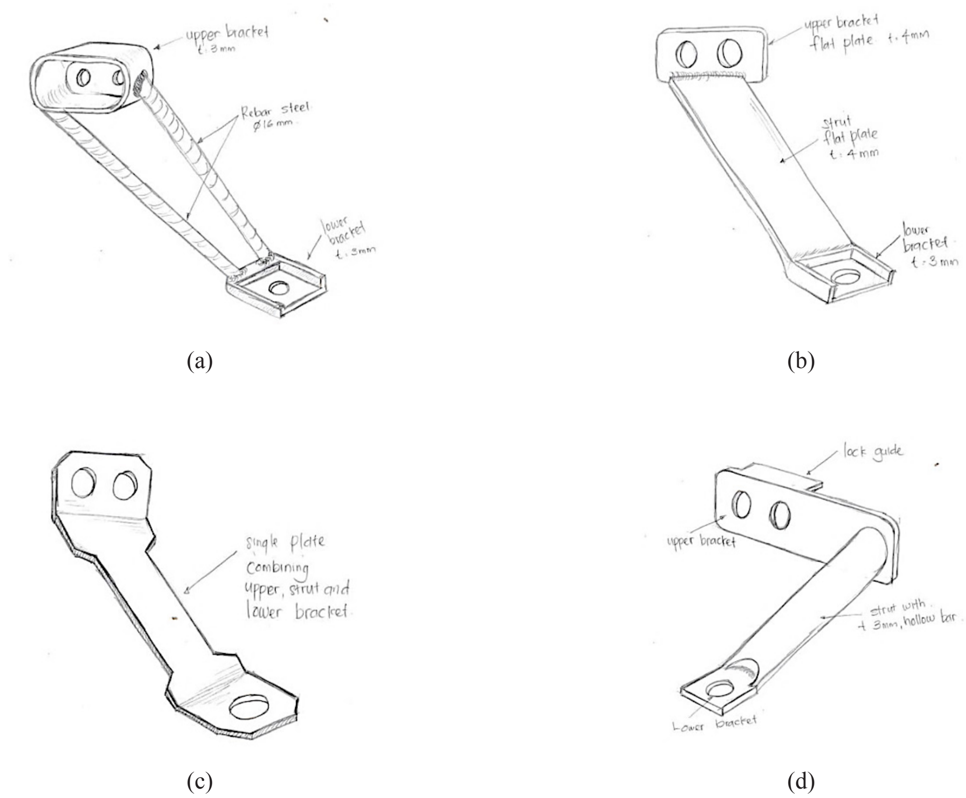

FIGURE 7. Conceptual Design (a) Design 1 (b) Design 2 (c) Design 3 (d) Design 4

Figure 7a Illustrate that to reduce weight, a strategic modification was implemented, which involved replacing the existing 35 mm diameter hollow steel strut. This was replaced with two solid rebar steel elements chosen for their increased strength compared to the original material. The decision to keep the lower and upper brackets in their current configuration stemmed from their critical interface with the main frame chassis (upper bracket) and the strut tower, which is an integral part of the suspension system for the lower bracket. The specific rebar steel used had a diameter of 16 mm, which was deemed both economically viable and structurally ideal for the demands placed on the strut bar. Solid rebar steel was chosen for its superior strength characteristics, which ensured increased load-bearing capacity and structural integrity. It is worth noting that the research at this point avoids exploring the granularities of detailed design specifications and comprehensive structural analyses. The primary goal remains to establish proof of concept and lay the groundwork for the subsequent stages of design development.

The second concept (Figure 7b) shows that the design employs a flat plate with a thickness of 4 mm. In the current scenario, this modification simplifies the fabrication process and lowers costs. The upper bracket is also converted to a flat plate. However, the lower bracket retains its original design. Design 3 (Figure 7c), on the other hand, depicts a single plate that has been shaped by forging and bending to form a single plate bracket with a seamless condition. This design will eliminate joint processes such as welding.

The final design, shown in Figure 7d, revealed a strategic change in the position of the load-bearing bar. This modification was made with the explicit goal of reorienting the distribution load and thus strengthening the overall structural integrity. When compared to other design iterations, the resulting structure was more rigid. This modification also provided a significant benefit in facilitating the exploration of various materials during Finite Element Analysis (FEA). Specifically, the modified configuration provided an ideal platform for subjecting the structure to FEA examination, with a focus on the use of various materials, including bio-composites. This multifaceted approach not only improved structural strength but also provided a valuable avenue for comprehensive material testing and analysis within the context of engineering optimization.

CONCEPTUAL DESIGN SELECTION USING ANALYTICAL HIERARCHY PROCESS (AHP)

The evaluation of all conceptual designs with respect to each main criterion and sub-criterion was carried out using the pairwise comparison technique. This method systematically compares entities to determine preferences or assess their contribution to a set of subjective attributes. In this context, the assessment was grounded in the critical criteria for the electric vehicle strut bar, with material and patent attributes identified as significantly more critical than cost.

Following the application of TRIZ principles, the final conceptual designs for the electric vehicle strut bar were selected through the AHP methodology. This involved ranking the developed conceptual designs based on their alignment with the predefined criteria. The ultimate selection was guided by the product design specifications (PDS) within the AHP framework, where in each criterion at every hierarchical level was evaluated according to its relative importance using pairwise comparisons. Table 6 provides a detailed illustration of this evaluative process.

TABLE 6. Scale for pairwise comparison for design evaluation (Sapuan, et al. 2011; Nazri, et al. 2016; Ramik, 2020)

Relative Intensity/Score	Definition	Explanation
1	Equal value	Those two requirements are same value
3	Slightly more value	Difference slightly favors one requirement over another
5	Essential or strong value	Different strongly favor one requirement over another
7	Very strong value	A requirement is strongly favored, and its dominance is demonstrated in practice
9	Extreme value	The evidence favoring one over another of the highest possible order affirmation
2,4,6,8	Intermediate value between two adjacent judgements	When compromise is needed
Reciprocal	Reciprocal for inverse comparison	

Table 7 mentions that the Analytic Hierarchy Process (AHP) was used to evaluate and rank four conceptual design alternatives based on a variety of criteria, with a particular emphasis on the Size criterion. The first step involved creating a pairwise comparison matrix in which each concept was compared to the others. The matrix was then normalized, and the priority vector for each concept was calculated, indicating their relative importance based on the Size criterion.

TABLE 7. AHP pairwise comparison respect to the size criteria.

Size	Concept 1	Concept 2	Concept 3	Concept 4
Concept 1	1.00	3.00	2.00	4.00
Concept 2	0.33	1.00	0.33	3.00
Concept 3	0.50	3.00	1.00	5.00
Concept 4	0.25	0.33	0.20	1.00
Total	2.08	7.33	3.53	13.00

The pairwise comparisons were systematically arranged into a matrix format, and the corresponding priority vector, w, was determined through a mathematical synthesis process using Equation 1, as detailed in the following section.

$$w = \frac{1}{n}\sum_{j=1}^{n} \frac{a_{ij}}{\sum_{i=1}^{a} a'} \text{ , } i,j = 1,2,\ldots,n \tag{1}$$

The priority vector derived from the normalized matrix revealed that Concept 1 was the most favorable design alternative with a priority of 0.4407. This result shown in Table 8 indicates that Concept 1 is the optimal choice when evaluating designs based on size considerations. Concept 3 followed with a priority of 0.3292, performing well but still ranking below Concept 1. In contrast, Concept 2 and Concept 4 were ranked third and fourth with priorities of 0.1554 and 0.0747, respectively, making them less favorable when the Size criterion is considered.

TABLE 8. Normalized matrix for priority

Size	C1	C2	C3	C4	Priority
C1	0.4800	0.4091	0.5660	0.3077	0.4407
C2	0.1600	0.1364	0.0943	0.2308	0.1554
C3	0.2400	0.4091	0.2830	0.3846	0.3292
C4	0.1200	0.0455	0.0566	0.0769	0.0747

To ensure the reliability and consistency of the AHP results, a Consistency Index (CI) and Consistency Ratio (CR) were calculated to assess the coherence of the pairwise comparisons as shown in figure 8. The principal eigenvalue (λ_{max}) of the comparison matrix was determined to be 4.14833, which is slightly higher than the number of criteria (4), indicating minor inconsistencies. The Consistency Index (CI) was calculated to be 0.04944, which is significantly below the threshold of 0.10, suggesting that the judgments made during the pairwise comparison process were reasonably consistent. This measures the consistency of the pairwise comparison matrix. The formula for CI is:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{2}$$

This is a ratio of the Consistency Index (CI) to the Random Consistency Index (RI). The formula for CR is:

$$CR = \frac{CI}{RI} \tag{3}$$

Similarly, the Consistency Ratio (CR) was found to be 0.05494, which is also well below the acceptable threshold of 0.10, further confirming that the pairwise comparisons were conducted with a high degree of consistency.

Table 9. Reliability and consistency of AHP results.

Wt. Sum Vec	Con. Vect.		
1.86415	4.22993	Lambda	4.14833
0.63623	4.09500	CI	0.04944
1.38937	4.22067	CR	0.05494
0.30255	4.04771		

These consistency measures reinforce the reliability of the derived priority vector, which ranks the design concepts according to the Size criterion. Since both the CI and CR values are below the established thresholds, the analysis indicates that the priority rankings are based on consistent and dependable comparisons. The results of the AHP analysis suggest that Concept 1 should be prioritized for the Size criterion, followed by Concept 3, Concept 2, and Concept 4. The low CI and CR values demonstrate that the methodology used to derive the rankings is robust and consistent, ensuring the credibility of the results. These findings can now be integrated with evaluations of other criteria, such as Size (S), Weight (W), Connection (Cn), Design (D), Structure (S), Raw Material (RM) and Fabrication (F), to support a comprehensive decision-making process for selecting the optimal design concept show in Table 10.

TABLE 10. Result of the AHP analysis

	S	W	Cn	D	S	RM	F	Priority
C1	0.44	0.22	0.09	0.09	0.31	0.14	0.07	0.23
C2	0.16	0.17	0.15	0.18	0.14	0.22	0.24	0.18
C3	0.33	0.53	0.27	0.45	0.08	0.52	0.58	0.35
C4	0.07	0.08	0.49	0.28	0.47	0.12	0.11	0.24

Based on the radar chart derived from the AHP method in figure 8, Concept 3 performs the best overall, excelling in Weight and Fabrication, which are critical for functionality and manufacturability. Concept 4 stands out in Connection and Structure, making it ideal for applications requiring strong structural performance. Concept 1 shows strength in Size but falls short in other criteria, while Concept 2 is balanced across all areas but lacks standout performance. Therefore, Concept 3 is recommended as the top choice, with Concept 4 as a strong alternative depending on the prioritization of criteria.

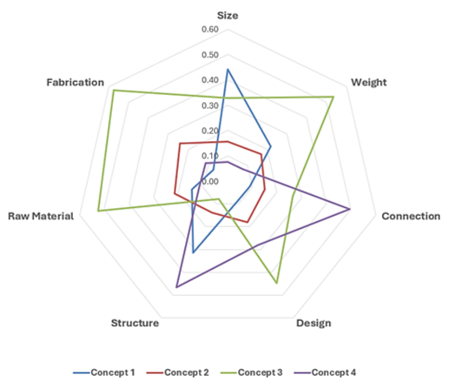

FIGURE 8. Radar chart of result of AHP

An FEA study was conducted to compare Design 3 to the current strut bar design which went through detail design as shown in figure 9.

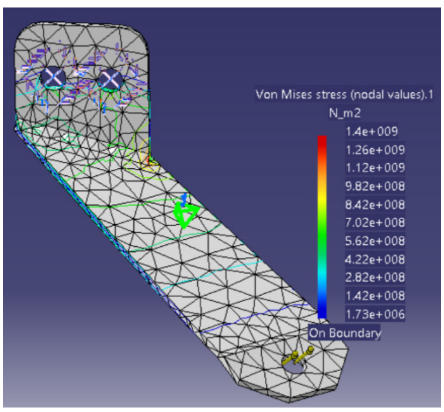

FIGURE 9. Detail Design 3 with FEA Simulation Result

A previous study by Mansor et al. (2024) found that Design 3 had 1400 MPa of maximum strength higher than the original design which was 138 MPa.

IMPLICATIONS FOR PRACTICE

Design Thinking remains the primary guiding approach in this framework proposal, while TRIZ is specifically used during key technical-analytical phases: idea generation and subsequent prioritization and selection of optimal concepts for advancement in New Product Development (NPD). The importance of selecting the best concept for the prototype phase is deemed critical for product success, mirroring the importance of generating ideas that lead to the final concept. As a result, TRIZ is used for both activities, with its set of analytical tools. For simplicity, this entire stage retains its original name, "problem treatment," as it represents the phase in NPD where the problem is effectively addressed to formulate the final concept(s).

This serves as the research's analytical core, providing a nuanced understanding of how the integrated methodology transforms the landscape of idea generation and product development through a rigorous examination of both quantitative and qualitative findings.

CONCLUSION

Finally, this study provides an in-depth examination of incorporating TRIZ principles into the design thinking methodology, revealing its impact on the idea generation process in product development. The convergence of these approaches is revealed through a theoretical lens and empirical investigations, providing actionable insights. The combination of TRIZ's systematic problem-solving approach and design thinking's user-centered approach results in a synergistic methodology that fosters creativity while also structuring the translation of ideas into tangible proposals. The study emphasizes the transformative impact on idea generation, streamlining the transition from ideation to real-world solutions, and effectively addressing complex design challenges. Real-world applications and case studies demonstrate the integrated approach's practical utility and adaptability, which contributes to the development of innovative products.

This research contributes to theoretical understanding as well as practical applications by providing a conceptual foundation and actionable insights. Recognizing limitations opens possibilities for future research, and a call to action encourages designers to embrace the synergy for continuous improvement and innovation, making this research a guiding beacon in the ever-changing landscape of product development.

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DECLARATION OF COMPETING INTEREST

None.

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