

# The Development of an Assessment Tool for Successful Product Development Based On DFMA and AHP Approach: Automotive Industry Case Study

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## Abstract

Successful product development is critical in the automotive industry, offering benefits such as optimised manufacturing, reduced costs, and faster market entry. Despite available tools, the complexity of design resources makes the process challenging. This study aimed to develop an assessment tool for evaluating successful product design in the automotive sector, starting with identifying success criteria from reputable research. Expert Choice software was employed to analyse the significance and weightage of the identified criteria. As a result, there are 19 criteria were prioritised across four key categories. The requirements such as product design, cost-effectiveness, safety, and environment. Notably, the most crucial criteria identified were recyclable materials (0.139), end-of-lifecycle considerations (0.118), and sustainable manufacturing (0.108984), while the least important were standardisation (0.0155), cabin ergonomics (0.022), and fire safety (0.0158). The resulting assessment tool, validated by four industry and academic experts, showed promise in helping practitioners self-evaluate successful product design within the automotive industry.

## 1. Introduction

The automotive sector is an essential industry in the global economy, generating about \$3.5 trillion in revenue in 2020 and manufacturing over 77 million vehicles [1-2]. This industry employs millions and significantly impacts related sectors such as manufacturing, transportation, and retail. Recent advancements in the automotive industry involve a shift toward electric and self-driving technologies due to strict emission regulations and a growing demand for sustainable transportation solutions.

Design for Manufacturability and Assembly (DFMA) is a vital design approach in the automotive industry that optimises product designs for easy manufacturing and assembly. DFMA helps identify opportunities for simplification, standardisation, and cost reduction by minimising the number of parts, reducing component complexity, and ensuring ease of assembly without specialised tools. The method has played a vital role in enhancing effectiveness and cutting production expenses, especially in the 1980s and 1990s, when companies such as Toyota and Ford were the first to establish their concepts [3-4].

Despite the availability of multiple engineering tools and software for product design, the automotive industry requires assistance optimizing the design process due to these resources' complexity and time-intensive nature. Successful product development is crucial across various industries, including the automotive sector, as a well-designed product can streamline the manufacturing process, reduce costs, and shorten the time from invention to market. However, current tools may need to adequately consider dynamic factors, such as integrating green and

sustainable elements in product development. With increasing demands from diverse stakeholders, there is a need to consolidate information into product design requirements. Hence, it is essential to analyse successful product design criteria to develop a quick and effective assessment tool for engineers.

The study aims to create a tool for assessing successful criteria for product design in the automotive industry and improving decision-making, design efficiency, and industry alignment.

## 2. Review of Previous Studies

### 2.1 Design for Manufacturing and Assembly

Successful product development is essential in various industries, including the automotive industry. A successful product design could ease the manufacturing process, reduce manufacturing costs, and shorten the invention to market time (e.g. the delivery time of a vehicle). In product development, many engineering tools and software are available to assist the engineer in product design and development. Still, the complexity of these tools could make the design work troublesome and time-consuming. For example, training and practising the software required more extended time. In addition, with the increased demands for successful product definition from diverse stakeholders, there is a need to understand and consolidate this information into product design requirements. Therefore, a study of current successful factors in product design is essential, particularly to determine the critical criteria to consider a product as successful quickly before a conclusive decision can be made. Therefore, it is essential to analyze the current successful product design criteria and simplify them to assist the engineer in decision-making, such as developing a quick and effective assessment tool.

### 2.2 Benefits of DFM and DFA

Based on prior research, implementing DFM and DFA in the manufacturing process provides various advantages such as cost reduction, enhanced product quality and reliability, shortened time-to-market, reduced assembly process time, future-proofing products, improved communication and teamwork, minimized environmental impact and lowered risk factor, as demonstrated in Table 1.

**Table 1** Several benefits in manufacturing industries using DFM & DFA

No	Benefits	Description
1	Cost reduction	Considering material usage early in the design process and reducing the number of parts, DFM can lower manufacturing and assembly costs.
2	Improved Product Quality and Reliability	Applying thought to DFM and DFA early in the process can improve product quality and reliability without compromising cost. DFMA enables a 'right-first-time' approach to product development, leading to highly reliable and durable products with a reduced failure rate.
3	Shorter Time to Market	DFM simplifies manufacturing processes, eliminates revisions and delays, and promotes a 'right-first-time' approach to product development.
4	Reduced Assembly Process Time	The knock-on effect of reducing assembly process time enables products to reach the market faster, minimising the time spent in the pre-revenue production phase.
5	Future-Proofing Products	DFM should be utilised throughout the entire product life cycle, including upgrades, to prevent issues that may arise late in product development. It can save clients from costly errors and delays.
6	Dialogue and Teamwork	DFA promotes collaboration between designers and manufacturing engineers, resulting in reduced costs, improved product reliability, and faster time to market.

7	Environmental Impact	DFMA minimizes the product's environmental impact during manufacturing and its life cycle by reducing wastage of materials, motion, inventory, and overprocessing.
8	Risk Reduction	Proper quality assurance processes are implemented during manufacturing and assembly to manage health and safety risks.

## 2.3 Successful Product Development in Different Industries

Successful product design in different industries requires having a thorough understanding of the target market, considering social impact, and working with diverse teams [5]. The criteria for product success can vary across different industries. Launching a successful product is a team effort where designers focus on ensuring usability, utility, and overall user experience. However, several external factors beyond the designer's control can influence the outcome of new product development, leading to either success or failure. Figure 1 below shows the main factors contributing to recent product development success [5].



Fig. 1 The factors of success for new product development [5]

### 2.3.1 Product Design

Successful product design criteria vary across different industries. However, some common factors include integrated design and manufacturing, automation, a multidisciplinary approach, education and training, a systems approach to costs, and energy costs. These criteria are relevant in several industries, including logistics, aerospace, automotive, computer, and electronics [6]. For example, metal matrix composites are advanced materials used in the aerospace industry for high-temperature fighter aircraft engines, the National Aerospace Plane skin and engines, high-temperature missile structures, high-speed mechanical systems, and electronic packaging. Similarly, advanced materials have automotive applications in pistons, brake components, connecting rods, and rocker arms [6]. The effectiveness of design management in product design and development depends on how well it is coordinated with other managerial processes related to production and marketing, making a holistic and interdisciplinary approach to product design essential [6].

### 2.3.2 Cost-Effective

Cost-effective product design is a complex process that involves a multifaceted approach in different industries such as logistics, elevators, automotive, sheet metal, polymer, aerospace, electrical, computer, electronic, and railway industries [7]. Optimizing product design through Design for Manufacturing (DFM) is crucial to achieve cost-effectiveness. DFM helps reduce costs, improve quality, and speed production [8]. Factors that affect cost-effectiveness include material selection, part count, geometry, tolerances, and manufacturing methods. It is also essential to consider design simplification, manufacturing process efficiency, and Design for Assembly (DFA) .

### 2.3.3 Safety

Several critical safety criteria must be met to ensure safe product design for industries such as logistics, elevators, automotive, sheet metal, polymer, aerospace, electrical, computer, electronic, and railway. These include following safety standards and regulations set by national and international organizations, industry associations, and professional bodies [9]. Potential hazards and risks should be analyzed, and safety measures should be developed to prevent or lessen them. Implementation of safety measures such as elimination, substitution, engineering controls, and administrative controls can decrease hazards [9]. Testing and evaluating safety performance against criteria and specifications can identify gaps in safety design and necessary improvements or corrections [9]. Safety information should be documented and communicated to customers and users to show safety compliance and educate them about safe use and maintenance.

### 2.3.4 Environment

To design sustainable products, companies need to measure the environmental impact, identify a product's environmental impact across its life cycle, and apply design strategies that promote sustainability. Companies can use six complementary strategies to guide their sustainable design efforts, including dematerialization, design for improved product lifecycle, and choosing green materials [10]. Additionally, companies must define their product sustainability goals as requirements, including recycled content, recyclability, reusability, transitioning to a circular economy, and leveraging sustainable frameworks such as sustainable development goals (SDGs) or environmental, social, and governance [10].

## 2.4 Assessment Tools

The automotive industry uses several environmental assessment tools to evaluate the environmental impact of vehicles throughout their lifecycle, from material extraction to end-of-life disposal. Table 2 displays popular tools for conducting life cycle assessments and environmental impact analysis in automotive design.

**Table 2** Several environmental assessment tools

No	Assessment tool	Reference	Description
1	GREET (Greenhouse gases, Regulated Emissions, and Energy Use in Technologies)	[11]	The US Department of Energy developed GREET estimation throughout a vehicle's life cycle.
2	Eco-Calculator	[12]	Developed by the European Commission, Eco Calculator calculates a vehicle's environmental performance, considering various factors such as energy use, emissions, and recycling.
3	Life Cycle Assessment (LCA)	[13]	LCA is an essential tool to evaluate a material's environmental performance, considering the production, use, and end-of-life phases of a vehicle's life.

## 3. Research Design

The methodology chosen and used for this project consists of four stages: Criteria Extraction, Analytic hierarchy process (AHP) survey, Tool development, and assessment tool validation. Past literature was analysed to identify criteria for successful product design in the automotive industry. The AHP survey aims to determine the importance of these requirements and will be sent to university experts and industry engineers. The AHP survey will have 16 respondents. A product design assessment tool was developed using Microsoft Excel based on the AHP survey results, and four experts in the automotive industry will validate it.

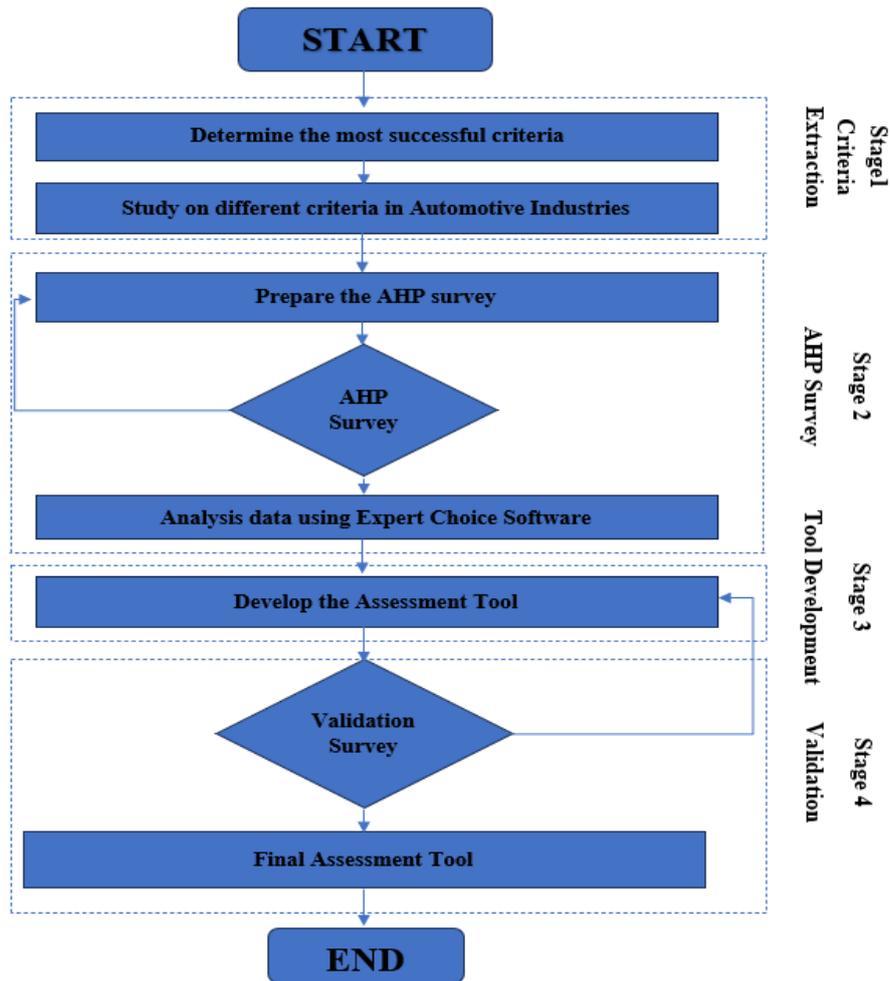


Fig. 2 Framework of process stages and investigative methods used in this study

### 3.1 Research Stages

The research methodology is divided into four stages: Criteria extraction, Analytical Hierarchy Process (AHP) survey, Tool development, and Assessment tool validation.

#### 3.1.1 Stage One: Criteria Extraction

During the first stage, the automotive industry has obtained successful product development and design criteria from previous studies and journals. These criteria include technical skills, creativity, ease of manufacture, manufacturability, assembly, meeting consumer demands, safety and regulatory requirements, aesthetics, vehicle cost, materials selection, and integration of advanced features like autonomous driving and infotainment options.

#### 3.1.2 Stage Two: Analytic Hierarchy Process (AHP) Survey

AHP was a multi-criteria decision-making tool developed by Thomas L. Saaty in 1977 for systematic decision-making [14]. AHP broke down the criteria into several sub-criteria aggregated to conclude. Then, experts needed to rate the importance of each criterion on a scale from 1 to 9 (1 = equally important; 9 = much more critical) [15]. In addition, Expert Choice software was used for the AHP data analysis and to determine the priority weightage [15]. The selected successful product design criteria from the previous stage were used. The AHP method was chosen for the survey stage to assess the importance of the specified criteria and the weightage between each criterion and sub-criteria. The respondents for the AHP survey were academic experts and engineers working in the automotive sector (referred to in Table 3 below).

**Table 3** Respondents who will participate in the AHP survey

No	Position	Expertise	Industry/institutions
AHP-1	Automotive engineer	<ul style="list-style-type: none"> <li>Practical experience in car manufacturing and the automotive industry.</li> </ul>	Automotive Manufacturing
AHP-2	Automobile Engineer	<ul style="list-style-type: none"> <li>Expertise in vehicle dynamics, powertrain, and automotive electronics.</li> <li>Knowledge of automotive design, development, and manufacturing processes.</li> </ul>	Automotive Manufacturing
AHP-3	Senior Lecturer	<ul style="list-style-type: none"> <li>Extensive product design principles, mechanical systems, and automobile engineering knowledge.</li> </ul>	Higher Education, Academic Research Institutions
AHP-3	Assistant Professor	<ul style="list-style-type: none"> <li>Expertise in internal combustion engines and engine component design.</li> <li>Proficiency in CAD and simulation software for designing mechanical parts.</li> </ul>	Higher Education, Academic Research Institutions
AHP-4	Automotive Engineer	<ul style="list-style-type: none"> <li>Strong grasp of automotive engineering principles, including vehicle systems and manufacturing processes.</li> <li>Practical experience in car manufacturing or the automotive industry.</li> </ul>	Automotive Manufacturing
AHP-5	Senior Lecturer	<ul style="list-style-type: none"> <li>Comprehensive knowledge of automotive engineering subjects, including vehicle dynamics, engine design, and electronics.</li> </ul>	Higher Education, Academic Research Institutions
AHP-6	Product Designer	<ul style="list-style-type: none"> <li>Proficiency in product design principles and techniques.</li> </ul>	Consumer product design firms
AHP-7	Design Engineer	<ul style="list-style-type: none"> <li>In-depth knowledge of product costing and cost analysis techniques.</li> </ul>	product design consultancies
AHP-8	PLC Design Engineer	<ul style="list-style-type: none"> <li>Expertise in programmable logic controllers (PLCs) and their application in automotive systems.</li> </ul>	Automotive manufacturing companies
AHP-9	Product Designer	<ul style="list-style-type: none"> <li>Specialization in automotive sheet metal design and manufacturing.</li> </ul>	Sheet metal fabrication companies.
AHP-10	Automotive Engineer	<ul style="list-style-type: none"> <li>Comprehensive understanding of automotive manufacturing processes and quality control.</li> <li>Practical experience in a car manufacturing environment.</li> </ul>	Car manufacturing companies
AHP-11	Senior Lecturer	<ul style="list-style-type: none"> <li>Extensive knowledge of automotive engineering and combustion engine technologies.</li> </ul>	Higher Education, Academic Research Institutions
AHP-12	Assistant Professor	<ul style="list-style-type: none"> <li>Deep understanding of automobile engineering principles.</li> <li>Research expertise in automotive engineering and a record of publications.</li> </ul>	Higher Education, Academic Research Institutions
AHP-13	Professor	<ul style="list-style-type: none"> <li>Extensive knowledge of mechanical engineering and manufacturing processes.</li> </ul>	Higher Education, Academic Research Institutions

<b>AHP-14</b>	PhD student	<ul style="list-style-type: none"> <li>Advanced knowledge in automotive engineering and specific research areas.</li> </ul>	Automotive R&D centers
<b>AHP-15</b>	Assistant Professor	<ul style="list-style-type: none"> <li>Proficiency in CAD/CAM software and knowledge of production management.</li> </ul>	Higher Education, Academic Research Institutions
<b>AHP-16</b>	Assistant Professor	<ul style="list-style-type: none"> <li>Combined expertise in manufacturing, product design, and cost analysis.</li> </ul>	Higher Education, Academic Research Institutions

The AHP survey compared two criteria or sub-criteria. The answer was in numbers, each representing a weightage scale. The respondents needed to rank the criteria that defined the importance of influencing successful product design in the automotive sector according to their experience.

**Example:** If we consider a particular factor, say "Criteria 2" is more strongly important than "Criteria 1," we might respond by selecting the answer as below:

Scale:

1 = Equal, 2 & 2' = Moderate important, 3 & 3' = Strong important,  
4 & 4' = Very strong important, 5 & 5' = Absolute important

**Table 4** Example of the AHP questions

Absolute important		Equal					Absolute important			
Criteria	5	4	3	2	1	2'	3'	4'	5'	Criteria
C1							●			C2

### 3.1.3 Stage Three: Tool Development

In this stage, the analysed data from Expert Choice software was used to develop a successful product design assessment tool for the automotive industry. The assessment tool was created using Microsoft Excel software. The device used the form of choices, and the user had to select the current successful product design criteria available in their company. The selection of successful product criteria with its weightage was obtained from the AHP survey. The level of success measures was determined by the selected criteria in the assessment tool, with a score given by the user.

### 3.1.4 Stage Four: Assessment Tool Validation

The tool was validated by four experts, including academics and industry professionals with automotive sector knowledge. Refer to Table 5 for the list of participating experts.

**Table 5** Respondents participating in tool assessment validation

Experts no	Expertise
<b>Expert 1</b>	Expertise in vehicle dynamics, powertrain, and automotive electronics. Knowledge of automotive design, development, and manufacturing processes.
<b>Expert 2</b>	Expertise in internal combustion engines and engine component design. Proficiency in CAD and simulation software for designing mechanical parts.
<b>Expert 3</b>	Practical experience in car manufacturing and the automotive industry
<b>Expert 4</b>	Proficiency in CAD/CAM software and knowledge of production management.

## 4. Results and Discussion

### 4.1 Screening stages

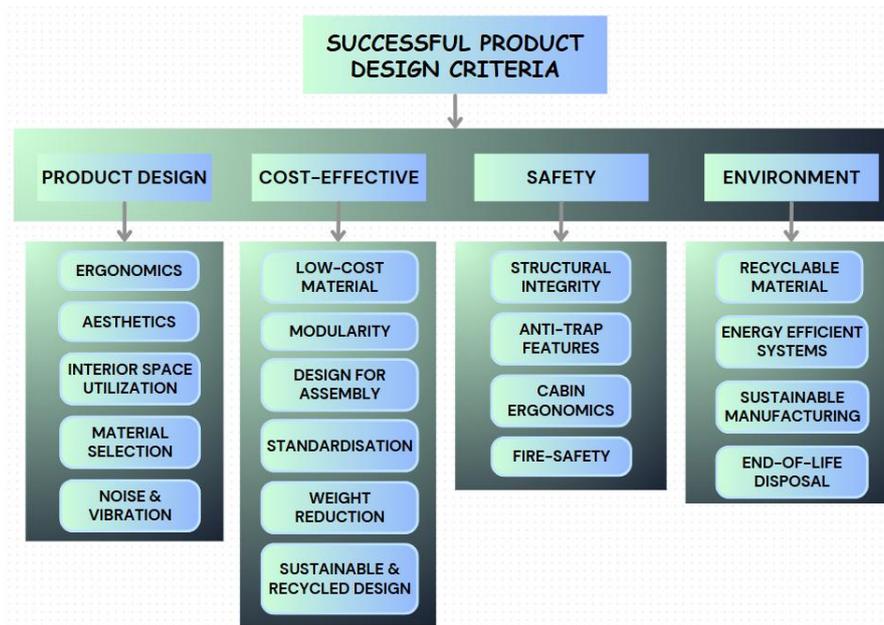
The product development criteria were chosen from prior articles and journals during the screening phase. The requirements were categorised into primary groups, each with its sub-criteria. Table 6 below displays the effective product development criteria in the automotive sector identified from previous research.

**Table 6** List of the criteria and sub-criteria that have been selected for this project

No	Main criteria	No	Sub-criteria
C1	Product design	C1-1	Ergonomics
		C1-2	Aesthetics
		C1-3	Interior space utilization
		C1-4	Material selection
		C1-5	Noise & Vibration
C2	Cost-effective	C2-1	Low-cost material
		C2-2	Modularity
		C2-3	Design for assembly
		C2-4	Standardization
		C2-5	Weight reduction
		C2-6	Sustainable & recycled design
C3	Safety	C3-1	Structural integrity
		C3-2	Anti-trap features
		C3-3	Cabin ergonomics
		C3-3	Fire safety
C4	Environment	C4-1	Recyclable materials
		C4-2	Energy-efficient systems
		C4-3	Sustainable manufacturing
		C4-4	End-of-life disposal

### 4.2 AHP Survey Stages

This section processes the criteria using a pairwise comparison survey design. The AHP survey design is derived from the AHP framework, as depicted in Figure 3. The AHP survey utilized Google Forms to collect data, specifically by requesting respondents to perform pairwise comparisons for the formulated questions. The respondents were asked to rate the importance of each comparison on a scale of 1 to 5, with 0 indicating equal importance.



**Fig. 3** AHP framework for main and sub-criteria

The weighted criteria were analysed using Expert Choice 11 software to determine the local and global weight of each criterion. Table 7 shows the weight of each criterion. Furthermore, the consistency of the results is also being evaluated to ensure that there is less than 0.01 inconsistency to ensure the results are valid and represent the investigated case studies.

**Table 7** Weight of each criterion determined using expert choice software

Main criteria	Local weight of criteria	Sub-criteria	Local weight of sub-criteria	Global weight	Rank
<b>Product design</b>	0.214	Ergonomics	0.248	0.0531	6
		Aesthetics	0.221	0.0473	8
		Interior space utilization	0.234	0.0501	7
		Material selection	0.14	0.0300	13
		Noise and vibration	0.157	0.0336	11
<b>Cost-effective</b>	0.225	Low-cost material	0.166	0.03735	10
		Modularity	0.1	0.0225	16
		Design for assembly	0.141	0.031725	12
		Standardization	0.069	0.015525	19
		Weight reduction	0.131	0.029475	14
		Sustainable and recycled design	0.393	0.088425	5
<b>Safety</b>	0.105	Structural integrity	0.365	0.038325	9
		Anti-trap features	0.272	0.02856	15
		Cabin ergonomics	0.212	0.02226	17
		Fire-safety	0.151	0.015855	18

<b>Environment</b>	0.456	Recyclable material	0.307	0.139992	1
		Energy-efficient systems	0.195	0.08892	4
		Sustainable manufacturing	0.239	0.108984	3
		End-of-life disposal	0.26	0.11856	2

### 4.3 Assessment Tool Development

Based on the AHP global weight of each criterion in Table 8, these data were used to develop a successful automotive design assessment tool. A successful automotive design assessment tool was developed using Microsoft Excel software. The assessment tool has four main criteria. Users need to rate every main criterion according to which one is important according to the 1 to 5 scale, where 1 is low important, and 5 is extremely important. Table 8 shows the scale and its description used in the assessment tool questions.

**Table 8** Scale of the assessment tool

Rank	Meaning	Score
0	Not available	0 of the criteria global weight
1	Low important	$1/5 \times$ Global weight of criteria
2	Important	$2/5 \times$ Global weight of criteria
3	Fair	$3/5 \times$ Global weight of criteria
4	Very important	$4/5 \times$ Global weight of criteria
5	Extremely important	$5/5 \times$ Global weight of criteria

When using the assessment tool, the user needs to give a score (1-5) for each criterion based on which one is the most important for successful product design in the automotive industry. Upon completion of scoring, the results of the successful product design performance index will be calculated based on the inserted score for each criterion. In addition, the tool will show some recommendations for improving the field or areas that require change to achieve successful product design in the automotive industry. Figure 4 shows the home page of the assessment tool, where the user needs to fill in the name. Figure 5 shows an example of assessment tool criteria and scale where the user needs to fill in the score (1-5). Figure 6 shows an example of the assessment tool's results with recommendations.

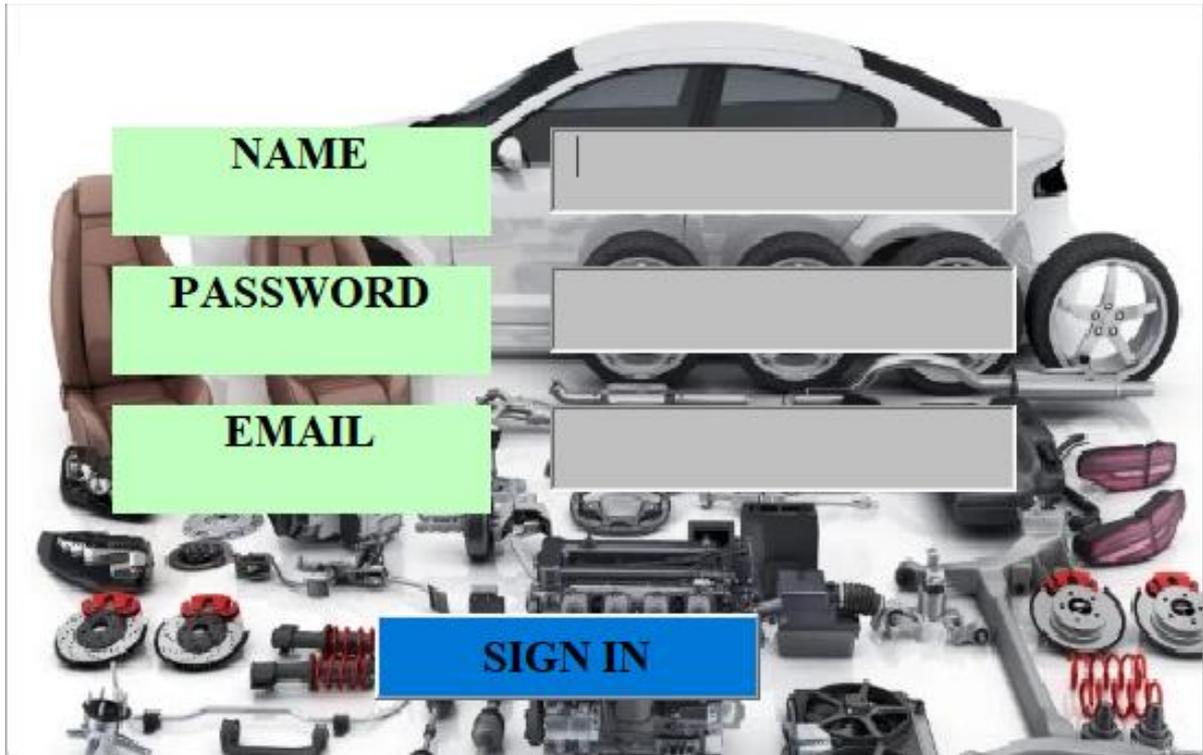


Fig. 4 Main interface of the assessment tool

**PRODUCT DESIGN** **INSTRUCTION**

- User, click the checkbox that you agree with.
- Then, user rates from 0 to 5 for sub-criteria agree with.
- Finally, the user clicks "CALCULATE" for the gating score.

77 %

SUB-CRITERIA	DESCRIPTION	EXAMPLE	SCORE
ERGONOMICS	Automotive designers focus on creating comfortable and user-friendly interiors for drivers and passengers. This includes designing seats, controls, and interfaces that reduce fatigue and enhance convenience during long drives.	• Adjustable seating	4 ▾
AESTHETICS	Car manufacturers invest significant effort in creating vehicles that perform well and look visually appealing. Aesthetic considerations influence exterior design elements such as body shape, curves, and colour choices.	• Exterior design	4 ▾
INTERIOR SPACE UTILIZATION	Effective interior space utilization ensures that the vehicle's interior is both spacious and functional. This includes designing the layout to maximize legroom, headroom, and storage options while maintaining a comfortable and aesthetically pleasing environment.	• Flexible seating configurations	4 ▾
MATERIAL SELECTION	Material selection is critical for ensuring durability, functionality, and sustainability in the automotive industry.	• Sustainable materials	4 ▾
NOISE & VIBRATION	Automotive engineers work to minimize unwanted noise and vibration in vehicles to enhance the overall driving experience. This involves incorporating sound insulation materials, optimizing engine and exhaust systems for quieter operation, and designing suspension systems to absorb road vibrations.	• Sound insulation • Engine and transmission mounts	4 ▾

CALCULATE

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Fig. 5 Examples of the assessment tool criteria and scale

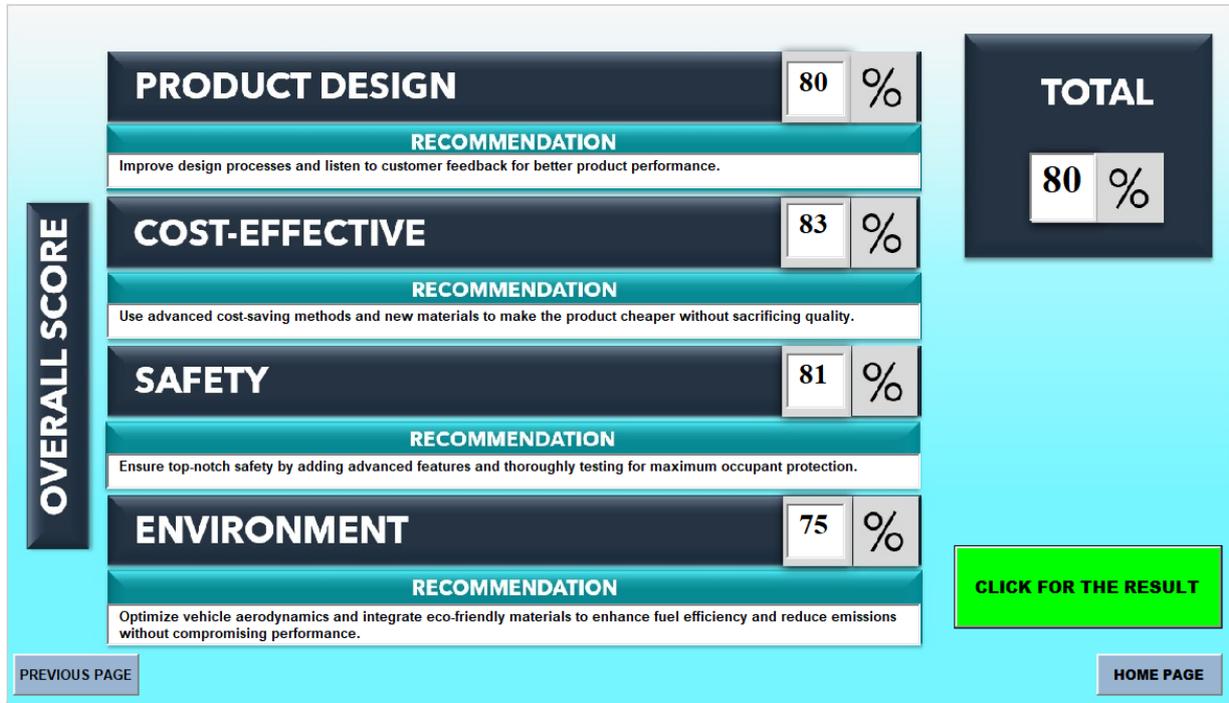


Fig. 6 Example of the results of the assessment tool with recommendations.

#### 4.4 Validation and Expert Feedback

The development assessment tool has been validated through a short survey by experts with experience in the automotive industry. Specifically, the experts were asked to evaluate the tool's design, user-friendliness, and results and provide further feedback if necessary. Four experts participated in the validation process, as shown in Tables 9 and 10 below. The feedback obtained was mainly positive and confirmed the tool's feasibility.

Table 9 Validation feedback from participants

Expert no.	Feedback
Expert 1	Nice concept. Need to improvement
Expert 2	Need to improve in suggestion.
Expert 3	It is quite complicated but understandable. You need to improve some criteria.
Expert 4	Good

**Table 10** Validation results

	Expert 1	Expert 2	Expert 3	Expert 4
User interface	Very good	Very good	Good	Very good
Quality result estimation	Good	Good	Very good	Good
Flexibility	Good	Fair	Fair	Good
Knowledge-based system	Good	Very good	Very good	Fair
Presentation of results	Very good	Good	Good	Good
Automotive term used	Good	Good	Very good	Good
Logical description	Very good	Good	Good	Fair
Usefulness level	Good	Good	Very good	Good
Information level	Good	Good	Good	Very good

## 4.5 Discussion

This section comprehensively overviews the Analytical Hierarchy Process (AHP) survey results and insights. The interpretation of the AHP findings is grounded in the priority rankings derived from the weighted significance of each criterion. Utilizing Expert Choice software for data evaluation, the AHP survey reveals that environmental considerations and cost-effectiveness emerge as the paramount criteria, with product design and safety also being critical but slightly less emphasized. Interestingly, 41 industry experts and seasoned engineers pinpoint recyclable materials, end-of-life disposal, sustainable manufacturing processes, and energy-efficient systems as vital for the automotive sector, as outlined in Table 4.2. Assessing their weightage illuminates their pivotal roles in driving successful product design in this industry. However, aspects such as standardization, fire safety, and modularity are deemed less vital within the automotive realm. Despite this, depending on the industry's specific needs, these criteria may still offer substantial value to product design efforts.

Furthermore, the current landscape of the automotive industry demonstrates a strong preference for environmental concerns over mere product design out of necessity and strategic foresight. This shift is mainly due to stringent global regulations on emissions, the push for recyclability, and the imperative for sustainable production methods, which compel car manufacturers to prioritize ecological issues to comply with legal requirements and secure a competitive edge. Moreover, the growing consumer demand for eco-friendly vehicles, driven by a heightened awareness of environmental sustainability, significantly influences market trends and purchasing decisions. Aligning with these environmental priorities enhances a company's brand image and positions it favourably for future market dynamics, marking a strategic evolution from traditional product design focal points. This collective emphasis underscores the automotive industry's strategic pivot towards prioritizing environmental criteria, indicating a substantial departure from conventional design priorities.

### 4.5.1 Product Design Criteria

Product design is essential in the automotive industry as it directly impacts usability, comfort, and overall customer satisfaction. This criterion, with a significant local weight of 0.214, includes several critical sub-criteria. Ergonomics (0.248 local, 0.0531 global weight, rank 6) ensures vehicles are comfortable and easy to use, reducing fatigue and enhancing the driving experience [16]. Aesthetics (0.221 local, 0.0473 global weight, rank 8) play a crucial role in attracting consumers, influencing their purchase decisions, and fostering brand loyalty. Interior space utilization (0.234 local, 0.0501 global weight, rank 7) optimizes the use of space within the vehicle, enhancing comfort and functionality [17]. Material selection (0.14 local, 0.0300 global weight, rank 13) involves choosing high-quality materials that improve the vehicle's durability and overall quality. Lastly, noise and vibration reduction (0.157 local, 0.0336 global weight, rank 11) are vital for providing a quiet and smooth driving experience, significantly impacting the perceived quality and comfort of the vehicle [17]. While product design is crucial for user satisfaction and market appeal, it is given a relatively lower weight than cost-effectiveness and environmental impact due to economic pressures, market dynamics, and the need to balance high-quality design with manufacturing costs and sustainability goals [17].

### 4.5.2 Cost-Effective Criteria

Cost-effectiveness is critical in the automotive industry, ensuring vehicles remain competitively priced without compromising quality. With a local weight of 0.225, this criterion encompasses several vital aspects. Utilising low-cost materials (0.166 local, 0.03735 global weight, rank 10) helps reduce production costs while maintaining quality standards [18]. Modularity (0.1 local, 0.0225 global weight, rank 16) allows easy customisation and repair, extending the vehicle's lifecycle and reducing costs. Design for assembly (0.141 local, 0.031725 global weight, rank 12) simplifies the manufacturing process, increasing efficiency and reducing production costs. Standardisation (0.069 local, 0.015525 global weight, rank 19) uses standard components to lower costs and streamline supply chains. Weight reduction (0.131 local, 0.029475 global weight, rank 14) improves fuel efficiency and performance, lowering operational costs [19]. Sustainable and recycled design (0.393 local, 0.088425 global weight, rank 5) focuses on using eco-friendly materials and practices, reducing the environmental footprint and appealing to eco-conscious consumers. Cost-effectiveness is crucial but has a slightly lower weight than environmental impact due to the increasing importance of regulatory shifts, consumer demand for sustainability, and the long-term perspective on sustainability practices [19].

### 4.5.3 Safety Criteria

Safety is crucial in the automotive industry and aims to protect drivers and passengers. With a local weight of 0.105, this criterion includes several essential sub-criteria. Structural integrity (0.365 local, 0.038325 global weight, rank 9) ensures the vehicle can withstand impacts and stresses, safeguarding occupants and meeting regulatory standards. Anti-trap features (0.272 local, 0.02856 global weight, rank 15) prevent entrapment and injury, enhancing user safety [20]. Cabin ergonomics (0.212 local, 0.02226 global weight, rank 17) designs a comfortable and ergonomic interior to reduce driver fatigue and injury risk, promoting safer driving conditions. Fire safety (0.151 local, 0.015855 global weight, rank 18) ensures the vehicle meets fire safety standards, providing crucial protection during a fire. These safety features collectively enhance the vehicle's overall safety rating and reliability, which is critical for consumer trust and satisfaction [21]. Safety receives a lower weight because high standards are a baseline expectation in the automotive industry. Innovations in safety are often incremental, and while safety is non-negotiable, it might not be the leading factor influencing purchasing decisions compared to cost and design [21].

### 4.5.4 Environment

Environmental impact is increasingly significant in the automotive industry, reflecting the growing emphasis on sustainability. This criterion has the highest local weight of 0.456, highlighting its significant influence. Using recyclable materials (0.307 local, 0.139992 global weight, rank 1) minimizes waste and environmental impact, supporting sustainable practices [22]. Energy-efficient systems (0.195 local, 0.08892 global weight, rank 4) reduce fuel consumption and emissions, aligning with regulatory standards and consumer expectations for greener vehicles. Sustainable manufacturing processes (0.239 local, 0.108984 global weight, rank 3) reduce the environmental footprint, conserve resources, and meet the increasing need for eco-friendly creations. End-of-life disposal (0.26 local, 0.11856 global weight, rank 2) ensures that vehicles can be easily recycled and disposed of responsibly at the end of their lifecycle, minimising environmental impact [23-24]. These environmental considerations are crucial for meeting regulatory requirements, enhancing brand reputation, and appealing to environmentally conscious consumers. Environmental impact receives the highest weight due to increasingly stringent regulations, global trends towards sustainability, growing consumer demand for eco-friendly products, and the long-term viability associated with sustainable practices.

## 5. Conclusion and Recommendation

The study carefully identifies the critical criteria for successful product design based on Design for Manufacturing and Assembly (DFMA) principles and AHP. It demonstrates a deep understanding of the factors contributing to excellent design and functionality. After the study, four experts created and validated an assessment tool. All three objectives of the study were accomplished by developing an assessment tool for successful product design in the automotive industry.

However, the study has certain limitations. One limitation is the potential for subjectivity and bias when relying on a small group of experts to identify and prioritize criteria. Depending on a small group of experts may lead to skewed results and impact the generalizability of the findings. Additionally, it is possible that the selected criteria only cover some relevant factors influencing successful product design, potentially overlooking essential aspects such as market trends, consumer preferences, and technological advancements.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

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