Saudi Arabia vision-2030 is mainly focused on industrialization to reduce reliance on oil revenue. Localized Manufacturing (LM) concept, which has gained its importance worldwide in this fast-changing technological world to meet customers' unique needs of 21st century. Now-a-days, manufacturing industry is shifting from standard product development to customized product development keeping in view the growing unique customer-'s needs. The research objective of this research was to maximize LM Application in the Kingdom of Saudi Arabia to meet unique customers' needs.

Automobile industry was selected to apply Industry 4.0 technologies i.e., 3D Printing/Additive manufacturing. The specifications, fulfilling the customer's unique needs have been incorporated to manufacture the desired part by 3D printing/additive manufacturing. Data was collected from Saudi automobiles customers regarding their unique needs on a particular automobile part. Using the Product Design and Development methodology by Ulrich et al data was collected, analysed and as a result of data analysis, a model for maximization of localized manufacturing was developed for implementation of LM technique. Results shows that using Industry 4.0 concept, customers' unique needs can be satisfied and fulfilled in less time and it will be more economical as compared to standard/conventional manufacturing/production methods. Based on the results of this research a model for maximization of localized manufacturing is developed utilizing Industry 4.0 technique

Keywords: Localized Manufacturing, Industry 4.0, Saudi Arabia Auto Industry, Automotive Spare Parts

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DEVELOPMENT OF A LOCALIZED PRODUCTION MODEL FOR THE AUTOMOTIVE INDUSTRY, BUILT INTO THE CONCEPT OF INDUSTRY 4.0 IN THE KINGDOM OF SAUDI ARABIA

Abdullah Awadh Aljuaid
PhD Scholar*
Syed Athar Masood
PhD, Associate Professor*
Javed Ahmed Khan Tipu
Corresponding author
PhD, Assistant Professor*
E-mail: javed.ahmed@iiu.edu.pk
Imran Shah
PhD, Assistant Professor
Department of Aerospace Engineering
College of Aeronautical Engineering
National University of Science and Technology
Risalpur, District Nowshera, KPK, Pakistan, 24090
*Department of Mechanical Engineering
International Islamic University
Sector H-10, Islamabad, Pakistan, 46000

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1. Introduction

Localized manufacturing is an important aspect of Saudi Arabia's Vision 2030 plan, which seeks to reduce its reliance on oil revenue and diversify the economy. One of the key sectors in focus for this plan is the automotive industry, which has a high potential for growth and job creation. The Kingdom of Saudi Arabia is one of the largest importers and exporters of automotive parts, but it aims to produce these components locally through localized manufacturing. This would enable the country to increase its competitiveness in the global market, enhance regional and global trade, and develop local skills and capabilities.

However, implementing localized manufacturing in the Saudi Arabian automotive industry is not without its challenges. Infrastructure limitations and a lack of local suppliers/lack of expertise, Saudi Arabian customers special unique needs are some of the major challenges facing industry today to meet their unique demands on time which requires immediate attention that needs to be addressed. In modern conditions, conducting scientific research on Industry 4.0 is crucial for several reasons that directly relate to satisfying customer needs and maintaining a competitive edge in the market. Some of the reasons why scientific research in this domain is necessary to meet customer demands are:

– innovation and product development: Industry 4.0 technologies enable the creation of innovative products and services that can better meet evolving customer needs. Scientific research helps companies understand how these technologies can be applied to develop new and improved offerings, enhancing customer satisfaction and loyalty;

– customization and personalization: Industry 4.0 allows for greater customization and personalization of products and services. Through research, companies can develop systems that gather and analyze customer data to tailor offerings to individual preferences, resulting in a more personalized customer experience;

– efficiency and cost reduction: Industry 4.0 technologies streamline operations, automate processes, and optimize resource utilization. Scientific research can identify the most effective ways to implement these technologies, leading to improved efficiency and cost savings, which can then be passed on to customers through competitive pricing;

– real-time responsiveness: Industry 4.0 enables real-time data collection and analysis, allowing companies to monitor

customer behavior and market trends in real-time. This enables quicker responses to changing customer preferences and market demands, ensuring that products and services remain relevant and desirable;

– quality improvement: The integration of IoT and data analytics can provide insights into product usage and performance. By analyzing this data, companies can identify areas for quality improvement, leading to higher customer satisfaction through more reliable and durable products;

– competitive advantage: Companies that lead in adopting and leveraging Industry 4.0 technologies gain a competitive advantage in the market. Continuous scientific research helps maintain this advantage, allowing businesses to stay ahead of the curve and consistently deliver products and services that exceed customer expectations.

In summary, scientific research on Industry 4.0 is essential for understanding, adopting, and optimizing cutting-edge technologies that can revolutionize auto industry by satisfying customer's unique needs.

2. Literature review and problem statement

Localized Manufacturing, in conjunction with Industry 4.0 concepts and techniques, has gained attention from researchers for various purposes, including assessing improvements and benefits [2]. Taking a territorial approach is significant due to the interconnected factors encompassed within a territory, such as localized externalities, production activities, cultural traditions, skills, know-how, proximity relationships, cultural elements, values, and local governance models.

The localization trend of Chinese companies can be attributed to mounting pressures from local society and government, along with rising labor costs in China [3]. The concept of distributed manufacturing has also received scholarly attention, particularly in relation to the maker's movement, fab labs, additive manufacturing, and digital fabrication. It involves a network of small-scale manufacturing units that enable localized production in community-based workshops [3].

To illustrate the methodology used in this research, several examples can be cited. "Localized Manufacturing in the Automotive Industry: A Comparison of Mexico and South Africa" by Scott and Singh compares the development of localized manufacturing in Mexico and South Africa's automotive industries, highlighting challenges and opportunities. The study finds that Mexico's geographic proximity to the US market and well-developed infrastructure have contributed to its success in developing a localized automotive industry.

A study "Localized Manufacturing and Innovation in the Chinese Automotive Industry," examines how localized manufacturing promotes innovation in the Chinese automotive industry. It reveals the strategies employed by Chinese automakers to enhance competitiveness and accelerate innovation [4].

"Industry 4.0: Opportunities and Challenges for Localized Manufacturing in the Automotive Industry" explores the benefits and challenges of Industry 4.0 for localized manufacturing in the automotive sector. The study emphasizes how technologies like 3D printing and artificial intelligence can improve efficiency and reduce costs [5].

Investigation for the impact of localized manufacturing on the Iranian automotive industry in the study, "The Impact of Localized Manufacturing on the Automotive Industry in Emerging Markets: A Case Study of Iran." Addresses the challenges and opportunities, highlighting how localized manufacturing can enhance competitiveness but may face obstacles such as limited access to technology and a shortage of skilled labor [6].

An empirical analysis, "Localized Manufacturing in the South African Automotive Industry," examines factors influencing the adoption of localized manufacturing in South Africa. The study evaluates its impact on job creation and economic development, revealing the potential for job creation and economic growth while noting challenges such as inadequate investment in infrastructure and a shortage of skilled workers [7].

The paper [3–7] presents the results of research on localized manufacturing and shown that localized manufacturing has created job opportunities, economic development, competitiveness, innovation. However, it lacks in fulfilling customers unique requirements. The reason for this may be that there may be not so many unique demands of customers in their countries [3–7] as against to Saudi Arabian customer due to high customers purchasing power. A way to overcome these difficulties, this approach was used as demonstrated in [1] while acknowledging the challenges and opportunities associated with its implementation.

Industry 4.0 has the capability to offer manufacturing organizations with profitable business models, higher efficiency, quality, and improved workplace conditions, however it has become apparent that the concept of Industry 4.0 still lacks a clear understanding and is not fully established in practice yet. [8]. It has gained considerable attention among researchers and practitioners given potential benefits, however, a fact needs to be noted is that research contributions are sometimes difficult to be implemented in practice because of a series of factors e.g., from the implementation perspective, industries are still holding doubts in implementing these new technologies, because of unclear possible benefits, lack of clear implementation details, and the seemingly large investments required, from the standardization perspective, there is still a lack of common accepted standards, software, and hardware [9]. Industry 4.0 technologies may be grouped into physical and digital technologies. Physical technologies mainly refer to manufacturing technologies such as additive manufacturing and how the application of Additive Manufacturing has evolved to include greater functionality and embrace a wider range of applications beyond the initial intent of prototyping. [10]. Industry 4.0 technologies are complex and integrated architecture manufacturing-information technology integration, the findings show that Industry 4.0 is related to a systemic adoption of the front-end technologies, in which Smart Manufacturing plays a central role, further their results also show that the implementation of the base technologies is challenging [11]. Industry 4.0 technologies seek to overcome modern-day challenges – global competition, volatile markets and demand, increased customization, they underline the importance of developing and commercializing customer-oriented novel business models based on innovative hybrid product and service solutions and individualization as a further possibility to leverage competitiveness. [12]. Manufacturing has gaining importance for the first-time for the economic mobility within Saudi Arabia as well in foreign countries, the aim of the Kingdom is to support and localize industrialization, as it has already begun to develop some of the less complex industries, it recommended to make use of scientists, researchers and specialists in the field of industrial engineering to support and develop the local manufacturing in the Kingdom, in order to optimize solutions to many of the problems raised in different departments in the field. [13]. The automobile spare parts requirement in the Kingdom Saudi Arabia is one of the largest of Gulf market, with rapid growth. Their finding concluded that it will be helpful for designing

the features of a local brand as per the preferences of the local market. Market dynamics indicates a strong consumer base. Future prospects are also promising, as there is strong domestic demand. This can be tapped if production is localized, leading to a development of an entire new manufacturing sector [14]. The cost incurred on purchase of automobile spare parts is around $500 million from the United States during last years. The study explores the preferences of consumers towards automobiles in the Saudi Arabian market. Consumer behavior was tested on six dimensions: mileage (fuel efficiency), resale value, maintenance cost, pollution (environment-friendly), product image, country of make. Analysis of the results shows that out of these six dimensions, only two dimensions mileage (fuel efficiency) and maintenance cost have significant variance [15]. Within few years, technologies such as additive manufacturing and 3D printing will only be used in the production of some parts of the final product because of its efficiency and lower costs, however, localization could face certain challenges. For the manufacturer, this includes re-thinking the way in which products are fabricated and assembled, adapting to changes that could enable a fully flexible and efficient manufacturing processes, and achieve efficient cross-functional communication with their suppliers and customers [16]. This research article presents a literature review related to localization of automobiles spare parts manufacturing in the Kingdom of Saudi Arabia. The localization of auto parts manufacturing in Saudi Arabia supports the economic diversification, promotes youth employment to achieve vision-2030 of Kingdom of Saudi Arabia as majority of auto spare parts sold in the Kingdom are imported from outside therefore it is necessary to develop the industrial sectors in general, and automobile's in particular. Saudi Arabia has the potential to become one of the leading automobile and spare parts manufacturers in the world [17]. The primary objective is to shed light on the opportunities offered by the localization of auto parts manufacturing in Saudi Arabia and to provide solutions and facilitate on the best way forward in this quest. Saudi Arabia is the largest automobile and auto spare parts re-export hub for the Middle East region. With the increasing demand, projections sales of automobile can grow up to more than one million units and can place Saudi Arabia at the 16^{th} spot in the globe however there are many challenges especially in terms of customer perception and the brand image in Saudi Arabia [18]. The automotive market in Saudi Arabia has been one of the fastest growing industries in the area given the availability of resources, infrastructure, and the booming economy. The government of the Kingdom of Saudi Arabia has also sought to provide huge potential opportunities and facilities to car manufacturers and it has developed plans to localize the auto industry in future as Saudi Arabia had a low level of manufacturing production growth rates i.e., 0.82 % [19], it also contributes in creating new job opportunities for people of Saudi Arabia in the manufacture of auto parts. The car factories in the Middle East are Japanese companies such as Toyota and Korean companies such as Hyundai, and both the companies have a large market share in the automotive industry of Saudi Arabia for many years, it had been noticed that people in Saudi Arabia showed consumer preferences for frequent change of cars, adopt latest trends, seek distinction and uniqueness and obviously are willing to pay premium price. [17]. Studies carried out by the Auto Car Association of Saudi Arabia that Saudi Arabia recorded a four percent annual import growth in the automotive industry in 2014, which is the largest in the region [20]. These studies have made Saudi Arabia an attractive destination for auto manufacturers, and boosting the auto industry [20].

Keeping in view the conclusions of the researchers cited above e.g., concept of Industry 4.0 still lacks a clear understanding and it is not fully established in practice yet, it is difficult to be implemented in practice because of its unclear possible benefits, seemingly large investments required, implementation of the base technologies is a challenging task, people in Saudi Arabia showed consumer preferences for frequent change of cars, adopt latest trends, seek distinction, uniqueness and obviously are willing to pay the premium prices. This allows to assert that it is expedient to conduct a study on the automobile parts manufacturing within the Kingdom of Saudi Arabia using Industry 4.0 technology while satisfying Saudi automobile customer's unique needs.

3. The aim and objectives of the study

The aim of this study is to devise a model to incorporate localized manufacturing and Industry 4.0 concepts; this study endeavors to contribute to the fulfillment of Saudi Arabia's Vision 2030 plan. This will make it possible to be more accurately assess the Saudi Automobiles customer's unique demands with cost effective development beneficial for manufacturers as well.

To achieve this aim, the following objectives were accomplished:

– to collect data by Saudi Arabian automobile customers by performing the surveys;

– to analyze the data as per methodology of product design and development;

– to develop a structured production model built into the concept of Industry 4.0 technology while satisfying customer's unique needs.

4. Materials and methods

As the objectives' of this research were to collect data from Saudi Arabian automobile customers by performing the surveys, its analysis and to develop a structured production model built into the concept of Industry 4.0, therefore the main hypothesis of this study is assumed that Industry 4.0 technology have the potential to satisfy Saudi automobile customers unique needs. It is further assumed that Saudi automobile customers have the desire for uniqueness and customized automobile parts as per their needs and they are willing to pay the premium price for that. To simplify this research, only one automobile part i.e., car dashboard is presented in this paper.

Extensive literature review was carried out related to LM/Industry 4.0. Automobile industry has been selected to apply LM/Industry 4.0 technique in Kingdom of Saudi Arabia. Using the Product Design and Development methodology by Ulrich, Eppinger and Maria, [7] as shown in Fig. 1, an exhaustive list of automobile part was developed keeping in view the Industry 4.0 concept, data was collected from the customers regarding their unique requirements on the proposed automobile part [18]. Customer needs were correlated with possible design solutions in a metric developed for this purpose [19]. The metrics were further analyzed for bench marking with the existing product with respect to technical specifications/prices. Specifications were analyzed with respect to target specification [17], and finally target specifications were developed for the required part. Using final specification, a 3D Design model can be developed and the product can be develop using the structured model developed as shown in Fig. 3.

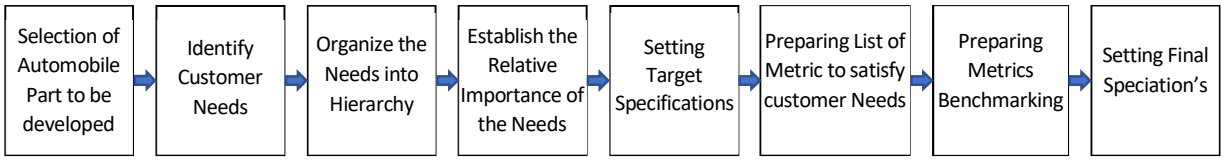

Fig. 1. Data collection and analysis methodology [7]

Fig. 1 illustrates the detailed methodology, adopted in this research. Several steps of this methodology were performed after brain storming sessions and in consultation with experts. The flow chart of process is shown for the ease of understanding.

5. Development of structured model to enhance localized manufacturing by fulfilling customer unique needs

5. 1. Data by Saudi Arabian automobile customers: methodology

An extensive literature review was conducted on localized manufacturing (LM) and Industry 4.0 technology. The automobiles parts were selected as the target industry to apply LM/Industry 4.0 techniques in the Kingdom of Saudi Arabia. Product Design and Development methodology by Ulrich et al was employed to develop an exhaustive list of automobile spare parts that can be developed using Industry 4.0 concept. Customer requirements/needs for the proposed automobile part were collected, and a metric was developed to correlate customer demands with possible design solutions. The benchmarking analysis was performed by comparing the technical specifications and prices of existing products with the proposed product. Target specifications and final specifications were developed for the required part as shown in Fig. 2. A structured model for the implementation of Industry 4.0 was developed to maximize the LM technique by incorporating customer's unique needs.

Data collection and analysis methodology adopted in this study has been elaborated which comprises as selecting an automobile part which can be developed by employing Industry 4.0 technique. Saudi automobiles customers were approached to describe their needs to be incorporated in a particular automobile part. Following the methodology of [7], final specifications were set for final development of the required part.

5. 1. 1. Customer needs survey and its importancer

An exhaustive list of parts was developed keeping in view the possible customers' needs and the capabilities of 3D printers. As a sample, the expectations of customers from the Dashboard of the automobile are listed and priorities as per the weightage given by the customers and are shown in the following Diagram in Table 1. The product Design methodology of Ulrich and Eppinger was used to perform this work.

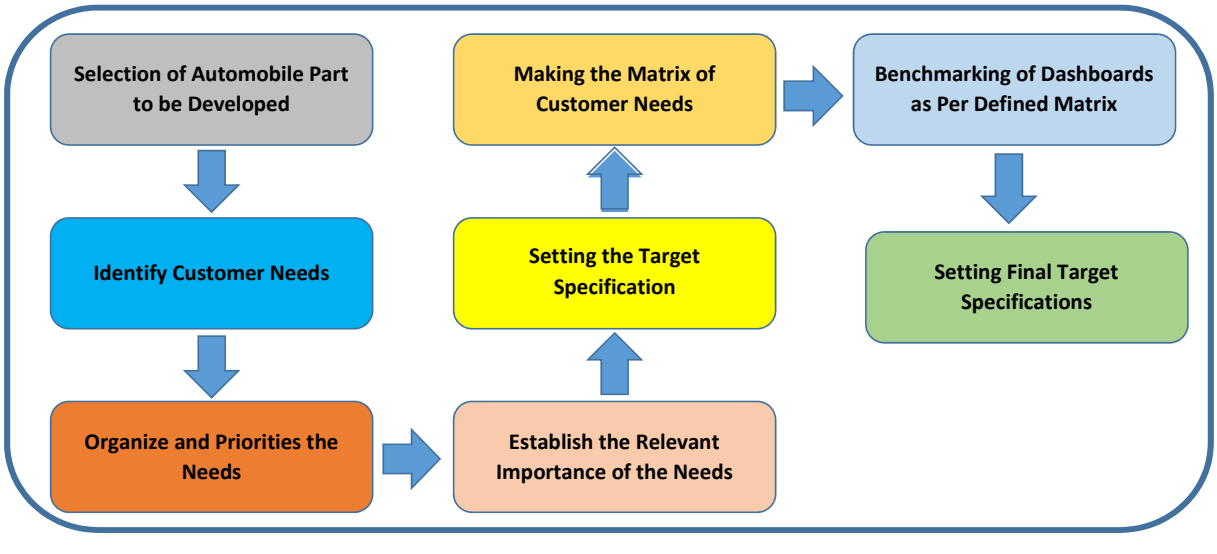

Fig. 2. Data Collection and Analysis Methodology

Table 1

Customer needs survey and its importance rating

Part/ Product name-dashboard		
S. No.	Customer needs/requirements	Importance/significance
1	2	3
1	Boost safety of driver and passengers by incorporating airbag within	5
2	Light weight (should be made of composite material as per sanctity of accessories)	4
3	Should have smart Echo system	5
4	Incorporate fog emission system supported by cooling system	3
5	Global positioning system	4
6	Should have foldable/slide-able tray for dine in	5

Continuation of Table 1

1	2	3
7	Colour should be compatible with car colour	4
8	Should have drinking water bottle holder	3
9	More flexible material	3
10	Good damping capability	4
11	Digital System	3
12	Easy Replacement/portable	1
13	Gauges of proximity sensors	4
14	Contribute to look of vehicle's interior	5
15	Swift/optimized dimensions/Improve the car's aerodynamic collisions:	4
16	Offers good ventilation in respect of return fresh air	5
17	Should have a manual option for Electric/Fuel/CNG drive	2
18	Should have digital/analogue lightened display	4
19	Material should be long lasting	5
20	Compatible in both dry and wet environment	4
21	Cost effective	5
22	Easy cleaning	3

Table 1 shows the data collected from Saudi customers' needs related to car dashboard with its importance rating given by the customers. High rating indicates the need is highly important (numbered as 5) and less rating means need is less important (numbered as 1) than others.

5. 2. Customers' needs metrics

The customers' needs metrics were carefully developed through a comprehensive process that involved extensive brainstorming sessions with experts and peers [7, 21, 22]. The primary objective was to create a set of metrics that effectively captured and measured the various needs of the customers.

To begin with, a collaborative approach was adopted, involving cross-functional teams from different departments within the organization [7]. These teams consisted of subject matter experts, product managers, customer service representatives, and market research analysts. Their diverse perspectives and insights were invaluable in shaping the metrics development process.

The first step was to identify the key customer needs that were critical to the success of the products or services offered by the organization [21, 23]. This involved conducting thorough market research, analyzing customer feedback, and studying industry trends. By understanding the customers' pain points, desires, and expectations, the teams were able to gain valuable insights into the areas that needed to be addressed.

After identifying the key needs, the teams proceeded to define suitable units for each metric [23]. These units were carefully selected to ensure clarity, accuracy, and consistency in measurement. For example, if the metric was related to product performance, the unit was based on factors such as cost, quantity of material, and size. On the other hand, if the metric focused on customer satisfaction, the unit was finalized as a percentage or ratings.

Significance played a crucial role in determining the metrics to be included in the final set [21, 22]. The teams evaluated the importance and impact of each metric on the overall customer experience and business objectives. Metrics that were deemed highly significant in terms of their influence on customer satisfaction, loyalty, and profitability were prioritized for inclusion.

Throughout the process, the teams sought continuous feedback and validation from customers, as their insights were essential in refining and fine-tuning the metrics [7]. Iterative feedback loops were established to ensure that the metrics accurately reflected the evolving needs and expectations of the customers.

In conclusion, the development of the customers' needs metrics involved a collaborative and iterative process that incorporated the expertise of various stakeholders [7, 21, 22]. By identifying key customer needs, defining suitable units, and considering significance, the metrics were designed to provide valuable insights into customer satisfaction, drive continuous improvement, and guide strategic decision-making as shown in Table 2.

Table 2 shows customers' needs with importance rating and units of measurement by combining similar needs with respect to units of measurements to easily handle all the needs and evaluate their importance.

Table 2

Breakdown of Metrics Needs, Importance, and Units

Metric No.	Needs	Metric	Importance/Significance	Units
1	1	Contribution in ensuring safety	5	%
2	2, 7, 9, 19, 20	Material	5	Kg
3	21	Cost	5	SAR
4	3, 5	Smart System	3	%
5	11, 12, 18, 20	Versatility	3	%
6	12	Installation	4	SAR
7	4, 16	HVAC (Level of automation)	1	Binary
8	7, 14	Look (Colour match-ability)	4	Binary
9	12, 22	Maintenance (Maintainability)	1	SAR
10	17	Easy Operation	5	Binary
11	13	Vehicles Protection	4	%
12	10	Damping Property	4	Binary
13	11	Digital System	5	Binary
14	6, 8, 15	Size/Add-on	4	Sqft

5. 2. 1. The Needs-Metrics Matrix

The Needs-Metrics Matrix, also known as Table 3 [7], was developed as a tool to analyze and categorize customer needs based on their similarity. The matrix serves as a visual representation that helps identify patterns and relationships among different needs and allows for efficient analysis and prioritization.

The process of developing the Needs-Metrics Matrix involved a thorough examination of the identified customer needs [21, 22]. These needs were typically derived from market research, customer feedback, and other sources of customer insights. The needs could encompass a wide range of aspects, such as product features, performance, pricing, customer support, or user experience.

Once the needs were identified, the next step was to evaluate their similarity [21, 22]. This involved analyzing the commonalities and connections between different needs to determine which ones were closely related to each other. For example, if there were multiple needs related to product reliability and durability, they would likely be grouped together as they address similar concerns.

Based on this analysis, the Needs-Metrics Matrix was constructed [7]. The matrix typically takes the form of a table or a grid, where the rows represent different customer needs and the columns represent relevant metrics or measures. Each cell in the matrix indicates the degree of relevance or impact of a specific metric on a particular need.

The similarity of needs is reflected in the arrangement of the matrix. Similar needs are typically grouped together either in adjacent rows or columns, facilitating a clear visual representation of their interconnectedness. This arrangement allows decision-makers to easily identify clusters or themes of needs that can be addressed together.

The metrics included in the matrix are carefully selected based on their relevance to the identified needs [21, 22]. These metrics could be quantitative measurements, qualitative assessments, or a combination of both. The metrics serve as objective indicators to evaluate the extent to which a particular need is being met or how well it aligns with customer expectations.

By using the Needs-Metrics Matrix, organizations can gain valuable insights into customer needs and prioritize their efforts accordingly [7]. The matrix helps in identifying the most critical needs that require immediate attention and provides guidance on which metrics should be monitored and improved to enhance customer satisfaction and drive business success.

It's important to note that the specific structure and content of the Needs-Metrics Matrix as shown in Table 3 may vary depending on the organization, industry, and specific context. Categorization/customization is often required to ensure that the matrix accurately reflects the unique needs and priorities of the business and its customers.

In Table 3, the relation of Customer needs with the product characterization and attributes is evaluated. This also shows that there are several product attributes and characteristics, which have the relation with many of the customer's needs.

Table 3

Categorization of needs

Matrics	Needs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
		Contribution in ensuring safety	Material	Cost	Smart system	Versatility	Installation	HVAC	Look	Maintenance	Easy operation	Vehicles protection	Damping property	Digital system	Size/ Add-on
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Boost safety of driver and passengers by incorporating airbag within	✓	×	×	×	×	×	×	×	×	×	×	×	×	×
2	Light weight (should be made of composite material as per sanctity of accessories)	×	✓	×	×	×	×	×	×	×	×	×	×	×	×
3	Should have smart Echo system	×	×	×	✓	×	×	×	×	×	×	×	×	×	×
4	Incorporate fog emission system supported by cooling system	×	×	×	✓	×	×	✓	×	×	×	×	×	×	×
5	Global positioning system	×	×	×	✓	×	×	×	×	×	×	×	×	×	×
6	Should have foldable/slide-able tray for dine in	×	×	×	×	×	×	×	✓	×	×	×	×	×	×
7	Colour should be compatible with car colour	×	✓	×	×	×	×	×	×	×	×	×	×	×	×
8	Should have drinking water bottle holder	×	×	×	×	×	×	×	×	×	×	×	×	✓	×

Continuation of Table 3

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
9	More flexible material	×	✓	×	×	×	×	×	×	×	×	×	×	×	×
10	Good damping capability	×	×	×	×	×	×	×	×	×	×	×	✓	×	×
11	Digital System	×	✓	×	×	✓	×	×	×	×	×	×	×	×	×
12	Easy Replacement/ portable	×	×	×	×	×	✓	×	×	✓	×	×	×	×	×
13	Gauges of proximity sensors	×	×	×	×	×	×	×	×	×	×	✓	×	×	×
14	Contribute to look of vehicle's interior	×	×	×	×	×	×	×	✓	×	×	×	×	×	×
15	Swift/optimized dimensions/Improve the car's aerodynamic collisions	×	×	×	×	×	×	×	×	×	×	×	×	×	✓

Note: ✓ – indicates having mutual relation; × – indicates that there is no relation.

5. 2. 2. Metrics benchmarking

Metrics benchmarking is a process that involves comparing and evaluating key performance metrics of a company against those of its top market-leading competitors [24]. This practice allows organizations to assess their own performance, identify areas of improvement, and set performance targets based on industry-leading standards.

To conduct metrics benchmarking, an organization selects a set of relevant metrics that are crucial for measuring performance in their specific industry or market [24]. These metrics can include financial indicators (such as revenue growth, profitability, or return on investment), operational metrics (such as production efficiency or cycle time), customer satisfaction metrics (such as Net Promoter Score or customer retention rate), or any other performance indicators that are considered important for success in the industry.

Once the metrics are identified, the organization gathers data from its own operations and compares it with data from the top market-leading manufacturers in their industry [24]. This data can be collected through various sources, including publicly available reports, industry publications, market research, or direct engagement with competitors, if possible.

Table 4, as mentioned [24], represents the outcome of these metrics benchmarking exercises. The table typically consists of rows and columns, where each row represents a specific metric, and each column represents a different market-leading manufacturer. The table is designed to present a comparative view of how each manufacturer performs in relation to the selected metrics.

The metrics listed in Table 4 are typically aligned with the organization's strategic goals and areas of focus [24]. By comparing their own performance against that of the market leaders, organizations can gain insights into areas where they excel or lag behind their competitors. This allows them to identify best practices, learn from industry leaders, and set realistic targets for improvement.

The metrics in Table 4 may include numerical values, percentages, or qualitative rankings, depending on the nature of the metric and the available data. The purpose is to provide a clear representation of how each manufacturer performs on each metric, highlighting their strengths and weaknesses in relation to industry benchmarks.

By analyzing Table 4, organizations can identify specific metrics where they need to improve and develop strategies to bridge the performance gaps. This can involve implementing process improvements, adopting new technologies, enhancing customer service, or any other action deemed necessary to achieve a competitive edge.

It's worth noting that metrics benchmarking is an ongoing process, as the performance of market-leading manufacturers may evolve over time [24]. Regular updates and reassessments of the benchmarks are essential to ensure that the organization remains aligned with the current industry standards and continues to strive for excellence.

Overall, metrics benchmarking, as represented in Table 4, provides organizations with valuable insights into their performance relative to market-leading manufacturers. It enables informed decision-making, helps prioritize improvement efforts, and drives continuous progress toward achieving and surpassing industry benchmarks.

Table 4 shows the comparison among the automotive parts manufacturing companies in Saudi Arabia. This comparison was performed by doing benchmarking of such companies. The parameters were selected based on similarity and in consultation of experts.

Table 4

Benchmarking of dashboards as per matrix defined

Metric No.	Needs	Metric	Imp	Units	Company-I	Company-II	Company-III	Company-IV	Company-V
1	2	3	4	5	6	7	8	9	10
1	1	Contribution in ensuring safety	5	%	90	80	85	85	100
2	2, 7, 9, 19, 20	Material	5	Kg	10	8	8.5	9	7.5
3	21	Cost	5	SAR	210	180	190	170	170
4	3, 5,	Smart System	3	%	70	80	85	90	100
5	11, 12, 18, 20	Versatility	3	%	0.8	0.9	0.75	0.85	0.9

Continuation of Table 4

1	2	3	4	5	6	7	8	9	10
6	12	Installation	4	SAR	80	90	75	80	75
7	4, 16	HVAC (Level of Automation)	1	Binary	0	0	0	0	1
8	7, 14	Look (colour match- ability)	4	Binary	0	0	1	1	1
9	12, 22	Maintenance (Maintainability)	1	SAR	10	8	8	9	8
10	6, 17	Easy Operation	5	Binary	1	0	1	0	1
11	13	Vehicles Protection	3	Intensity	60	50	60	55	60
12	10	Damping Property	4	Binary	1	1	0	1	1
13	8	Digital System	5	Binary	0	1	1	0	1
14	15	Size/Add-on	3	sqft	6	6.5	4	5	6

5. 2. 3. Comparative benchmarking chart

The comparative benchmarking chart, also referred to as Table 4, represents the results of a comparative benchmarking analysis conducted by an organization. Comparative benchmarking involves comparing the performance of different entities or organizations in order to identify best practices, areas for improvement, and opportunities for innovation [25].

In Table 5, the chart is presented in a tabular format with rows and columns. Each row typically represents a specific performance metric, while each column represents a different entity or organization that was included in the benchmarking analysis.

To conduct the comparative benchmarking analysis, the organization first selects a set of relevant performance metrics that align with its strategic goals and objectives [26, 27]. These metrics could include financial indicators, operational efficiency measures, customer satisfaction ratings, or any other key performance indicators that are deemed important for success.

Once the metrics are identified, data is collected from the various entities or organizations included in the benchmarking analysis. This data can be obtained through a variety of sources, such as industry reports, public disclosures, surveys, or direct engagement with the entities themselves.

In Table 5, each cell represents the performance of a specific entity or organization on a particular metric. The data could be numerical values, percentages, ratings, or any other appropriate format for the specific metric being measured.

The purpose of the comparative benchmarking chart is to provide a visual representation of how each entity or organization performs in relation to the selected metrics. By comparing the performance of different entities side by side, organizations can gain valuable insights into relative strengths and weaknesses, identify areas for improvement, and set performance targets based on industry-leading practices.

Analyzing Table 5 allows organizations to identify entities or organizations that demonstrate exceptional performance on specific metrics. These entities can serve as benchmarks or role models, providing insights into best practices and potential strategies for improvement. It also highlights areas where the organization may be falling behind or underperforming compared to its peers, prompting the need for action and improvement initiatives.

The comparative benchmarking chart in Table 5 is a dynamic tool that should be regularly updated and reassessed. As performance standards and industry practices evolve, organizations need to ensure that their benchmarking analysis remains relevant and up to date.

Table 5

Comparative benchmarking chart based on perceived satisfaction of needs

S. No.	Needs	Imp	Company I	Company II	Company III	Company IV	Company V
1	2	3	4	5	6	7	8
1	Boost safety of driver and passengers by incorporating airbag within	5	■	■■■	■■	■■■	■■
2	Light weight (should be made of composite material as per sanctity of accessories)	5	■■	■■■	■■■■	■■	■■
3	Should have smart Echo system	5	■■■	■■	■■■	■■	■■■
4	Incorporate fog emission system supported by cooling system	3	■■■■■	■■	■■■■	■■	■■
5	Global positioning system	3	■■■■	■■■■	■■■■	■■■■	■■■■
6	Should have foldable/slide-able tray for dine in	4	■■■	■■■■	■■	■■■	■■■
7	Colour should be compatible with car colour	1	■■	■■	■■■	■■■■	■■■
8	Should have drinking water bottle holder	4	■■	■■■	■■	■■	■■■■
9	More flexible material	1	■■■	■■	■■■	■■■■	■■■■
10	Good damping capability	5	■■■	■■■■	■■■■	■■■	■■■■
11	Digital System	3	■■	■■	■■■	■■■	■■■■■
12	Easy Replacement/portable	4	■■	■■■■	■■■■	■■	■■■■
13	Gauges of proximity sensors	5	■	■■■■■	■■■	■■■■	■■■
14	Contribute to look of vehicle's interior	3	■■	■■■	■■■■■■	■■■	■■■

Continuation of Table 5

1	2	3	4	5	6	7	8
15	Swift/optimized dimensions/ Improve the car's aerodynamic collisions	5	■■	■■■■	■■	■■■	■■■
16	Offers good ventilation in respect of return and fresh air	5	■■■	■■■	■■■■	■■■	■■■
17	Should have a manual option for Electric/Fuel/CNG drive	5	■	■	■■■	■■■	■■■■■
18	Should have digital/analogue lightened display	3	■	■■■■	■■■■■	■■■■	■■■
19	Material should be long lasting	3	■■■■	■■■	■■	■■■	■■
20	Compatible in both dry and wet environment	4	■■	■■■■■	■■■	■■	■■■■
21	Cost effective	1	■	■■■■	■■■■	■■■	■■■■■
22	Easy cleaning	4	■■■	■■■	■■■	■■■	■■■

Note: ■ *– less perceived satisfaction of the need;* ■■■■■ *– greatest satisfaction of the need*

The comparative benchmarking chart presented in Table 5 enables organizations to gain insights into their performance relative to other entities or organizations [25]. It serves as a visual reference for identifying best practices, areas for improvement, and opportunities for innovation, ultimately driving continuous improvement and fostering competitiveness in the market.

5. 2. 4. Target specifications were set as per customers' needs

Setting target specifications involves defining specific requirements and standards for a product or service to meet the needs and expectations of customers. This process ensures that the final offering aligns with customer preferences and performs competitively in the market.

To set target specifications, a thorough understanding of customers' needs is essential). This can be achieved through various methods, including market research, customer surveys, feedback analysis, and direct engagement with customers. By gathering insights into their preferences, pain points, and desired features, organizations can gain a clear understanding of what customers expect from the product or service.

Once the customers' needs are identified, the next step is to analyze the available market specifications. Market specifications refer to the existing offerings in the market, including competitor products or similar solutions already available. By evaluating these market specifications, organizations can gain insights into the current industry standards, technological advancements, and features that customers are already accustomed to.

Table 6, as mentioned, represents the outcome of this analysis and presents the available market specifications. The table typically consists of rows and columns, where each row represents a specific requirement or specification, and each column represents different market offerings or competitors. The table serves as a visual representation of the key features, functionalities, or performance attributes offered by different products in the market.

Based on the customers' needs and the analysis of market specifications, target specifications are then defined. These specifications aim to strike a balance between meeting customers' expectations and being competitive in the market. Target specifications can include performance metrics, design elements, pricing considerations, quality standards, or any other criteria that are important for the success of the product or service.

The target specifications defined in this process are typically documented and communicated within the organization. They serve as a reference point for product development, design, manufacturing, and marketing teams. Adhering to these specifications ensures that the final offering meets the desired customer experience and performance standards.

It's important to note that target specifications may require ongoing adjustments and refinements as customer needs evolve or market dynamics change. Regular monitoring of customer feedback, market trends, and advancements in technology can help organizations stay agile and adapt their target specifications accordingly.

Detail analyses of customers' needs and specifications of product/market were performed before settling the target specification, there are shown in above Table 6. These are the key any product development and innovation process.

Table 6

Target specifications as per analysis

Needs	Metric	Imp	units	Marginal Value	Ideal Value
1	2	3	4	5	6
1	Boost safety of driver and passengers by incorporating airbag within	5	%	85	100
2	Light weight (should be made of composite material as per sanctity of accessories)	3	kg	9	7.5
3	Should have smart Echo system	5	%	80	100
4	Incorporate fog emission system supported by cooling system	5	Binary	0	1
5	Global positioning system in every international language	3	Binary	0	1
6	Should have foldable/slide-able tray for dine in	4	Binary	0	1
7	Colour should be compatible with car colour	3	Binary	0	1
8	Should have drinking water bottle holder	4	Binary	0	1

Continuation of Table 6

1	2	3	4	5	6
9	More flexible material	1	Binary	0	1
10	Good damping capability	4	Binary	0	1
11	Digital System	1	Binary	1	1
12	Easy Replacement / portable	5	%	80	90
13	Gauges of proximity sensors	3	%	55	60
14	Contribute to look of vehicle's interior	4	Binary	0	1
15	Swift/optimized dimensions/ Improve the car's aerodynamic collisions	4	sqft	4.5	5
16	`Offers good ventilation in respect of return and fresh air	3	Binary	O	O
17	Should have a manual option for Electric/Fuel/CNG drive	3	Binary	0	1
18	Should have digital/analogue lightened display	5	%	80	100
19	Material should be long lasting	5	Kg	9	7.5
20	Compatible in both dry and wet environment	4	Kg	9	7.5
21	Cost Effective	5	SAR	190	170
22	Easy Cleaning	3	SAR	10	9

5. 2. 5. Setting final specifications

Setting final specifications involves defining the specific requirements and standards that a product or service must meet in order to be considered complete and ready for market release. The process of setting final specifications takes into consideration both the marginal specifications, which represent the minimum acceptable standards, and the ideal specifications, which represent the desired or optimal performance levels.

To establish the final specifications, a comprehensive analysis is conducted to understand the market landscape and the expectations of customers. This analysis includes evaluating the available marginal and ideal specifications in the market, which serve as reference points for defining the final specifications.

Table 6, as mentioned, represents the outcome of this analysis and presents the marginal and ideal specifications available in the market. The table typically consists of rows and columns, where each row represents a specific requirement or specification, and each column represents different market offerings or competitors. The table serves as a visual representation of the different performance levels, features, or attributes offered by various products in the market.

The marginal specifications in Table 6 indicate the minimum acceptable standards that a product or service should meet to fulfill customers' basic needs and expectations. These specifications represent the baseline performance or functionality that customers consider essential. They provide a reference point for organizations to ensure that their final offering meets the minimum requirements to compete effectively in the market.

On the other hand, the ideal specifications in Table 6 represent the desired or optimal performance levels that customers aspire to have in a product or service. These specifications go beyond the minimum requirements and aim to deliver superior performance, enhanced features, or exceptional quality. They serve as a guide for organizations to set ambitious goals and differentiate their offering from competitors.

By considering both the marginal and ideal specifications, organizations can define the final specifications that strike a balance between meeting customer expectations and being feasible to achieve. The final specifications should encompass the essential features and functionality required to satisfy customers while also striving to exceed their expectations and deliver a superior offering.

The process of setting final specifications requires careful consideration of various factors, including market demand, technological feasibility, cost constraints, and the organization's capabilities. It involves making informed decisions to optimize the product or service based on customer preferences, competitive positioning, and the overall business strategy.

It's worth noting that setting final specifications as shown in Table 7 is an iterative process that may involve multiple revisions and adjustments. Continuous monitoring of market trends, customer feedback, and advancements in technology helps organizations stay responsive to changing market dynamics and ensure that their final specifications remain relevant.

Setting of final specifications (Table 7) involves both considering the marginal and the ideal specifications (Table 6) keeping in view the available specifications of the competitors (Table 5).

Table 7

Final specifications of needs as per analysis

Metric No.	Metric	Units	Value
1	2	3	4
1	Boost safety of driver and passengers by incorporating airbag within	%	100
2	Light weight (should be made of composite material as per sanctity of accessories)	kg	8
3	Should have smart Echo system	%	100
4	Incorporate fog emission system supported by cooling system	Binary	1
5	Global positioning system in every international language	Binary	1
6	Should have foldable/slide-able tray for dine in	Binary	1

Continuation of Table 7

1	2	3	4
7	Colour should be compatible with car colour	Binary	1
8	Should have drinking water bottle holder	Binary	1
9	More flexible material	Binary	Yes
10	Good damping capability	Binary	1
11	Digital System	Binary	1
12	Easy Replacement/portable	%	100
13	Gauges of proximity sensors	%	60
14	Contribute to look of vehicle's interior	sqft	60
15	Swift/optimized dimensions/ Improve the car's aerodynamic collisions	sqft	5
16	Offers good ventilation in respect of return and fresh air	Binary	Yes
17	Should have a manual option for Electric/Fuel/CNG drive	Binary	1
18	Should have digital/analogue lightened display	%	100
19	Material should be long lasting	kg	7.5
20	Compatible In both dry and wet environment	kg	7.5
21	Cost Effective	SAR	170
22	Easy cleaning	SAR	9

5. 3. Development of a structured model using Industry 4.0 Technology while satisfying customers unique needs

Based on the data collected from Tables 1–7, and to enhance localized manufacturing using Industry 4.0 concept, a structured model was developed as shown in Fig. 3.

In the developed model as shown in Fig. 3, customer's unique demand will be incorporated and it will be analyzed as per customer's unique demand and follow the methodology as depicted in Fig. 1 for a particular automobile part. After analyzing and evaluation, the required automobile part will be manufactured through 3D software in a lean and agile manner.

6. Discussion about the results of developed model for localized manufacturing

A structured model was developed to optimize localized manufacturing through Industry 4.0 concepts as shown in Fig. 3, ensuring efficient and cost-effective fulfillment of unique demands of automobile customers. The collected data on customer needs and demands was analyzed using the Ulrich et al methodology. The Localized Manufacturing Model was utilized to define target specifications and swiftly develop the required parts through 3D printing and additive manufacturing techniques.

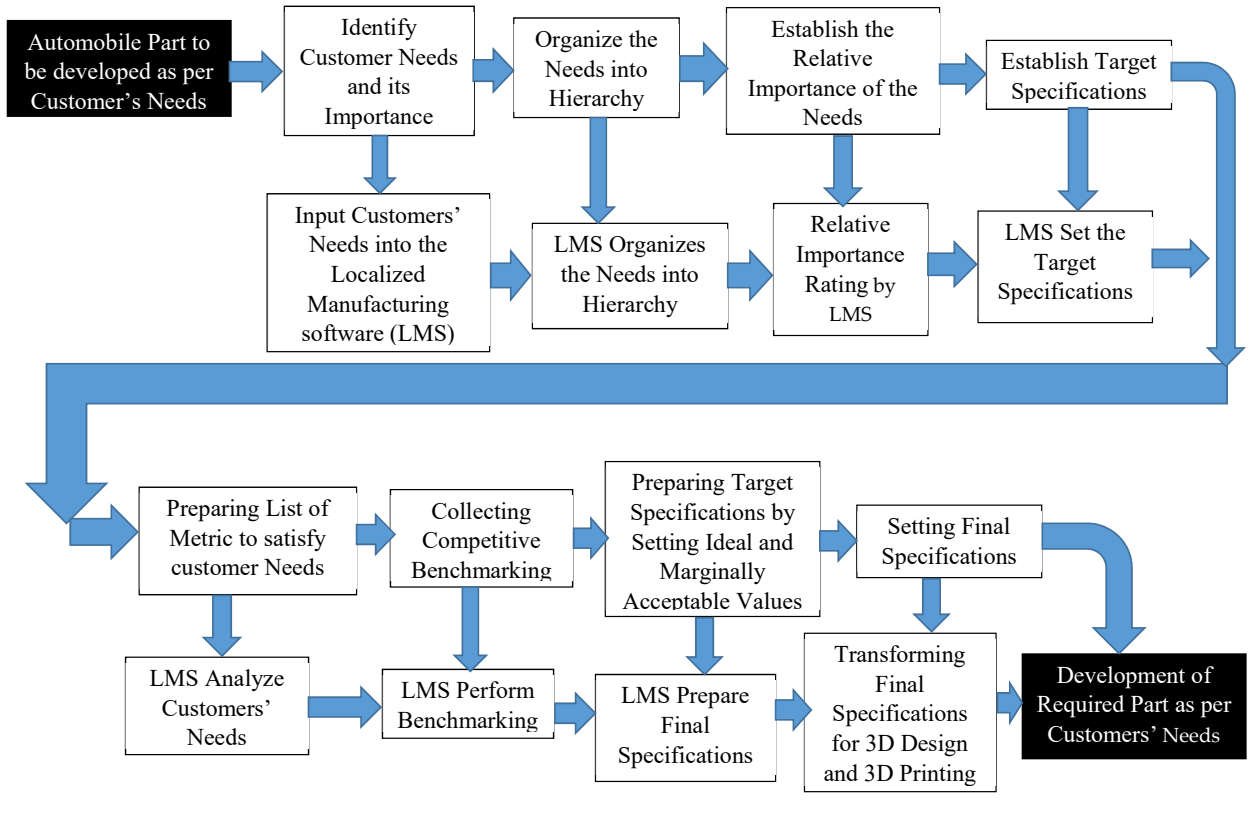

Fig. 3. Structured Production Model built into the concept of Industry 4.0 Technology while satisfying customer's unique needs

The Ulrich et al product design and development methodology was employed to select automobile parts suitable for development using Industry 4.0 technologies, such as 3D printing/Additive Manufacturing. This systematic approach integrated customer needs and benchmarked competitor specifications to establish final specifications for the selected parts.

The developed Localized Manufacturing Model facilitated comparison of the final specifications with competitor benchmarks, enabling the establishment of final specifications based on competitive prices.

The model that maximizes localized manufacturing through Industry 4.0 concepts offers several advantages. It enables the just in time and cost-effective fulfillment of customers' unique demands and needs, while also promoting the use of modern technologies like 3D printing and additive manufacturing, which significantly reduce production time and costs.

However, the disadvantage associated with this model is that only those automobile parts can be developed which are manufacture-able by 3D printing or additive manufacturing process which can be overcome by integrating through advanced software.

It is important to note that the model has some limitations for example if there are many unique expectations or needs of customer having relation with several design or product attributes at the same time, than its hard to get the co-relation and individual/mutual impact of these attributes with customer unique needs to satisfy them. Therefore, in this case if we are dealing them manually it becomes lengthy job, so it's proposed to build a software on the basis of this model, which in this research was not developed because of lack of finances/time constraints.

This research contributes to the development of the automotive industry by offering a model that effectively meets customers' unique demands and needs, incorporating modern technologies. Future research could explore the utilization of other Industry 4.0 concepts, such as artificial intelligence, machine learning, and the Internet of things, to further enhance the model.

In conclusion, the structured model that maximizes localized manufacturing through Industry 4.0 concepts presents a valuable solution for the Saudi Arabian automobile industry to efficiently meet customers' unique demands and needs at a competitive price.

7. Conclusions

1. A survey was conducted to know Saudi customers' unique needs for a particular automobile part. Saudi automobile customers have shown great interest in expressing their unique needs for a particular automobile part. They have indicated some unique needs such as a car dashboard should have foldable/slide-able tray for dine in the automobile which is not available in most of the automobiles which needs to be addressed by automobile manufacturers.

2. The data collected from the survey was thoroughly analyzed employing the techniques advocated by Ulrich et al. The data analyses facilitated the bench marking of the automobile part with the same automobile part in the market with respect to its prices, technical specifications and aesthetics. This approach not only facilitates a clearer understanding of customer needs but also streamlines the translation of these needs into the final part development.

3. On the basis of through analysis of the data collected of this research, a structured production model has been developed which can develop the required part by using Industry 4.0 technology and fulfilling all customers unique needs in a most efficient and economical way. This model has the capability to be adopted by any production sector which has some unique demands/needs of the customer when fulfilling these demands/needs on the standardized part is a difficult job, e.g., the integration of a structured production model within the framework of Industry 4.0 technology offers numerous advantages when it comes to satisfying customer's unique needs: Industry 4.0, enable the collection of real-time data. This data can be analyzed to create highly customized and personalized products that cater for individual customer preferences: With the structured production model, manufacturing processes can be easily adapted and reconfigured to accommodate changes in customer requirements, integrating a structured production model within the context of Industry 4.0 technology enables manufacturers to address customers' unique needs efficiently and effectively. The combination of advanced technologies, data analytics, flexibility, and responsiveness empower companies to provide highly customized products.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Data cannot be made available for reasons disclosed in the data availability statement.

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