Conference Paper

An Analytic Hierarchy Process Approach in Decision-Making for Material Selection in an Automotive Company: A Case Study

Cheng Jack Kie, Ahmed Khalif Hassan, Norhana Mohd Aripin, and Rafiuddin Mohd Yunus

Faculty of Industrial Management, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang

Abstract

This study is an approach to investigate and to choose the suitable material for the fabrication of tools trolley to ensure the good quality of the product. The project team of an automotive manufacturing company is planning to fabricate 100 sets of tools trolley in the assembly shop. This study was developed to describe an approach based on Analytic Hierarchy Process (AHP) that can assist decision-makers and continuous improvement engineers in determining the most suitable material to be employed in fabrication process at the early stage of the product development to reduce the cost. The selected main criteria are Material Strength, Material Cost, Procurement Lead Time and Duration of Fabrication Process while the four materials that will be considered in this study are Aluminium, Steel Tube, and Square Tube. Finally, the results show that Square Tube is recommended as the most suitable material for the in-house tools for trolley fabrication.

Keywords: analytic hierarchy process, decision-making, continuous improvement, fabrication process.

Corresponding Author:
Cheng Jack Kie
jackkie@ump.edu.my

Received: 5 August 2019
Accepted: 14 August 2019
Published: 18 August 2019

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the FGIC2019 Conference Committee.

1. Introduction

Material process selection is a method to determine the most suitable material to fabricate a product. Many researchers have agreed on the importance of material selection process, especially during the early stage of the product development phase. Determining the most suitable and appropriate material in the early stage can avoid additional cost if changes are needed to be carried out after the early stage of the product development process (Ravisankar, Balasubramanian & Muralidharan, 2004). However, it is a difficult task with a complex decision because various factors have to be considered during the process.

Analytic Hierarchy Process (AHP) is a tool that can be used at the conceptual design stage in the product development process (Hambali *et al.*, 2010; Subramanian &

How to cite this article: Cheng Jack Kie, Ahmed Khalif Hassan, Norhana Mohd Aripin, and Rafiuddin Mohd Yunus, (2019), "An Analytic Hierarchy Process Approach in Decision-Making for Material Selection in an Automotive Company: A Case Study" in *FGIC 2nd Conference on Governance and Integrity 2019*, KnE Social Sciences, pages 472–484. DOI 10.18502/kss.v3i22.5067

Ramanathan, 2012). According to Vaidya and Kumar (2006), AHP is widely implemented for selection and evaluation based decision-making, usually in the area of manufacturing, engineering, healthcare, education, and many more. AHP has been used to solve multi-criteria decision-making problems based on experience and skills of the experts by determining the factors that impacted the decision process (Subramanian & Ramanathan, 2012). The tools trolley which acts to transport tools and small parts safety is generally made from few materials such as stainless steel, carbon steel, aluminum, iron, and copper. Each material has different material strength, material lead time, and the price of the material can be very expensive to manipulate the cost. In the fabrication process, there are many processes involved with different amounts of costs of material and equipment, quality of material, and fabricating time (Kalpakjian and Schmid, 2014). In an automotive manufacturing industry, the fabrication process gives the Continuous Improvement (CI) Engineers different types of problems, where the selection of appropriate material is one of the critical issues. By doing this study, the problem faced by the engineers is solved using AHP. This technique will assist in determining the most appropriate material to fabricate the tools trolley, which will meet the product's specifications and requirements. Thus, the main focus of this study is to explore the potential use of AHP in assisting CI projects to evaluate and determine the most appropriate material for producing tools trolley in an automotive company. Besides that, this paper briefly reviews the concepts and applications of multiple criterion decision analysis.

This paper is organized into five sections where after the broad introduction was firstly discussed in Section 1. The literature of past studies related to AHP and Continuous Improvement are presented in Section 2. Next, the chosen methodology, which is AHP, will be elaborated in Section 3 while Section 4 encompassed results and discussion. Then, a conclusion with the point of discussion on limitations and suggestion for future studies are provided in the last section of this paper.

2. Literature Review

In order to make a good decision, the decision-maker must be able to first define the problem, the need, and purpose of the decision, then using this information to develop criteria that can be used to evaluate the potential alternative actions to take. The beauty of Analytic hierarchy process and continuous improvement are discussed in the following section, respectively.

2.1. Analytic hierarchy process

Dweiri and Al-Oqla (2006) mentioned that the Analytic Hierarchy Process (AHP) is one of the multi-criteria decision-making tools that incorporated the behavior of its decision-maker in the decision model. Professor Thomas L. Saaty developed AHP techniques in the 1970s to improve the decision-making process when multiple criteria are involved in the process. Since then, the method is widely used, refined, and studied. AHP technique is one of the most commonly used multi-criteria decision methods in decision making (Subramanian & Ramanathan, 2012). The main flexibility of this method is AHP considered a systematic approach that includes both the tangible and intangible factors and finally provides a structured solution to problems in the industries.

The advantages of AHP method is the technique uses both qualitative data collected from judgment values which based on experience and intuition apart from quantitative data of a problem (Subramanian & Ramanathan, 2012; Vaidya & Kumar, 2006). Besides that, the application of AHP allows the investigated problems to be broken down hierarchically where a set of criteria will be arranged in a hierarchy order so that it can be evaluated subjectively based on the importance according to scores or weights. To develop an AHP model, there are three important phases which are problem structuring, judgments comparison, and analyzing priorities. In the structuring phase, a decision-making model is developed and then is transposed to a hierarchy form. Then, for each alternative obtained will be evaluated according to the criterion's weight in the judgment phase.

A hierarchy can be used to study the interaction of its components and how these interactions impact the whole system. Therefore a hierarchy is one form of abstraction or representation of a system's structure (Hambali *et al.*, 2010). Hierarchies work by separating the reality of human thinking into several sets and subsets. The decision making alternatives can be rated once weights are assigned to the developed hierarchy. Weights are assigned through expert comparison using judgment scale. These scales are usually ranged from 1 (equally preferred) to 7 (extremely preferred). These numerical values represent the intensity of the alternatives compared to criteria.

Due to the mathematical elements used in AHP, researchers are keen to adopt the technique (Dweiri & Al-Oqla, 2006; Hambali *et al.*, 2008). With the properties of using multi-level objectives, criteria, sub-criteria, and alternatives, AHP is suitable to be used to solve decision problem. Through pairwise comparison, data are obtained using weightage of the importance of the criteria and the alternatives in terms of each decision criteria.

AHP is also commonly applied in task selection where the method is used not to find the correct answer but to aid decision-makers finding the best answer. Not only for academic studies, but AHP is also widely used in organizations, especially for an organization to explore their strategies and their competitors (Vaidya & Kumar, 2006). AHP is suitable to be used to groups of decision-makers who shared common objectives, worked in a cooperative environment and of the same status.

2.2. Continuous improvement (CI)

Currently, the implementation of sustainable improvement is gaining increase attention (Bhasin, 2008; Hassini, Surti & Searcy, 2012). With that, several guidelines were developed to support continuous improvement implementation (Sundar, Balaji & Kumar, 2014). Strategic Management, Kaizen, Six Sigma, and Total Quality Management are some of the well-known methods used in continuous improvement (Garcia, Rivera & Iniesta, 2013). Each of these methods uses different tools for improvement.

One way for the continuous improvement to be successful, there is a need to include staff involvement. With that, Total Quality Management adopts tools and plan of doing, check, act approach (Moeuf *et al.*, 2016) that are capable of integrating learning culture to drive organization change (Amirteimoori, Despotis & Kordrostami, 2014; Moeuf *et al.*, 2016). On the other hand, Six Sigma approach aims at reducing variability in organizational processes through the defining, measuring, analyzing, improving and controlling improvement cycle are used to support this approach (Garcia, Rivera & Iniesta, 2013). As for Kaizen, this tool adopted scenario that allows continuous improvement in personal, family, social, and work-life (Anand & Kodali, 2008) which aimed to change for the better (Bhasin, 2008; Gupta & Jain, 2013). However, there are researchers that mentioned that Kaizen is not only a continuous improvement tool, but it also serves as the means and result of human and non-human resources management in the pursuit of business excellence (Hassini, Surti & Searcy, 2012).

As such, a vast literature argues that characteristically the tools that support Kaizen are process-oriented and human-based, as Kaizen is incremental, continuous, and participatory (Anand & Kodali, 2008; Moeuf *et al.*, 2016; Zhang *et al.*, 2012). Therefore, Kaizen, as a continuous improvement tool, stressed that efforts of all people involved in the organization are important to achieve the improvements that can contribute to the achievement of superior results (Hassini, Surti & Searcy, 2012; Sundar, Balaji & Kumar, 2014), while understanding management as the maintenance and improvement of working standards (Amirteimoori, Despotis & Kordrostami, 2014).

3. Methodology

This case study was done in an automotive manufacturing company in Pahang. Moving forward towards the lean manufacturing concept, the company is encouraging continuous improvement projects and activities. In a lean manufacturing concept, reducing waste and increasing value-adding operation time is the main target. To reduce the waste of walking in the production time, fabrication of tools trolley was proposed to increase the efficiency rate. The project team is planning to fabricate 100 sets of tools trolley (shown in Figure 1) in the assembly shop for the used in the assembly line.

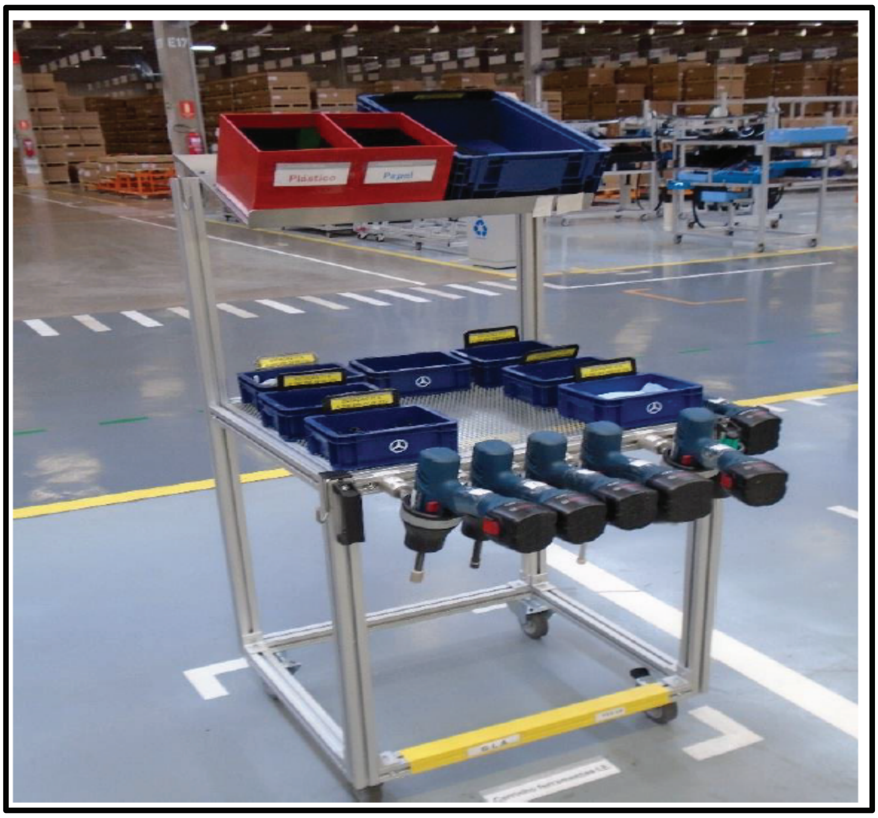

Figure 1: Tools Trolley in an Assembly Shop (**Source:** Authors' own work).

As the company, in-house Continuous Improvement (CI) Workshop has the capacity of fabricating the trolley. Therefore CI-engineers need to plan on the design and choose the correct material for the trolley. All fabrication tools and machine such as cutting machine, tightening tools, welding machines, and measuring devices are available in the workshop. The material for the fabrication must be strong to withstand the weight of the tools, equipment, and some fittings parts. Project lead time is short. Therefore the procurement and fabrication lead time must be minimized to ensure the project completion is on schedule. Material cost should also be within the budget allocation. The data collection phase is crucial in any research. Several aspects come into play in the data

DOI 10.18502/kss.v3i22.5067

collection process. The three most crucial aspects are the cost of the selected data collection method, the accuracy of data collected, and the efficiency of data collection. In this study, data were collected via structured, face-to-face interviews. The interview session was conducted with the participation of Project Engineers, Project Leaders, Continuous Improvement Operators, and Assembly Operators. All the participants are involved in the tools trolley project. A pilot test to validate the questionnaires was conducted with two Managers, and some amendments have been made based on the given feedback. Besides that, the researcher also reviewed a few products' catalogs that describe in details about each material specification to developed comprehensive criteria and alternatives. Information collected from the participants via interview is gathered to determine which criteria are the most important in deciding which material to select for tools trolley fabrication. With the information gathered, the AHP method can be performed. AHP is a decision-making tool that involves structuring criteria into a hierarchy and the relative importance of these criteria is then assessed. Alternatives for each criterion are compared, that relies on the judgment of the interviewed participants. An overall ranking scale of the alternatives is determined.

The AHP selection method follows the following steps. Firstly, define the objective of selection, follows by developing a hierarchical framework based on the collected information on criteria and alternatives, construction of pairwise comparison set matrix, calculation of preferences against criteria of pairwise comparison, ranking the criteria, developing an overall priority ranking, performing a consistency check on the result and finally selection of the best alternatives.

4. Results and Discussion

The main purpose of this study is selecting the most suitable material for the fabrication process of the tool trolley in order to produce a good quality product. From the interview conducted with the Project Engineers, Project Leaders, Continuous Improvement Operators, and Assembly Operators, information on criteria and alternatives are successfully gathered. The selected main criteria are Material Strength, Material Cost, Procurement Lead Time, and Duration of Fabrication Process. According to the participants, these four criteria are the most important and needed to be considered when considering which material to use in the fabrication process of the tool trolley. As for the alternatives, Aluminium, Steel Tube, and Square Tube are chosen by the participants as the potential materials that can be considered in order to construct the tool trolley. The defined objective, four different criteria, and three possible alternatives are shown in Figure 2.

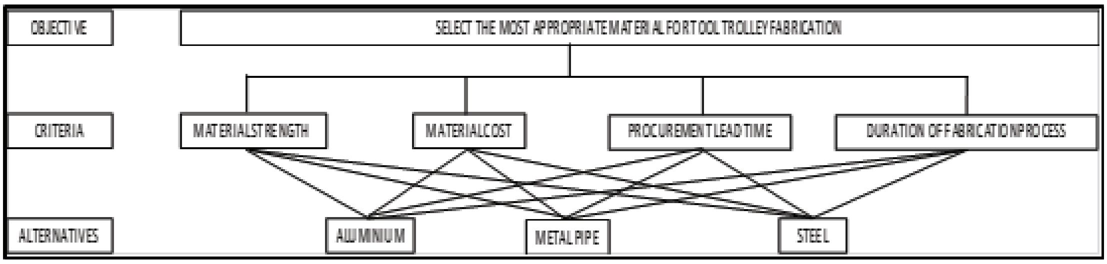

Figure 2: Hierarchy Structure of the Criteria (**Source:** Authors' work).

4.1. Pairwise comparison

The score of each criterion was calculated using pairwise comparison. The decision was done by comparing two alternatives against one criterion, and then the indicated preferences will be recorded. The pairwise comparison scale measurement that was used is shown in Table 1.

Table 1: Pairwise Comparison Scale.

Preference Level	**Numeric Value**
Equally Preferred	1
Moderately Preferred	2
Strongly Preferred	3
Very strongly Preferred	4
Extremely Preferred	5
Source: Taylor (2019)	

Table 3 depicted the pairwise comparison of alternatives (Aluminium, Steel Tube, and Square Tube) against criteria (Material Strength, Material Cost, Procurement Lead Time and Fabrication Lead Time). The data collected are based on the expert judgment of the participants during the interview.

Material strength			
	Aluminum	Steel Tube	Square Tube
Aluminum	1	3	1/4
Steel Tube	1/3	1	1/5
Square Tube	4	5	1

Procurement lead time			
	Aluminum	Steel Tube	Square Tube
Aluminum	1	1/4	1/5
Steel Tube	4	1	1/2
Square Tube	5	2	1

Material cost			
	Aluminum	Steel Tube	Square Tube
Aluminum	1	1/4	1/5
Steel Tube	4	1	1
Square Tube	5	1	1

Fabrication lead time			
	Aluminum	Steel Tube	Square Tube
Aluminum	1	3	5
Steel Tube	1/3	1	4
Square Tube	1/5	1/4	1

Figure 3: Result for All Criterion (**Source**: Authors' own work).

4.2. Calculation of preferences

The next step in AHP is to prioritize the decision alternatives within each criterion. This will assist the CI-engineers in determining the most suitable material based on the criteria provided. Preference score result and normalized matrix with row average were calculated as shown in Figure 4.

From Figure 4, the calculated results showed that for the criteria of Material Strength, Square Tube is the most preferred alternative with the score of 0.67, followed by Aluminium and Steel Tube with the score of 0.23 and 0.10 respectively. For the second criteria, Procurement Lead Time, Square Tube scored the highest at 0.57, followed by Steel Tube with 0.33 and Aluminium with 0.09. The third criteria, Material Cost shows that the participants agreed that Square Tube with the score 0.47 is the most cost-effective as compare to Steel Tube and Aluminium with the score of 0.43 and 0.10. For the Fabrication Lead Time, as the last criteria are chosen by the participant, Aluminium was ranked first with 0.62, followed by Steel Tube and Square Tube with 0.28 and 0.096 respectively.

Material strength				
Material	Aluminum	Steel Tube	Square Tube	average
Aluminum	0.1875	0.3333	0.1724	0.231082
Steel Tube	0.0625	0.1111	0.1379	0.103847
Square Tube	0.7500	0.5556	0.6897	0.66507
				1.000000

Procurement lead time				
Material	Aluminum	Steel Tube	Square Tube	average
Aluminum	0.1000	0.0769	0.1176	0.09819
Steel Tube	0.4000	0.3077	0.2941	0.333937
Square Tube	0.5000	0.6154	0.5882	0.567873
				1.000000

Material cost				
Material	Aluminum	Steel Tube	Square Tube	average
Aluminum	0.100	0.111	0.091	0.100673
Steel Tube	0.400	0.444	0.455	0.432997
Square Tube	0.500	0.444	0.455	0.46633
				1.000000

Fabrication lead time				
Material	Aluminum	Steel Tube	Square Tube	average
Aluminum	0.6522	0.7059	0.5000	0.619352
Steel Tube	0.2174	0.2353	0.4000	0.284228
Square Tube	0.1304	0.0588	0.1000	0.096419
				1.000000

Figure 4: Comparison of Criteria against Alternatives Normalize Matrix (**Source:** Authors' own work).

After determining the preference of materials against the chosen four criteria, next is to determine among the four criteria, which criteria is the most important to the least important where these criteria will be the major reason which material will be chosen for the fabrication of tools trolley. With the relative importance or weight of the criteria used to rank the criteria from the most important the least important, the result of the ranking and normalize matrix of the chosen four criteria are shown in Figure 5. Results in Figure 5 indicated that among the four criteria, Fabrication Lead Time with the score of 0.44 is considered the most important criteria in determining which material to choose for tool trolley fabrication. The second most important criteria are the Material Cost (score of 0.24). Material Strength and Procurement Lead Time scored 0.19 and 0.13, respectively.

Criterion	material strength	material cost	Procurement lead time	Fabrication lead time
Material strength	1	2	1/2	1/4
Material cost	1/2	1	2	1/2
Procurement lead time	2	1/2	1	1/3
Fabrication lead time	4	2	3	1

Criterion	material strength	material cost	Procurement lead time	Fabrication lead time	average
Material strength	0.1333	0.3636	0.0769	0.1200	0.1869
Material cost	0.0667	0.1818	0.3077	0.2400	0.2432
Procurement lead time	0.2667	0.0909	0.1538	0.1600	0.1349
Fabrication lead time	0.5333	0.3636	0.4615	0.4800	0.4351
					1.0000

Figure 5: Criteria Normalize Matrix (**Source:** Authors' own work).

4.3. Overall ranking

As the preference of materials (alternative) against the chosen four criteria (Figure 4) and the preferable criteria (Figure 5) are determined, the next step is to determine given all the preferences calculation and ranking, ultimately which material should be chosen to fabricate the tools trolley. Hence, an overall score of each criterion is computed by multiplying the values in the criteria preference vector by the preceding criteria matrix and summing the products as in Figure 6.

Figure 6 showed the overall ranking of the three materials. Based on the result, Square Tube ranked the highest with 0.36 as compared to Aluminium with a score of 0.35 and Steel Tube with a score of 0.29. As Square Tube scored the highest, Square Tube should be selected as the most suitable material for the in-house tools trolley fabrication, followed by Aluminium and Steel Tube.

4.4. Consistency check

The last step in AHP is to check the level of consistency of the developed pairwise comparison matrixes so that the results are reliable and can be recommended to the management for decision making. The degree of consistency for the pairwise

Material Strength	Material Cost	Procurement Lead Time	Fabrication Lead Time
0.23108	0.10067	0.09819	0.61935
0.10385	0.43300	0.33394	0.28423
0.66507	0.46633	0.56787	0.09642

X

Criterion
0.18685
0.24317
0.13492
0.43506

Material	Score
Aluminium	0.35036
Steel Tube	0.29341
Square Tube	0.35623

Figure 6: AHP Overall Ranking (**Source:** Authors' own work).

comparison in the decision criteria matrix is determined by computing the ratio of Consistency Index (CI) to Random Index (RI).

CI/RI = **0.06593/0.90** = **0.07326**

In this case study, the consistency result is 0.07326, which is <0.10. Therefore, the results obtained are correct and efficient.

5. Conclusion and Recommendation

Table 2 shows the comparison of material selection alternatives of tools trolley concerning weight and ranking. It is found that Square Tube is the best material to be considered from the factors of Material Strength, Material Cost, Procurement Lead Time, and Fabrication Lead Time.

Table 2: Comparison of Materials, Weight, and Ranking.

Material	**Score/Weight**	**Ranking**
Aluminium	0.35036	2
Steel Tube	0.29341	3
Square Tube	0.35623	1
Source: Authors' work		

Selecting the appropriate material in the fabrication process is a crucial decision. The use of AHP is proved to assist CI Engineers to evaluate and select the best material based on the criteria aspects of a decision. It is proved that the AHP is a useful method in solving the material selection for the fabrication process problem during the conceptual design stage. The imprecise decision can cause the product to be remanufactured and not in an optimized condition. Having developed the objective functions and constructed the AHP, the specific objectives were achieved. From the interview session with the respondents, there were some limitations on the data collection. The fabrication lead-time scoring was measured only based on the interview result with the CI Operator. The data was typically based on the judgment and experience of the evaluation scores. Another limitation is on the validity of procurement lead time. This limitation happened due to the unavailability of procurement personnel during the interview session. Therefore, the data was obtained from the Project Leader based on previous experience. Also, it was challenging to gather the entire participants in one sitting session due to the schedule constraint.

To improve the accuracy of the scoring on the fabrication lead time, an alternative approach to obtain the data could be used. It is recommended to have measurable data based on the actual cycle time of tools trolley fabrication using Aluminium, Steel Tube, and Square Tube. Another recommendation is to have an interview session with the procurement personnel to get more accurate and feasible data. Also, it is recommended to set an appointment with the involved parties at the same time and get the full commitment. As a recommendation for future study, researchers can explore more alternatives to catch up with the latest technology in the lean manufacturing concept.

Acknowledgement

We would like to thank Faculty of Industrial Management and FIM's Governance and Integrity Centre, Universiti Malaysia Pahang for the financial support by sponsoring this paper to be presented in the FGIC 2nd Conference on Governance and Integrity 2019.

References

[1] Anand, G. & Kodali, R. (2008). Selection of lean manufacturing systems using the PROMETHEE. *Journal of Modelling in Management*, 3(1), 40-70.

[2] Amirteimoori, A., Despotis, D. & Kordrostami, S. (2014). Variables reduction in data envelopment analysis, *International Journal of Advanced Manufacturing Technology*, 63(5), 735–745.

[3] Bhasin, S. (2008). Lean and performance measurement. *Journal of Manufacturing Technology Management*, 19(5), 670-684.

[4] Dweiri, F. & Al-Oqla, F. M. (2006). Material selection using analytical hierarchy process. *International journal of computer applications in technology*, 26(4), 182-189.

[5] Garcia, J. L., Rivera, D. G. & Iniesta, A. A. (2013). Critical success factors for Kaizen implementation in manufacturing industries in Mexico, *International Journal of Advanced Manufacturing Technology*, 68(1–4), 537–545.

[6] Gupta, S. & Jain, S. K. (2013). A literature review of lean manufacturing. *International Journal of Management Science and Engineering Management*, 8(4), 241-249.

[7] Hambali, A., Sapuan, S. M., Ismail, N. & Nukman, Y. (2010). Material selection of polymeric composite automotive bumper beam using analytical hierarchy process. *Journal of Central South University of Technology*, 17(2), 244-256.

[8] Hambali, A., Sapuan, S.M., Ismail, N. & Nukman, Y. (2008). Use of Analytical Hierarchy Process (AHP) for Selecting the best Design Concept. *Journal of Technology*, 49(2), 1–18.

[9] Hassini, E., Surti, C. & Searcy, C. (2012). A literature review and a case study of sustainable supply chains with a focus on metrics. *International Journal of Production Economics*, 140(1), 69-82.

[10] Kalpakjian, S. & Schmid, S. R. (2014). Manufacturing engineering and technology. K. V. Sekar (Ed.). *Upper Saddle River*, NJ, USA: Pearson.

[11] Moeuf, A., Tamayo, S., Lamouri, S., Pellerin, R., Lelievre, A. & Montreal, P. (2016). Strengths and weaknesses of small and medium sized enterprises regarding the implementation of lean manufacturing, *Management and Control MIM 2016*, 49(12), 71–76.

[12] Ravisankar,V., Balasubramanian,V. & Muralidharan, C. (2004). Selection of welding process to fabricate butt joints of high strength aluminium alloys using analytic hierarchic process. *Journal of Materials and Design*, 27(3), 373–380.

[13] Subramanian, N. & Ramanathan, R. (2012). A review of applications of Analytic Hierarchy Process in operations management, *International Journal of Production Economics*, 138(3), 215-241.

[14] Sundar, R., Balaji, A. N. & Kumar, R. S. (2014). A review on lean manufacturing implementation techniques. *Procedia Engineering*, 97, 1875-1885.

[15] Smith, G. A., Kozuschek, M. A. & Nelson, D. A. (2001*). U.S. Patent No. 6*,314,834. Washington, DC: U.S. Patent and Trademark Office.

[16] Taylor, B. W. (2019). *Introduction to Management Science*. Pearson Education Limited. UK

[17] Vaidya, O. S. & Kumar, S. (2006). Analytic hierarchy process: An overview of applications, *European Journal of Operational Research*, 169(2), 1-29.

[18] Zhang, Q., Irfan, M., Khattak, M. A. O., Zhu, X. & Hassan, M. (2012). Lean Six Sigma: a literature review. *Interdisciplinary Journal of Contemporary research in business*, 3(10), 599-605.