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RANKING ALTERNATIVE ROUTES FOR PEDESTRIAN WALKWAYS FOR A FACTORY BY APPLYING ANALYTICAL HIERARCHY PROCESS

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The Analytical Hierarchy Process (AHP) is one of the Multi Criteria Decision-making (MCDM) methods developed by Thomas Lorie Saaty. It can be defined as the theory of measurement through pairwise comparisons, relying on expert judgments of priority scales. This study aims to compare the alternative pedestrian routes within the production area of a manufacturing company located in Manisa, Türkiye, utilizing AHP. AHP is selected as a suitable tool for this case study, since it allows inclusion of tangible and intangible criteria and consideration of sub-criteria as part of the decision-making process. Three alternative pedestrian routes were evaluated by applying the AHP method to define the best route enabling access for pedestrians to the targeted area in the manufacturing building. The decision criteria were defined by expert decision makers of the company and are in line with criteria such as safety, cost effectiveness, and time, utilized broadly for layout selection related studies in manufacturing as per the conducted literature review. The best alternative route was determined as Route 1, and the main criteria priorities were ranked as Criteria 1- "Operational Health and Safety (OHS) Risk Assessment," Criteria 4 "Restricted access to the material warehouse," Criteria 2 "Investment Feasibility" and Criteria 3 "Walking Time." As a conclusion, AHP is effectively applied to prioritize the tangible and intangible criteria and select the most suitable pedestrian routes within a manufacturing facility.

Key Words: *Analytical Hierarchy Process, Pedestrian Route Selection, Manufacturing.*

Jel Codes: *C02, C44, J81.*

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BİR FABRİKANIN İÇİNDEKİ YAYA YÜRÜME YOLLARI İÇİN ALTERNATİF GÜZERGÂHLARIN ANALİTİK HİYERARŞİ PROSESİ İLE SIRALANMASI

ÖZET

Analitik Hiyerarşi Süreci (AHP), Thomas Lorie Saaty tarafından geliştirilen Çok Kriterli Karar Verme (ÇKKV) yöntemlerinden biridir. AHP ikili karşılaştırmalar yoluyla bir ölçüm teorisidir ve öncelik ölçeklerini türetmek için uzmanların yargılarına dayanır. Bu çalışmanın amacı Manisa, Türkiye'de bulunan bir imalat firmasının üretim alanı içerisindeki alternatif yaya güzergahlarını Analitik Hiyerarşi Süreci (AHP) kullanarak karşılaştırmak ve en uygun seçeneği belirlemektir. AHP, karar alma sürecinin bir parçası olarak somut ve soyut kriterlerin dahil edilmesine ve alt kriterlerin dikkate alınmasına olanak tanıdığı için bu çalışma için uygun yöntem olarak seçilmiştir. Üretim binasında yayaların hedeflenen alana ulaşmasını sağlayacak en uygun güzergahı belirlemek için üç alternatif yaya güzergahı değerlendirilmiştir. Karar kriterleri, şirketin uzman karar vericileri tarafından tanımlanmıştır. Güvenlik, maliyet ve zaman gibi kriterler literatürde imalat alanında yerleşim seçimi ile ilgili çalışmalarda yaygın olarak kullanılmaktadır. En iyi alternatif rota Güzergâh 1 olarak belirlenmiş olup, ana kriter öncelikleri Kriter 1- "İş Sağlığı ve Güvenliği Risk Değerlendirmesi", Kriter 4 "Malzeme deposuna kısıtlı erişim", Kriter 2 "Yatırım Fizibilitesi" ve Kriter 3 "Yürüme Süresi" olarak sıralanmıştır. Sonuç olarak AHP, üretim tesislerinde yayalar için en uygun yürüme güzergahları için kriterlerin önceliklendirilmesinde ve en uygun güzergâhın belirlenmesinde etkili bir araç olarak kullanılmıştır.

Anahtar Kelimeler: *Analitik Hiyerarşi Prosesi, Yaya Yürüme Güzergâhı Seçimi, Üretim.*

Jel Kodları: *C02, C44, M11.*

1.INTRODUCTION

Decision-making can be explained as making a selection between alternatives. Multi-Criteria Decision-making (MCDM) aims for the possible "best/appropriate" solution meeting

various defined criteria. The best solution refers to the decision to be taken due to the decision process, with the greatest benefit or minimum cost. MCDM can be defined as a set of methods that constitutes a sub-branch of Decision Science incorporating different approaches. Being one of them, Analytical Hierarchy Process (AHP) can be effectively applied, especially in the presence of subjectivity and whenever the decision criteria of the problem is hierarchically composed of respective sub-criteria (Yıldırım, Önder, 2014). Moreover, AHP enables to simplify the Decision-making process with its structure of arranging the problem into its parts, constructing a hierarchy using those parts, offering a mathematical algorithm on judgments then applying a synthesis at the end (Saaty, 2012).

AHP is one of the best MCDM methods that can be applied for the solution of production management problems, such as plant or facility location selection (Ozdemir and Sahin, 2018; Meysam

Mousavi et al., 2013; Rahman et al., 2018); production planning (Jung,2011), assembly line balancing (Nagy et al., 2020) and disassembly line balancing (Avikal et al., 2013); transportation (Moslem et al., 2023), and vehicle routing (Balaji et al., 2019).

In this case study, AHP is applied to define and select the most suitable pedestrian route to reach the Entry Quality Control (EQC) Office within the manufacturing area of a household appliances producer located in Manisa, Türkiye. In the current state, employees use dedicated pedestrian paths to walk through the factory. Suppliers and interns are allowed to move through dedicated pedestrian routes being accompanied by a company employee. The company has decided to define a single route for suppliers and interns to reach the EQC Office. The manufacturing process itself will not be impacted by the decision. Alternatives are defined as Route 1, 2, and 3. Expert decision makers have defined the four main decision criteria as "Occupational Health and Safety (OHS) Risk," "investment feasibility," "walking time," and "ensured restricted access to the material warehouse." Three OHS-related sub-criteria are defined as "pedestrian safety for interns and suppliers," "material damage accident risk," and "injury and fatal damage accident risk." Decision makers are the OHS Expert, the Technical Manager and the Quality Manager of the company. The decision criteria are of tangible and intangible nature. A comparison against the literature resulted with found correspondence regarding lean manufacturing related studies aiming for waste elimination in terms of time, distance and cost.

2. LITERATURE REVIEW

Multi Criteria Decision Making satisfies a strongly decision-making process in an extensive area of alternatives and criteria where in some cases the criteria can conflict with each other (Aruldoss, Lakshmi and Venkatesan, 2013). The history of MCDM methods as a discipline is not based to very old days. Most of the methods has its origins late until 1950s and 1960s. Today there are various kinds of MCDM methods like AHP, TOPSIS, VIKOR, MACBETH, ELECTRE, ANP and etc. The main advantages of AHP within MCDM methods allowing to use the quantitative criteria with qualitative ones; having a consistency index algorithm; having a pairwise comparison scale and having an sub algorithm of calculation of relative weights of criteria (Mu and Rojas, 2018).

AHP is introduced by Myers and Alpert in 1968 as one of the MCDM methods and has been developed as a model by Thomas Lorie Saaty in late 70s and early 80s. AHP has found wide use in solving MCDM problems (Yıldırım, Yeşilyurt, 2014).

Criteria may be abstract and may not have metrics to serve as guides for ranking alternatives. AHP provides a convenient method to weigh the priorities of alternatives using all criteria and obtain the desired overall ranking. Moreover, AHP is a theory of measurement through pairwise comparisons and relies on expert judgment to derive priority scales. It is these scales that measure intangible assets relatively. Comparisons are made using an absolute judgements scale, which represents how superior one element is over another concerning a particular characteristic. Judgments can be inconsistent, and how to measure inconsistency and improve judgments to achieve better consistency whenever possible is a topic of AHP (Saaty, 2008).

Academic research on MCDM in manufacturing, is highly focusing on supplier selection and lay-out definition related studies. According to bibliometric analysis of AHP specifically, 18% of the 150 studies assessed were in manufacturing (Vaidya, 2004). A decadal study from 2012 to 2021 constituting the strategic map of AHP research shows that AHP methodology is preferred for supply chain related decision making, such as selecting the best optimized supply chain model, performance measurement of supply chain and decision related to plant location selection as well (Pereira and Bamel, 2022).

AHP is frequently applied for production management areas from planning to organizing which consist of any decision problems. Rahman et al. (2018) applied AHP for facility location selection between five districts, for plastic manufacturing industries with 10 criteria. Mousavi et al. (2012) used integrated AHP with other methods to decide the plant location selection problem between three places with five criteria. Nagy et al. (2020) used AHP for the solution of Assembly Line Balancing Problems to determine the importance of criteria of main ones as time balance, equipment and skill which all have sub-criteria as well.

AHP is frequently applied for the solution of transportation problems, which is a part of production management. Moslem et al. (2023) performed a review on the implementation of AHP in transportation problems for the last 20 years. According to their research on 58 papers, mostly classical AHP method is used in public transport and logistics problems.

Additionally, AHP is frequently applied for the implementation of lean manufacturing concepts focusing on the reduction and elimination of waste. The lean principles are introduced based on the Toyota Production System (TPS), and Toyota is presented as one of the first lean practices (Womack and Daniels, 1990). Despite lean practices being developed and applied by Toyota decades earlier, the term “Lean” became known worldwide through the book “The Machine that Changed the World” by Womack and Jones in 1990. Today, Lean Manufacturing concepts are applied worldwide in diverse industrial sectors (Aitken, Christopher and Towill, 2002). The main objective of lean is waste elimination by reduced or optimized supplier, customer, and internal variability (Shah and Ward, 2007). Examples of types of waste found in manufacturing processes are unnecessary transport of parts under production, inventory (stacks of parts waiting to be completed or finished products waiting to be shipped), unnecessary motion (of people working on products), unnecessary waiting (by people to begin the next step), over-processing, over-production, and product defects (Ohno, 1988).

A study conducted on lean concept selection in a manufacturing organization utilizing AHP methodology, used the lean manufacturing criteria for defining the best manufacturing concept considering the elimination as the seven wastes as sub-criteria (Vinodh, Shivraman and Viswesh, 2012). Ramnath, Elanchezhian and Kesavan have applied AHP to justify selecting an assembly system.

According to the study, the important factors are operator distance travelled, floor space required, work in process inventory, and operator walking time. Here, AHP is carried out among lean-kitting, traditional and just in time assembly to find optimal assembly method (Ramnath et. al, 2010). Hadi-Vencheh and Mohamadghasemi have utilized a mixed AHP–NLP methodology for facility layout design. The decision criteria defined included quantitative criteria, such as distance in meters, proximity, shape ratio and qualitative criteria, such as accessibility, maintenance and flexibility (Hadi-Vencheh and Mohamadghasemi, 2012). Similarly, Al-Hawari, Mumani, and Momani state the Closeness gap value cluster as one of the decision criteria for facility lay out selection based on their study "Application of the Analytic Network Process to facility layout selection." Closeness gap is related to reduction of Material Handling Cost for all transport within the facility, including personnel flow (Al Hawari et.al, 2014). Abdalla, Kızıl and Canbulat (2013) applied AHP for mine layout selection with the target to develop a AHP based method to select the most viable panel orientation for longwall operation. The longwall panel length was one of the defined decision criteria. The layout with the greatest panel length, would require more complex gas drainage and was identified as the least preferable compared to other layouts (Abdalla, et.al, 2013).

Waste elimination is also related to topics, such as minimization of workers' absence or damage caused by work accidents in the context of OHS hazards. Safety essentially means the absence of risk, and a safe state is defined by the absence of something. The expected measures or indicators are therefore diminishing numbers of negative events (Hollnagel, 2008). Product safety refers to the quality of a product and its utilization without risk (Rausand and Utne 2009), whereas human safety deals with accident prevention in work situations (Sadeghi et al. 2015). Effective safety management cannot be only reactive but must also be proactive (Holnagel, 2008). Operational improvements integrated with safety priorities can support the improvement of overall business performance (Abad, Lafuente, & Vilajosana, 2013).

Furthermore, legislative requirements and binding standards on OHS must be adhered to as well. According to the Turkish Ministry of Labor and Social Security's Work Life Report 2020, "being struck by falling objects" ranks fifth and "traffic accidents" rank fourth among work accident causes in Türkiye, supporting also the significance of OHS for manufacturing performance. In this study, safety is included as sub-criteria under Human Issues as well (Al-Hawari, Mumani, and Momani, 2014).

The examples above support that, time (in terms of distance), cost and safety related decision criteria are applied for best layout selection utilizing the AHP method.

AHP is also applied for performance measurement and critical Total Quality Management (TQM) factors prioritization in manufacturing, targeting enhanced business performance and customer satisfaction. TQM can be defined as a manufacturing philosophy that aims for customer satisfaction and positive business performance in terms of cost and quality. The American Society for Quality (www.asq.org) defines TQM as a management approach to long-term success through customer satisfaction. In a TQM effort, all members of an organization participate in improving processes, products, services, and the culture in which they work. Nguyen, Tucek and Pham (2023) applied AHP to explore key factors and specific indicators of the TQM 4.0 model with Industry 4.0 technical tools applied into the TQM system, for implementation in manufacturing enterprises. Koilakuntla, Patyal, Modgil and Ekkuluri (2012) applied AHP in an attempt to design and develop a model by which one can estimate their industry specific factor weightages for each factor concerning selected TQM Key performance indicators (KPIs) that are crucial to the industry. Chin, Pun and Chan (2002) Applied AHP to investigate the critical factors and sub-factors that determine the adoption and implementation of TQM in the state-owned enterprises and foreign joint ventures in China with reference to the Shanghai manufacturing industries.

In this study, different from the examples given in the literature review of application of AHP in the production management field, method has been used to compare the alternative pedestrian routes within the production area of a manufacturing company: Firstly, relatively weighting the criteria, then giving a ranking of the routes in the factory by modelling the expert judgments with AHP method.

3. METHOD AND MATERIAL

The stages of the AHP method were given in the following steps as defined by Saaty (2008):

- Defining the decision-making problem.
- Structuring the decision hierarchy in a way that shows the goal of the decision first starting from a broad perspective and then the goals from the middle level to the lowest.
- Preparing pairwise comparison matrices.
- Using priorities from comparisons to evaluate priorities at the level below and repeating for each item. Then, obtaining the overall priority by summing the weighted values for each element at the level below, and continuing this process until the final priorities of the alternatives at the bottom are obtained.
- Multiplying the importance weights of the criteria with the importance weights of the options (alternatives) and finding the priority value for each option.
- Calculating the consistency ratio to measure whether decision makers compare the criteria or options consistently. According to Saaty's scale, if the ratio is below 0.10, the matrix is considered consistent, otherwise the matrix must be rearranged.

Priority values are considered by decision makers to prepare the pairwise comparison table for the defined criteria and the alternative options given in the Table1.

Table 1. Saaty Scale

1	Equally important		
3	Moderately more important	1/3	Moderately less important
5	Strongly more important	1/5	Strongly less important
7	Very Strongly more important	1/7	Very Strongly less important
9	Extremely more important	1/9	Extremely less important
2,4,6,8 : Intermediate values		1/2, 1/4,1/6, 1/8: Intermediate values	
Adapted from Saaty, 2008			

The Consistency Ratio (CR) can be calculated for each matrix, all being below the acceptable value (0,1) utilizing the respective formula for Consistency Index (CI) and Random Index (RI) as per Saaty's definition and given in Eq 1 and Eq 2.

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

$$CR= CI/RI \quad (2)$$

where λ_{max} is the eigenvalue of the decision matrix, n is the dimension of the decision matrix and the RI can be found using Table 2, according to n.

Table 2. Random Index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49
Source: Saaty, 1994										

In this case study, AHP is applied to define and select the most suitable pedestrian route to reach the Entry Quality Control Office (EQC) within the manufacturing area of a household appliances producer located in Manisa, Türkiye.

The criteria defined for selecting the most suitable pedestrian route as part of the manufacturing facility layout are as follows:

1. Occupational Health and Safety (OHS) Risk

a. Pedestrian safety for interns and suppliers

b. Material Damage Accident Risk

c. Injury and Fatal Damage Accident Risk

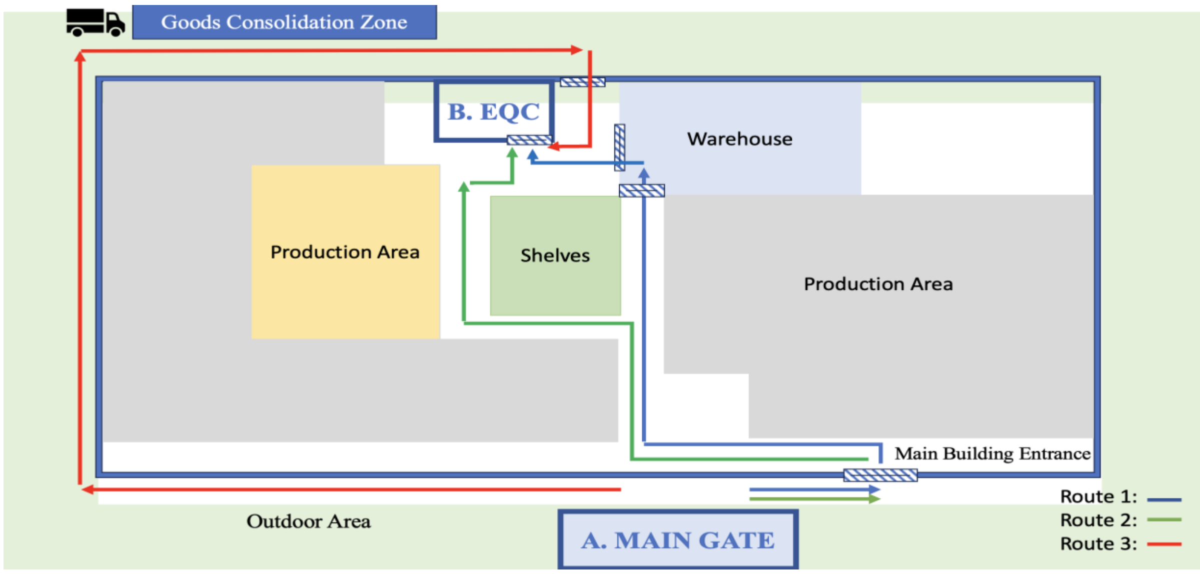
2. Investment Feasibility

3. Walking Time

4. Ensured Restricted Access to Material Warehouse

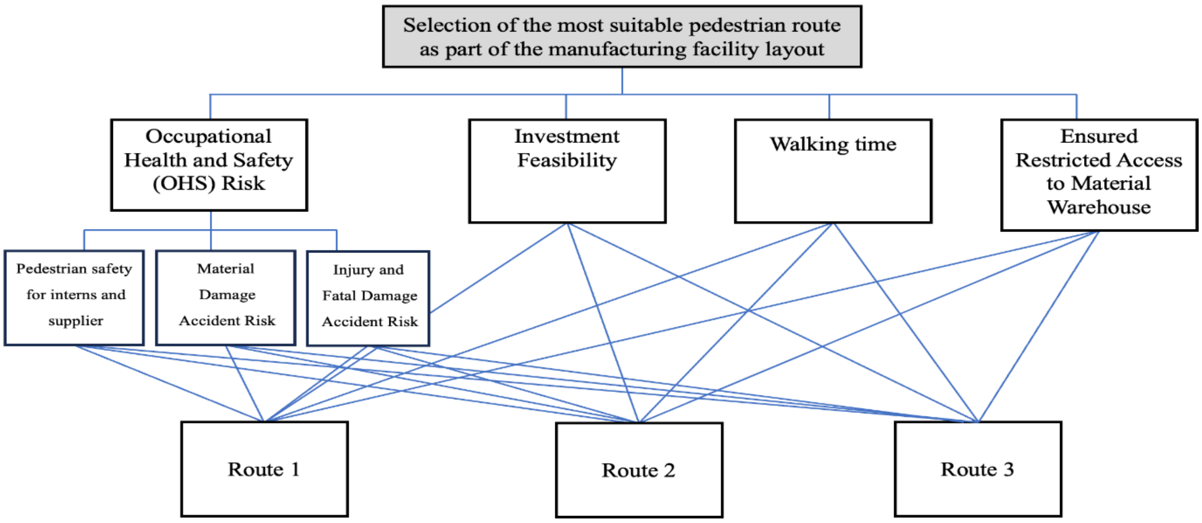
The decision criteria were defined by expert decision makers and were compared against the literature. Examples of existing studies in manufacturing utilizing the AHP method were examined. As a result, an overlap regarding lean manufacturing related lay-out selection studies which aimed for maximized waste elimination in the manufacturing process considering the time, cost and safety related criteria was detected. However, it must be considered that the literature covers the selection of the manufacturing layout in a broader sense with an impact on the manufacturing concept or production design, whereas this study aims for the selection of suitable pedestrian routes within the production area, without impacting the manufacturing process or concept itself. As employees use dedicated pedestrian paths to walk through the factory, suppliers visiting the company and interns are allowed to move through different pedestrian routes to reach the EQQ Office being accompanied by a responsible company associate. It is desired to define a single route for suppliers and interns to reach the EQC Office. Alternative routes 1, 2 and 3 are defined, as shown in Picture 1.

Picture 1: Pedestrian Routes Alternatives to reach the EQC Office.



In the Picture 1, all three alternatives can be seen as Route 1, Route 2 and Route 3. Also, the hierarchical structure of the problem is given in Picture 2.

Picture 2: Hierarchy of the Problem



4. ANALYSIS AND FINDINGS

The process was applied for each of the three decision makers (Technical Manager, Quality Manager and OHS Expert). The pre-informed voluntary consent forms have been signed by the expert DMs, corresponding ethical values in the research.

After modelling the views of DMs with matrices and applying the AHP Algorithm, consistency of views of DMs were checked using the Consistency Index formulas given in Eq1 and Eq2. The results showed that the views were consistent since all CR were below the upper limit value 0,1 as given in the Table3.

Table 3: Consistency Check Results

	CI	CR
DM1: OHS Expert	0,0303	0,0337
DM2: Technical Manager	0,0407	0,045
DM3: Quality Manager	0,08	0,09

The comparison matrix showed the importance levels of the factors relative to each other within a certain logic for defined criteria. The arithmetic mean operator was used to combine the views of DMs. The average values of all three decision makers pairwise comparison matrix was utilized, as shown in Table 4.

Table 4: Pairwise Comparison Matrix for Decision Criteria - All Experts Average

Main Criteria	1.OHS Risk Assessment	2.Investment Feasibility	3.Walking time	4. Ensured Restricted Access to Material Warehouse
1.OHS Risk Assessment Result	1,00	6,33	7,00	4,00
2.Investment Feasibility	0,16	1,00	2,33	0,86
3.Walking time	0,19	0,56	1,00	1,14
4.Restricted Access to Material Warehouse	0,26	2,50	3,44	1,00
Total SUM	1,61	10,39	13,78	**7,00**
Sub Criteria	1.1 Pedestrian safety for interns and supplier	1.2 Material Damage Accident Risk	1.3 Injury and Fatal Damage Accident Risk	
1.1 Pedestrian safety for interns & supplier	1,00	9,00	0,45	
1.2 Material Damage Accident Risk	0,11	1,00	0,12	
1.3 Injury & Fatal Damage Accident Risk	4,00	8,67	1,00	

The normalized matrix was obtained by dividing each column value by the column total. Then, the percentage importance weights of the option or criterion were defined by calculating the row averages of the normalized matrix, as shown in Table 5.

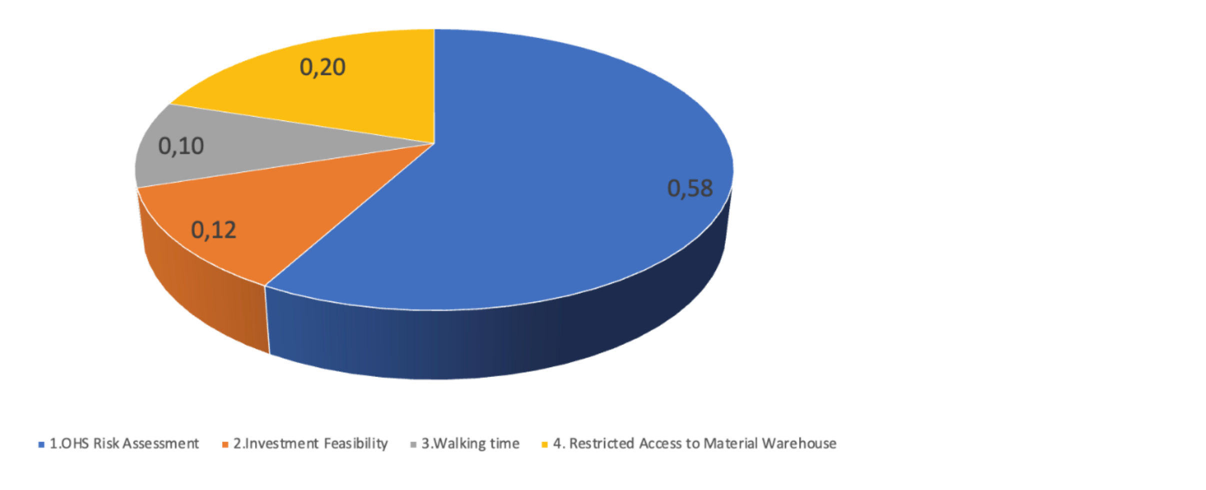
Table 5. Normalized Matrix Encompassing Priority Vector Calculation

Main Criteria	1.OHS Risk Assessment	2.Investment Feasibility	3.Walking time	4.Ensured Restricted Access to Material Warehouse	Average
1.OHS Risk Assessment	0,62	0,61	0,51	0,57	0,58
2.Investment Feasibility	0,10	0,10	0,17	0,12	0,12
3.Walking time	0,12	0,05	0,07	0,16	0,10
4. Restricted Access to Material Warehouse	0,16	0,24	0,25	0,14	0,20
Sub Criteria	1.1 Pedestrian safety for interns and supplier	1.2 Material Damage Accident Risk	1.3 Injury and Fatal Damage Accident Risk	Average	Weighted Average (Main criteria weight: 0,58)
1.1 Pedestrian safety for interns and supplier	0,20	0,48	0,29	0,32	0,19

1.2 Material Damage Accident Risk	0,02	0,05	0,07	0,05	0,03
1.3 Injury and Fatal Damage Accident Risk	0,78	0,46	0,64	0,63	0,36

OHS risk assessment was evaluated as most important decision criteria by all three expert decision makers.

Picture 3. Pie Chart Presenting Average Percentage Importance Weights



The pairwise comparison matrix and normalized matrix for the alternative options is shown in Tables 6 and 7.

Table 6. Pairwise Comparison of Alternative Options

1.OHS Risk Assessment			
	Route 1	Route 2	Route 3
Route 1	1,00	4,00	7,00
Route 2	0,25	1,00	1,04
Route 3	0,14	0,96	1,00
2. Investment Feasibility			
	Route 1	Route 2	Route 3
Route 1	1,00	3,67	6,00
Route 2	0,27	1,00	3,00
Route 3	0,17	0,33	1,00
3. Walking Time			
	Route 1	Route 2	Route 3
Route 1	1,00	3,67	6,67
Route 2	0,27	1,00	4,33
Route 3	0,15	0,23	1,00
4.Ensured Restricted Access to Material Warehouse			
	Route 1	Route 2	Route 3
Route 1	1,00	0,11	0,14

Route 2	9,00	1,00	1,82
Route 3	7,28	0,55	1,00
1.1.Pedestrian safety for interns and supplier			
	Route 1	Route 2	Route 3
Route 1	1,00	4,33	4,67
Route 2	0,23	1,00	0,78
Route 3	0,21	1,29	1,00
1.2. Material Damage Accident Risk			
	Route 1	Route 2	Route 3
Route 1	1,00	6,00	6,33
Route 2	0,17	1,00	3,04
Route 3	0,16	0,33	1,00
1.3. Injury and Fatal Damage Accident Risk			
	Route 1	Route 2	Route 3
Route 1	1,00	7,00	3,72
Route 2	0,14	1,00	1,09
Route 3	0,27	0,91	1,00

Table 7. Normalized Matrix for Alternative Options Encompassing Priority Vector Calculation

1.OHS Risk Assessment				Relative Weight
	Route 1	Route 2	Route 3	
Route 1	0,72	0,67	0,77	0,72
Route 2	0,18	0,17	0,12	0,15
Route 3	0,10	0,16	0,11	0,12
2.Investment Feasibility				Relative Weight
	Route 1	Route 2	Route 3	
Route 1	0,69	0,73	0,60	0,68
Route 2	0,19	0,20	0,30	0,23
Route 3	0,12	0,07	0,10	0,09
3: Walking time				Relative Weight
	Route 1	Route 2	Route 3	
Route 1	0,70	0,75	0,56	0,67
Route 2	0,19	0,20	0,36	0,25
Route 3	0,11	0,05	0,08	0,08
4. Ensured Restricted Access to Material Warehouse				Relative Weight
	Route 1	Route 2	Route 3	
Route 1	0,06	0,07	0,05	0,06
Route 2	0,52	0,60	0,62	0,58
Route 3	0,42	0,33	0,34	0,36
Sub-Criteria 1.1. Pedestrian safety for interns and supplier				Relative Weight
	Route 1	Route 2	Route 3	
Route 1	0,69	0,65	0,72	0,69

Route 2	0,16	0,15	0,12	0,14
Route 3	0,15	0,19	0,16	0,17
Sub-Criteria 1.2. Material Damage Accident Risk				Relative Weight
	Route 1	Route 2	Route 3	
Route 1	0,75	0,82	0,61	0,73
Route 2	0,13	0,14	0,29	0,19
Route 3	0,12	0,04	0,10	0,09
Sub-Criteria 1.3. Injury and Fatal Damage Accident Risk				Relative Weight
	Route 1	Route 2	Route 3	
Route 1	0,71	0,79	0,64	0,71
Route 2	0,10	0,11	0,19	0,13
Route 3	0,19	0,10	0,17	0,15

Once the importance weights of the criteria were multiplied by the importance weights of the alternative options, the priority value of each option was calculated.

The importance weights of the criteria were multiplied by the importance weights of the alternative options shown in Table 5 to find the priority value of each option. The calculation method was shown for Route 1 as an example. The same process was applied for Route 2 and 3: (0,68*0,12)+(0,67*0,10)+(0,06*0,20)+(0,69*0,19)+(0,73*0,03)+(0,71*0,36)=0,57

Ultimately, the option with the highest value was presented as the best option for the decision problem. The outcome of the evaluation resulted in Route 1 being the best alternative, followed by Route 2 and Route 3. Ranking is shown in Table 8.

Table 8. Priority Value - Final Ranking

Alternatives	Final Ranking
Route 1	0,57
Route 2	0,25
Route 3	0,18

As a result of the present study, Route 1 was selected utilizing the AHP method as the best option. The main criteria priorities were ranked as Criteria 1- “OHS Risk Assessment,” Criteria 4 “Restricted access to the material warehouse,” Criteria 2 “Investment Feasibility” and Criteria 3 “Walking Time.” The OHS sub-criteria priorities were ranked as Sub-criteria 1.3 “Injury and Fatal Damage Accident Risk,” Sub-criteria 1.1 “Pedestrian safety for interns and supplier” and Sub-criteria 1.2 “Material Damage Accident Risk.”

5. CONCLUSION

As per existing literature, AHP can be effectively applied, especially in the presence of subjectivity in a problem, and when the decision criteria of the problem are hierarchically composed of respective sub-criteria. Research shows that in relevance to the manufacturing field, the AHP methodology is mainly utilized for supply chain related decision-making encompassing topics like supply chain optimization and lay-out selection related studies. The criteria cost, time and safety are considered in respective studies in relevance to lean manufacturing and waste elimination.

The main contribution of this case study to the existing literature is to provide a practical example of AHP being successfully applied as a Multi-Criteria Decision-Making method in the field of manufacturing. This case study presents tangible criteria, such as cost and time, and intangible criteria, such as occupational health and safety related risk definition as defined by expert decision makers of a real company. The limitation of this study is that the decision-making process is targeting pedestrian routes only. It differentiates itself from other lay-out selection studies due to its lack of impact on the production concept or process itself. However, the same principles apply when it comes to decision-making for route selection in a manufacturing facility. In consideration of the above, AHP is assumed a suitable method for this case study and has been successfully applied to define the most suitable pedestrian route as Route 1 for a manufacturing site, based on tangible and intangible criteria defined by expert decision makers of the company.

The examples of AHP application in the field of manufacturing as per existing literature can be further expanded. In addition to more frequently applied supply chain optimization and lay-out selection related decision-making examples, the practitioners can apply AHP for other topics as well such as route selection at manufacturing sites. Researchers can further expand their studies focusing on the presence of hierarchically composed criteria and sub-criteria for any decision-making process in the field of manufacturing. Based on existing practices such as risk identification, location selection, supply chain improvement, lay-out optimization, ensured occupational safety, additional scope can be identified in collaboration with the practitioners. The pre-requisite would be the presence of hierarchically composed sub-criteria defined by expert decision makers as presented in this study.

Furthermore, researchers can focus further on other MCDM techniques that can be combined with AHP in the field of manufacturing. As AHP and TOPSIS (The Technique for Order of Preference by Similarity to Ideal Solution) can be combined for weighting criteria, VIKOR can support the application of AHP by resolution of conflicting decision criteria. Moreover many other MCDM techniques can be used with AHP as a hybrid method.

In conclusion, whether applied individually or in combination with other MCDM techniques, AHP is a suitable method to support practical decision making in the field of manufacturing. Furthermore, potential exists to expand the scope of application for both, practitioners and researchers.

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