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Analytical Hierarchy Process (Ahp) In Manufacturing And Non-Manufacturing Industries: A Systematic Literature Review

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ABSTRACT

Analytical Hierarchy Process (AHP) is commonly used by many decision-makers in many industry to solve particular problems. However, the effective implementation of AHP for decision making in industries still becomes a question. This research aims at developing a systematic literature review using the real cases implementing AHP, both in manufacturing and non-manufacturing industries, from 2000 to 2020. To obtain research results, we select seventy-eight cases and utilize AHP combined with other methods. The results of this study show that twenty-two scientific works of literature combine AHP with other methods. GIS method and Expert choice software are the most frequently implemented methods combined with AHP. The finding of this study is expected to be a reference and recommendation for researchers or practitioners in using AHP in various industries.

Keywords: Analytical Hierarchy Process, Systematic Literature Review, Decision Making

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INTRODUCTION

We see that many economic indicators, currently, are showing a declining tendency, such as a minus economic growth, weakening stock market performance, and poor supply chain due to the COVID-19 (Gates, 2020). The COVID-19 is a virus appearing in December 2019 and has been the largest threat in our society. Droplets can transmit this virus from the infected ones, then spread rapidly. Until now, no pharmaceutical treatment is known to be effective, so this virus has become the center of international attention. (Gao et al., 2020); (Sun et al., 2020); (Rothan & Byrareddy, 2020); (Dong et al., 2020) (Ayenigbara, 2020); (Cortegiani et al., 2020). The government mandates a social distancing program and instructs the less important businesses to close to slow down the spread of the epidemic. However, this has an impact on various industries because the government limits activities and workers. (del Rio-Chanona et al., 2020). This outbreak came suddenly and affected the global economy and caused spillover damage. It also creates demand and supply shocks in the manufacturing and non-manufacturing industries, such as the sports industry, restaurant business, entertainment, events, banking, oil and gas, IT and many more (Ozili & Arun, 2020); (Inoue & Todo, 2020); (Ramasamy & Reddy, 2020).

As a consequence, the productivity of many companies decreases, and so does the sales turnover. Hence, companies should work harder to tackle this pandemic. We need to know that in dealing with problems, we will have to make the right decision to take a step forward in order to find the solutions. A decision making based on quantitative and numeric approaches will produce a better result (Hopkins, 2011). One of the methods which can be used to support a decision-making process is the Analytical Hierarchy Process (AHP). AHP method is chosen in this study because it utilizes a qualitative and quantitative analysis. Besides, it breaks down the elements related to the decision making to be regulation, criteria, and scheme (H. Li et al., 2018); (Liu et al., 2018). AHP method is a ranking process used in decision making and widely used throughout the world, both in manufacturing and non-manufacturing industries, such as government agencies, educational institutions, health facilities, and others.

AHP is a model of Multi-Criteria Decision Making (MCDM), allowing a decision-making system to have appropriate techniques for ranking the managerial problems critically (Aziz et al., 2016). AHP was introduced by Myers and Alpert in 1968 and developed by Thomas Saaty at Wharton School of Business in the 1970s (Oktafianto et al., 2018)**;** (Kasap & Subaşı, 2017). This present study generally aims at exploring the implementation and effectiveness of the AHP method in manufacturing and non-manufacturing industries for tackling their real cases. Through a systematic literature review, we are informing researchers and practitioners of the precise information regarding the paradigm of companies or industries in implementing the AHP method.

METHODS

Systematic Literature Review

Webster & Watson (2002) define an effective literature review as something that creates a strong foundation for advancing science (Levy & J. Ellis, 2006). This study employs a systematic literature review method, i.e., a systematic review utilizing tight and explicit criteria for identifying, evaluating, and synthesizing particular topics of literature critically (Cronin et al., 2008). A systematic review relates to the meta-analysis, which summarizes bodies of literature into a single comprehensive paper (Bolderston, 2008). Therefore, it can provide a reliable summary and description of the pieces of evidence in a specific field (Bolderston, 2008). Parahoo (2006) explains that a systematic review must elaborate time framework of which the literature is selected. Besides, it must elaborate on the method to evaluate and synthesize research findings so that the readers can assess the reliability and validity of that review (Ramdhani et al., 2014). Criteria used in a systematic literature review can be seen in the figure as follows:

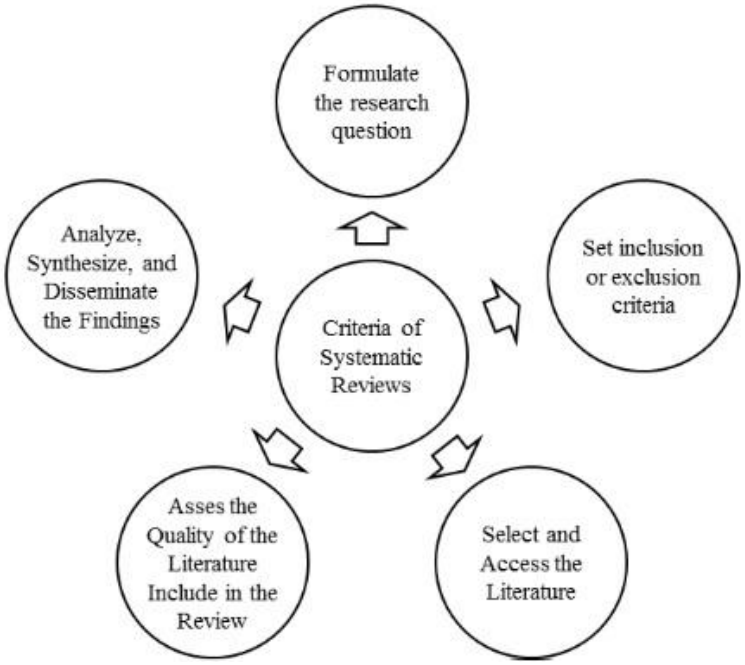

Figure 1. Criteria in a systematic literature review
Source: (Ramdhani et al., 2014)

The following is the explanation of systematic literature review criteria using AHP method utilized in this study:

1. *Formulate the research questions*
   We formulated questions related to the AHP method in this present study. The problems to be analyzed were selected from the entire problems, which were considered essential and complicated. This problem selection requires a particular analysis. The problems formulated in this present study include a) what is AHP? b) how is AHP used in the manufacturing industry? and c) how is AHP used in the non-manufacturing industry?
2. *Set inclusion or exclusion criteria*
   The criteria of the previous relevant works of literature to be selected in this study are as follows:
   a) Related to the AHP concept and AHP implementation in manufacturing and non-manufacturing industries.
   b) Published in journals from 2000 until 2020. Other publications, such as news reports, books, and book reviews, are exuded in this study.
3. *Select and access the literature*
   This step was conducted by collecting journal articles from some websites, namely, Elsevier, Researchgate, and Science Direct. The keywords used for finding journal articles include AHP in manufacturing and non-manufacturing industries.
4. *Assess the quality of the literature included in the review*
   Subsequently, we manually selected the literature to obtain the relevant papers. These papers must undoubtedly have a relationship with AHP. We acknowledge that there might be other relevant journal articles overlooked in the selection process. From this selection, we obtained 101 papers, which include: 24 journal articles related to AHP in the manufacturing industry, and 54 of them related to AHP in the non-manufacturing industry. We also obtained 23 journal articles outside those two industries but related more to the literature of AHP.
5. *Analyze, synthesize and disseminate the findings*
   The next step conducted was to review the selected literature. The relevant journal articles were mapped into two categories, namely, AHP in manufacturing and non-manufacturing industries using Microsoft Excel software. This mapping technique helps us differentiate different AHP methods in both industries. This process was conducted to answer the research questions and identify the information useful for further AHP studies.

Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is a Multi-Criteria Decision Making (MCDM) system that is most commonly used primarily in operation management (Vaidya, 2006); (Abdullah et al., 2013); (Phudphad et al., 2017);(Gupta et al., 2015). This AHP method is used to help many decision-makers in companies and government bodies for making the right decisions (González-Prida et al., 2012); (Ivanco et al., 2017). AHP was developed in 1970 by Thomas Saaty (Bhola et al., 2017). AHP method provides a facility to breakdown complex problems by ranking them hierarchically into criteria, sub-criteria, and alternatives. AHP also allows us to calculate and compare the competing alternative variables as well as give weight to each criterion, followed by scoring, which is an impact of the criteria in the decision (González-Prida et al., 2012); (De Luca et al., 2020). According to (Saaty, 1990), to make the right decision, a decision-maker has to know and identify problems, goals, criteria, and sub-criteria for evaluating the alternatives.

Steps in the Analytical Hierarchy Process

According to (Russo & Camanho, 2015), six phases need to be undertaken in the AHP method, namely,

1. *Define the problem and determine the kind of knowledge sought*
   Of the entire problems selected, in this research, we picked only those with high complexity to be further

analyzed. Then, we determined the criteria as all as their sub-criteria for all the stakeholders.

2. *Structure the decision hierarchy*

This structure is built from the top (goal of decision), going to the middle (criteria) until the bottom (sub-criteria and alternatives). Conceptually, we can access the correlated problems after determining the main goals so we can find solutions, either using the top-down (from criteria to alternatives) or the bottom-up (from alternatives to criteria) approaches. This mechanism is shown in Figure 2 as follows.

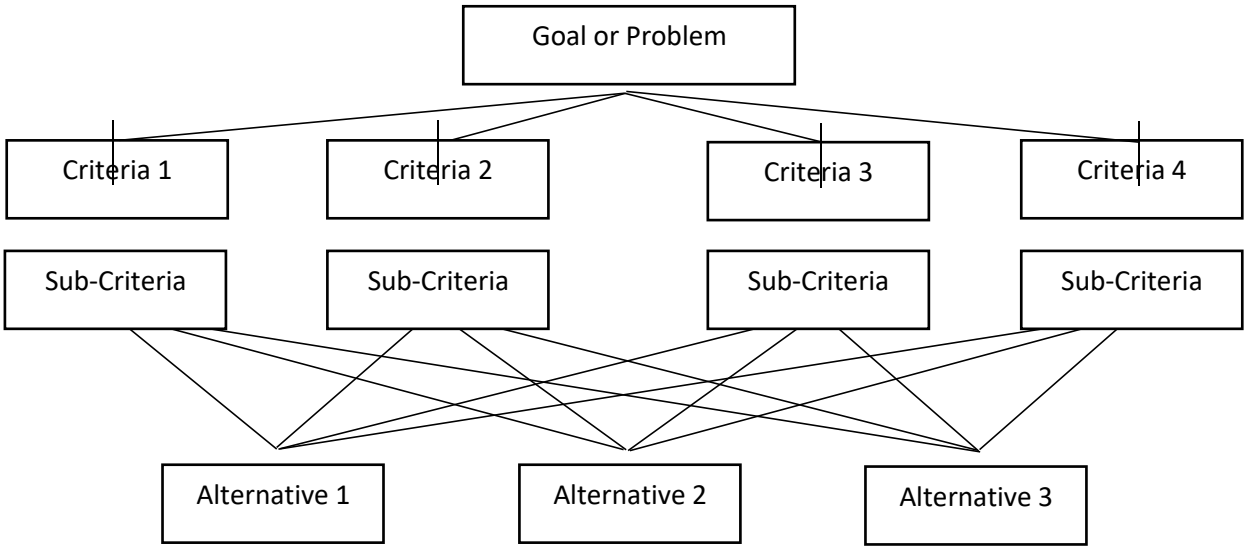

Figure 2. Hierarchical structure based on the AHP method

3. *Construct matrices to calculate a set of pairwise comparison*

Comparison is conducted through scale, demonstrating, "how many times or how dominant is an element as compared to other elements related to the compared criteria or property. A verbal scale is used to measure either quantitative or qualitative criteria. The scale ranges from "the same" (Number 1) until "extremely more important than" (Number 9). Paired-matrix comparison is filled using numbers to represent the relative importance of an element to other elements.

Table 1. Scale of Comparison

Intensity of Importance	Verbal scale
1	Both elements are equally important
3	One element is slightly more important than the other
5	One element is essential and slightly important than the other
7	One element is more important than the other
9	One element is absolutely more important than the other
2,4,6,8	Values of the two elements being compared are close to each other

4. *Calculate the relative weight of the elements to each level*

In this step, we made a formulation to calculate the value of each criterion included in a matrix by priority implementation and alternative comparison. The best alternative has the highest value (priority). According to (Saaty, 1990), the procedures in AHP include:

a) The comparisons of the paired comparison are synthesized to obtain the overall priority. It can be done by conducting the steps as follows:
   - Adding the values of each column in the matrix.
   - Dividing each value in the column by the total value of the respective column to obtain the normality of the matrix.
   - Adding values of each row and dividing them by the number of elements to obtain the average value.

b) Measuring consistency of decision making. Knowing this consistency is essential because a good decision does not result from the considerations with low consistency. The things that can be done here are as follows:
   - Multiplying each value of the first column by the relative priority of the first element. It also goes for the rest of the column.
   - Adding the value of each row.
   - That value is then divided by the respective value of the relative priority element.
   - Adding the result of that division with the number of elements. The obtained value is called λ max.

c) Calculating Consistency Index (CI) using the following formula:

$$CI = (\lambda \max - n) / n$$

Given,

n = number of elements.

F. Calculating Consistency Ratio (CR) using the following formula:

$$CR = CI / IR$$

Given,

CR = Consistency Ratio

CI = Consistency Index

IR = Index Random Consistency

d) The List of Index Random Consistency (IR)

Table 2. The List of Index Random Consistency (IR)

Size of Matrix	Random Consistency

1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

e) Checking Hierarchical Consistency

If the value is more than 10%, the assessment of judgment data must be improved. However, if the consistency ratio (CI/IR) is less or the same as 0.1, the calculation result is said to be correct.

5. *Check and balance of decision*.

This phase is essential to check whether the hierarchy is consistent or not. If it is found to be inconsistent, the data assessment should be improved under the expectation of decision-makers or stakeholders.

6. *Decision documentation.*

It is essential to record all the reasons supporting the ways and reasons why a decision is made. The records can provide guidance or assistance for process justification to the third party so that it can be reflected in the future.

ANALYSIS

Selected Articles

This section discusses seventy-eight articles related to the method and statistical data. Those articles are analyzed descriptively to answer the problems formulated in this study. All journal articles in this study are about the evaluation of specific real cases using the AHP method. As an exception, twenty-three journal articles are utilized to support our understanding of the related method.

The seventy-eight selected articles are shown in Figure 3. Figure 3 demonstrates that the studies on AHP increased since 2007, indicating that the use of this method increased every year. Although it decreased in 2009, the use of the AHP method generally showed an increasing trend from 2010 until 2020. It also shows that the use of AHP has been widely accepted from time to time.

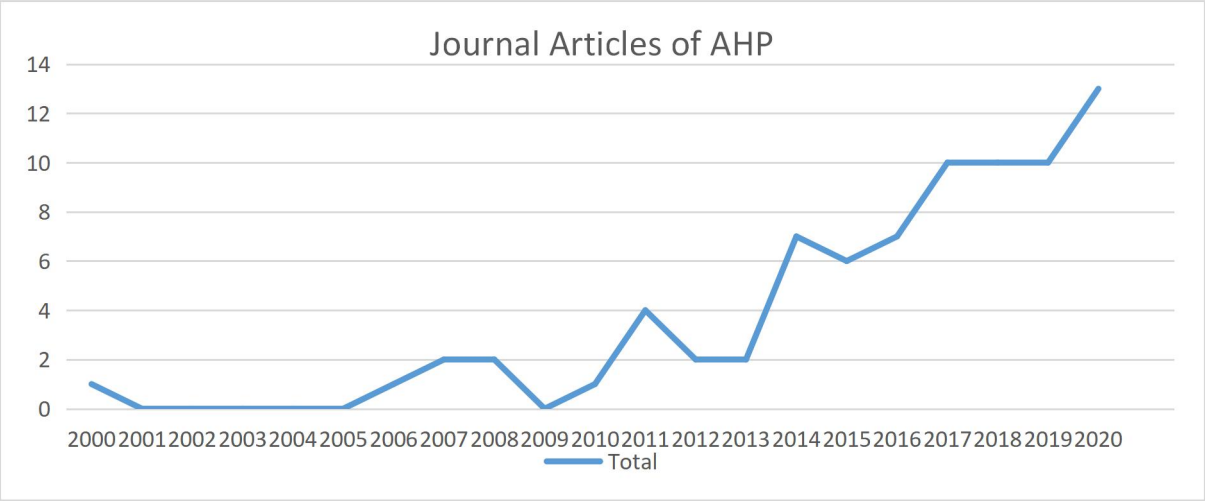

Figure 3. Journal classification based on the year

Development of AHP per period

All journal articles that we study are categorized based on year, namely, period 1,2,3, and 4.

a. Period 1 is for the journal articles published from 2000 to 2005. Here, we find one article using AHP. The AHP method is implemented in selecting a construction firm in the construction industry. Eight criteria are taken by the stakeholders to compare several contracting firms as a result of the ranking process. In this period, the AHP method is used using a manual approach without any software of data processing (Fong & Choi, 2000).

b. Period 2 demonstrates that AHP has successfully been conducted in various work frameworks, such as human resource management (HRM), technology (ICT), health, and construction (Islam & Rasad, 2006); (Gerdsri & Kocaoglu, 2007); (Tan et al., 2007); (Burhanuddin et al., 2010). AHP can also be combined with other methods, such as Fuzzy Logic and Delphi (Ierace & Cavalieri, 2008); (Gerdsri & Kocaoglu, 2007)

c. Period 3 explains that AHP has several drawbacks. Several journal articles developed AHP with other supporting systems, such as Decision Support System (DSS). DSS can maintain data in the database and recall information at any time. Web-based DSS can simplify and reduce data acquisition time, as compared to the paper-based reporting system that people use these days (Burhanuddin et al., 2010). In their study, (Sandeep et al., 2011) discuss problems in selecting suppliers. They utilize AHP only for obtaining weights of the criteria, and the next step is handled using Grey Relational Analysis (GRA) method. Hence, a much better decision can be obtained.

d. Period 4 discusses the AHP method with a combination of web-based software commonly used in the data processing. Expert Choice is software that simplifies the implementation steps of the AHP method in processing criteria data for conducting a paired-comparison (Eskander, 2018); (Phudphad et al., 2017); (Doheim et al., 2016); (Piri et al., 2019). Besides, AHP is commonly combined with GIS

method in selecting geographical-based locations (Piri et al., 2019); (Kazakis et al., 2015); (Seejata et al., 2018); (Arshad et al., 2020); (Lentswe & Molwalefhe, 2020).

Analytical Hierarchy Process in Manufacturing Industry

Of the entire articles studied in this research, we obtained 24 journal articles used the AHP method in the manufacturing industry.

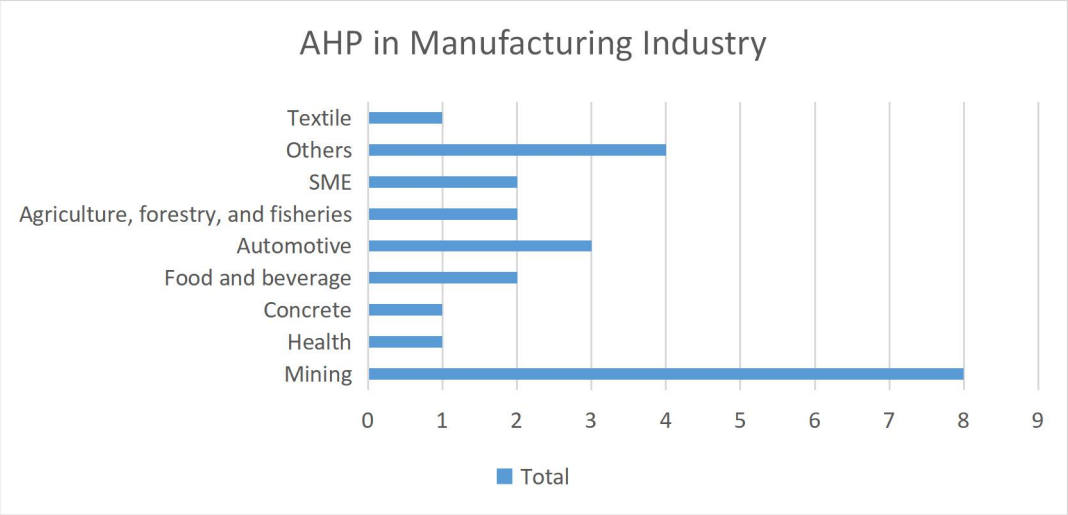

Figure 4. Journal Article Classification based on Manufacturing Industry

In the category of manufacturing industry, we can see that AHP is implemented in various industries. The mining industry is the industry that utilizes AHP method the most (Jianqing Zhang, 2011); (Chao-nan et al., 2011); (Rahimdel & Ataei, 2014); (Gupta et al., 2015); (Kasap & Subaşı, 2017); (Chen et al., 2017); (Kolahi et al., 2018); (Eriyeti et al., 2019). Several studies have implemented AHP within that industry. As an example, coal firms utilized the AHP method to measure the operational risks of employees working at the coal production site (Kasap & Subaşı, 2017). This sector industry faces various risks, ranging from production until final delivery. In practice, the AHP method can be used to identify the risks that will be faced by workers at an open mining site and assess various risks, including the risk of being infected by a particular disease and having an accident. The risks or exposures considered in production include failure in machinery, fall, broken hand tools, gas leaking, explosion, dusty, broken transportation facilities, vibration, and landslide (Kasap & Subaşı, 2017). Paired-comparison data of various criteria reveal that landslide is the most significant risk at an open mining site with a weight of 24.7%. The subsequent risks include noise and vibration. The risk related to gas is in the lowest category. Measurement result using the AHP method shows that employees become the alternative with a value of 25.3%, meaning that they are the ones facing the highest risk at the coal mining site. AHP is a method that is reliable and comprehensive for evaluating risks at the mining sites (Chao-nan et al., 2011). AHP method can be implemented in making decisions in various aspects, such as making the practical decision at metal mine (Eriyeti et al., 2019), selecting the best and primary crusher at Golegohar steel mine in Iran (Rahimdel & Ataei, 2014), and identifying solution in the implementation of Respiratory Protection Program (RPP) for protecting employees at Petrokimia Indonesia (Kolahi et al., 2018). Besides, AHP is used to determine Human Error factors in electricity procurement (Chen et al., 2017), identify solar panel firms that are aware of Sustainable Manufacture (Gupta et al., 2015), and set the weights of each factor for controlling purpose of a gas mine company (Jianqing Zhang, 2011).

Also, the AHP method is commonly used in the automotive industry (Koç & Burhan, 2015); (B. Li & Chang, 2011); (Pereira et al., 2016). AHP was also used to determine a strategic store location from various store locations (Koç & Burhan, 2015), identify unwanted event or failure of a jet engine (Pereira et al., 2016), and network planning of energy supply in the hybrid car (B. Li & Chang, 2011).

In agriculture, forestry, and fisheries industries, AHP was used to methodologically evaluate the optimum warehouse location (García et al., 2014) and asses compatibility of various shrimp farming technologies with low investment (Zulkarnain et al., 2020),

For SME (small and medium enterprises), AHP was used for strategic maintenance decisions and selecting the construction firm (Burhanuddin et al., 2010) as well as for measuring the implementation of green manufacturing (Singh et al., 2020).

In the health industry, AHP was utilized to determine the suitable location of the Astragalus plantation (Piri et al., 2019). In the industry producing concrete, AHP was used to evaluate the process of concrete-based Additive Manufacturing (AM) (Foteinopoulos et al., 2019).

Furthermore, in the food and beverage industry, AHP was used in selecting a boiler for the soda ash industry (Hasnain et al., 2020) and evaluating operators' performance so that they have an equal production performance (Rani et al., 2014). In the textile industry, AHP was utilized to select suitable technology and suppliers based on twelve factors related to manufacturing technology and supply chain (Mondragon et al., 2019).

In other industries, AHP was utilized in selecting appropriate design concepts and product development of wheelchairs (Ariff et al., 2008). AHP and GRA were also used in selecting suppliers in the pump industry in India (Sandeep et al., 2011). Furthermore, AHP was used to determine the three-input rank that is considered necessary in Single Point Incremental Forming (SPIF) viewpoint (Bologa et al., 2018). AHP contributed

effectively in selecting the most appropriate strategy for equipment maintenance in various industries (Ierace & Cavalieri, 2008).

In the manufacturing industry, AHP is widely used for making decisions, planning, optimization, and location selection. AHP has been an effective supporting system when combined with other methods, such as Weighted Decision Matrix (WDM), Fuzzy Logic, GRA, BBN, Fuzzy AHP, GIS, and TOPSIS. AHP can also be implemented in various software, such as Expert Choice, as can be seen as follows (Piri et al., 2019); (Arshad et al., 2020); (Eriyeti et al., 2019); (Eskander, 2018).

Analytical Hierarchy Process in non-Manufacturing Industry

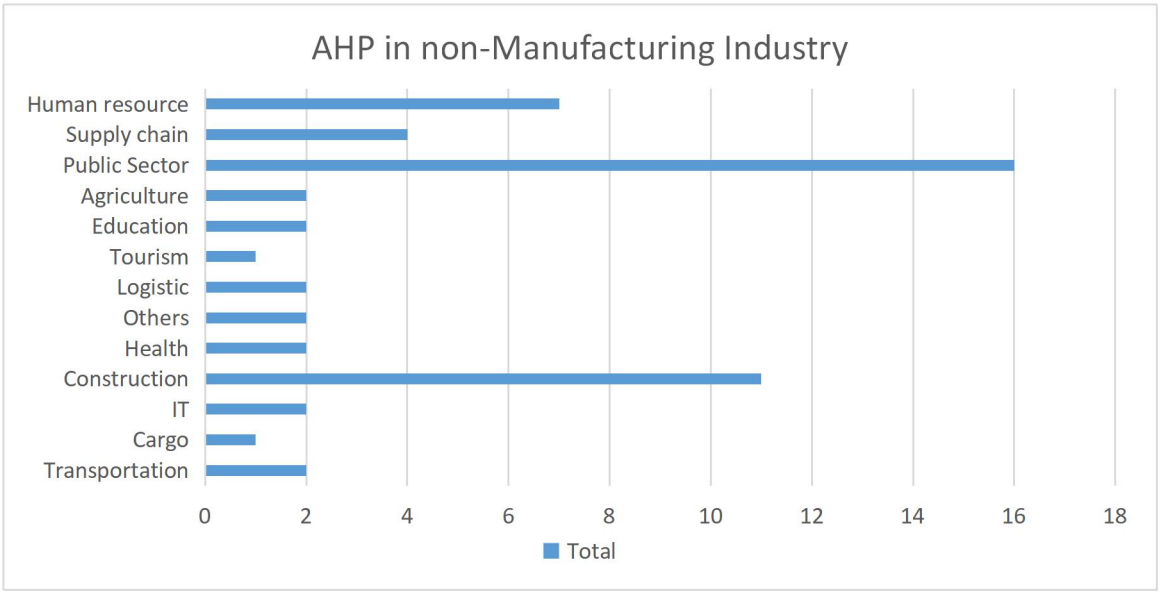

Figure 5. Journal Article Classification based on non-Manufacturing Industry

From the comparison result of the journal articles in this study, we find that AHP has been one of the effective decision making systems in the non-manufacturing industry. The journal articles in the non-manufacturing industry consist of 54 articles. Statistical data evidence that AHP is widely used in public sector institutions. Thailand's government utilized the AHP method combined with Geographic Information Systems (GIS) in determining the causes or factors that contributed to flooding in that country. Through those two methods, the government could find out the locations that were prone to flooding (Seejata et al., 2018). Italy also used AHP to identify the areas prone to flooding (Kazakis et al., 2015). In the study of (Doheim et al., 2016), AHP was used to collect the assessment results for selecting architectural design in the construction of Natural Smoke Ventilation (NSV) and Natural Thermal Ventilation (NTV). The criteria from firefighters and construction engineers were processed to obtain an effective result. In Austria, Vienna government utilized AHP to determine various locations and the studies using this approach were implemented in each decision making process for determining the right locations (Anderluh et al., 2020). AHP was also used to analyze the vulnerability status of water resource system in Rawalpindi and Islamabad (Shabbir & Ahmad, 2016). AHP was utilized to determine the best locations in Seremban City, Malaysia (Aburas et al., 2017), while in Taiwan, AHP was used to determine and rank the criteria affecting Social Education (SE) Energy saving and carbon reduction (ESCR) (Tung et al., 2014). AHP was once used to analyze the risks in the tunnel construction project in China, primarily related to the risks construction project (Shuping et al., 2016). Indonesian government utilized AHP for developing new software in the context of e-government with the criteria consisting of personnel, requirement, organization, business, operation, and technology. The alternative methods for developing software include Waterfall, Incremental, Prototyping, Extreme Programming, Scrum, and Rational Unified Process. The results showed that prototyping was the most appropriate method for developing software in the Ministry of Foreign Affairs (Helingo et al., 2017). AHP was used to determine the weights of priority factors in the project of pavement and road maintenance in Mumbai India (Ahmed et al., 2017). In addition, AHP was used in India to rank the road safety, facilitating the decision makers to determine the locations to be improved (Agarwal et al., 2013). Another implementation of AHP in Indonesia was the measurement of urban population in facing the risks of earthquake (Jena et al., 2020). In England, AHP was used to evaluate international location decision among corporations undertaking business expansions (Atthirawong & Maccarthy, 2014). In a Polish journal, AHP was used to make decision for assessing residential ground plot (Dmytrów & Gnat, 2019).

In addition to being implemented by government and construction firms, AHP was embraced by firms in the human resource field. Several firms successfully utilized AHP in measuring risks, ranking the criteria, and making decisions. Works of literature show that AHP was successfully utilized in making lay-off decisions among firms. AHP method facilitates companies to rank criteria and set weights in each alternative affecting lay-off decisions (Oktafianto et al., 2018).

Furthermore, AHP was used as a supporting decision in evaluating employee performance at some firms. (Islam & Rasad, 2006) explain that the AHP method can be easily

implemented by companies and can accommodate several decision-makers in evaluating employee performance. Other studies confirm that AHP was used to identify and prioritize employee motivation dimensions (Sekhar et al., 2016); determine rank indicators of human resources in Malaysia (Abdullah et al., 2013); learn safety factors of human resource information system and explore the significances of those factors in affecting working climate (Phudphad et al., 2017); and assess employee performance (Santony et al., 2019).

AHP was adapted by e-commerce companies in the development of website quality, primarily in measuring the service quality of the website, which is called as AHP-WEBQUAL (AHP-WQ) (Pathania & Rasool, 2017). That study tries to measure customer assessment on various criteria determining website service quality. Besides, that study explores customer preference for the existing e-commerce website. Among all dimensions of WEBQUAL 4.0, Indian customers perceived that usage aspect as the most critical dimension of website quality, followed by information quality and interaction quality. That study contributes to the practitioners and academics by proposing novel application AHP in measuring website service quality of some e-commerce companies. AHP was also proven to be successful in evaluating the impact of technology on the attainment of organizational goals (Gerdsri & Kocaoglu, 2007).

AHP is a method with various implementations. In the health environment, AHP was used to rank particular ice creams to diabetic patients. Those three ice creams in that study are Vanilla Breyers Homemade, Breyers Vanilla, and Ben & Jerry Butter Pecan. The considered criteria in selecting the ice cream are sugar, protein, cholesterol, and fiber, which are the ingredients of the ice cream. The results of AHP demonstrate that Ben & Jerry Butter Pecan is enriched by the four criteria, followed by Brayers vanilla and Brayers Homemade vanilla (Gaikwad et al., 2015). Besides, AHP was once utilized as a method in selecting optimum USG equipment (Marciano et al., 2018).

In a journal article, AHP was used in the construction industry in optimizing ready-mix concrete for construction. That paper tries to classify, investigate, and rank the causes affecting the productivity of the batch plant. For obtaining the results, the researchers in that study invited experts to answer several questions in the questionnaire. The considered causes that were more effective were identified in the batch plant. In total, forty-five (45) related causes were classified into five (5) main groups (Abdel Khalek et al., 2018). In several journal articles, AHP was used in the construction industry for selecting construction companies; determining locations; and deciding customer priority (Wei et al., 2020) (Arshad et al., 2020), (H. Li et al., 2018), (Rochikashvili & Bongaerts, 2016), (Reisi et al., 2018), (Fong & Choi, 2000), (Eskander, 2018) (Erdogan et al., 2017) (Chiang et al., 2017) (Jabbarzadeh, 2018) (Anjomshoae & Hassan, 2019) (Ramadhani & Handayati, 2020).

Furthermore, another study identified public and expert perspectives on large-scale PV solar systems using AHP. The three-level AHP was developed for prioritizing the factor weight affecting investment and installation of that large-scale PV solar system. The AHP model involves six main criteria, namely, financial, technological, political, social, environmental, and safety criteria. That study analyzes AHP results in Japan and the Malaysian context by comparing results in the two countries for observing public and expert perceptions of the system. From the AHP analysis, it was observed that investment and installation of solar PV in Japan consider financial factor as the most important one with a score of 28.7 percent, followed by safety (19.7 percent) and political factor (16.3 percent).

Meanwhile, Malaysia showed more attention to the safety factor with a score of 20.5%, followed by financial factor and political factor of 18.5 percent and 18.2 percent, respectively. The assessment in that analysis benefits decision-makers in stipulating the long term policies for promoting solar PV and renewable energy in general (Huda et al., 2017).

In the logistic sector, AHP was used as a method for evaluating firm performance and analyzing the risk of logistics warehouse fires (Jiansheng Zhang & Tan, 2012), (Shaoyun, 2012). In transportation, AHP was used to test and rank particular factors that were considered essential by passengers in urban areas of the Philippine (Mayo & Taboada, 2020) and Italy (De Luca et al., 2020)in selecting public transport. AHP was used for assessing risk factors and alternatives in the supply chain, analyzing supply chain, and proposing the new design method of the supply chain. Thus, it allows an organization to utilize its resources and arrange supply chain drivers to attain responsive level and wanted efficiency (Badea et al., 2014), (Tramarico et al., 2015), (Al-Husain & Khorramshahgol, 2020).

Furthermore, in the tourism sector, AHP was used to assess and evaluate self-ability by determining priority levels of core competency and competency indicators empirically, which are essential for international MICE professionals with an English fluency (Tang, 2014).

In a study using the cargo industry case, AHP was used to evaluate transport route variants. That study confirmed the suitability of the multi-criteria method based on the AHP approach for determining the best transportation routes, such as those used for large cargoes in the city of Szczecin (Poland). The departure point and destination point for large cargoes in the city of Szczecin were chosen based on the available data on the condition of road and tram infrastructure, as well as ongoing engineering projects. Three alternative routes for transporting large cargoes were chosen according to this assumption. The results from the AHP method and the developed tree hierarchy show that the highest general priority is achieved by the T3 route (0.6750), which means that this is the most preferred route for transporting huge cargo through the city of Szczecin. Transporting large cargo via this route will have the lowest impact on the quality of life of city dwellers, reducing congestion and urban green areas, as well as road infrastructure. Also, another important thing is that it will ensure the safety of people in the city. The solution to the problem of large cargo, as proposed in this study, produces not only a methodological dimension derived from the modification of the AHP method but also a practical dimension. The results show that there is a single licensed operator that verifies and confirms the selected cargo routes. The criteria system adopted depends on the city size, geographical location, communication links, and many other factors that can change dynamically. Therefore, it is essential to verify this system in other cities in order to create the sub-criteria, which better reflects the criteria (Wolnowska & Konicki, 2019).

In a study using the agriculture sector, the AHP method was used to select the best tractors in Ghaemshahr and

Ahvaz, Iran. In that study, a descriptive-analytic approach was used. The data were collected using a literature review and interview through questionnaire dissemination. The population of the study consists of 25 tractors in the two cities, whereby the 15 of them were randomly selected to be further analyzed using AHP. Research results show that the most significant factor for selecting a tractor is the maintenance aspect (49.4 percent), while the least significant one is the ergonomic aspect (7 percent). The selection of tractor matters substantially for the users in the two cities. The findings of the study confirm compatibility among criteria, purposes, and options (Amini & Amin, 2016). Meanwhile, in the spare part industry, AHP was used to measure the effectiveness of couriers for distributing spare parts made by PT Mitra Bisnis (Ismoyo, 2019). In another industry, AHP was used for selecting the best marketing strategy (Al-dawalibi et al., 2020). AHP was also implemented in ranking each relative parameter of groundwater recharge (Lentswe & Molwalefhe, 2020)

In the educational sector, AHP was implemented as a method for evaluating the student learning process (Sudaryono et al., 2020). In another journal article, AHP was used to understand knowledge status, behavior, and practice regarding HIV/AIDS among different groups in order to provide pieces of evidence in health education (Tan et al., 2007).

FINDING

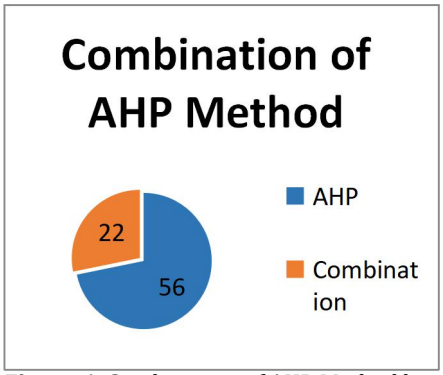

Figure 6. Combination of AHP Method based on Journal Article

Of the seventy-eight journal articles implementing AHP in manufacturing and non-manufacturing industries, it was found that twenty-two cases used AHP combined with other methods. This finding evidences that in a particular condition, AHP needs to be combined with other methods in order to gain maximum results.

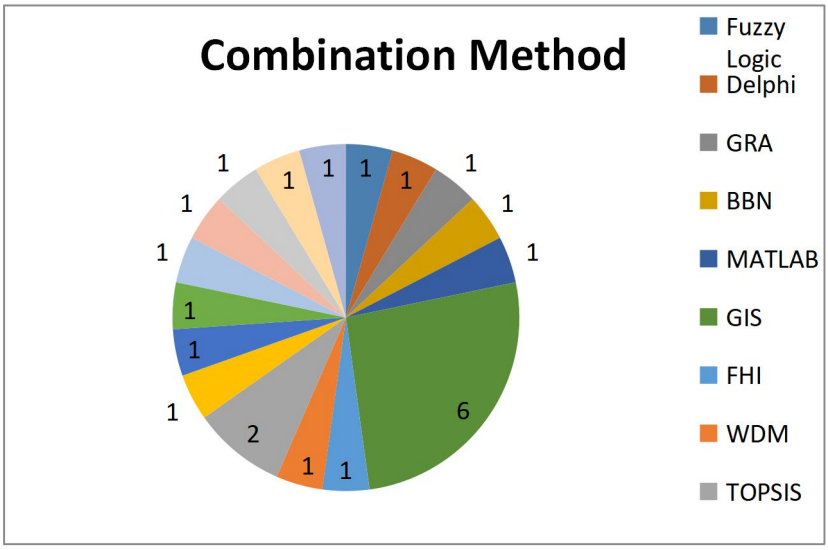

Figure 7. Classification of the Combination Method

Of the twenty-two cases combining AHP with other methods, we find that GIS (Geographic Information System) is the method that mostly combined with AHP. As an example, AHP was combined with GIS in selecting the appropriate area for planting Astragalus. The criteria obtained using the GIS method consisted of six, namely rainfall, temperature, slope, height, texture, and soil orientation. Furthermore, AHP was applied to process predetermined criteria (Piri et al., 2019).

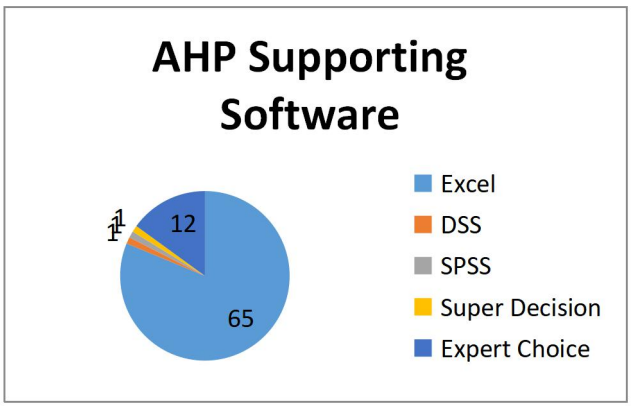

Figure 8. Classification of AHP Supporting Software

Finally, of the seventy-eight articles using AHP, we find that Expert Choice, DSS, SPSS, and Super Decision are the

most used software, as shown in Figure 8. Microsoft Excel was utilized in the classification. In the last period, we find that twelve articles use Expert Choice software for determining criteria, alternatives, and data processing.

CONCLUSION AND RECOMMENDATION

Conclusion

This systematic literature review shows a heterogeneous description of AHP implementation in both manufacturing and non-manufacturing industries. We find that there is an urgent need for each industrial issue applying the AHP method because, among the twenty-two cases in various industries, AHP was combined with other methods for perfecting the results. If not, the researc results would not be consistent.

We explain that AHP is based on a hierarchical structure and embedded criteria. If stakeholders utilize an inappropriate assumption, they will find bias results. Hence, the AHP hierarchy must not only rely on a single information source, but also other methods, such as GIS. As technology progresses, AHP was implemented in various software; one of them is Expert Choice. There are twelve journal articles in this study, applying AHP with Expert Choice software. This software helps the implementation of AHP to be easier and more precise.

Recommendation

Even though AHP can be used in numerous companies, this method is often complemented with other methods in order to attain organizational goals better. Additionally, it is possible to have a modified AHP, combined with other tools or techniques under the companies' needs. Specific further studies on this matter, therefore, are needed, and primarily related to other sectors not covered in this present study. That further studies may profoundly and more accurately investigate the determination of effective methods in assisting criteria determination in AHP.

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