INCITEST 2020

The 3rd International Conference on Informatics, Engineering, Sciences & Technology

UNIVERSITAS KOMPUTER INDONESIA
UNIKOM

"Humanized Technology : The Digital To Win Competition"

PROCEEDING

UNIKOM International Conference on Informatics, Engineering, Sciences & Technology (INCITEST) 2020

PAPER • OPEN ACCESS

Preface

To cite this article: 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **879** 011001

View the article online for updates and enhancements.

PREFACE

It is our great honor and pleasure to introduce the Proceedings of the 3rd International Conference on Informatics, Engineering, Science, and Technology (INCITEST 2020). The event is valuable and meaningful since it brings together scientists, engineers, researchers, practitioners, students, and civil society organization representatives to nurture research networks between universities and industries. With its main theme on "Humanized Technology, the Digital Journey to Win Competition", this event is expected to serve as a platform of gathering for anyone interested in exploring potential solutions and answering issues and challenges to enter the 5.0 society. Amid the worldwide spread of the novel coronavirus (COVID-19) and the uncertainty surrounding the end of this pandemic, there are several issues we should describe as follows:

1. Universitas Komputer Indonesia (UNIKOM) as the organizer of INCITEST 2020 will hold the conference on 11th June 2020 in an online or virtual format. The organizing committee will manage the conference from our campus which is located in Bandung, West Java Province, Indonesia.

2. In this correlation, we should adhere to the regulation of the government of West Java Province and the government of the Republic of Indonesia which currently is implementing Large-Scale Social Restrictions to reduce the risk of virus transmission. Therefore, the online conference is considered the best way we can do to serve our participants concerning the fact that people safety is second to none. In this condition, there is no specific date deemed safe to which we could postpone the conference until either worldwide travel or crowd-gathering is safe again. We have all put so much effort in preparing the papers, organizing the event, as well as conducting the review process, working on the program, and everything surrounding it that we feel very motivated to pull this through

3. The conference is divided into two sessions: plenary and parallel sessions. In the plenary session, we will use zoom as the media. Besides, to assure the dissemination of the conference to all participants, we will also broadcast the plenary session live using Open Broadcaster Software (OBS) connected to

YouTube live streaming and IG TV. Moreover, we will use live chat on YouTube and Google forms for the discussion session.

4. The plenary session will be chaired by one moderator who will not only be critically summarizing the keynote presentations but also handling participants' enthusiasm in asking any possible questions. In doing so, the participants will be following the conference at their respective personal corners through YouTube live streaming and IG TV.

5. The plenary session will be presented by our keynote speakers in online format (via Zoom) from each country such as Prof. Abdulkareem from Malaysia, Prof. Yuto Lim from Japan, and Irfan Dwi Sumitra, Ph.D. from Indonesia. Each keynote has 45 minutes duration including the discussion session.

6. Following the success of INCITEST 2018 and 2019, the enthusiastic responses to the call-for-papers in the third INCITEST were increasing. More than 450 papers were submitted to the organizing committee from both local and foreign participants. A peer-review process has been conducted to all the articles based on their originality and quality, resulting in 347 accepted papers to be presented.

7. Of 347 accepted papers, 216 of them will be presented via Zoom in the duration of 10 minutes for each paper. Additionally, 129 papers will be displayed in the poster session (the link of the posters will be available on the INCITEST website).

8. The parallel session will be divided into 10 classes; each class will be participated by around 21 to 22 presenters. A parallel session chair will manage the presentation time and discussion session in each class. Each presenter should present their paper within 5 minutes via Zoom. 5 minutes after the presentation will be given to each of them for the discussion session.

We hope that with the above arrangement, we can serve our participants in the best way we could. The conference's success is also due to the hard work of all involved parties. Therefore, the organizing committee would like to express appreciation to all supporters, sponsors, and participants for a great contribution to

the conference's success. Many thanks go as well to all of the reviewers who helped us maintain the quality of manuscripts included in the Proceedings published by IOP. We also express our sincere thanks to the members of the organizing team for their hard work.

Finally, our continuing success of this conference series can be one of indicator that we have through our right pathway to realign technology with the best interests of humanity. We hope this first time experience of the online conference in the 3rd INCITEST will bring fruitful outcomes as well as give the participants great experience in an online conference.

Thank you

Best Regards,

Dr. Poni Sukaesih Kurniati, S.IP, M.Si.

The Chief of the Conference

PAPER • OPEN ACCESS

List of Committees of INCITEST 2020

To cite this article: 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **879** 011002

View the article online for updates and enhancements.

LIST OF COMMITTEES OF INCITEST 2020

Organizing Committee:

1. Dr. Lia Warlina.
2. Dr. Poni Sukaesih Kurniati, S.IP., M.Si.
3. Bobi Kurniawan, S.T., M.Kom
4. Senny Luckyardi, S.P

Advisory Board & Scientific Committee:

1. Dr.Phil Michael Grosch – Karlsruhe Institute of Technology KIT, Germany
2. PD Dr. Andreas Ufen – German Institute of Global and Area Studies, Germany
3. Prof. Hiroyuki Iida – Japan advanced Institute of Science and Technology
4. Ryuhei Uehara, Ph.D – Japan Advanced Institute of Science and Technology
5. Dr. Eng. Farid Triawan – Tokyo Institute of Technology, Japan
6. Prof. Rongtau Hou – Nanjing University Of Information Science and Technology, China
7. Prof. Tinghuai Ma – Nanjing University of Information Science and Technology, China
8. Assoc. Prof. Bing Han- Xidian University, China
9. Assoc Prof M. Roil Bilad – Universiti Teknologi Petronas, Malaysia
10. Assoc Prof. Zulfan Adi – Universiti Teknologi Petronas, Malaysia
11. Assoc. Prof. Dr. Masnizah Mohd – University Kebangsaan Malaysia
12. Dr. Nordin Abu-Bakar- Universiti Teknologi Mara (UiTM) Malaysia
13. Prof. Nursuriati Jamil-Universiti Teknologi Mara (UiTM) Malaysia
14. Assoc. Prof. Dr. H. Eddy Soeryanto Soegoto – Universitas Komputer Indonesia
15. Dr. Ir. Herman S – Universitas Komputer Indonesia
16. Dr. Yeffry Handoko Putra – Universitas Komputer Indonesia
17. Dr. Andi Harapan, M.T – Universitas Komputer Indonesia
18. Dr. Dhini Dewiyanti Tantarto, M.T – Universitas Komputer Indonesia
19. Dr. Henny, ST.,M.T – Universitas Komputer Indonesia
20. Dr. Salmon Priadji Martana, ST.,M.T – Universitas Komputer Indonesia
21. Dr. Y. Djoko Setiarto, ST.,M.T – Universitas Komputer Indonesia
22. Irfan Dwiguna Sumitra, M.Kom., Ph.D – Universitas Komputer Indonesia
23. Dr. Ade Gafar Abdullah – Universitas Pendidikan Indonesia
24. Dr. Eng. Asep Bayu Dani Nandiyanto – Universitas Pendidikan Indonesia
25. Syeilendra Pramuditya, PhD – Institut Teknologi Bandung, Indonesia
26. Prof. Dr. Norita Md Norwawi- Universiti Sains Islam Malaysia
27. Prof.Dr.Setyawan Purnama,MSi – Universitas Gadjah Mada
28. Dr. Sandra Sukmaning Adji – Universitas Terbuka

PAPER • OPEN ACCESS

Peer review statement

View the article online for updates and enhancements.

Peer review statement

All papers published in this volume of *IOP Conference Series: Materials Science and Engineering* have been peer reviewed through processes administered by the proceedings Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

Industrial Engineering

Design Models for Estimating Customer Volume Based on Competitors

I Andriana, H Henny, C M Saputra and D Darmawan

Open abstract   View article   PDF

012177

Designing Universal Smartphone Case with Solar Powered Chargers

H Henny, D Purwadi, H Hardianto and O Widilestariningtyas

Open abstract   View article   PDF

012178

Design for Human Safety and Health in Manufacturing System

H Henny, A Jaelani, H Haryanto and I Andriana

Open abstract   View article   PDF

012179

Database Design for Distribution Simulation Game

A Santosa, A M Rinaldy and D Andriani

Open abstract   View article   PDF

PAPER • OPEN ACCESS

Maintenance Strategy Selection in Spinning Mills Industry Using Fuzzy AHP

View the article online for updates and enhancements.

Maintenance Strategy Selection in Spinning Mills Industry Using Fuzzy AHP

Gabriel Sianturi[1*], Agus Riyanto[2], Racka Maulana[3]

[1,2,3]Industrial Engineering Department, Universitas Komputer Indonesia, Jalan Dipatiukur 112-116 Bandung, Indonesia

Email: *gabriel.sianturi@email.unikom.ac.id

Abstract. The aim of this paper is to develop a multi-criteria decision making based on the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) to select the best maintenance strategy for a spinning mill industry. The maintenance process can enhance reliability, quality of the products, cost, and other aspects. Therefore, the selection of appropriate maintenance strategies is a critical issue for manufacturers. Fuzzy AHP approach is proposed as the selection problem includes uncertainties and difficulty in evaluating alternatives and criteria with definite expressions. The process of decision making involves the comparison of three alternatives of feasible maintenance strategy which are corrective maintenance, periodic maintenance, and predictive maintenance. Each alternative is evaluated against criteria according to the priorities of the decision-makers. The criteria are feasibility, cost, reliability, safety and production quality. The result shows that reliability is the most important criterion with the weight of 0.309, followed by safety (0.235), quality (0.193), cost (0.190), and feasibility (0.074). Periodic maintenance has the highest alternative with a total score of 0.423 and it is ranked first, predictive maintenance is ranked second with a score of 0.355, and corrective maintenance has the lowest rank with a score of 0.222. According to the results, periodic maintenance is chosen as the best maintenance strategy. Finally, the proposed method is successfully applicable in maintenance strategy selection.

1. Introduction
In today's competitive manufacturing environment, maintenance plays a significant role in production activities. Maintenance is the set of all activities meant to keep a system into a condition where it can perform its function [1]. Machine failure may cause various business problems such as failure to meet delivery dates, poor product quality, loss of industrial reputation, loss of profit and opportunity [2]. The selection of appropriate maintenance strategies is an important task for a manufacturing firm as a maintenance strategy can highly affect the manufacturing expenditures. Maintenance costs can reach 15 to 70 percent of total production costs, varying according to the type of industry [3].

A large number of studies have been devoted to select a maintenance strategy. In the literature, Muinde *et al* proposed the Analytical Hierarchy Process (AHP) for selecting maintenance strategy in the cement industry [2], while Bevilacqua and Braglia have described an application of AHP for selecting best maintenance strategy in an oil refinery industry [3]. Shyjith *et al* and Kirubakaran described the use of a combination of AHP and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to select an optimum maintenance strategy [4,5]. Narges Hemmati *et al* proposed a fuzzy-ANP approach [6] while Mahdi Bashiri *et al* proposed a fuzzy interactive linear assignment method for selecting maintenance strategy [7].

The purpose of this paper is to focus on the use of Fuzzy Analytic Hierarchy Process (Fuzzy AHP) method to select the best maintenance strategy for a spinning mill company and help decision-makers to select the best one. Fuzzy AHP is the extension of the Analytic Hierarchy Process. By using Fuzzy AHP, the uncertainty and imprecision associated with the decision maker's perception in the conventional Analytic Hierarchy Process can be reduced.

2. Method

Fuzzy Analytic Hierarchy Process (Fuzzy AHP) method is the combination of the Analytic Hierarchy Process (AHP) and the fuzzy set theory. The Analytic Hierarchy Process (AHP) was firstly proposed by Thomas Saaty [8] has been widely used to solve various multiple criteria decision-making problems. However, due to vagueness and uncertainty in the decision maker's judgment, AHP may be unable to accurately capture the decision maker's judgment. Therefore, fuzzy logic is introduced to reduce the vagueness and uncertainty in conventional AHP and to give a more accurate description of the decision-making process [9].

Fuzzy AHP has been widely applied in the various field for solving Multi Criteria Decision Making problems. For example, Fuzzy AHP was applied for the evaluation and selection of a supplier for a gear motor company [10], for the selection of alternative concepts in the conceptual design phase [11,12], etc. In Fuzzy AHP the linguistic variables used for the judgment of comparison values are expressed into fuzzy numbers. Linguistic variables are variables whose values are not numbers but words or sentences from a natural language. A linguistic variable is generally decomposed into a set of linguistic terms (e.g low, high). Fuzzy numbers are a fuzzy subset of real numbers, representing the expansion of the idea of the confidence interval [13]. In this study for computational simplicity, triangular fuzzy numbers are adopted to characterize the membership function. Triangular fuzzy numbers can be denoted by $\tilde{A} = (l, m, u)$, where l, m and u stands for lower, middle and upper value, respectively, of the fuzzy number $\tilde{A}$.

A fuzzy number $\tilde{A}$ on R would be triangular fuzzy numbers if its membership function $\mu_{\tilde{A}}(x): R \rightarrow [0,1]$ is equal to: [13]

$$\mu_{\tilde{A}}(x) = \begin{cases} (x - l)/(m - l), l \leq x \leq m \\ (u - x)/(u - m), m \leq x \leq u \\ \quad\quad 0, \ x < l, x > u \end{cases} \tag{1}$$

2.1. The steps of Fuzzy AHP

The steps of Fuzzy AHP for selection maintenance strategy are as follows:

Step 1: Forming a committee of decision-makers
A committee of decision-makers from the staff of the company is formed.

Step 2: Determining selection criteria and the alternative maintenance strategies
The decision-makers determine the alternative maintenance strategies and the selection criteria

Step 3: Constructing hierarchy structure
At this step, the decision problem is decomposed into a hierarchy. The top-level of the hierarchy represents the overall goal that is to choose the best maintenance strategy, the intermediate level represents the selection criteria affecting the decision, and the bottom level represents the alternative strategies.

Step 4: Identifying linguistic variables
The linguistic term and linguistic variable are expressed using a triangular membership function.
The linguistic terms and corresponding triangular fuzzy numbers are given in Table 1 [10]

Step 5: Comparing the selection criteria or alternative strategy
Decision-makers compare the selection criteria via linguistic terms shown in Table 1.

Table 1. Linguistic terms and triangular fuzzy number

Saaty's scale	Linguistic terms	Triangular fuzzy numbers
1	Equally important	(1,1,1)
3	Moderately important	(2,3,4)
5	Strongly important	(4,5,6)
7	Very Strongly important	(6,7,8)
9	Extremely important	(9,9,9)
2		(1,2,3)
4	Intermediate values	(3,4,5)
6		(5,6,7)
7		(7,8,9)

Step 6: Constructing pairwise comparison matrix
Pairwise comparison matrix $\widetilde{A}^k$ is shown in equation (2), $\tilde{a}_{ij}^k$ indicates the kth decision maker's preference of ith criterion over j^{th} criterion via triangular fuzzy numbers [10].

$$\widetilde{A}^k = \begin{bmatrix} \tilde{a}_{11}^k & \tilde{a}_{12}^k & \cdots & \tilde{a}_{1n}^k \\ \tilde{a}_{21}^k & \tilde{a}_{22}^k & \cdots & \tilde{a}_{2n}^k \\ \vdots & \vdots & & \vdots \\ \tilde{a}_{n1}^k & \tilde{a}_{n2}^k & & \tilde{a}_{nn}^k \end{bmatrix} \tag{2}$$

Step 7: Aggregating of group decisions
For aggregating group decisions, the geometric mean is used as equation (3):

$$l_{ij} = \left(\prod_{k=1}^{K} l_{ijk}\right)^{1/K}, m_{ij} = \left(\prod_{k=1}^{K} m_{ijk}\right)^{1/K}, u_{ij} = \left(\prod_{k=1}^{K} u_{ijk}\right)^{1/K} \tag{3}$$

where (l_{ijk}, m_{ijk}, u_{ijk}) is the fuzzy evaluation of decision-makers k (k=1,2,3,....,K)

Step 8: Updating pairwise comparison matrix
New pairwise comparison matrix is obtained as equation (4)

$$\widetilde{A} = \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & & \tilde{a}_{nn} \end{bmatrix} \tag{4}$$

Step 9: Calculating fuzzy weight of criteria
The fuzzy weight matrix is calculated by Buckley's geometric mean method [14]
The geometric mean of fuzzy can be calculated by using equation (5):

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{a}_{ij}\right)^{\frac{1}{n}}, \text{ for all } i \tag{5}$$

Where $\tilde{r}_i$ is the geometric mean of fuzzy comparison values of criterion i to each criterion.

Fuzzy weight $\widetilde{w}_i$ of the ith criterion indicated by a triangular fuzzy number is as follows :

$$\widetilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \dots \oplus \tilde{r}_n)^{-1} \qquad , i= 1,2, \dots ,n \tag{6}$$

$$\widetilde{w}_i = (lw_i, mw_i, uw_i)$$

Where lw_i, mw_i, uw_i stands for the lower, middle, and upper values of the fuzzy weight of the ith criterion.

Step 10: Defuzzyfication
Since fuzzy weight, $\widetilde{w}_i$ are still fuzzy numbers, $\widetilde{w}_i$ has to be defuzzified into crips numbers by using the Center of Area method as follows :

$$w_i = \frac{l\widetilde{w}_i + m\widetilde{w}_i + u\widetilde{w}_i}{3} \qquad , i=1,2,3\dots,n \tag{7}$$

Step 11: Normalization of non fuzzy number
The non fuzzy weights $\boldsymbol{w_i}$ have to normalized by using equations (8) :

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{8}$$

Where W_i represents normalized weight of the ith criterion

Step 12: Checking consistency of the comparison matrix
To check the consistency of the comparison matrix, the consistency rate (*CR*) has to be calculated. The *CR* is defined as a ratio between the consistency of a consistency index (*CI*) and the consistency of a random consistency index (*RI*). The Consistency Ratio (CR) is calculated by using the formula as in equation (9) and the value of CR should not exceed 0.1 [8]. The RI values for the different number of criteria are shown in Table 2.

$$CR = \frac{CI}{RI} \tag{9}$$

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \tag{10}$$

Where: λ_{max} is eigen vector and n is the number of criterion

Table 2. Random Index (RI) values for n number of criterion

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

Step 13: Calculating the weight of alternatives
At this step, the alternative maintenance strategies are compared among others with respect to each selection criteria. To find the weight of alternatives, similar procedures to that described in step 5 to step 12 are performed.

Step 14: Calculating the total score and ranking the alternatives
The total score for each alternative is calculated by using equation (11)

$$S_j = \sum_{i=1}^{n} WC_{ij} W_i \tag{11}$$

Where : WC_{ij} = weight of alternative *j* for the *i*th criterion, W_i = weight for *i*th criterion, *n* = number of criteria, S_j =total score of alternative *j*.
Finally, each alternative is given a rank corresponding to its total score.

3. Result and Discussion

PT XYZ is one of the yarn spinning company and is located in Bandung, Indonesia. The maintenance manager of the company feels that the current maintenance strategy is not efficient to fulfill the company's present objectives, hence the maintenance manager considered to perform the appropriate maintenance strategy for the next company's maintenance strategy. The complexity of manufacturing systems makes it difficult to decide about maintenance strategy, therefore a well-designed decision process is needed to help managers on minimizing decision failures. In this study, the Fuzzy AHP method is proposed for solving the manager's problem.

Five selection criteria and three alternatives of maintenance strategies were determined by decision-makers on the company. The selection criteria are:

a. Feasibility, refers to the acceptance of workers of the strategy socially and professionally. Feasibility criterion includes the efficiency strategy to perform the task effectively and the accessibility to the technology required [15].

b. Cost, refers labor cost, training cost, spare parts and hardware cost

c. Reliability, means the ability of the strategy to preserve significant items within the facility, maximize the time between failures, provide inspections with no diagnostic errors, keep all equipment and machine accessible for inspections, and implement reliable techniques [15].

d. Safety, includes human safety, environment safety, machine, and facility safety.

e. Production quality refers to the ability of the strategy to increase production quality.

The alternative to maintenance strategies are:

a. Corrective Maintenance (CRM)

   The definition of Corrective Maintenance according to the standard PrEN13306: Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function [16].

b. Periodic Maintenance (PRM)

   In Periodic maintenance or Time-based maintenance, decisions (e.g., preventive repair times/intervals) are determined based on failure time analyses. The aging of some equipment is estimated based on failure time data or used based data. Periodic maintenance assumes that the failure (characteristic) of equipment can be predicted by the time [17].

c. Predictive Maintenance (PDM)

   The definition of Predictive Maintenance according to the standard PrEN13306: Condition based maintenance carried out following a forecast derived from the analysis and evaluation of significant parameters of the degradation of the item. Predictive maintenance is performed continuously or at intervals according to the requirements to diagnose and monitor a condition or system [16].

To decompose the decision problems of choosing the best maintenance strategy, three levels of hierarchy structure is constructed as shown in Figure 1.
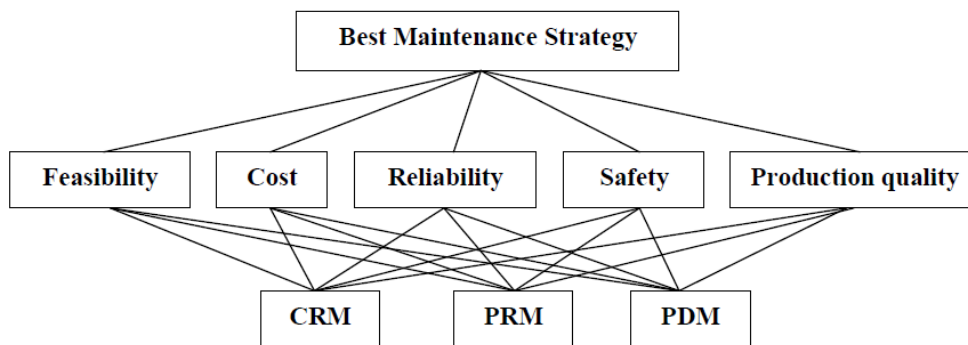
Figure 1. Hierarchy structure

During the decision process, decision-makers compare the selection criteria by using the linguistic variable and corresponding triangular fuzzy number as is shown in Table 1. After doing constructing pairwise comparison matrix, calculating the fuzzy weight of criteria, defuzzyfication, and normalization of the nonfuzzy number, the weight of each criterion can be found. The level of inconsistency in the comparison matrix is acceptable as the value of consistency ratio (CR) is less than 0.1. To find the weight of alternatives CRM, PRM, PDM are compared among others with respect to each selection criteria and the procedures are similar to that described in step 5 to step 12. Finally, the total score and the rank of each alternative can be obtained. The weight of each criterion, the weight of alternatives with respect to each criterion, total score, and rank of each alternative are tabulated as shown in Table 3.

Table 3. Final result

Criteria	Weight of criteria, W	Weight of alternative maintenance strategy, WC		
		CRM	**PRM**	**PDM**
Feasibility	0.074	0.765	0.108	0.126
Cost	0.190	0.339	0.331	0.331
Reliability	0.309	0.124	0.469	0.407
Safety	0.235	0.101	0.514	0.386
Production quality	0.193	0.203	0.451	0.346
Total score, S_j		0.222	0.423	0.355
Rank		3rd	1st	2nd

Table 3 shows that the reliability criterion has a weight of 0.309, safety 0.235, production quality 0.193, cost 0.190, and feasibility 0.074. Also, it can be seen from Table 3 that Periodic Maintenance (PRM) has obtained the highest total score among three alternatives with a total score of 0.423 and PRM is ranked first. Predictive maintenance (PDM) and Corrective maintenance (CRM) have obtained at the second and third rank with 0.355 and 0.222. Based on the final results, Periodic Maintenance is selected as the best maintenance strategy for the company.

4. Conclusion

Maintenance plays a significant role in production activities. An appropriate maintenance strategy can improve the availability of production equipment and avoid unnecessary expenditures in maintenance. Selection of appropriate maintenance strategy is a crucial task for the company, therefore it needs multi criteria decision making to evaluate the strategies. In this paper, the Fuzzy AHP method was proposed for the evaluation and selection of the best maintenance strategy for a spinning mill company. Fuzzy AHP was used for reducing the vagueness and uncertainty of the decision maker's judgment. Three alternatives of maintenance strategies were to be considered and evaluated with

respect to five criteria. Finally, this paper shows that Fuzzy AHP is successfully applicable as an evaluation technique for the maintenance strategy selection problem.

References

[1]   ER-RATBY, M., & MABROUKI, M. 2018. Critical Study of the Different Types of Maintenance Used in Industry *Journal of Applied Sciences, Engineering and Technology,* **15**, pp. 91-97

[2]   Muinde, P. M. 2015. Maintenance strategy selection using analytic hierarchy process: a case study. *Journal of Sustainable Research in Engineering*, **1**(4), pp. 21-29.

[3]   Bevilacqua, M., & Braglia, M. 2000. The analytic hierarchy process applied to maintenance strategy selection. *Reliability Engineering & System Safety*, **70**(1), pp. 71-83.

[4]   Shyjith, K., Ilangkumaran, M., & Kumanan, S. 2008. Multi-criteria Decision Making Approach to Evaluate Optimum Maintenance Strategy in Textile Industry *Journal of Quality in Maintenance Engineering* **14**, pp. 375-386

[5]   BALAKRISHNAN, K., Mani, I., & Karthikeyan, M. 2016. Maintenance Strategy Evaluation Based On Ahp Â€"Topsis. *Journal Of Advances In Chemistry*, **12**(26), pp. 5744-5751.

[6]   Hemmati, N., Galankashi, M. R., Imani, D. M., & Farughi, H. 2018. Maintenance Policy Selection: a Fuzzy-ANP Approach *Journal of Manufacturing Technology Managemen,*. **29,** pp. 1253-1268

[7]   Bashiri, M., Badri, H., & Hejazi, T. H. 2011. Selecting optimum maintenance strategy by fuzzy interactive linear assignment method. *Applied Mathematical Modelling*, **35**(1), pp. 152-164.

[8]   Saaty, T. L. 1990. How to make a decision: the analytic hierarchy process. *European journal of operational research*, **48**(1), pp. 9-26.

[9]   Kabir, G., & Hasin, M. A. A. 2011. Comparative analysis of AHP and fuzzy AHP models for multicriteria inventory classification. *International Journal of Fuzzy Logic Systems*, **1**(1), pp. 1-16.

[10]   Ayhan, M. B. 2013. Fuzzy AHP Approach for Supplier Selection Problem: A Case Study in a Gear Motor Company *International Journal of Managing Value and Supply Chains (IJMVSC)*, **4**, pp. 11-23

[11]   Renzi, C., Leali, F., Pellicciari, M., Andrisano, A. O., & Berselli, G. 2015. Selecting alternatives in the conceptual design phase: an application of Fuzzy-AHP and Pugh's Controlled Convergence. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, **9**(1), pp. 1-17.

[12]   Sianturi, G., & Wijaya, T. 2019, November. Fuzzy Analytic Hierarchy Process Method for Selecting the Best Design Concept of Corn Shelling Machine. In *IOP Conference Series: Materials Science and Engineering*, **6629**(5), pp. 052014

[13]   Hsieh, T. Y., Lu, S. T., & Tzeng, G. H. 2004. Fuzzy MCDM approach for planning and design tenders selection in public office buildings. *International journal of project management*, **22**(7), pp. 573-584.

[14]   Buckley, J. J. 1985. QFuzzy Hierarchical Analysis, ϱFuzzy. *Sets and Systems*, **17**, pp. 233-247.

[15]   Abdulgader, F. S., Eid, R., & Daneshvar Rouyendegh, B. 2018. Development of Decision Support Model for Selecting a Maintenance Plan Using a Fuzzy MCDM Approach: A Theoretical Framework. *Applied Computational Intelligence and Soft Computing*, **2018**.

[16]   PrEN 13306, 1998 *Draft European Standard-Maintenance Terminology*. European Committee for Standardization, Brussels

[17]   Ahmad, R., & Kamaruddin, S. 2012. An overview of time-based and condition-based maintenance in industrial application. *Computers & industrial engineering*, **63**(1), pp. 135-149.