A Fuzzy-AHP-Based Decision Support System for Maintenance Strategy Selection in Facility Management

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***Abstract*—In facility management, maintenance plays an important role in the sustainable development of buildings, involving safety, technical, economic and environmental aspects. An effective building maintenance strategy is critical in improving equipment reliability and availability, maintaining a comfortable environment, enhancing energy efficiency and minimizing the life-cycle cost of the building. Hence, a company's competitiveness and profitability can be improved significantly if unintended failure can be avoided. However, in the current maintenance process, maintenance knowledge and expertise are usually very subjective while the conventional approach is not sufficiently systematical to explain the judgement and assessment criteria. In addition, even though applications of optimization approaches in the maintenance process have been considered, exploring acceptable reasoning for vague information, such as costs, risk assessment and expert feedback is lacking, in the consideration of different maintenance strategies. Therefore, in this paper, a fuzzy-AHP-based decision support system (FADSS) is proposed for assisting in the multi-criteria decision-making process so as to determine the most cost-effective and efficient maintenance strategy. To evaluate the proposed system, a case study is conducted regarding building facilities maintenance. It is found that, through formulating the most suitable strategy, the work efficiency can be improved, and the maintenance costs can be minimized.**

I. INTRODUCTION

Building facilities maintenance involves general repairs to facilities, equipment, mechanical and electrical components of building services installations in the buildings, which have a relatively shorter life span than the building structure. Defects, wear and tear in the mechanical and electrical components may lead to malfunction of equipment and undesirable accidents, or even fatal consequences. It is therefore necessary to have strategic planning so as to avoid exceeding the designed life-span and avoiding sudden breakdown of services. In the past, maintenance was considered to be non-value added, but deemed to be an essential component in the manufacturing industry merely. Appropriate and effective maintenance management traditionally was not provided because it was not perceived as a mechanism for developing a competitive edge, and was classified as an additional cost in maintaining plant operation. The trends of maintenance have been changing in terms of its importance over the past decades, as shown in Fig. 1 [1]. Nowadays, complex building management requires minimum down time, cost effectiveness and higher quality. The evolution of maintenance, as shown in Fig. 1, has gone through a major change from the reactive approach "fix it when it breaks" to a proactive approach of "run through remaining useful life". Many companies disregard the benefits of maintenance, and believe that maintenance only generates additional costs so as to be a burden to the financial structure. The latest approach is to maximize system reliability and availability by developing new strategies and techniques, such as computerized systems, condition monitoring, failure modes and effects analyses, hazard studies, expect systems etc. Hence, maintenance is now significantly important in many companies.

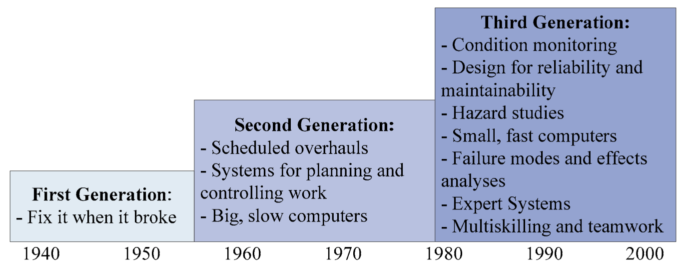

Fig. 1. Changing trend in maintenance management [1]

Even though many optimization approaches have been developed in this area, quantitative measures for selecting between different maintenance strategies are lacking. Moreover, conventional analysis requires that the selection of arbitrary values in pairwise comparison is insufficient and cannot deal with an expert's experience and knowledge when an uncertainty or a linguistic variable environment exists. Thus, inadequate and ineffective maintenance management should be adopted. It may cause a large amount of loss in profitability annually in the market [2]. According to Freedonia Group Inc., the significance of building maintenance has continued to grow. Revenues for building maintenance services in the US market are forecast to increase by 4.3% per year to nearly US$176.5 billion in 2017 [3]. However, it is impossible to achieve the goals of optimizing economic effects, equipment performance and labor resources simultaneously [4]. Therefore, a strategic approach in making cost-effective maintenance decisions is critical especially for capital-intensive industries, enabling all the business goals of a company to be met. In this paper, a fuzzy-AHP-based decision support system (FADSS) has been developed for effectively handling the operational variations and uncertainties. This approach avoids the complex inference process, and it significantly reduces the computational complexity.

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This paper is divided into six sections. Section 2 reviews the literature including building facilities maintenance management, cloud computing applications, and the fuzzy analytic hierarchy process. In Section 3, the research design and methodology of FADSS are described. Section 4 of the paper introduces a case study in which the maintenance priority of a property management company is assessed, evaluated and discussed. This analysis provides insight on the various factors considered in formulating maintenance priority. Section 5 is the results and discussion from implementing the FADSS. Finally, the conclusions are drawn in Section 6.

II. Literature Review

A. *Building Facilities Maintenance Management*

The rapid development of new technologies has made facilities and equipment more complex and reliable. Maintenance management is moving from the traditional philosophy “breakdown and scheduled maintenance" to the adoption of preventive maintenance and condition-based maintenance concepts [1]. It is estimated that around 18-30% of additional maintenance cost was incurred due to poor maintenance planning, and therefore it is vital to have a strategic process for optimizing and prioritizing maintenance activities [5-6]. Maintenance may be performed strategically in different approaches in terms of various criteria, such as cost, risks, and seriousness of consequences. Maintenance strategies that are currently applied in the building maintenance industry can be classified into corrective maintenance [7-10], preventive maintenance [11-15] and predictive maintenance [16-17]. Corrective maintenance, a reactive approach, is adopted in situations when signals for repairs and equipment failure occur, for example light fitting replacement and dual redundancy in PLC control systems. However, this approach is not able to handle unexpected failures and incidents so that it may cause large production losses and possible injuries in the facilities. Preventive maintenance, a pro-active approach, is carried out according to a planned schedule and at specified intervals in order to reduce probability of failure. In general, preventive maintenance requires outage of production and assembly for visual inspection, repair and replacement, regardless the conditions at the predetermined time. It leads to unnecessary maintenance and costs more than in carrying out the replacement or repair work at the time of failure. Predictive maintenance is an alternative to preventive maintenance, also a pro-active approach, by installing sensors for data collection in order to recognize the changes in performance and conditions of the building facilities. When the system reaches critical points, established by monitoring the collected data, the system will notify the building management office to carry out maintenance. It may sometimes be used synonymously with condition-based maintenance. However, this approach requires a larger initial investment than other approaches for setting up the building management system and installing various sensing technologies. Consequently, such a maintenance approach offers an opportunity to improve equipment reliability and availability, to maintain a comfortable environment, to enhance energy efficiency, to minimize life-cycle cost of building etc., resulting in improving competitiveness and economic gain as unintended failure can be eliminated. The goal of maintenance is to optimize cost, to eliminate risks and to maximize the value and performance during the building life-cycle. In order to collect and manage the collected data and knowledge, cloud computing is a promising tool to provide a secure platform to store and analyze the data.

B. *Cloud Computing Applications*

With the rapid growth of the Internet network, the concept of cloud computing was developed to handle and analyze information on the Internet [17]. Cloud computing services are able to handle seven applications, namely image processing, natural language processing, crowd computing, sharing Internet data, sensor data applications, multi-media, and social networking. The hardware and software become the services to the general public, called the public cloud. The users are only required to pay per use so that such cloud computing services are much more applicable in small and medium businesses. In view of the cloud architecture, it is classified into data center, Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) [18]. The data center places the hardware facility and infrastructure for the cloud computing. It is built in a remote area with a high stability of power supply and low frequency of natural disasters. IaaS enables the authority for managing hardware, servers, and networking components. Users can subscribe to the services according to their own demand. PaaS is an integrated environment for developing customized applications. The sensing technologies can be connected to store and analyze the collected data. Finally, SaaS is the finished application in which the users can access via the Internet when they are authorized. These services take advantage of the high reliability, large storage capacity and processing power. In order to handle the collected information for facility maintenance, artificial intelligence can be applied in the cloud computing environment to select the most appropriate maintenance strategy.

C. *Decision Making Methods in Maintenance Strategies*

The decision-making process for formulating maintenance strategies requires the evaluation of alternative criterions. This is classified as multi-criteria decision making (MCDM) [19]. Maintenance management can be defined as the combination of all techniques, associated with facilitating the decision-making by maintenance personnel so as to retain a desired function of an item or system. In fact, there are several methods that have been developed to select and design maintenance strategies which support the performance of maintenance management decision-making process, including analytic hierarchy process [20], knowledge based analysis [21], neural networks [22] and fuzzy logic [23]. Knowledge-based approaches and neural networks are used to formulate the solutions with certain numerical attributes and explicit knowledge. Fuzzy logic and analytic hierarchy process are deemed to be the suitable techniques for handling uncertain information and multi-criteria decision making respectively. The Analytic Hierarchy Process (AHP) provides an effective method to deal with complex decision-making and can assist in identifying and weighing criteria [24]. It is a theory of measurement through pair-wise comparisons and relies on the judgements of experts to derive priorities. AHP develops priorities among all the criteria and sub-criteria within each level of the hierarchy, and gives a weight for each evaluation criterion according to the decision makers pairwise comparisons of the criteria. The higher the weight is, the more important the corresponding criterion is. For a fixed criterion, the AHP assigns a score to each option according to the decision maker's pairwise comparisons. The higher the score, the better the performance of the option. Finally, the AHP combines the criteria weights and the options scores, thus determining a global score for a consequent ranking. However, AHP cannot completely reflect the importance of data collected since some expert preferences involve uncertainty and imprecision [25]. It is difficult to use precise and definite value to present the linguistic judgements. In order to deal with the problems of data ambiguity, fuzzy analytic hierarchy process (FAHP) based on triangular fuzzy numbers is proposed to solve complex decision problems with consideration of the subjective evaluations [26]. Due to its advantages, fuzzy AHP has been widely applied in many areas, such as supplier selection, asset management, and risk assessment [27-28]. Wang et al., [29] adopted FAHP to select the optimum maintenance strategies for manufacturing equipment. Ouma et al. [30] used FAHP to facilitate decision making for ranking the importance of pavement maintenance alternatives. Therefore, it is shown that FAHP is a promising tool in selecting an appropriate maintenance strategy in facility management.

In summary, building facilities maintenance has an important role in recent years. Based on various criteria and situations, the maintenance strategy should be specific and aligned to the companies' objectives. In order to achieve these objectives, cloud computing environment provides a certain infrastructure and platform to store the information and knowledge. Through applying FAHP, the most appropriate maintenance strategy can be selected. Therefore, the efficiency and effectiveness of facilities maintenance can be maximized.

III. Methodology

In this paper, a fuzzy-AHP-based decision support system (FADSS) is proposed to select the most suitable maintenance strategy for facility management. Fig. 2 shows the system architecture of FADSS which consists of two tiers, namely front-end tier and back-end tier. The front-end tier is the scope and physical facilities related to formulating the maintenance strategy; Back-end tier is related to the system setting and computations of FAHP.

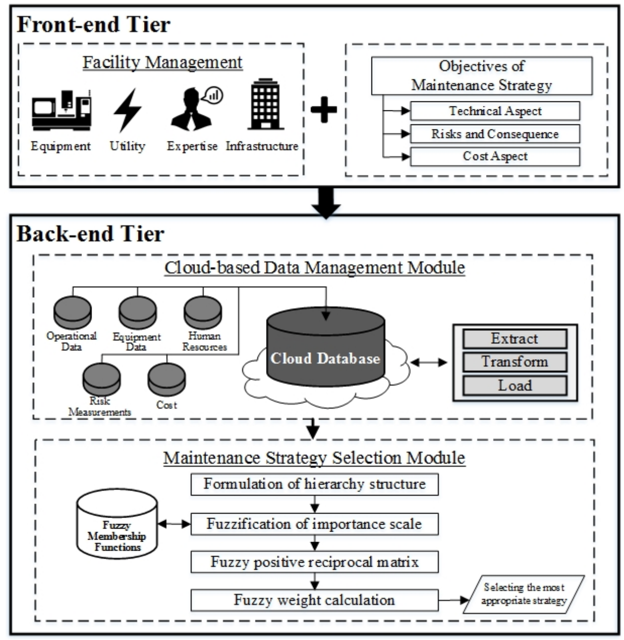

Fig. 2. System architecture of FADSS

A. *Front-end Tier*

The front-end tier consists of the major elements in facility management and the objectives of developing maintenance strategy. For the facility management, it basically covers the infrastructure, equipment, utility, and maintenance expertise, that are correlated with each other in maintenance work. On the other hand, according to a company's specific culture and business objectives, the objectives of maintenance strategy development can be affected. There are three directions to consider in the development of a maintenance strategy, i.e. technical aspect, risk and consequence, and cost aspect. This information provides a clear scope for developing the maintenance strategy, and also supports the computations in the back-end tier.

B. *Back-end Tier*

In the back-end tier, data management and the selection mechanism are considered in two modules, aimed at selecting the most appropriate maintenance strategy for a particular facility.

1) *Cloud-based Data Management Module*

There is a large amount of data collected which is related to the formulation of a maintenance strategy. The data includes operational data, equipment data, human resources, risk measurements, and cost, which are used to establish the hierarchy structure for the strategy selection. All the data is then stored in the cloud-based database which is a secure and efficient data storage. Some open source cloud database services are applicable for the proposed system, such as Oracle Cloud – MySQL. They are well-developed and have user-friendly interfaces to manage the stored data. The maintenance staff can access to the database everywhere, at any time, only if they are able to connect to the Internet. On the other hand, the process of extract, transform, and load (ETL) is applied to the collected data. The information is parsed to JSON or XML data format to develop a cloud-based system for FADSS effectively. Once all the information is handled properly, it can be effectively applied to further analytics.

2) Maintenance Strategy Selection Module

To evaluate the priority and formulate a follow-up plan for maintaining the building services equipment and minimizing the costs, a FAHP is proposed in this module. In FAHP, the importance intensity is fuzzified to handle vague and linguistic values. In the process of decision-marking, the weights of the criteria and scores of alternatives are then assessed and derived from fuzzy pairwise comparison matrices. The Lambda-Max method [31] is adopted to formulate the weightings of the criteria and alternatives. In summary, FAHP has the following four steps:

Step 1: Formulation of hierarchy structure

The first step in applying FAHP is to understand the objectives and develop the specific hierarchy structure with various decision criterion. The prioritization problem can be broken down into a hierarchy of interrelated decision criterions. Under the criteria, various attributes are defined and used to compare the importance that affect the decision-making process. All information within the hierarchy is provided by maintenance personnel and experts with decision-making responsibilities.

Step 2: Fuzzification of importance scale

In order to establish the comparison matrix, the importance scores are collected by pairwise comparisons. However, in real-life situations, it is difficult to clearly define a score in the pairwise comparisons. Therefore, positive triangular fuzzy values are applied to represent the linguistic variables. Table I shows this fuzzification process for the linguistic variables. There are five linguistic variables: equally important (EI), slightly important (LI), strongly important (MI), very strongly important (VI), and absolute important (AI). The membership functions are stored in a separate database, and retrieved for the fuzzificiation process. The positive triangular fuzzy numbers for the above five linguistic variables are EI: [1, 1, 1], LI: [2, 3, 4], MI: [4, 5, 6], VI: [6, 7, 8], and AI: [8, 9, 10].

TABLE I. MEMBERSHIP FUNCTIONS OF FADSS

Linguistic Variable	Explanation	Fuzzy No.
Equally Important (EI)	Activities contribute equally to the objective	1,1,1
Slightly Important (LI)	Judgement slightly inferior tone criterion to another	2,3,4
Strong Important (SI)	Judgement strongly inferior tone criterion to another	4,5,6
Very Strong Important (VI)	Judgement slightly favour one criterion over another	6,7,8
Absolute Important (AI)	Judgement strongly favour one criterion over another	8,9,10

Step 3: Fuzzy positive reciprocal matrix

Since the linguistic variables have been fuzzified, they can be presented in a form of matrix (T_{ij}) as in (1). Before calculating the fuzzy weights in FAHP, a reciprocal matrix should be created.

$$\widetilde{T_{ij}} = \begin{bmatrix} \widetilde{d_{11}} & \cdots & \widetilde{d_{1j}} \\ \vdots & \ddots & \vdots \\ \widetilde{d_{ij}} & \cdots & \widetilde{d_{ij}} \end{bmatrix} \quad (1)$$

where d_{ij} is determined by the preference of the decision maker between i and j criterions via positive triangular fuzzy number.

Step 4: Fuzzy weight calculation

In the final step, the fuzzy weights are calculated by using the Lambda-Max method [31]. By defining α-cut and interval arithmetic, the upper and lower bounds of the weights can be calculated by using the hierarchical analysis. Compared with the weight at α=1, the fuzzy weight for positive triangular fuzzy numbers can be finalized. In order to ensure the fuzziness of the calculated weights, the comparisons between upper/lower bound weight and weight at α=1 are required, as shown in (2) and (3). Through the defuzzification process, the exact ratings for the maintenance strategy can be finalized. Therefore, the most appropriate strategy can be selected based on the defuzzified values.

$$K_l = min\left\{\frac{w_{im}}{w_{il}} | 1 \le i \le n\right\} \quad (2)$$

$$K_u = max\left\{\frac{w_{im}}{w_{iu}} | 1 \le i \le n\right\} \quad (3)$$

,where K is the adjustment index to ensure $w_l \le w_m \le w_u$.

IV. CASE STUDY

This section covers the company background, problems in the company and Implementation of FADSS in the company.

A. Company Background

ABC Company is a property management company that is currently managing a 50-storey commercial building in the Kowloon district in Hong Kong. The daily jobs involve a variety of administrative tasks, including handling property maintenance, supervising building repairs and controlling expenses. As maintenance cost is one of the main expenditure items and is almost 20 to 30% of overall operation cost, an appropriate strategy is important to maintain the reliability levels of the building facilities operation while at the same time keeping the costs minimized. Therefore, there is a need to develop cost-effective maintenance management system. The main tasks of cost-effective maintenance management include the optimization and scheduling of maintenance activities. Maintenance scheduling is vital for operating and maintaining building facilities reliably and economically. It is essential to find the optimal maintenance schedule, balancing between the reliability, benefits and cost of maintenance.

B. *Problems in ABC Property*

The Property Manager has problems in setting priorities due to limited resources for addressing maintenance. The techniques and factors in assessing values for the prioritization process in the maintenance activities are not robust, and the assessment of defect levels are based on the technician's personal judgment. The current maintenance process for support equipment is "ad-hoc" basis, where replacement activities are managed on case basis depended upon the allocation of fund in annual budget. The inspection results are highly subjective. All the inspection results are expressed qualitatively using linguistic and vague terms, and vary from one technician to another, depending on their experience, inherent knowledge and reasoning. This may lead to making ineffective maintenance decisions, inefficient control of maintenance and increase of repair expenditure. There is lack of a systematic approach for prioritizing the maintenance strategy, resulting in large variance and inconsistency in the reporting of defect levels. Hence, additional costs may be incurred, and may cause unexpected accidents in the facility.

C. *Implementation of FADSS*

In order to assist the Property Manager to improve the strategic planning of maintenance management, the FADSS is developed and adopted to solve the problem. The FADSS consists of cloud-based data management and integration of fuzzy set theory and AHP. Consistency in the FAHP results is achieved by implementing a systematic prioritization model where the criteria are defined at the beginning by the property managers. Hence, the maintenance staff can obtain consistent results in the proposed system. The output of the FAHP is developed to suggest appropriate settings in prioritizing of maintenance and repair activities on the basis of agreed criteria. The strategy is either corrective, preventive and predictive. The proposed system is able to reduce subjective knowledge and information in the decision making process.

In this case study, the process of periodic thermal scanning on existing electrical distribution equipment is shown in Fig. 3. The Property Manager is required to assign an appropriate strategy for this maintenance work.

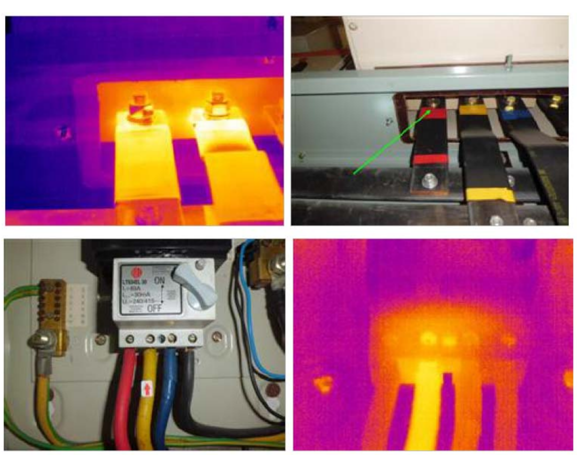

Fig. 3. Thermal scan condition of an electrical distribution equipment

The proposed methodology allows experts to rank and access the priority of each maintenance activity for inclusion in their planning and maintenance programme. Three levels of priority are considered: Corrective Maintenance (S1), Preventative Maintenance (S2), and Predictive Maintenance (S3). The advantage of fuzzy set theory facilitates the assessment to be made in a linguistic, quantitative and qualitative manner. Maintenance staff are consulted to get the linguistic variables in terms of importance of each criterion. Hence, the hierarchy structure can be built and the strategy weights can also be calculated.

Data collection is conducted through interviews with the Property Manager, engineers and technicians to determine the dominant factors. The five proposed dominant criterions are "Operation Flexibility (C1)", "Reliability (C2)", "Safety (C3)", "Installation Cost (C4)" and "Operation and Maintenance Cost (C5)". The criteria of operation flexibility and reliability can be affected by the workers' health status and contract requirements of the facility. Safety criteria are related to the probability of equipment failure and the seriousness of the consequences. When applying various maintenance strategies, the installation cost refers to implementing the advanced technologies, such as sensors, to capture the corresponding data automatically. On the other hand, the operation and maintenance may be varied according to the inspection duration (man-hours) and cost of purchasing components. Through integrating all these factors, a hierarchy structure can be established, as shown in Fig. 4. It supports the computations of the FAHP model to prioritize the maintenance strategy. Therefore, the most suitable and cost-effective maintenance strategy can be determined.

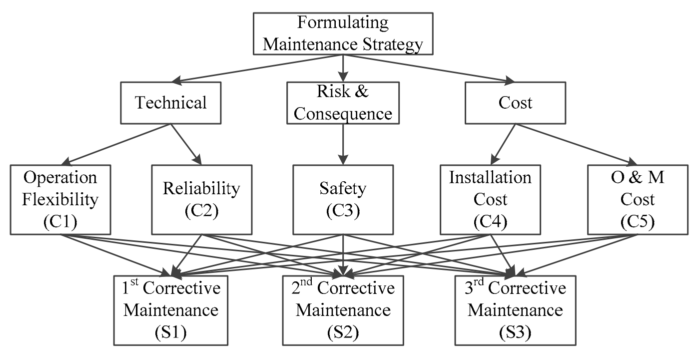

Fig. 4. Hierarchy structure of FAHP

According to the preferences determined in the interviews with Property Manager and senior maintenance engineers, pairwise comparison matrices for above criteria can be formulated. The criteria and alternatives have been evaluated in the decision-making process. Table II shows the fuzzy comparison matrices by applying the positive triangular fuzzy numbers. Through applying the Lambda-Max method, the geometric mean of the fuzzy comparison values of each criterion is calculated. The weight of the criterion is then defuzzified by the center of area method. Relative fuzzy weight, relative non-fuzzy weight and normalized weights of each criterion are shown in Table III.

TABLE II. FUZZY COMPARISON MATRICES FOR CRITERIA

Criteria	C1	C2	C3	C4	C5
C1	(1.00, 1.00, 1.00)	(1.00, 1.00, 1.00)	(6.00, 7.00, 8.00)	(0.25, 0.33, 0.50)	(0.25, 0.33, 0.50)
C2	(1.00, 1.00, 1.00)	(1.00, 1.00, 1.00)	(6.00, 7.00, 7.00)	(0.25, 0.33, 0.50)	(0.25, 0.33, 0.50)
C3	(0.13, 0.14, 0.17)	(0.14, 0.14, 0.17)	(1.00, 1.00, 1.00)	(4.00, 5.00, 6.00)	(4.00, 5.00, 6.00)
C4	(2.00, 3.00, 4.00)	(2.00, 3.00, 4.00)	(0.17, 0.20, 0.25)	(1.00, 1.00, 1.00)	(0.25, 0.33, 0.50)
C5	(2.00, 3.00, 4.00)	(2.00, 3.00, 4.00)	(0.17, 0.20, 0.25)	(2.00, 3.00, 4.00)	(1.00, 1.00, 1.00)

TABLE III. GEOMETRIC MEANS, FUZZY & NORMALIZED WEIGHTS OF CRITERIA

Criteria	Geometric means	Fuzzy Weight	Normalized Weight
C1	(0.82, 0.95, 1.15)	(0.13, 0.19, 0.27)	0.189
C2	(0.82, 0.95, 1.12)	(0.13, 0.19, 0.27)	0.187
C3	(0.78, 0.87, 1.00)	(0.13, 0.17, 0.24)	0.171
C4	(0.70, 0.90, 1.15)	(0.11, 0.18, 0.27)	0.180
C5	(1.06, 1.40, 1.74)	(0.17, 0.28, 0.42)	0.274

After calculating the normalized weights for the criteria, the same approach is adopted to determine the weights of the strategies with respect to each criterion, as shown in Table IV. By aggregating the results for each strategy, the finalized scores of the strategies are presented in Table V. It is revealed that strategy S2, which is the preventive maintenance, has the highest total score. Therefore, it is suggested that preventive maintenance is the best strategy among the three in the periodic thermal scanning work.

TABLE IV. NORMALIZED NON-FUZZY RELATIVE WEIGHTS OF EACH STRATEGY AND EACH CRITERIA

Strategies	C1	C2	C3	C4	C5
S1	0.393	0.140	0.250	0.151	0.118
S2	0.275	0.575	0.522	0.425	0.403
S3	0.333	0.284	0.227	0.425	0.479

TABLE V. AGGREGATED RESULTS FOR EACH STRATEGY ACCORDING TO EACH CRITERIA

Criteria	Weights	Scores with respect to related criteria		
		S1	S2	S3
C1	0.189	0.393	0.275	0.333
C2	0.187	0.140	0.575	0.284
C3	0.171	0.250	0.522	0.227
C4	0.180	0.151	0.425	0.425
C5	0.274	0.118	0.403	0.479
Total		0.203	0.435	0.362

V. RESULTS AND DISCUSSION

In FAHP, data interpretation is simplified, which provides a more realistic and reliable solution for complex decision making processes. It can convert the specific verbal appreciation into the numeric values. Through the implementation of FADSS, the ABC Company can establish the most efficient and cost-effective maintenance strategy by considering five aforementioned criteria. According to the case study, the priority of work is classified as moderate class (S2). Relevant maintenance work need not to be carried out immediately or in the near future, and the work could be deferred, as necessary, within a given period. The results of applying the FAHP show that it not only can reduce the subjectivity associated with inspection results, but also be used to assist the Property Manager / engineers in making strategic decisions, such as ‘repair / replace immediately’, ‘Schedule in next maintenance cycle’ or ‘do nothing’. By enabling the effective use of data for knowledge-based FAHP, the efficiency for scheduling of maintenance work has been improved. There is an advantage of scheduling the inspection work so as to handle the seriously defective equipment immediately. In view of the maintenance cost, since the costs are factored in the FAHP structure, the experts and managers are able to control the cost for maintenance work. Therefore, the efficiency of the maintenance work can be maximized, while the incurred cost can be controlled and minimized.

VI. CONCLUSIONS

Maintenance strategy in facility management is important but there is a lack of a systematic approach to determine how the maintenance strategy, work efficiency and costs are recorded in most companies. In order to select the most suitable maintenance strategy, the domain expert has to consider various criteria in a subjective manner. However, the strategic planning may be inefficient and inconsistent so that the maintenance work performance can be greatly affected. Therefore, a fuzzy-AHP-based decision support system (FADSS) is designed for enhancing strategic planning of maintenance work. Through applying cloud-based data management and the fuzzy analytic hierarchy process, the Property Manager can manage the collected data and select the most appropriate strategy systematically. It has the ability to handle vague and imprecise information for effective strategic planning, therefore, FADSS is more applicable in real-life situations. To conclude, the developed model can provide a clear direction in formulating various maintenance plans in facility management, enabling companies to improve the efficiency of maintenance work and minimize the corresponding costs.

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