An artificial neural network analysis of the satisfaction of hospital building maintenance services

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Abstract. Modern hospital buildings are very large, complex, sophisticated, and costly structures. The productivity of the hospital building users is influenced by the building performance. Maintenance services are conducted on the buildings to ensure optimum building performance and users’ satisfaction. However, many instances, have been recorded dissatisfactions among the hospital building users with respect to the performance of the maintenance services. This research investigated the satisfaction of private hospital building users with respect to maintenance services through a survey questionnaire that included ten satisfaction of maintenance services. The data revealed that the users are most satisfied with the standard of workmanship, cleanliness of the maintained area, communication with users during maintenance works, and degree of politeness and kindness of the maintenance workers. Using the nine/ten as the independent variables, an artificial neural network model to predict the satisfaction of users with maintenance services was presented. The model revealed that cleanliness and tidiness of the maintained area and the quality of maintenance works are the main predictors of the total maintenance service delivery of the maintenance organisations.

Keywords: private hospitals, building performance, benchmarking, maintenance organisation, productivity.

1. Introduction
Hospitals are building-based organisations because the expenditure on the building operation is more than 50% of their asset base. Apart from the salaries of the staff, the operational cost of hospital buildings is the most significant item on a hospital’s balance sheet. Hospitals are large enterprises and are one of the most challenging buildings to construct and operate. The users of the hospital buildings, especially the patients depend on the building performance to facilitate their recuperation process and procedures. The productivities of the medical and non-medical staff depend on the condition and performance of the building. For the continued operation of the hospital to happen, maintenance functions are required. Therefore, the standard of maintenance depends on the services that the building offers. As a result, hospital building maintenance organisations are under severe pressure. A maintenance organization is a service provider whose purpose is to provide elegant maintenance services with minimum disturbance and disruptions at less cost. In Malaysia, despite the increasing expenditure on investment in hospital buildings, the performance of the hospital buildings is low. While the backlog of maintenance demand is increasing, the levels of criticisms and complaints in the media and research literature on the poor performance of the hospital buildings in Malaysia due to maintenance-related practices and processes...
are plenty and increasing [1, 2,3,4] and expectations of users have not been met. Therefore, there is a need for empirical research to examine the building maintenance services of hospitals. Because the hospital maintenance organisation needs to know whether or not their users are satisfied or not with the services provided. Although there is increasing awareness among hospitals about the importance of maintenance, the hospitals lack a logical, holistic and consistent approach to conduct maintenance that focuses on user value systems as the key reference point for maintenance management decisions and actions.

2. Background and theoretical framework
Hospitals are generally divided into public and private hospitals. Government is the largest provider of healthcare in most countries through its extensive network of hospital and primary care clinics in the public sector. There are 144 public hospitals and 210 private hospitals in Malaysia [5]. A private hospital is profit-oriented and is funded through payment for medical services. A well-maintained building is critical for the delivery of a hospital’s corporate business objectives. Hospital buildings are procured to create a suitable, conducive, and adequate environment that can support and encourage patients’ recovery and allow staff to perform their duties productively. When maintenance of a building is not well managed, it often leads to buildings that are very expensive to own or operate in the long run. Hospital organisation that does not own their buildings, the rents are usually the highest payments in the hospital’s annual balance sheets. However, there are a lot of defects in hospital buildings [1,7]. Defect in buildings compromises the performance of the buildings. Hence, it is a necessity to conduct maintenance in hospital buildings to meet their intended design and construction function as well as maintain the user’s satisfaction levels [1]. Satisfaction is the pleasure that felt after a need is fulfilled [8]. Satisfaction has been described to include an outcome and a process. This research is more concerned with the process in the satisfaction of the maintenance service delivery.

2.1. Users’ satisfaction in building maintenance
The hospital building is any person, group, or organization that uses the building as an occupier, owner, tenant, visitor or other stakeholders. To continue to justify the investment or uptake in the building maintenance, the performance of the buildings and the service delivery requires evaluation by the building users. Because the building is a capital good [9]. Therefore, the evaluation of maintenance services is a strategic tool to evaluate building performance and maintenance services. The user’s evaluation can be carried out using different methods, including surveys, interviews, and case studies. Largely, it involves inciting a response from the building users on the different aspects of the service delivery process. What to include on the list of evaluation criteria depends on the purpose of the evaluation. User satisfaction is a technique to increase user experience and provide feedback to stakeholders for future development. It measures the difference between experience and expectation. Building user satisfaction is evaluated with reference to expectations. Based on an extensive review of the literature on the maintenance services [9,10,11] and discussion with hospital building users, the following services may determine the level of satisfaction of hospital building user regarding the service provided by the hospital maintenance department condition of buildings, service quality, speed of service delivered, failure to meet the needs and expectations, the ineffective scope of works, building appearance, well-functioning of building equipment, attitude and behaviour of building management staff, execution time, operating hours, convenient to the user, interaction with maintenance personnel, cleanliness after repaired, the staff appearance. Therefore, the maintenance service criteria for the buildings are expected to cover all the above features, and a failure in the delivery of the performance requirements will have severe consequences on the satisfaction of the users with the maintenance service and building performance.

3. Method of data collection and analytics
The primary data were collected through online survey questionnaires based on snowball sampling. Snowball sampling is a non-probability sampling technique that is used if there is less information on the potential respondents. However, one of the limitations of this technique is that the number of respondents will not be known to the researcher. However, the technique is an inductive technique.
Snowballing is a data collection method where the survey is administered to available, accessible, and willing respondents [12]. The respondents were requested to help forward the form to friends and associate that are competent to provide an answer to the questions. The method is appropriate where sufficient information on population size and sample frame is not available. However, its findings may not be generalizable, but with large respondents, the finding can be a representative [12]. The questionnaires were administered to the hospital building’s users through an online survey from 14/07/2020 to 28/08/2020. The building users were asked based on pieces of evidence to tick the degree on how they are satisfied with the services that the maintenance organisation provides to the hospital building users. In order to evaluate the user’s level of satisfaction, Likert Scales of 5 points were used. Where 5 = extremely satisfied, 4 = very satisfied, 3 = satisfied, 2 = less satisfied and 1 = least satisfied. Two and 3 are located in between.

Artificial neural networks (ANN) technique was used to create a model for maintenance services. ANN is a type of non-parametric artificial intelligence model. ANN is suitable for systems that demonstrate a definite relationship between the dependent and independent variables, but one that is too complex to analyze using traditional techniques of correlations, regression analysis, and group differences. ANN method has a higher capability to model nonlinear and functions accurately. It can accommodate multiple parameters without any computation problems. However, unlike fuzzy system models where the internal workings are transparent, ANNs do not readily reveal how a particular answer was obtained [13]. In addition, ANNs do not indicate the direction of the relationship between dependent and independent variables. In other words, it is not clear from the results of the relationship between the dependent variable and the independent variable is negative and positive. Artificial neural networks have not been applied to model building maintenance services. One hidden layer seems adequate in our ANN model estimation. First, Multilayer Perceptron (MLP) was selected as the network to be trained. Automatic architecture selection was then selected, which automatically identifies the best possible network architecture with only one hidden layer. The minimum and maximum numbers of hidden layer units were selected to be 3 and 50 respectively. The dataset is divided into three samples. Firstly, the training sample used to optimize the network weights (supervised learning process). Secondly, the testing sample used to check the error during the learning process. Finally, the holdout sample used for validation; after the training of the network done, the holdout sample assesses the predictive accuracy of the network in a ratio of 70% 20% and 10% for the divisions.

4. Analysing the results of the survey
The survey pooled 538 forms and 207 completed responses were received during the survey period spanning over one month. The data revealed that 60% are medical staff (i.e., doctors, nurses, therapists, and pharmacists). The remaining 40% include (i.e., executive, cashier, cleaner). More than 50% of users have been using the hospitals for more than 4 years.

4.1. Results of the descriptive statistics
The Omega value of the reliability of the factors is 0.851 and the validity ranges from 0.6 to 0.89. The Kaiser's Measure of Sampling Adequacy was significant χ2 (91) = 857.560, p<0.001), N=.830) indicating that the data were drawn from the same population and that the services were related. The results of the one-sample t-test revealed that all the services are statistically significant (Hr: U≥U0). The small standard errors are small which means that the measurements are representative. The survey found that more than 50% of the users measured that they were either very satisfied or extremely satisfied with the maintenance services. 31% measured that they are satisfied, but 19% acknowledged that they were least satisfied or less satisfied with the maintenance services. The cumulative ASI score for all the services is 73.11% while the cumulative standard deviation (SD) was 16.45%.

4.2. Results of the ANN Model
All the 10 services were used to create an ANN model. In this model, 74.4.0%of the total 207 datasets were used for training, 16.9% for testing, and 8.7% percent are stored as a holdout sample. The Relative Error during training (0.181%), testing (0.198%), and holdout (0.199%) confirmed the correctness of
the model for predicting the maintenance service delivery. The sum of squares error for the training is 18.81 and 4.45 for testing.

Figure 1 The architecture of the neural network

Figure 2 The architecture of the neural network
5. Discussion of the ANN model

Because of space constraints, a brief discussion is provided. The average relative errors were 18%, 20% and 19% for the training, testing, and holdout, which show that the precision of the model is relatively high. The relative errors are relatively constant across the training, testing, and the holdout. This is a confirmation that the model is not overtrained and that the error in future cases will be near to the error revealed in this research. The model suggests that the services can predict the overall service that the maintenance organisation provides the lowest minimum importance of about 60%. The primary drivers of satisfaction are the level of disruption due to maintenance work that is allowable in the hospital is very minimum. One of the differential factors between new construction and maintenance is that maintenance is conducted when users/occupants are still using the building. Because of this, maintenance is often disruptive to the user’s/occupant’s activities. To reduce this, the maintenance organisation must plan and execute the repair with minimum disruption and distraction to the users. Hence, the convenience of users is very critical. The ease to make a service request is a major predictor. It is imperative for the building users to know who to call when maintenance demand arises, especially in the emergency maintenance inwards, operation rooms, and theatre. Lack of information on personal that are responsible for repair and their availability could complicate the already tense situation at the hospital.

The data also revealed that the duration that the maintenance organisations take to complete the repair is critical to the users. Maintenance demand can happen at any time because the building materials and components have a finite life span and the materials and components deteriorate at different times. While some defects may be anticipated, some may not be anticipated. When maintenance demand arises, the users desire prompt response [10]. This is not surprising because of the tense condition in the hospitals, especially in critical areas and times. There has been a lot of complaining that, once repaired conducted, used /damaged materials and components are sometimes left behind. Leaving the users with the odious responsibilities to do the cleaning of the repaired materials/components and area. However, the data revealed many of the users are not satisfied with this particular service offer by the maintenance organisation. Additionally, many of the users are not satisfied with the time taken to complete the repair works. The maintenance organisation must make certain that the cleanliness of the maintained area remains a priority. The maintenance organisation needs to ensure that the standard of cleanliness is increased. The courtesy of the maintenance organisations to the building users is very important to the users. How users are treated by the maintenance organisation/employees has been identified as a critical factor to improve building user satisfaction by the maintenance organisations [9]. Therefore, it is interesting to find that the hospital building users measured courtesy as a major predictor.

6. Conclusion

There is literature on the development of performance measurement for maintenance services. The theory behind performance measurement of maintenance service should be measured based on outcomes with respect to the maintenance service delivery. Hospital organisations whether public or private seek to provide quality services with minimum resources. The relationship between building defect and building performance and ultimately users’ productivity and satisfaction is well posited. In other words, building maintenance is progressively recognized as a factor of production like other resources. The building and its management need to be considered as an investment rather than as liabilities. On the one hand, university buildings are factors of production. On the other hand, the building cannot remain new through its entire life span. The value of the building decreases unless maintenance is administered to the building. Maintenance should be positively planned, strategically organize, proactively lead, holistically controlled, and dynamically implemented if the best value is critical. In order for the building to serve its purpose effectively and efficiently, there is the need for a change in mindset in the way they are the view and the ways they are managed. Hospital buildings are procured to provide an enabling environment for health care delivery. Thus, the need to have a capable maintenance organization is on the increase. In that regard, the essence of the maintenance department should be to enhance users’ satisfaction and to improve productivity. This research uses 9 satisfaction factors to create an ANN model to predict the performance of the building and satisfaction with the
service that the building maintenance organisation provides in the hospitals. Although there has been substantial research concerning patient satisfaction with medical care, there have been no attempts to empirically investigate hospital building users with maintenance services. It is hard to determine how much satisfaction or how happy the building’s user with the maintenance services

7. References

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