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ASSET CONDITION ASSESSMENT MODEL FRAMEWORK FOR HEALTHCARE FACILITIES

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The poor healthcare facilities performance costs the USA tens billions of dollars each year. There are several factors affect the critical assets of healthcare facilities such as the physical condition of the facility, infection prevention, life safety, and hospital revenue loss. The objective of this research is to develop an asset condition assessment model for healthcare facilities. The model identifies several factors, especially the condition, capacity, and code compliance of a facility's infrastructure. The asset condition assessment model has been developed based on the mechanical, electrical and plumping systems and evaluates the asset condition based on its age, life expectancy, recent condition assessment and energy efficiency among other factors. The data was collected from different hospitals in Indiana. This model has been developed using the Regression analysis technique. The model has been validated through analytical and mathematical methods. Results showed average validity at 88.32%. The developed model will help the healthcare facilities managers to prioritize the budget allocation and to reduce the impact of consequences of asset failure, which will improve the healthcare infrastructure performance.

Keywords: Asset management, Critical assets, Hospitals, Regression analysis.

1 INTRODUCTION

Healthcare environment quality is linked to patient safety, clinical output, patient stress, patient outcome and staff stress. Healthcare facility directors need to ensure that complex systems are working properly as a part of maintaining the physical environment within healthcare settings (Lucas 2012). Effective facility directors take actions to ensure that healthcare facilities are clean and well-maintained.

2 BACKGROUND

Facility management (FM) is "the integral planning, realization and management of buildings and accommodation, services and resources which contribute towards the effective, efficient and flexible attainment of organizational goals in a changing environment" (Regterschot 1990). Alexander *et al.* (2002) suggest that FM is "the management of non-core company assets to support and increase the efficiency of the main business of the organization."

The exponential growth of healthcare FM has greatly improved healthcare effectiveness and quality. Healthcare facilities management is one of the most vital components of successful healthcare services. These services can be broken down into two categories: hard and soft facilities management. Hard facilities management (FM) includes property maintenance and management; soft facilities management (FM) is the management of support services (Reuvid and

Hinks 2001). Hard FM includes the built environment: the estate, electricity, indoor air, property, water supply and structural fabric. On the other hand, cleaning, catering, security, laundry and waste management comprise soft FM (Liyanage and Egbu 2008).

Previous studies developed a facility failure analysis model that links healthcare delivery processes to facility failures at a hospital. The model assists in ranking and identifying the failures that highly affect service delivery to prioritize maintenance activities (Mohammadpour and Leila 2015, Ali and Hegazy 2013). A clear, precise knowledge of asset performance and condition is necessary for all management decisions in terms of assessing renewal needs, maintenance, and rehabilitation. Premature failure due to a lack of asset knowledge necessitates replacing the asset, an action that has major consequences related to business potential loss and risk.

To address the above issues, a tool for assessing asset criticality is necessary in capital needs decision-making. According to this body of knowledge, critical asset condition assessment in terms of criticality was addressed by very limited research. This is considered a major research gap, as maintenance strategy is a main part of the healthcare facilities management.

3 RESEARCH OBJECTIVES AND POINT OF DEPARTURE

The main objective is to develop a model framework to evaluate and prioritize the asset critical condition for the healthcare facilities. This main objective can be broken down into the following sub-objectives:

- Identify the asset criticality for healthcare facilities.
- Identify and determine the main factors and sub factors influencing asset criticality for healthcare facilities.
- Develop a model framework of asset condition assessment.
- Validate the developed model.

4 FACTORS AFFECTING THE ASSET CRITICALITY

Based on the literature review and the experts' interviews, asset condition assessment (ACA) factors are identified and selected. Four main categories incorporated in the research include fifteen other sub factors (Salem and Elwakil 2018a) as shown in Table 1.

Table 1. Asset criticality factors in healthcare facilities (Salem and Elwakil, 2018a).

Physical Condition	Environmental Aspects	General Safety	Revenue Loss
Age/Life Expectancy	Lead	Life Safety	Labor Hours
Condition Assessment	Asbestos	Physical Safety	No. of Work Orders
Parts Availability	Mold		Repair Cost
Code Compliance	Water Contamination		
Energy Efficiency	Indoor Air Quality		

5 RESEARCH METHODOLOGY

The research methodology used in this research consists of several steps started with literature review, followed by collecting data, ranking the asset condition assessment (ACA) factors, developing the ACA regression analysis, results, conclusion and recommendations.

The methodology used to evaluate the facility was based on its spaces. The patient risk space, the principal element evaluated, was measured according to numbers provided by patient risk groups and Infection Control Risk Assessment (ICRA) standards. The physical aspects, quality of the environment of care, general safety procedures, and hospital revenue loss impact were automated and integrated using several modeling techniques to develop an ACA critical rating model for the healthcare facility equipment. Regression analysis is a robust statistical methodology that can be used to determine the relationship between two or more quantitative or qualitative independent variables to predict the dependent variable (Al-Zwainy *et al.* 2013). The regression analysis technique was conducted to measure the relationship between these factors and the asset risk score. The rationale for using this methodology rather than the traditional AHP methodology was its use of the model factor weights in the representation of their behaviors.

6 DATA COLLECTION

Data collected in this research was qualitative and quantitative as shown in Figure 1.

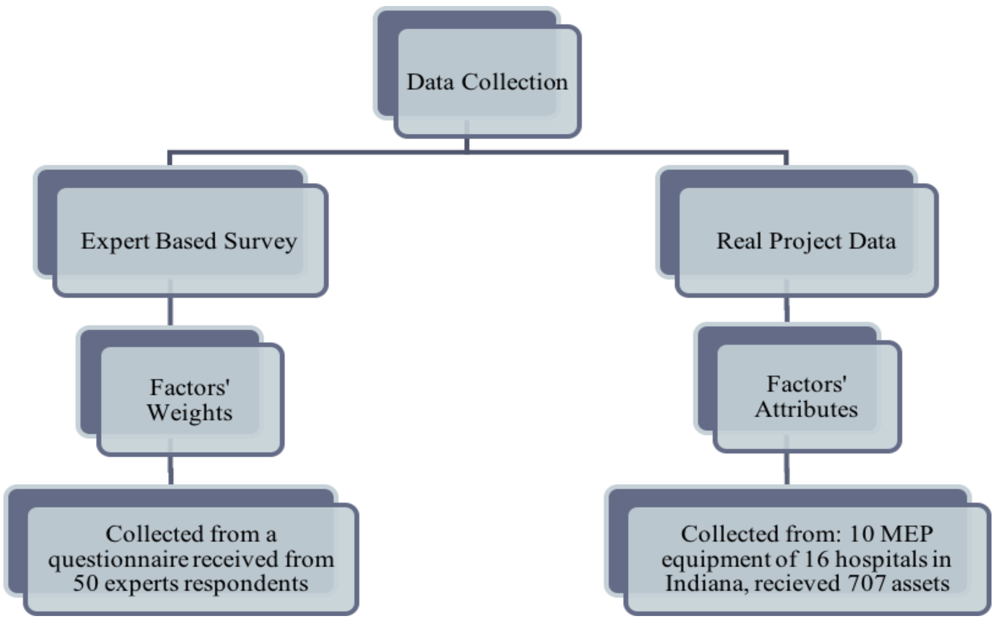

Figure 1. Main data collection process.

The study population was limited to Indiana healthcare facilities. The primary sample was based on the convenience and availability of the healthcare directors and professionals, including professionals from related disciplines such as infection prevention, life safety, and administration. The participants selected were 83 healthcare professionals in Indiana. The population samples varied by position and affiliated department. Valid case study data were collected from 707 MEP equipment types operated in 16 Indiana hospitals. The MEP equipment types utilized in this study were chillers, boilers, air handling units, cooling towers, condensate storage tanks (return and deaerator), generators, electrical switch gear, fire pumps, medical air/gas/vacuums, and water softeners. The MEP equipment is considered one of the main assets in hospitals.

7 DEVELOPMENT OF ASSET CONDITION ASSESSMENT MODEL

Salem and Elwakil (2018b) used the analytic hierarchy process (AHP) to rank critical asset condition assessment factors. A pair-wise comparison matrix of the main factors and their subfactors was used to obtain the factors' relative weights, or their importance among the other factors. The logical consistency CR of the overall priority weights was used to verify the reliability and consistency of the expert survey results. The results showed that the General Safety Factors with the highest priority and effect on the Asset Condition Assessment (0.31), followed by Environmental Considerations (0.27), Physical Factors (0.24), and Revenue Loss Factors (0.19). The Life Safety Sub factor had the highest weight of the General Safety Factors (0.65), followed by physical safety (0.11). The Code Compliance score was the highest of the Physical Factors (0.37), and the Repair Cost Sub factor was the highest of the Revenue Lost Factors (0.46). At 0.03, Age/Life Expectancy had the smallest contribution, as shown in Figure 2. Finally, the overall weights were decomposed to calculate the critical average weight of each factor in the framework (Saaty 1980, 1994).

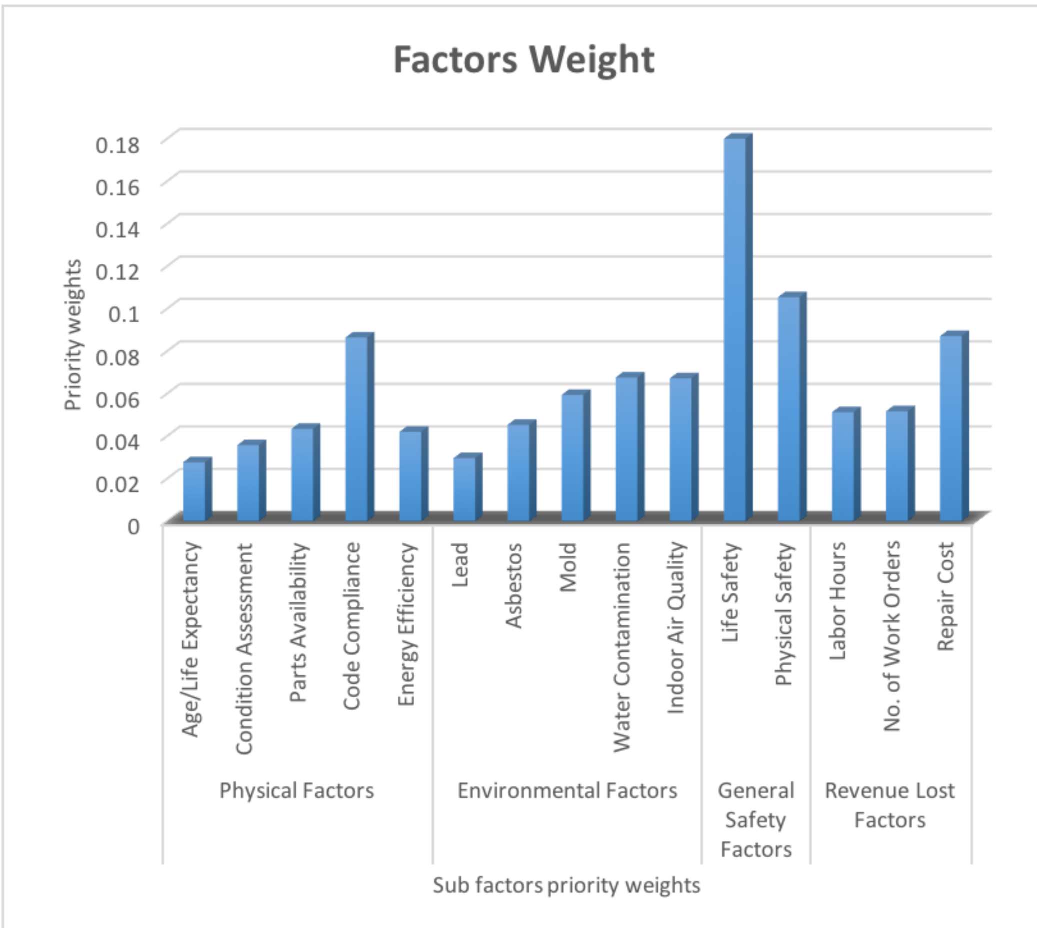

Figure 2. Critical asset factors relative weights.

The next step was to combine the collected factors' weights and effect attribute factors into one model representing the experts' knowledge that could be used in the ACA Critical Score model. Due to the multiple scales used to determine the case study attribute values, the attribute effects were normalized to a scale from 0 to 1.

To develop the AHP/Regression methodology for the ACA rating model, the factors' weights and normalized effect attributes were multiplied. The regression analysis technique was conducted to measure the relationship between these factors and the asset risk score. The rationale for using this methodology rather than the traditional AHP methodology was its use of the model factor weights in the representation of their behaviors.

The R^2, adjusted R^2, mean square error (*S* or *MSE*), and Mallow's *Cp* values were used to select the best ACA model based on the highest R^2, highest adjusted R^2, minimum MSE, and *Cp* closest to the number of independent variables can be summarized in Table 2.

Table 2. ACA model summary.

S	R-sq	R-sq(adj)	R-sq(pred)
0.0573766	90.56%	90.44%	90.24%

The Analysis of Variance (ANOVA) shows that the P-value (statistical significance) was 0.000 for the developed regression model. The null hypothesis was rejected at a significance level of 0.05. The F-test results demonstrated that the developed model was statistically sound. The P-value and the F-test results showed that the model reflected satisfactory results. Table 3 features the model's statistical analyses, including the constants, coefficients, F-values, and P-values.

Model verification was completed to test the validation of the model. The verification used the 141 case studies to compare the results of the developed model with the facility directors' rating scale. The results of the validation process show that AVP was 88.32%, which indicates that the developed ACA critical rating model was robust and its results satisfactory.

Table 3. Coefficients and statistical analyses.

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.0152	0.0133	1.15	0.252	
Redundancy	0.29027	0.00816	35.57	0.000	1.60
Energy Efficiency	-0.562	0.270	-2.08	0.038	3.41
Environmental Aspects	0.0421	0.0223	1.89	0.059	1.09
Life Safety	1.4327	0.0451	31.75	0.000	2.92
Physical Risk	2.027	0.137	14.84	0.000	2.73
Labor Hours	3.108	0.219	14.20	0.000	2.34
Work Orders	2.290	0.243	9.44	0.000	1.72

8 CONCLUSION

The present research aims to develop an asset condition assessment model of the healthcare facility asset in terms of its criticality, which will assist in the decision-making process related to capital needs. This model will improve the asset management of healthcare buildings, one of the largest national infrastructure sectors. The patient risk space was the main factor considered by the developed ACA model. The ACA critical rating model framework consists of four main factors: Physical, Environmental, General Safety, and Revenue Loss. Regression analysis technique was used to develop the asset condition assessment model based on the aforementioned factors. The model validation process showed that the robustness of the developed ACA critical rating model at 88.32%. The developed ACA model has the potential to reduce the amount of time and money spent on decision making processes, allowing leaders to allocate funding in ways that better serve hospital communities and patients.

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