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Modeling of Healthcare Facility Maintenance Staff Using Publicly Reported Hospital Metrics

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Operational staffing is an ongoing concern for the built environment industries. The proper staffing of maintenance personnel at hospital facilities to ensure optimal operations in the event of emergencies and disasters is an issue that has been the focus of continuing research. While a fair amount of scholarship has been dedicated to healthcare staffing in hospitals, such as nursing, there is a lack of research on identifying proper staffing for facility management related professions in hospital facilities. Numerous utilization metrics, such as admissions, and facility metrics, such as Gross Square Feet (GSF), have been proposed as potential predictive measures for making staffing allocations. This study was conducted to identify predictors of maintenance Full Time Equivalents (FTEs) using publicly published data by the Washington State Department of Health. A linear regression was performed on maintenance FTEs at these healthcare facilities using the predictor variables, GSF, admissions, available beds, and Plant, Property, & Equipment (PPE), $R^2 = .625$, $F(3,84) = 46.59$, $p = .000$. This research suggests that benchmarking efforts can be supplemented through regularly published hospital data to utilize a wide variety of predictor variables. Future research should focus on developing models that can be applied at a national level.

Key Words: Healthcare, Facilities Management, Benchmarking, Maintenance staffing ratios

Introduction

It is estimated that the operational costs of managing a building over its lifetime dwarf the construction costs two to one (Gallaher et al., 2004). Businesses have come to realize that the operational lifecycle costs of maintaining a building must be as well managed as the construction process itself. (Sullivan et al., 2010). Labor accounts for at least 50% of the operational lifetime costs of maintaining and operating a facility (Kirtane, 2012). Recent research has noted significant shortages of tradespeople in the construction industry (Bigelow et al., 2019, 2021), which has also been noted in facilities management (Sullivan et al., 2010). The same tradespeople shortages are affecting both industries as facilities management is highly composed of tradespeople. As a result of these labor shortages, increasing attention is being given to built environment staffing. Staffing levels are one of the most frequently discussed topics in the facilities management profession. These

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discussions are particularly commonplace in the healthcare industry where multiple organizations are attempting to develop ratios of Full-Time Equivalents (FTEs) that can guide the proper assignment of staff to the operations and maintenance of healthcare facilities (NASEM, 2020).

Guidance as to appropriate staffing, such as benchmarking information is not readily available and some healthcare facilities are reluctant to share financial details with other facilities in the standard benchmarking survey collection process. Low levels of participation in a benchmarking survey can be problematic because the results are less generalizable and applicable to the industry being benchmarked. Different healthcare facilities typically utilize different key performance indicators (KPIs) to manage their healthcare business such as discharges, occupied beds, admissions, and Gross Square Feet (GSF) (Cleverly & Cleverly, 2011; Kirtane, 2012; NASEM, 2020). There is no universal metric to benchmark facility staffing. This can often complicate the identification of similar peer facilities to benchmark against. While GSF is a universal facilities management (FM) metric, this is not necessarily the case in healthcare facilities management as hospitals contain complex spaces that demand unique maintenance and cleaning operations (NASEM, 2020).

The absence of adequately similar benchmarking reports or information, however, can be supplemented through information that is readily available for healthcare facilities, such as reported Plant, Property, and Equipment (PPE), available beds, admissions/discharges, and GSF, which are reported in different formats for facilities across North America. Using differing data sets that connect utilization and facility metrics, predictive patterns of staffing ratios can be assessed and validated that can be generalized to healthcare FM staffing throughout North America. Washington State provides public access to hospital financial and operating characteristics (Washington State Department of Health, 2018). Using this publicly provided data, this study was undertaken to identify utilization metrics that can be used to accurately predict healthcare facility staffing needs in the state of Washington, as a preliminary step in developing a national data set.

Healthcare facilities have unique needs compared to other organizational facilities including, "…the need for an increased focus on the urgency and timeliness of service and a higher degree of specialized regulatory accreditation and code compliance" (NASEM, 2020, p. 28). Consequently, healthcare facilities must operate with high reliability to retain functionality in emergency and disaster events. Thus, developing industry specific facility staffing ratios utilizing readily available and reported hospital facility information is essential to ensuring the constant operability of these facilities. These staffing ratios also must be balanced to minimize expenses and ensure that these facilities are not overstaffed compared to their peers.

Literature Review

The importance of facilities management in delivering high quality health care services has been an area of academic research interest for at least the past two decades (Shohet & Lavy, 2004; Shohet, I., 2006) Healthcare facilities are considered critical infrastructure (CISA, 2020) and therefore their ability to maintain reliable operational performance under all circumstances is both mandated and of the utmost importance. With such high operational demands, minimizing operational costs is an area of utmost importance to remaining competitive among their peers.

As a result, healthcare staffing has been an ongoing research interest (Anonymous, 2002; Kirtane, 2012) as reductions in payouts for Medicare and Medicaid spurred interest to reduce operating costs. Labor costs, representing 50% of operating costs, are often the focus of these continuous improvement initiatives. The literature suggests that there are numerous metrics that can be used to allocate staffing in healthcare facilities. Some of these include adjusted patient days, adjusted discharges, case mix index, and equivalent patient units (Cleverly & Cleverly, 2011), adjusted occupied beds, outpatient conversion factor (Kirtane, 2012) and GSF (IFMA, 2010, NASEM, 2020). Recent research indicates the case mix index has been found to be particularly effective in managing nursing staff allocation (Han, Chen, & Li, 2018). Cleverly & Cleverly (2011) report that measures such as adjusted patient days and adjusted discharges have numerous critics in healthcare finance leaders, who are looking for better ways to compare patient volume. Other research suggests effective staffing ratios managing effective labor solutions must utilize additional quality data, such as patient satisfaction (Anonymous, 2002).

An extensive literature revealed that unlike general healthcare staffing research such as nursing (Han, Chen, & Li, 2018; Bowblis, 2011) there exists very little research specific to healthcare facility maintenance staffing ratios. It is known, however, that IFMA has regularly included staffing ratios on facility FTEs/GSF in their healthcare facility benchmarking reports (IFMA 2010, 2013, 2020). It has been noted, however, that benchmarking using GSF may be problematic as it is not a regularly reported variable, and it fails to capture the complexity of what operations are occurring within the area footprint (GSA, 2012). More recently, the National Academies of Science, Engineering, and Medicine (NASEM) (2020) conducted research for the Veteran's Health Administration (VHA) where they developed and recommend a model for facilities staffing that utilizes building GSF and usage type, Facility Condition Index (FCI), facility age, managed acres, planned construction, and unique site requirements as key input metrics.

Washington State Dept. of Health is unique in its hospital financial reporting requirements of all healthcare facilities in the state. This public availability of data has facilitated ongoing research and overtime has created a unique database for researchers interested in hospital utilization and facility metrics (Coyne at al., 2009; Washington State Dept. of Health, 2018).

Research Objectives

1. To determine the best predictors of facility management maintenance FTEs at healthcare facilities in Washington State.

2. To develop a model for estimating the number of required facility management maintenance FTEs at healthcare facilities in Washington State.

Methodology

Data Collection

The data utilized in this analysis is available through the Washington State Department of Health (2018). The organization regularly publishes licensed hospital data annually based upon utilization and audited financial statements. This data includes PPE, construction in progress values, income statements with plant expenses (utilities, maintenance), plant staff expenses, FTE levels, admissions, patient days, available beds, and facility size in Gross Square Feet (GSF). A total of 105 acute care hospitals were identified to be used in this analysis. Not every hospital reported every variable used in this study. A total of 88 hospitals contained all the variables of interest in this study and were used in the analysis.

Analysis

The analysis method used in this study is a linear regression model of maintenance FTEs using GSF, admissions, available beds, PPE values, and a nominal GSF size category variable. Linear regression requires that the dependent variable be normally distributed and that the independent variables exhibit low collinearity. An initial linear regression model was run using all available independent variables. Independent variables with low collinearity tolerances (< .10) and large (>5) VIF scores in the initial model were excluded from the final linear regression model (Statology.org, 2020). The analysis was completed in International Business Machine's (IBM, 2020) Statistical Product and Service Solutions (SPSS) statistical software package version 26.

Study Variables

Independent

This study utilizes the following reported variables in the Washington State hospital data set: Exterior Gross Square Footage (GSF), admissions, available beds, Property, Plant, & Equipment (PPE), and a categorical variable GSF Size Category. Exterior Gross Square Footage is defined by ASTM E1836-08. The nominal variable GSF Size Category (0 or 1) was created as an initial exploratory analysis of the data indicated that healthcare facilities under 100,000 GSF exhibited a different correlational pattern than did facilities > 100,000GSF. GSF Size Category was created to indicate whether a facility is over 100,000 GSF.

Dependent

The dependent variable is the number of Maintenance Full Time Equivalents (FTEs). This variable is considered discrete as it is based on an integer count of employees. A Shapiro-Wilk test was run on the dependent variable, which indicated that the variable was not normally distributed. The normality of the dependent variable is a requirement for linear regression. The dependent variable was then log transformed and the Shapiro-Wilk test was run again, indicating that the log transformed variable was not significantly different from a normal distribution, thus meeting the standards for linear regression.

Results

Tests for Dependent Variable normality

Table 1: Shapiro-Wilk tests for dependent variable normality presents the results of the test conducted on the dependent variable, maintenance FTEs, before and after a log transformation. The variable was log transformed after an initial test indicated that the variable was significantly different than a normal distribution. The log transformation of the dependent variable, maintenance FTEs approximates a normal distribution sufficiently, which is a prerequisite for linear regression.

Table 1

Shapiro-Wilk tests for dependent variable normality

Variables	Statistic	df	Significance
Maintenance FTEs	.626	88	.000
Ln (Maintenance FTEs)	.978	88	.156

Collinearity: Independent Variable Correlation Matrix

Table 2: Spearman's Rho Correlations presents the correlations between the independent variables in the analysis. Spearman's Rho was used for this analysis as it appropriate for discrete variables such as beds available and admissions. All independent variables in this analysis show a moderate to strong linear relationship. Correlation is measured from 0 to 1, with 1 being a perfect relationship, and 0 being no relationship. Positive numbers represent linear relationships where both variables move in the same direction. Negative numbers represent linear relationships in which as one variable increases, the other variable decreases. GSF size category was not included in this analysis as it is a nominal variable.

Table 2

Spearman's Rho correlations

	GSF	**Beds Available**	**Admissions**	**PPE**
GSF	N/A	.696	.755	.863
Beds Available	.696	N/A	.910	.721
Admissions	.755	.910	N/A	.788
PPE	.863	.721	.788	N/A

All correlations are significant (2-tailed) at the p = .000 level. N = 88

Tests for Independent Variable Collinearity

The Collinearity Tolerance and Variance Inflation Factor for the independent variables are calculated in *Table 3: Collinearity Tolerance and Variance Inflation Factor*. The collinearity tolerances in Table 5 indicate that some of the variables may be repetitive due to their collinearity. Available Beds and Admissions both have a low tolerance score (<.10) and a large (>5) Variance Inflation Factor (Statology.org, 2020). As a result, both Available Beds, and Admissions were removed from the model to eliminate collinearity issues that can affect the validity of the results.

Table 3

Collinearity Tolerance and Variance Inflation Factor (VIF)

Independent Variables	**Collinearity Tolerance**	**VIF (Variance Inflation Factor)**
PPE	0.389	2.567

GSF Size Category	0.708	1.413
Available Beds	0.060	16.780
Admissions	0.055	18.022
GSF	0.308	3.248

Adjusted Final Model: Predictors of Maintenance FTEs: GSF, GSF Size Category, and PPE

Table 4: Final Model R^2 Summary provides a summary of the strength of the linear regression model. The R^2 value means that the model accounts for approximately 62.5% of the scores in the data set. It is a measure of the strength of the linear relationship between the independent variables and the dependent variables. The adjusted R^2 is a more conservative estimate that includes non-significant variables effect on the model. The standard error of the estimate is the measure of the variation of an observation made around the calculated regression line.

Table 4

Final Model R^2 Summary

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
	.790	0.625	0.611	0.76695

Table 5: Final Model ANOVA summary reports the Analysis of Variance statistics that are derived in testing the significance of the linear regression model. This test determines whether means between the groups are equal and whether this is due to chance. The F-statistic represents the ratio of variation between samples/variation within the samples. A larger F value is indicative that the variables are having a greater effect than the random variation within the samples. The adjusted final model was significant, $R^2 = .625$, $F(3,84) = 46.59$, $p = .000$.

Table 5

Final Model ANOVA summary

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
	Regression	82.222	3	27.407	46.594	.000
	Residual	49.410	84	0.588		
	Total	131.632	87			

Table 6: Model Coefficients and test for the significance and collinearity of the independent variables

Presents the calculated coefficients for use in the linear regression model (B), t-tests for the significance of each independent variable and collinearity and VIF statistics indicating the strength of collinearity among the independent variables. The Collinearity Tolerance and VIF indicate that collinearity of the independent variables is within tolerance. The Unstandardized B indicates the coefficients for use in the linear regression equation for estimating maintenance FTEs.

Table 6

Model Coefficients and test for the significance and collinearity of the independent variables

	Unstandardized B	**Std. Error**	**t**	**Sig.**	**Collinearity Tolerance**	**VIF**
(Constant)	2.158	0.153	14.083	0.000		
PPE	1.143E-09	0.000	3.145	0.002	0.452	2.210
GSF Size Category	-0.886	0.200	-4.429	0.000	0.732	1.366
GSF	7.260E-07	0.000	2.770	0.007	0.426	2.348

Maintenance FTE Linear Equation

The linear equation is the product of a regression model that can be applied to the data. This equation allows the facility practitioner to estimate the mean number of maintenance FTEs for Washington State Hospitals using GSF, GSF Size Category, and PPE. The equation is as follows:

$$\text{FTEs} = 10^{(2.158 + 1.124*10^{\wedge}-9(\text{PPE}) - .886(\text{GSF Size Category}) + 7.26*10^{\wedge}-7\ (\text{GSF}))}$$

Discussion

The results of this study suggests that there are numerous hospital metrics that can be used to predict or manage healthcare facility management staffing ratios. The significance of GSF size category suggests that smaller hospitals (<100,000 GSF), have a lower linear trajectory than their larger counterparts. The collinearity of PPE, GSF, admissions, and available beds suggests that these available metrics offer some predictive potential in calculating FTEs. On the other hand, their collinearity also suggests that not all the measures will be needed in predictive models. Many of these measures may be related through their expression of hospital volume, size, or complexity. Regardless, there are still additional variables that need to be identified in terms of their impact on healthcare maintenance staffing allocations to make more accurate predictions. Since hospital metrics are not reported consistently, benchmarking FTEs may require some flexibility in understanding these metrics and how multiple metrics can be used to aid in difficult staffing decisions.

Plant, Property, and Equipment (PPE) is a financial value that is commonly reported and publicly available for hospitals in Washington State, making it an easily accessible metric that can be accessed for benchmarking purposes. The results of the regression model indicate that PPE together with GSF offer a strong predictive potential in estimating the number of needed maintenance FTEs at Washington Hospitals. One limitation of this model is that it utilizes the publicly mandated hospital metrics in Washington State, which limits its applicability to other areas.

Conclusion

This study identified and tested the predictive potential for healthcare facility characteristics for maintenance staffing needs. Gross Square Footage and Plant, Property, & Equipment values accounted for 62.5% of the variation in staffing allocations in Washington State hospitals. Examination of additional potential predictor variables for healthcare facility staffing is worthy of further exploration and future research. The need for benchmarking data for managing healthcare facility management staffing concerns is well documented and this analysis suggests that in the absence of official benchmarking surveys, it is possible to build performance databases that can be used to evaluate facility staffing ratios from widely reported financial data. In the absence of benchmarking surveys and resources, practitioners have and need options for guiding their staffing allocations to ensure efficient delivery of critical services in a competitive healthcare setting. Future research efforts will focus on the development of predictor variables for facility maintenance staff that can be more readily generalized and applied at the national level.

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