EFFECTS OF SPACE PER OCCUPANT ON JANITORIAL AND MAINTENANCE COSTS ACROSS THE NORTH AMERICA, ASIA, AND MIDDLE EAST REGIONS

by

Bhagyashree Uttam Rathod

A thesis submitted to the faculty of
The University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Master of Science in
Construction and Facilities Management.

Charlotte

2023

Approved by:

_____

Dr. Jake Smithwick

_____

Dr. Nicole Barclay

_____

Dr. Stephanie Pilkington

ABSTRACT

BHAGYASHREE UTTAM RATHOD. Effects of Space per Occupant on Janitorial and Maintenance Costs across the North America, Asia and Middle East. (Under the direction of DR. JAKE SMITHWICK)

This study explores the relationship between space per occupant and janitorial and maintenance costs in facilities management (FM). The research is based on data collected from International Facilities Management Association (IFMA) Operation & Maintenance benchmarking reports across North America, Asia, and the Middle East. The research methodology used in this study involved several steps, including survey rebuilding, sampling, data collection, cleaning, conversion, and analysis. The goal of the study was to investigate the effect of space per occupant on O&M costs and janitorial costs across different regions. The researchers used purposive sampling to select relevant data from three IFMA O&M Benchmarking surveys, resulting in a total of 2,092 responses collected across three regions. The data was then combined and managed using Microsoft Excel Spreadsheets. Data cleaning was done to remove errors, typos, and logical inconsistencies. The study provides a comprehensive understanding of space planning and facility sizes across different regions and budget allocation for janitorial and maintenance costs.

Data analysis involved both inferential and descriptive statistics to examine the quantitative and qualitative data and assess the effect of space management practices on maintenance budgets, janitorial budgets, and future planning growth of facilities. Basic correlation and descriptive statistics were used to investigate the average facility size, space per occupant, janitorial costs, interior maintenance costs, and total maintenance costs across various facility uses and industry sectors. Additionally, linear regression and Pearson correlation analysis were used to identify the relationship between space per occupant and janitorial cost and maintenance cost. Basic correlation

analysis was also used to analyze qualitative data to identify the factors that cause differences in space management practices.

The results and findings of the study show a significant relationship between space per occupant and janitorial cost and maintenance cost. Linear regression analysis and Pearson correlation analysis revealed that as the space per occupant increased, the janitorial and maintenance costs also increased. This finding provides insight into the importance of space planning and facility sizes for budget allocation for janitorial and maintenance costs. Additionally, the study provides useful information on space management practices across different regions, facility uses, and industry sectors, which can help facility managers make informed decisions in their budget planning and maintenance strategies.

The study findings suggest that effective space utilization strategies can help control janitorial costs, while customized maintenance plans are essential for addressing the specific needs of the facility. The study highlights the importance of data-driven decision-making in FM and identifies opportunities for future research to improve FM practices.

ACKNOWLEDGEMENT

First and foremost, I would like to express my gratitude to my advisor and mentor, Dr. Jake Smithwick, for his unwavering guidance and support throughout this academic journey. It has been an honor to work with you, and I am excited to continue working with you in the future. I would also like to extend my appreciation to my committee members Dr. Nicole Barclay, and Dr. Stephanie Pilkington for their invaluable support and insightful feedback. I am also grateful to my husband, Ashutosh Patil, for his understanding and unwavering support as I pursued my education. I must also express my gratitude to IFMA for the countless opportunities provided to me through their organization. Last but certainly not least, I would like to thank my parents and in-laws for their endless love and support in all aspects of my life. I am truly fortunate to have such an incredible academic, professional, and personal support network.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ABBREVATIONS

1. IFMA- International Facilities Management Association
2. O&M- Operation and Maintenance
3. FM- Facilities Management
4. TMC- Total Maintenance Cost
5. IMC- Interior Maintenance Cost
6. JC- Janitorial Cost
7. RSF – Rentable Square Feet
8. SF- Square Feet

DEFINITIONS

1. Interior Area - Respondents were asked to provide the interior gross floor area (GFA), which was defined as the portion of the inside finished surface of the permanent outer building wall which is 50% or more of the vertical floor-to-ceiling dimension. For example, if a window is more than 50% of the wall height, then the inside of the glass is the dominant portion. ANSI/BOMA Z65.1 provides additional details. The janitorial and maintenance cost metrics were based on the interior area. The nomenclature for the interior area is different in all three regions- in North American data it is mentioned as a rentable area, in Asia as a plannable area, and in the Middle East as an interior gross floor area.

2. Maintenance Cost Categories- Maintenance costs are divided into the following six categories: external buildings, interior systems, roads and grounds, utility/central system, process treatment/ environmental, and other costs not included in the other categories. The maintenance chapter provides detailed examples of costs included in each category.

3. Multi-Use- In this report, multi-use describes facilities with two or more primary uses, such as a single site that encompasses headquarters offices, as well as production or research facilities.

4. Other Assembly Use- These include sites such as innovation/maker spaces, shopping malls (outside of retail use), and mixed-use assembly sites.

5. Other Facility Use- These facilities' use types do not clearly fit into other existing categories and include use types such as multi-use laboratories spaces and production, specialty healthcare facilities, and other mixed-use sites.

6. Other Industrial Use- These include sites such as work areas, production, distribution, and other operational centers.

7. Other Institution and Industry Sectors- These other institutional industry sectors include smart cities, property management, and enterprise services.

8. Other Office Use- These categories include specialized office types such as back offices, software programming space, etc.

9. Rentable Square Feet (RSF) – Basis used for Janitorial and all types of maintenance costs.

10. Space per Occupant - The space per occupant calculation considers the total available floor space in a building or area and divides it by the number of occupants that will be using the space. The resulting figure represents the amount of square footage per person

CHAPTER 1. INTRODUCTION

a. Introduction

Facilities management (FM) professionals are responsible for ensuring the efficient operation of buildings and facilities. Their responsibilities include managing space utilization, janitorial and maintenance services, energy management, and sustainability practices. To optimize the performance of buildings and reduce operational costs, FM professionals need to adopt a data-driven approach to decision-making. This study is based on data collected from IFMA O&M benchmarking reports across North America, Asia, and the Middle East. The study investigates the relationship between space per occupant and janitorial and maintenance costs in FM. The findings suggest that effective space utilization strategies can help control janitorial costs, while customized maintenance plans are essential for addressing the specific needs of the facility. The study highlights the importance of data-driven decision-making in FM and identifies opportunities for future research to improve FM practices. In addition to discussing the roles and responsibilities of FM professionals, this study focuses on the IFMA O&M benchmarking report for North America, Asia, and the Middle East. The report provides data on FM practices, including space utilization, janitorial and maintenance costs, and sustainability practices. The study findings are based on an analysis of this data, which highlights the need for effective space utilization strategies and customized maintenance plans. The study also identifies the importance of space planning in FM. Space planning involves optimizing the use of available space to maximize efficiency and minimize costs. The study findings suggest that effective space planning can help control janitorial costs and improve overall FM performance. Overall, this study contributes to the literature on FM by highlighting the importance of data-driven decision-making, space planning, and customized maintenance plans. The study identifies opportunities for future research to improve FM practices,

including examining the impact of COVID19 on FM practices and costs, and analyzing the factors that affect janitorial and maintenance costs beyond space per occupant.

b. Problem Statement

Effective space management practices in commercial buildings have a significant impact on maintenance budgets, energy costs, and future planning growth. This study aims to identify the factors contributing to the variation in space management practices across different geographic regions - North America, Asia, and the Middle East - and analyze their impact on building operations, maintenance, energy costs, and future growth of facilities. The research utilizes IFMA O&M Benchmarking reports for all three regions to establish benchmarks for FM professionals to develop best practices for space management while comprehending their impact on operation and maintenance costs, janitorial expenses, and energy costs of a facility. Additionally, the study will assist FM professionals and organizations in making efficient decisions regarding facility design, management, and maintenance by considering the business needs and challenges specific to each region, ultimately helping to optimize building and maintenance expenses by optimizing space utilization.

c. Research Objectives

The objective of this research is to analyze the relationship between space per occupant and janitorial costs, as well as all types of maintenance costs, and to identify how building demographic factors (such as age, sector, facility use, and location) affect janitorial and maintenance costs. The research aims to provide FM professionals with valuable insights into space management practices,

maintenance budgets, and janitorial expenses, enabling them to optimize space utilization and reduce operation and maintenance costs while enhancing the comfort and productivity of building occupants.

d. Research Methodology Summary

The research methodology involved a comprehensive process of survey rebuilding, sampling, data collection, data cleaning, data conversion, and data analysis to identify the effect of space per occupant on O&M costs and janitorial costs across different regions. Purposive sampling was used to select relevant data from three IFMA O&M Benchmarking surveys, resulting in a total of 2,092 responses collected across three regions. The collected data were combined and managed using Microsoft Excel Spreadsheets.

The data was cleansed and managed for quality, and respondents who did not provide content or facility data were excluded. Data cleaning involved checking the combined MS Excel data file of respondents' surveys for errors, typos, and logical inconsistencies. Data analysis involved basic correlation and descriptive statistics to examine quantitative and qualitative data and assess the effect of space management practices on maintenance budgets, janitorial budgets, and future planning growth of facilities.

Finally, linear regression analysis and Pearson correlation analysis were performed to identify the relationship between space per occupant and janitorial cost and maintenance cost. The study provides a comprehensive understanding of space planning and facility sizes across different regions and budget allocation for janitorial and maintenance costs.

e. Research Scope

Facilities managers play a crucial role in organizing and managing the workplace. As FM is typically a cost center, it is essential that our actions align with the overall business goals and objectives. In this context, the way we organize the workplace can have a significant impact on building operations and maintenance costs. For instance, the space per occupant is a key factor that can influence the overall energy usage, janitorial costs, and maintenance expenses. By thinking strategically about how we organize space and optimize resource usage, we can generate cost savings and support the business objectives of the organization.

In summary, optimizing space utilization can help us achieve several objectives, including improving the workplace environment, reducing energy costs, and enhancing employee productivity. As a result, facilities managers should be mindful of the impact of their decisions on the overall business objectives and strive to develop best practices that align with these goals. By utilizing data-driven benchmarks and other relevant information, FM professionals can develop more efficient and cost-effective workplace management strategies that deliver value to the organization.

f. Summary of Report

This study aims to investigate the relationship between space allocation per person and janitorial and maintenance costs in three geographic regions. The data was collected from the IFMA O&M Benchmarking reports, which provided a combination of qualitative and quantitative data on facility sizes, types of facilities and industries, janitorial costs, and different types of maintenance costs. The data sampling method used was purposive sampling, as the available data from existing surveys were vast and needed to be defined according to the study's objectives. A total of 2,380

responses were included in the analysis after data cleaning and quality management, which involved checking for errors, typos, and logical inconsistencies. The data were analyzed using basic correlation analysis and linear regression analysis to identify the relationship between space per occupant and janitorial and maintenance costs. The results and findings of this study will provide insights into the nuances of space planning and facility sizes across different regions and budget allocation for janitorial and maintenance costs.

CHAPTER 2. LITERATURE REVIEW

I. Facilities Management

1. Facilities Management Concepts

There are many definitions for facilities management, all of which are different for individuals and organizations as per the understanding of the concept and the nature of work they do as facilities managers. According to IFMA 2022, “facility management” is an organizational function that combines people, place, and process with the physical environment, with the objective of enhancing the quality of life and the core business efficiency. According to Leaman (1992), facilities management unites design and management knowledge in the context of buildings in use.

FM is the coordination and management of services and processes that support the core business of an organization. It combines the planning, design, operation, maintenance, and improvement of the physical and environmental aspects of a building or facility, as well as the management of the people and resources required to deliver these services. FM includes a broad range of activities, such as maintenance, security, janitorial, and energy management, with the goal of ensuring that a facility is safe, functional, and cost-effective. The concept of facility management is changing as per the needs and constantly evolving as technology and business needs are changing across the globe. Facilities management is a relatively new, but widely misunderstood, profession. The ability to work with many disciplines is crucial to being a successful FM. These professionals should try to resolve conflicts and identify collaborations in the face of increasingly complex building systems and a greater diversity of user involvement and handling operational risk. (Finch and Zhang, 2013)

The wide range of activities required for the functioning of any facility from an FM perspective includes: [(IFMA website) (EPA, 2021) (ASHRAE, 2021) (OSHA, 2021)]

1. Operation and Maintenance- This includes maintaining and repairing facilities and equipment on a regular basis to ensure that they remain in good condition and function properly. HVAC system maintenance, electrical and plumbing repairs, and regular cleaning are included in Operation and Maintenance.

2. Janitorial Services- This includes managing the janitorial services of a facility, including the selection and management of cleaning contractors, as well as the creation of cleaning schedules and best practices as per policies and procedures.

3. Energy Management- This includes utilizing energy efficiently in a facility, including the implementation of energy-saving measures such as lighting control systems and HVAC optimization.

4. Space Management- This includes making optimal use of the available space within a facility, including the design, layout, and organization of the physical environment to maximize productivity and comfort. Space management also includes managing space per occupant in a facility (e.g., occupant density, space assignment, and planning).

5. Utility Services - This includes managing water, gas, and electricity services, including usage monitoring and optimization, and also managing the billing and payment process.

6. Procurement- This includes the management of procurement processes, such as the sourcing and purchase of equipment required for the operation and maintenance of a facility.

7. Waste management and Recycling- This includes the management of waste generated in a facility which includes the application of waste reduction and recycling programs.

8. Security Services - This includes the protection of facilities, people, and assets, along with the implementation of security systems and protocols and the management of access control and emergency response plans.

9. Sustainability Practices – This includes practices to minimize the impact on the environment by practicing energy efficiency, water conversation, and green building initiatives.

FM professionals work to create safe, comfortable, and efficient facilities that meet the needs of the organization and its occupants, with a focus on sustainability and regulatory requirements. Organizations can improve operational efficiency by cutting costs and improving the overall efficiency of managing a facility effectively. FM has recently expanded its role beyond the conventional maintenance or property management functions to include and ensure that facilities add value within the context of the objectives and goals of an organization. Facilities management is expanding to meet the current global changes that have caused client organizations to recognize facilities management as an important function (Adewunmi et al., 2017).

2. Benchmarking

As per IFMA, benchmarking is an ongoing and structured management process that measures work processes, protocols, and services to compare and improve organizational performance (International Facility Management Association 2022). Benchmarking assists businesses in learning how to improve their operations by examining what other similar companies do. Benchmarking is a distinct methodology, and it is a standardized assessment process. It offers a technique for using performance criteria to pursue improvement beyond best practices (Wauters, 2005). Benchmarking may be required within organizations due to the competitive environment in which they operate. Globalization, the global economic crisis, and the rapid advancement in the IT field have a significant impact on how businesses operate (Adewunmi et al., 2017).

Benchmarking may assist firms in reducing costs, increasing profits, and improving customer experience and satisfaction. Benchmarking consists of four basic processes: i) Plan, ii) Collect data, iii) Analyze the data and iv) Adapt (American Society for Quality (ASQ), 2021). Benchmarking is one method for organizations to create something new and learn as they respond to their competitors. The three most common types of benchmarking used are internal, competitive, and functional (generic) benchmarking (Mahmoud M. Yasin and Thomas W. Zimmerer, 1995). The evaluation of processes is a significant element of all types of benchmarking as it goes through a thorough analysis of input variables transformed into useful output values which will help organizations to obtain better efficiency (Hinton et al., 2000).

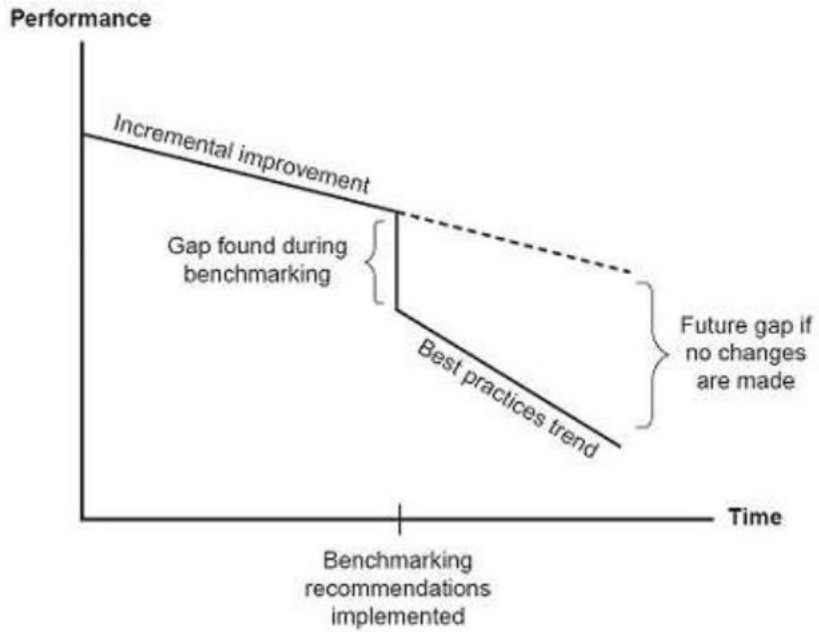

Figure 1. Incremental Quality Improvement vs Benchmarking Breakthroughs (*American Society for Quality (ASQ). (2021). What is Benchmarking? Technical & Competitive Benchmarking Process. Retrieved from https://asq.org/quality-resources/benchmarking)*

3. Benchmarking in Facility Management

Benchmarking in facilities management is described as the process of comparing a product, service process, or any activity or object with another sample set of competitors, with the objective to incorporate best practices for improving the existing system (William 2000, Wauters, 2005,). Benchmarking compares the performance of one facility to another, ideally with similar demographic features (such as size, location, or use). One of the most widely used metrics is gross area per occupant. Facility benchmarking must meet at least two requirements: comparable assets

(such as mechanical equipment or other systems) and comparable buildings (such as size and location) (Rusek et al., 2018).

Benchmarking in FM can save money only when quality and performance risks are considered in the business. It is important to select the right peer group, and the right parameters for comparison of product, service process, capital, etc. to develop an appropriate benchmark. For example, while comparing the cost of activities like cleaning, maintenance, and security, parameters like "cost per square foot or per capita" must be considered. But for this to work the standards and units used for floor area and cost must be accurate. Several organizations around the world use benchmarking in FM as a strategic planning tool to assist management in decision-making (Martsch, 2009). It is necessary to deliver data to support the submission of an operating budget that shows the levels at that the rest of the industry operates so that facility managers can utilize the data to generate spending plans for management (Padavano, 2004, Adewunmi et al., 2017).

The International Facility Management Association is a major player in the creation of international FM standards and works with policymakers around the world to inform and shape FM policy. IFMA offers career resources and continuing education, as well as three industry-recognized accreditations (FMP, SFP, and CFM). It is the largest source of digital archives of FM-related content and a year-round global event (IFMA, 2022). The operations and benchmarking reports published by IFMA for various geographic reasons are reputable sources on O&M benchmarking topics that help FMs evaluate the cost and service efficiency of their facilities.

FM benchmarking from a wider perspective that benchmarking in FM is not just about comparing costs of land, various services, or equipment but it also comprises space use, FM management, and Computer-aided facilities management systems (Wauters, 2005). FM should add value to the

organization and the effectiveness of the FM operation needs to be regularly evaluated. The establishment of the benchmarking framework will aid in simply reacting to the changes brought about by advancement in FM due to globalization, which necessitates the standardization of services, transparency, and comparability (Babawale, 2008). Williams *et. al.* (2012) describes the concerns related to benchmarking, such as sources of benchmarking, validity, and reliability of the parameters used for benchmarking, and reluctance to implement changes based on benchmarking data. For better results of benchmarking, there should be two-way communication between the service providers and IFMA to facilitate the organizations all the benefits of benchmarking (Adewunmi et al., 2017, p. 852).

4. Importance of Space management

Space management means the rational distribution and utilization of space that maximizes space usage in terms of frequency (frequency = number of hours a room is in use / total room availability) and occupancy (Abdullah, Ali, & Sipan, 2012). Effective space management enables facility managers to make the best use of available resources, such as space, equipment, and personnel. By utilizing space efficiently, facilities managers can reduce costs associated with unused or underutilized space. In the FM industry, space management refers to the planning, allocation, and utilization of physical space within a building or facility. This includes optimizing space to meet the needs of the organization and its employees while keeping the cost and practicality of the solution in mind. "*The cost of accommodating the average Federal associate typically runs $10,000 to $15,000 annually per person. Eliminating 100 workspaces can save an organization over $1M a year.*" (Workspace Utilization and Allocation Benchmark by GSA, 2011).

Facility managers must manage the space effectively in order to make efficient use of available space (Ibrahim et. al., 2010). According to the analysis of facility management definition, space management is one of the essential aspects of FM which should be prioritized (Ibrahim et al., 2010). The primary goal of space management is to make the best use of available space while ensuring that the facility meets the needs of the organization and its employees. Floor plan design, furniture layout, storage solutions, and resource allocation are all part of this process. Research related to space management is very important to consider as costs associated with space are the second highest cost after staff salaries in higher educational institutes (Ibrahim et al., 2010). Rent, utilities, maintenance, and other related expenses are all included in the cost of space management. These expenses can quickly add up, making space management a significant expense for many businesses. In some cases, the cost of space management can even outweigh the cost of salaries, particularly for organizations operating in high-cost real estate markets or requiring large amounts of space to accommodate their operations. Furthermore, the cost of space management can be influenced by factors such as the location of a facility and building care standards. Effective space management can assist organizations in lowering these costs by making efficient use of available space and resources. The cost of space management is an important factor in the operations of many organizations and FM professionals should consider these cost effects while making decisions related to space utilization and resource allocation.

"*Similarly, in the United States (U.S.), General Services Administration (GSA) recommended that a 17.6 m^2 area on average be required for an optimum workspace per person. Second, some countries provided standards or information of the building occupancy density, often including the workspace and public community space, mainly for building managerial and control purposes*." (Kang et al., 2018, p. 174). Public facilities should have enough space to meet their

operational needs, but this can be difficult to achieve over the life of a facility because spatial needs change while available space remains constant. Many current facilities have historic structures that were initially designed for purposes that were relevant then (Rusek et al., 2018). A comparison study on space-use analysis techniques and proposal of a novel method for determining space needs in public facilities" (Rusek et al., 2018) addresses the issue of suboptimal space management in public real estate, which can result in issues with required space and availability of space for public services, ultimately leading to a decrease in work productivity and low quality of public services. The article highlights that commonly used methods for space use analysis are not suitable for public offices due to the high cost, complexity, and variety of space use. The article proposes a novel, low-cost, activity-centered method for defining space needs that can be applied to a variety of public buildings. This method solves the problem of inefficient space management in public real estate and contributes to the field by presenting a new approach to determining space needs. A few of the most functional space management characteristics involve several aspects including the amount of time staff spends working in the office each day, desk and job-sharing practices, how frequently and for how long these resources are utilized within a facility, and the percentage of space utilized in a facility over a certain period of time is also considered. (Ilozor and Ilozor, 2006, p. 14)

Space management is significant not just from an optimization point of view but also from operations and maintenance costs. The building occupancy density allows FM to recommend appropriate workspace sizes for various management purposes, including building energy management. (Kang et al., 2018, p. 174) "*In the U.S., an office space of 100.11-399.09 square feet per person is recommended to be maintained for managing the office building. In addition, in*

South Korea, a person generally uses the office space of 216.38-604.95 square feet in the public office building" (Kang et al., 2018, p. 174)

As explained by Kang et al. (Kang et al., 2018, p. 174) previous studies on the effects of occupancy of energy management practices have been conducted to analyze the impact of occupancy information, such as occupancy pattern, number of occupants, and occupancy schedule on building energy consumption. The results showed that considering the occupancy information can increase the accuracy of predicting building energy consumption. However, those studies failed to provide an optimal occupancy density for reducing energy consumption. Some studies used data mining techniques for occupancy schedule learning and prediction and others evaluated the energy impacts of real-time and long-term occupancy density. The data for the number of occupants per space is the most critical input to be evaluated in space management as well has a significant impact on the precision of ENERGY PLUS simulation for institutional buildings (Yang et al., 2016, p. 203). Ultimately, effective space management can result in significant cost savings for a company by lowering rent, utilities, maintenance, and other expenses while also increasing employee satisfaction and productivity.

5. Space Budgeting

Space budgeting entails allocating current and future space to a function. This process is similar to financial budgeting (or planning) in many ways. (Harris, 2011, p. 29). Space budgeting refers to the process of physical space planning that involves space allocation, and space management to ensure efficient and effective use of available space in a facility. Budgeting and assigning space, data collection, reporting, evaluating, and decision-making and benchmarking are all part of the

space management process. (Harris, 2011). Space is comparable to money as a resource in FM. (Harris, 2011. All the aspects of financial budgeting can be applied to space budgeting which is space assessment or space audit, identifying the space needs, space allocation, budgeting, monitoring, and adjusting. Budgeting here basically means the costs involved in maintaining the space and required for relocation of personnel or equipment.

According to Harris (2011, p. 31), several universities have a policy that requires assigning particular square footage for research activities to each faculty member belonging to a particular discipline. Such an approach guarantees the optimal use of available space by allocating it based on the number of occupants. This method is effective in managing space and distributing resources in a manner that aligns with the user's objectives while also staying within budget constraints.

Space budgeting processes are complicated and are affected by various external and internal factors, but they are necessary and beneficial in guiding administrators through academic space allocation. (Harris, 2011, p. 40). Generally, building occupancy density is divided into two types of categories based on the type of space included: i) building occupancy density that includes only workspace and ii) building occupancy density that includes both workspace and public community space. (Kang et al., 2018, p. 173). This would help FM professionals to efficiently use the underutilized area by proper space audit and overutilized area to be reconfigured to meet the needs as per the changes in market conditions. It may also lead to employee work satisfaction by identifying the needs of the employees and allocating the space accordingly.

6. Effects of space management on energy and operations and maintenance

Space management has a significant impact on energy and the operation and maintenance of a building facility. By optimizing the use of natural light, improving building insulation, and optimizing the use of an HVAC system, space management can help reduce the energy consumption of a facility. Efficient use of space can also help in reducing the O&M costs by optimizing the space usage by allocating the amount of square footage per person or per workstation required to maintain to optimize the energy efficiency of the facility. Energy efficiency is a broad field of study that includes more than just reducing energy consumption through better building envelope and system design. It is also critical to make efficient use of energy and space (Udrea et al., 2017). Space management optimization contributes to the efficiency and success of many organizations. (Udrea et al., 2017). It is also found that many public and private sector offices underuse the space which ultimately causes inefficient space usage which will increase the O&M cost and energy cost.

Udrea et al. (2017) suggest that traditional methods, coupled with modern-day solutions, can lower energy usage in facilities by optimizing the use of energy and space. The integration of smart building technologies, such as occupancy sensors and energy-efficient HVAC systems, can significantly reduce energy consumption while enhancing the building's overall energy efficiency.

Udrea et al. (2017, p. 7) report that many public and private organizations are not fully utilizing their office spaces when compared to industry data. Therefore, efficient, and effective space utilization can help manage costs and improve productivity levels. Additionally, Kwok et al. (2011, p. 1688) found that energy consumption varies depending on the number of occupants present in a facility, as people emit heat and pollutants that increase the building's cooling load. Yang et al.

(2016, p. 193) highlight that proper interventions in occupant behavior can reduce energy consumption by up to 24.7% in commercial and residential buildings. By implementing a rational use of energy, facility managers can improve their facilities' sustainability and efficiency while reducing operating costs.

Proper space management can improve overall operations and maintenance as well. FMs can reduce building maintenance costs by minimizing the amount of space that requires maintenance. Moreover, effective space management can lower the risk of overcrowding, which may lead to higher maintenance costs due to potential building damages.

7. Energy Management

The systematic process of monitoring, controlling, and optimizing the use of energy in a facility is termed “energy management.” Energy management aims to reduce energy consumption, reduce energy costs and increase energy efficiency. Energy efficiency can be obtained by following these measures-

Energy audits can aid in identifying areas of energy waste and provide recommendations for proper energy management. The implementation of energy-efficient lighting systems can reduce a facility's energy consumption. Regular maintenance of HVAC systems can optimize their operation, and the use of energy-efficient equipment and temperature control on HVAC systems can reduce energy consumption on a large scale. This can be achieved through the implementation of a building automation system. The cooling load in buildings is affected by various factors, such as outdoor climate and building occupancy.

However, the impact of these factors varies based on the type of forecast, the weather zone, building orientation and type, occupancy behavior, and operational schedule (Kwok et al., 2011). A comprehensive energy management program for a facility should involve regular monitoring, continuous improvement, and employee participation. FM professionals can utilize the measures mentioned above to reduce energy consumption, decrease energy costs, and support more sustainable and efficient facilities. Numerous facilities are adopting green building initiatives by incorporating the use of renewable energy, sustainable practices, etc. Generally, energy audits are an effective tool that can assist FMs in developing energy-saving plans and achieving energy-saving objectives (Kwok et al., 2011).

The building energy management system (BEMS) is a computer-based control system installed in a building that monitors and controls various systems, including ventilation, lighting, power, fire, and security. The system uses hardware and software that can be configured in a hierarchical manner and may use proprietary protocols such as C-bus and Profibus, as well as Internet protocols and open standards to integrate with other facility management systems. BEMS optimizes energy usage and enhances comfort control, making it a valuable tool for FMs to tackle energy waste. (Finch and Zhang, 2013, p. 323).

The Building Energy Efficiency by Space Type (BEEST) method proposed by Kung-Jen and Chen- Hong, (2012) has been used to help individual departments in universities to manage the energy performance of their facilities. This method classifies different types of spaces into ‘space types' with defined standard operation settings and energy analyses which can be then performed to identify problem areas and recommend energy-saving plans. This study helped by developing a useful tool for managing complex energy management tasks. For improvement in the BEEST

method, monitoring actual space type and energy consumption per space type should be periodically analyzed.

8. Energy Optimization

FM professionals should take into consideration the number of occupants and space utilization to optimize energy usage by developing and implementing energy management strategies. This can be achieved through the utilization of occupancy sensors, energy-efficient practices, and conducting space and energy audits. Understanding the impact of the number of occupants and their required space on energy consumption is crucial. Optimizing energy can be achieved by optimizing space utilization and incorporating modernized energy management practices. Energy costs can be reduced by utilizing energy-efficient lighting systems, replacing those that consume excessive energy, and implementing building automation to monitor and control energy usage. Proper energy management requires an understanding of the space type, occupancy density, and behavior. (IFMA, 2022 and International Energy Agency- Energy Efficiency 2021.)

Many countries are focusing on reducing building energy consumption to combat climate change and global energy depletion. Buildings consume 40% of total energy globally, and building occupants play a significant role in energy performance. Therefore, it is crucial to simulate and predict energy usage while managing and controlling it using occupancy data such as the number of occupants and their behavior. Government regulations on energy performance and energy use apply to public office buildings, highlighting the importance of occupants and their information in regulating and reducing building energy consumption. This importance has been widely recognized and investigated in recent studies (Kang et al., 2018).

There are significant differences in the building energy performance predicted at the design stage and the actual performance delivered during the building operations stage due to differences in occupancy patterns. Predictions based on standard occupancy schedules can differ by up to 46% from actual energy demand from the real energy demand, while a lack of proper building management based on user occupancy can result in up to 50 % waste. (Rusek et al., 2022)

Impacts of changes in building use can have a direct impact on building energy performance and this leads to designing new strategies for improved sense of occupancy and energy demand for energy optimization. This also shows that consideration of space utilization per occupant at the design phase of a building and estimation of energy demand and actual usage as per the weather and geographical region. "*As a result, it was shown that buildings with an occupancy density* above *338.14 square feet/person could save up to 50.3% energy on average compared to those with an occupancy density below 338.14 square feet."* (Kang et al., 2018, p. 173).

The occupancy density data can be used by users who are interested in reducing the building energy consumption, to predict the energy consumption pattern as per the space type, and also to develop more accurate energy benchmark data to analyze the energy usage to monitor and control the building O&M. The COVID-19 pandemic has changed the perception of space utilization and impacts of hybrid and remote working. As mentioned by Rusek et al. (2022), the pandemic has altered the work culture; social distancing and remote working had a significant impact on working conditions and have also altered the energy consumption patterns.

9. Operation and Maintenance and Janitorial Costs

The operation and maintenance (O&M) activities in constructed facilities are the most time-consuming part of a building's lifecycle. In addition, energy and maintenance costs are the largest expense component of a property's sustainment budget (Róka-Madarász et al., 2016). Operation and maintenance costs refer to the expenses incurred to keep a building or facility running smoothly on a daily basis. These costs include regular maintenance, such as HVAC system maintenance, plumbing repairs, and electrical maintenance, as well as preventative and reactive maintenance in facilities. The role of a facilities manager is to efficiently manage the O&M costs and ensure that the facility functions effectively by using optimal resources.

Efficient building operation will result in lower energy consumption, lower maintenance costs, and lower environmental emissions (Sari, 2018). Unfortunately, in most countries around the world, efficiency in building O&M remains a problem which may be the primary reason for the failure of green buildings.

Janitorial services are one of the most common outsourced services in the FM industry. (Gorzig et. al., 2002). Janitorial costs are the expenses incurred when a facility is cleaned. These expenses commonly include labor, cleaning supplies, and equipment charges. This involves creating a schedule for cleaning the office spaces, selecting the appropriate cleaning equipment and supplies, and monitoring the cleaning process. To achieve both economic and managerial goals, buildings must have optimal provision Operation & Maintenance costs. Also, it was found that utility costs can be largely explained in terms of floor area construction (Sliteen et.al., 2011).

As explained by Sari (2018) the major challenge in developed countries like the United States, and Europe is the transition process from traditional reactive maintenance to proactive maintenance which includes the advancement of technology. Whereas in developing countries like Asia and Africa FM as an industry is comparatively new.

In addition to examining the relationship between space per occupant and janitorial cost, the researcher also attempted to review the data on janitorial cost and its relationship to occupancy. However, despite conducting a thorough search, no previous research studies were found on this topic, suggesting a gap in the existing literature.

2. Metrics and tools for Space Calculations in different facilities

1. Different calculations of space allocation for Public and Private offices

The calculation for space allocation for public and private offices varies because of the differences in their functions, organizational structures, and work practices. Generally, private offices have more flexibility in space allocation as the space utilization pattern changes according to market and business goals. Public offices, on the other hand, are designed based on legal requirements, policies, and accessibility standards, taking into consideration the population of the local area who will visit the facility. Typically, public office space is designed for 50 years, considering potential population and employee growth, while private offices have adopted the concept of open office space, flexible workspaces, co-working spaces, teleworking, desk sharing, and hoteling workstations for better space utilization in recent years.

Rusek et al. (2018) discuss the issue of inadequate space management in public real estate, which can lead to underutilization of space and decreased service quality. They suggest that the common methods used for space use analysis in the private sector are not suitable for public buildings, as they are often expensive and focused solely on the building. Instead, they propose using an activity-centered and low-cost method to determine space allocation in public offices. It is crucial for public offices to have sufficient space to accommodate the various public services carried out in the office space. However, the major challenge in designing space utilization plans for public offices is that the available space remains the same, while the needs of the facility may change over time.

As reported by General Services Administration in Workspace Utilization and Allocation Benchmark (2011), facility managers have aimed to reduce overall space use costs by making the workspace more efficient. This has involved developing more efficient design standards, resulting in a significant reduction in the typical office standard from around 250 square feet per workstation to around 190 square feet or less since the early 2000s. It is important for public office spaces to shift towards effective workspace that not only balances the space needs but also supports collaborative and individual workspaces just like private office spaces. Remote work and other types of hybrid work patterns are getting traction post-COVID times in both the public and private sectors.

2. Activity Based Working tools for Space Planning

Activity-Based Working (ABW) is a workplace strategy that empowers employees to choose their own desk location based on their work needs and preferences (Gocer et al., 2022,). ABW typically involves the design of a variety of spaces that support different types of work, such as

collaboration, socializing, and focused work. Compared to traditional office designs, ABW has a lower ratio of workstations to employees, which increases space utilization. This method enables a lower ratio of workstation and occupant, which is predicted to lead to increased space utilization over time.

Organizations could also develop guidelines designed to enhance space occupancy and utilization, as well as overall required performance such as storage belongings, clean desks, and collaboration to ensure ABW metrics are implemented in the design phase of a building. A major challenge for research in ABW-friendly offices is the ability to collect and/or have access to longitudinal data that could help design office spaces considering employee preferences. One of the possible advantages of spaces designed to support the ABW concept is enabling people to work from zones that fit their Indoor Environmental Quality preferences (Gocer et al., 2022,).

Various studies have shown a correlation between occupant satisfaction and IEQ-related parameters in workplaces designed with the ABW concept. Space utilization data is essential to understand the use of workspace in ABW offices. Various methods are used to analyze the occupancy patterns in ABW offices including systematic observations, behavioral mapping, wearable devices, barcode scanning, and real-time occupancy data for building automation systems. This concept focuses on the workspace designs that facilitate work productivity and employee satisfaction.

3. Utilization Frequency Occupancy (UFO) Method

The Utilization Frequency Occupancy (UFO) method is a space utilization rate proposed by the UK National Audit Office to evaluate space use in education buildings. (Rusek et al., 2018). This method is used to calculate the utilization rate, frequency rate, and occupancy rate of a space. FMs can determine effective space utilization by using the combination of these metrics and make decisions regarding the optimization of space depending on the data analysis. For instance, if an office conference room has a high utilization rate but a low occupancy rate, using this metric that space can be downsized as per the actual utilization rate.

The 'UFO' method is another name for the space utilization rate calculations. (Abdullah, Ali and Sipan 2012). "*The UFO method formula has the following form: Utilization rate = frequency * occupancy*" (Rusek et al., 2018, p. 327) where frequency refers to how often the space is used, and occupancy refers to the average number of people using a space at any given time. This method can be used to calculate the utilization rate for facilities where core activities take place such as youth centers, multipurpose halls, administrative halls, etc. (Rusek et al., 2018, p. 329)

4. Space Usage Analysis method (SUA)

The Space Usage Analysis (SUA) method is used in facilities management to evaluate space utilization in a facility. The aim of this method is to identify the areas of underutilization and overutilization to assist the FMs to make use of the space effectively. This method enables the immediate pairing between the user activities and available space depending on the space

demands. It helps architects to evaluate effective space usage in the planning and design phase of a building. (Kim & Fischer, 2014a; Kim, Rajagopal, Fischer, & Kam, 2013)

The SUA method can also be used to track the effects of facility changes, allowing facility managers to determine the extent to which space has been effectively utilized as per the demand. These metrics are helpful for large organizations with multiple facilities because it allows them to practice space optimization and apply them across multiple locations. It is a useful tool in FM as it allows facility managers to make data-driven decisions about how to optimize the use of space in a facility. It will help facility managers to improve the efficiency of the facility, and lower O&M costs and energy costs. This method is used to estimate the scope of user occupancy in the facility by evaluating the space usage which basically involves matching user activities and available space as well as forecasting the space utilization in a facility. (Kim & Fischer, 2014b; Kim, 2013). This method is becoming extremely relevant for space management (Gibson, 2000).

The SUA metrics transformed from manual analysis to automated computational applications, allowing the matching of available space and prediction of space utilization. It works effectively in the design phase of building construction but is not a good fit for the O&M phase. The future scope of this metrics study will prioritize space management during the O&M phase.

PROBLEM STATEMENT

The variation in space allocation and management practices in commercial buildings across different geographic regions has a significant impact on the maintenance budgets, energy costs, and future planning growth of a facility.

From a facilities management standpoint, space per occupant is decreasing in North America in commercial buildings and this has an impact on workplace design, building operation and maintenance, and work productivity. This change is the result of increased emphasis on sustainability, optimization of resources, growth of remote and hybrid working post-COVID, and rising real estate costs. The problems related to space per occupant in the Asia region from an O&M point of view are related to the challenges in balancing the need for efficient space utilization.

As the working population and market are growing rapidly in Asia, FM professionals are challenged to make the best use of available space. This leads to cramped and densely populated work environments with less space per occupant in office spaces. Also, the weather conditions in Asia have a hot and humid climate where energy consumption is high and the cost of maintaining comfortable indoor temperature is also high. This brings the challenge to adopting sustainability and optimization in terms of energy and space.

This research aims to address the significant variations in space management practices across North America, Asia, and the Middle East regions, and their impact on building operations, maintenance, energy costs, and future growth of facilities. The study will investigate the following research questions:

1. How does space per occupant in a facility affect janitorial costs?

2. how does space per occupant in a facility affect all types of maintenance costs?

3. How do other building demographic factors (such as facility age, industry sector, facility use, and location of a facility) affect the janitorial and maintenance costs of a facility?

By utilizing the IFMA O&M Benchmarking reports for all three regions, this study aims to establish benchmarks for FM professionals to develop best practices for space management while understanding the impact of these practices on the operation and maintenance costs, janitorial expenses, and energy costs of a facility. This research will assist architects, FM professionals, and organizations in making informed decisions regarding facility design, management, and maintenance that consider the unique business needs and challenges specific to each region. Additionally, the study will help optimize building and maintenance expenses by improving space utilization.

CHAPTER 3. RESEARCH METHODOLOGY

Introduction

This research study aims to investigate the impact of space allocation and management practices in commercial buildings across three different geographic regions, namely North America, Asia, and the Middle East. The decreasing space per occupant in North America has been found to have an impact on workplace design, building operation, maintenance, and work productivity due to factors such as increased emphasis on sustainability, growth of remote and hybrid working post-COVID, and rising real estate costs. On the other hand, the challenges related to space per occupant in Asia are related to the need for efficient space utilization, given the rapidly growing working population and market, leading to cramped and densely populated work environments with less space per occupant. Additionally, the hot and humid weather conditions in Asia present a challenge for energy consumption and maintaining comfortable indoor temperatures. This study will use the IFMA O&M Benchmarking report for all three regions to create a benchmark for FM professionals to develop best practices for space management and understand its impact on operation and maintenance costs, janitorial costs, and energy costs of a facility. This research will help FM professionals, architects, and organizations make more efficient decisions regarding facility design, management, and maintenance by considering the business needs and challenges specific to their respective geographic regions.

Table 1 – Phases of research

Phases of Research	Description
1. Survey Rebuilding	The survey was rebuilt through a comprehensive process that included discussions with subject matter experts, review of existing surveys, and recommendations on questions. Factors of other local geographical regions were taken into consideration for necessary changes.
2. Sampling	Purposive sampling method used to select relevant data from three IFMA O&M Benchmarking surveys. Total of 2,092 responses collected across three regions.
3. Data Collection	Data collected from IFMA O&M Benchmarking surveys on region, country, facility sizes, types of facilities and industries, janitorial costs, and different types of maintenance costs on one Microsoft Excel Spreadsheet as a single benchmarking database.
4. Data Conversion & Data Cleaning	For data conversion and cleaning, all cost and area data were converted to USD and Square Footage, respectively. A single benchmarking database was created with over 2,092 responses, 173,886 data points, and 45,000+ buildings with a total area of 2.4+ billion sq. ft
5. Data Calculation	Data calculation included space per occupant, average janitorial cost, and average maintenance costs (interior and total).
6. Data Analysis	Basic correlation analysis used to examine quantitative data and regression analysis used to analyze qualitative data.
7. Results and Findings	Linear regression analysis and Pearson correlation analysis were performed to identify the relationship between space per occupant and janitorial cost and maintenance cost.

Steps Involved in Research Methodology

The methodology followed in this study is based on the data analysis done for IFMA Operation and Benchmarking Survey Reports. It is based on the following steps-

Figure 2. Steps Involved in Research Methodology

1. Research design- Based on the data collected from IFMA O & M Benchmarking report for three regions, the study states to identify the effect of space per occupant in estimating O&M costs and Janitorial costs across different the three geographic regions. The survey data collected has a combination of qualitative and quantitative data which provides a comprehensive understanding of the nuances in space planning and facility sizes across different regions and budget allocation for janitorial and maintenance costs.

2. Sampling- This study focuses on the relationship between space allocation per person and janitorial and maintenance costs. The data sampling method used is purposive sampling, as the available data from existing surveys were vast and needed to be defined according to the study's objectives. Therefore, from the entire data set available from three different surveys, facility sizes, types of facilities and industries, janitorial costs, and different types of maintenance costs were considered. The total number of responses across the three regions is 2,092.
3. Data Collection- The process of data collection for this study involved combining the survey data from all three IFMA O &M benchmarking surveys. The data put together for this study was Region, Country, Facility sizes, types of facilities and industries, janitorial costs, and different types of maintenance costs which were managed using Microsoft Excel Spreadsheets.

4. Data Cleaning- The data collected from all three IFMA O&M Benchmarking reports was self-reported by each participant, which was cleansed and managed for quality. More than 500 respondents who did not provide content or facility data were excluded. The data were merged into one MS Excel file, which included the responses collected separately through the Qualtrics platform in three different raw data spreadsheets. FMs across various organizations provided an Excel file on over 2,092 responses, which was added to the benchmarking database primarily in the form of regions, facility demographics and characteristics, and operating costs. The data which included all the plannable/rentable/ interior gross area was converted to square feet and all the currency data which included janitorial, and all types of maintenance costs were converted to USD (In detail conversion

is mentioned in Currency conversion table later in the report). This conversion process was quite time-consuming. The different nomenclature for the Rentable square feet area and the use of different metric systems were all converted to Square Feet. Across the three regions, there were more than 25 countries, and because of currency conversion, the currency data for each respondent was converted to USD using different conversion rates for each response, based on the date of the last survey for consistency.

The second phase of cleansing and quality management involved checking the combined MS Excel data file of respondents' surveys for errors, typos, and logical inconsistencies. Survey responses that contained unusual and inconsistent data which developed errors while processing data like space per occupant and janitorial cost per RSF were removed from the database, for example, i) if a respondent has answered facility size question and did not answer the average number of people occupying the space in a facility, resulting into an error while converting raw data into space per occupant variable in Microsoft Excel, ii) if a respondent has answered facility size question and did not answer the annual janitorial costs question, resulting into an error while converting raw data into janitorial cost per square feet variable in Microsoft Excel. Data that was without any errors was included in the analysis to ensure the accuracy of the data for the report. This process made the data sample relatively small compared to the raw data combined across the three regions.

Data Analysis- This process involved basic correlation by carrying out inferential statistics such as Average facility size as per facility uses and industry sector, Average space per occupant as per facility uses and industry sector, Average janitorial costs vs space per

occupant across various facility uses and industry sectors, Average interior maintenance costs and total maintenance costs vs space per occupant across various facility uses and industry sectors and descriptive statistics such as Linear regression and Pearson Correlation between space per occupant and the janitorial costs, interior maintenance costs, and total maintenance costs. These inferential and descriptive analytics were used to examine quantitative and qualitative data and assess the effect of space management practices on maintenance budgets, janitorial budgets, and future planning growth of facilities. To identify the factors that cause differences in space management practices, basic correlation analysis will be used to analyze qualitative data.

Results and Findings- This process involved identifying the relationship identified between space per occupant and janitorial cost and maintenance cost by performing linear regression analysis and Pearson correlation analysis.

Survey rebuilding for each region

IFMA North America O&M benchmarking survey –

The survey on IFMA North America O&M benchmarking was done by updating an existing Research Report (IFMA North America O&M benchmarking 2017). Most of the questions in the survey were taken from a previous survey question bank. Along with updating the existing benchmark for the region data on facility O&M, the FM Organizations also wanted to incorporate new material into the survey based on industry trends. As a result, two new sections were added to the 2017 survey, one focused on security costs and practices and the other on technology, to capture facility practices and staffing.

IFMA Asia O&M Benchmarking survey -

The survey rebuilding for the Asia region was conducted by IFMA, which provides tools for measuring facility performance, energy management, and sustainability efforts. With an emphasis on operational efficiency and continuous improvement, the report addresses an increased regional focus on health and safety improvements, regulatory support, and cost and service efficiency. The IFMA Asia Operations and Maintenance (O&M) Benchmarking survey is designed considering the IFMA North America O&M benchmarking survey 2021, it provides detailed performance metrics on janitorial, maintenance, and utilities, as well as staffing profiles for FM professionals in several countries across the Asian region. As it was the first of its kind of study for that region, many questions related to Sustainability, Energy management practices, and impacts of COVID-19 on facility operations were not included in this survey (to reduce the overall time required to complete the survey).

IFMA Middle East O&M Benchmarking survey-

The IFMA Middle East Operations and Maintenance Benchmarking survey is the first of its kind to be released for this region. The survey questions were formulated by considering the IFMA North America and Asia region O&M Benchmarking Survey, as well as the needs of FM professionals in the Middle East. The main goal of the survey is to establish benchmarks for two key facility categories: janitorial and maintenance. Moreover, the survey aims to provide comprehensive performance benchmarks based on various demographic factors, such as the industry sector served by the facility, usage, whether it's

a single building or a portfolio of sites, ownership profile, age, size, and different geographical locations across the Middle East.

Data Collection: IFMA North America O&M Survey

The survey questions were crafted and pilot-tested by a committee of experts in collaboration with IFMA's research and benchmarking department. The questions were carefully examined to ensure clarity, relevance, and objectivity to obtain responses that are truly representative of industry practices. The survey was administered electronically using the Qualtrics online survey platform. The survey collected information on the facilities managed by respondents for the 12-month period before the onset of COVID-19. The committee of IFMA volunteers with expertise in housekeeping, maintenance, energy management, and sustainability reviewed previous survey questions and developed new questions to better align with current practices. The survey was sent electronically in May 2021 to over 12,000 IFMA professional members throughout North America, and approximately 1,904 surveys were returned.

Data Collection: IFMA Asia O&M Survey

IFMA aimed to include many Asian countries in this report and received responses from Australia, China, Hong Kong, India, Philippines, Singapore, Sri Lanka, and Vietnam. A committee of IFMA volunteers, who were experts in housekeeping, maintenance, energy management, and sustainability, reviewed previous survey questions and developed new ones that matched current practices. The survey was first sent to more than 4,000 IFMA professional members in Asia in July 2020, and it was updated based on IFMA's North American benchmarking report. The

committee ensured that questions were clear, concise, relevant, and objective to get accurate and representative responses. The survey was available only online via the Qualtrics platform, and respondents were asked to provide information about their facilities for a year-long time. About 279 surveys were returned in the 12-month time, and respondents provided cost data in their preferred local currency.

Data Collection: IFMA Middle East O&M Survey

This report includes responses from individuals in eight countries in the Middle East region, namely Bahrain, Egypt, Jordan, Kuwait, Qatar, Saudi Arabia, Turkey, and the United Arab Emirates. The survey used to gather this data was crafted by a committee of IFMA volunteers with relevant expertise who reviewed past surveys and created new questions to reflect current practices. After testing, the survey was sent electronically in January 2022 to over 1,000 IFMA professional members in the Middle East. About 123 surveys were returned in the 12-month time period, and respondents provided cost data in their preferred local currency.

Data Compilation of Three Regions in Microsoft Excel

This process involved compiling the survey data from the three regions into a single Microsoft Excel file. Each respondent was given a unique number for easy tracking and to avoid duplicate responses. This helped in managing the data in the Excel file and analyzing the data in a more organized and efficient manner. As this study is limited to the effects of space per occupant on janitorial and different maintenance costs across the three regions, the data considered for this study were as follows:

Table 2 – Different categories of Data gathered and used for the Analysis.

Sr. No.	Data Category
1.	Respondents (2092 nos.)
2.	Region (3 nos.)
3.	Country
4.	Currency
5.	Type of Space
6.	Number of buildings at one location and at different locations
7.	Industry Sectors
8.	Facility Uses
9.	Unit of Measurement for Facility Area
10.	Internal/ Plannable/ Rentable Facility Area
11.	Cleanable Area
12.	The average number of people occupying space
13.	Annual Vacancy rate (%)
14.	Total Janitorial Cost
15.	Total Maintenance Cost
16.	Interior Maintenance cost
17.	Exterior Maintenance Cost and all other types of maintenance cost

1. The main category for data in this study is region. Starting from the region category, data from North America, Asia, and the Middle East were merged into a single Microsoft Excel file. In North America, a total of three countries, namely the United States of America,

Canada, and Mexico, were included, with a total of 1904 respondents. In the Asia region, a total of eight countries were surveyed, namely Australia, China, Hong Kong, India, Philippines, Singapore, Sri Lanka, and Vietnam, with a total of 279 respondents. In the Middle East region, the survey was distributed across 18 countries, but responses were received from only eight countries, namely Bahrain, Egypt, Jordan, Kuwait, Qatar, Saudi Arabia, Turkey, and the United Arab Emirates, with a total of 123 respondents.

2. The second main category related to this study is the type of space and number of buildings at one location and the number of buildings at different locations was the same for all regions, so the compilation of these categories was comparatively convenient.
3. The next step in the data compilation process was to combine the various industry sectors, which were categorized across the three regions by considering common industry sectors. The industry sectors were then further subcategorized into Services, Manufacturing, and Institutional sectors as shown in the table below. This subcategorization of the industry sectors simplifies data analysis across different regions and various other aspects required for this study.

Table 3 – Types and Sub-types of Industry Sectors Used for Data Analysis

Types of Industry Sectors
Services
Banking
Financial
Health Care
Hospitality
Information Services
Insurance
Investment Services
Media
Other Services
Professional Services
Research

Telecommunications
Trade
Transportation
Utilities
Manufacturing
Aircraft
Building
Chemical/Pharma
Computer
Consumer Products
Electronics
Energy
Manufacturing
Motor Vehicles
Institutional
Association
Charitable Foundation
City /County
Corrections
Cultural
Educational
Federal Government
Military
Other Institution
Quasi-government
Religious
State

4. Facility Use is the next main category used for data compilation by combining various facility uses including different types of offices, industrial, assembly, and other types of facilities across the three regions for the ease of data management and data analysis.

Table 4 – Types and Sub-types of Facilities used for Data Analysis

Facility Type
Assembly
Community/Recreation Center
Religious
Stadium/Auditorium

Convention Center/Exhibit Hall
Other Assembly Use
Office
Branch/Regional Office
Headquarters
Mixed Use office
Other Office Use
Industrial
Manufacturing
Warehouse
Other Industrial Use
Other Facility
Biosciences
Correctional
Data Center
Education
Health Care
Judicial
Lodging & Hospitality
Library
Military
Multi-family Housing
Museum
Other Facility Uses
Recreational
Research & Development
Senior Housing
Sports & Entertainment
Transportation

5. The North American region has data available for the rentable area in a facility and the gross facility area, but Asia only has plannable areas, and the Middle East has Interior Gross Floor Area which basically means Rentable or Plannable area. The data obtained under this category was in Square Feet for many respondents in the North American region and was mixed as Square Meters and Square Feet for the other two regions.

Hence, all the data was converted to unit Square Feet by using the conversion factor. (1 Sq. meter = 10.764 Sq. foot). Converting all the area data into the unit system helped in understanding the changes in data and helped in comparing the data with IFMA O&M North America Report for data analysis.

6. The main driving factor for this study is the data received from surveys regarding the number of people occupying the space, which was then used to calculate the annual vacancy rate (%) and the space per occupant in square feet. This data was further subcategorized into different range categories, as mentioned later, for a better understanding of the occupant numbers per square foot area in a facility.
7. Janitorial costs include wages, benefits, staff support, supervision, administration, supplies, paper goods, and noncapital equipment. Most maintenance costs fall within the first three categories: external building maintenance, interior systems maintenance, and roads and grounds. The remaining two cost categories, utility system maintenance and process treatment/environmental system maintenance are costs likely incurred by manufacturing facilities and large campuses with central plants. Solid waste management — a category found under environmental system maintenance — refers to industrial waste that contains non-hazardous materials, such as by-products of production, and should not be interpreted as ordinary garbage, trash, or municipal waste. Respondents for IFMA O&M North America Survey provided Janitorial Costs and all types of Maintenance Costs data in U.S. Dollars (USD) or Canadian Dollars (CAD). The US$ to CA$ currency conversion rate is based on May 1, 2020. Respondents for the IFMA O&M Asia Survey provided Janitorial Costs and all types of Maintenance Costs data in their preferred local currency. All currencies were

converted to U.S. Dollars (USD) based on conversion factors from 18 May 2021. Respondents for IFMA O&M Middle East Survey provided Janitorial Costs and all types of Maintenance Costs data in their preferred local currency. All currencies were converted to U.S. Dollars (USD) based on conversion factors from 31 May 2022.

Currency Conversion Table

Table 5 – Currency Conversion Details

Region	Country	Currency	Currency Conversion Rate	Date of Conversion
Asia	Australia	U.S. Dollar ($, USD)	1	05/18/2021
	Bangladesh	U.S. Dollar ($, USD)	1	
	China	Yuan / renminbi (¥, CNY)	0.16	
	Hong Kong	Hong Kong Dollar (HK$, HKD)	0.13	
	India	Indian Rupee (₹, INR)	0.014	
	Indonesia	U.S. Dollar ($, USD)	1	
	Korea	Korean won (원, KRW)	0.00089	
	Macau	Macau pataca (MOP$, MOP)	0.13	
	Malaysia	Malaysian ringgit (RM, MYR)	0.24	
	Philippines	Philippine Peso	0.014	
	Singapore	Singapore Dollar (S$, SGD)	0.75	
	Sri Lanka	Sri Lankan Rupee	0.0051	
	Thailand	U.S. Dollar ($, USD)	1	
	Vietnam	U.S. Dollar ($, USD)	1	
Middle East				05/31/2022
	Bahrain	Bahraini dinar (.د.ب, BD)	2.6723	
	Egypt	Egyptian pound (£, EGP)	0.0538	
	Jordan	Jordanian dinar (دينار أردني, JOD)	1.4154	
	Kuwait	Kuwaiti dinar (دينار كويتي, KWD)	3.275	
	Qatar	Qatari riyal (ر.ق, QAR)	0.275	
	Saudi Arabia	Saudi riyal (ر.س, SAR)	0.267	
	Turkey	Turkish lira (₺, TRY)	0.0614	
	United Arab Emirates	United Arab Emirates dirham (د.إ, AED)	0.2723	
North America				
	Canada	Canadian Dollar (CAD)	0.702	05/01/2020

8. For Janitorial per Square Feet data Janitorial costs were divided by the respondent's rentable square footage if provided and Maintenance costs per Square Feet is Maintenance costs were divided by the respondent's rentable square footage if provided. As all the data for its costs are converted to USD and Facility area data to Square Feet the Cost per rentable/plannable or internal gross floor area data was in USD/Sq. Feet.

Considerations of using ranges in Facility Sizes and Development of Range

The data provided by respondents for facility sizes across three regions were naturally different for each respondent. So, to organize the facility size data with other parameters such as facility use, industry sector, and costs data, also for the ease of data management and data analysis, the development of range intervals was considered for facility sizes as mentioned in the table below.

Table 6 – Categories of Facility by Size

Facility size Category (Sq. Feet)
100000 or less
100,001-200,000
200,001-500,000
500,001-1,000,000
More than 1,000,000

Data Calculations

The calculation of space per occupant was done by dividing the average number of people occupying space annually by the Interior Gross Area in SF. The average janitorial and maintenance costs (interior and total) were calculated by dividing the janitorial costs and all types of maintenance costs in USD by the Interior Gross Area in SF. These calculations were necessary for analyzing the effect of space management practices on maintenance and janitorial budgets and were used in the inferential and descriptive statistics for the data analysis process.

Space per Occupant Calculation
Space per Occupant = $\frac{\text{Average number of people occupying space annually}}{\text{Interior Gross Area in SF}}$

Operation cost per SF Calculations
$\frac{\text{Janitorial/Maintenance costs(USD)}}{\text{Interior Gross Area in SF}}$

Considerations of using ranges for Space per Occupant data and Development of Range

The data calculated for Space per Occupant had different values for each respondent, depending on the number of people occupying the space and the available rentable/plannable/interior gross floor area. To organize the space per occupant data with other parameters, such as facility use,

industry sector, and cost data, and for ease of data management and analysis, range intervals were developed for space per occupant, as shown in the table below.

Table 7 - Categories of Facility by Space per Occupant

Space per Occupant Category (Sq. Feet)
50 SF per occupant or less
51-250 SF per occupant
251-500 SF per occupant
501-750 SF per occupant
750 SF or more per occupant

Data Analysis

In the data analysis phase, the study used basic correlation methods, including inferential and descriptive statistics, to examine both quantitative and qualitative data. The objective was to assess the impact of space management practices on maintenance and janitorial budgets, as well as future facility planning growth. The study also employed basic correlation analysis to identify the factors causing differences in space management practices. Finally, the study used linear regression analysis and Pearson correlation analysis to identify the relationship between space per occupant and maintenance and janitorial costs.

CHAPTER 4. DATA COLLECTION AND DATA ANALYSIS

Introduction

The main objective of this research is to understand the correlation between space density in a facility and janitorial costs and other maintenance costs across three regions North America, Asia, and the Middle East. It majorly concentrates on the effects of space per occupant on FM planning and budgeting decisions which are heavily based on janitorial costs, interior maintenance costs, and all other types of maintenance costs. Also, this study is related to the effects of all of these in three different geographical regions.

Data Limitations

The data limitations for this study can be identified in several areas. First, the number of responses varied across different regions, which could impact the reliability of the results as they may not represent the population accurately. Secondly, the data was self-reported by FM professionals, which raises questions about the accuracy and validity of the data. Since different individuals may have different standards and ways of reporting, it may result in biased or inconsistent data. Thirdly, there was inconsistency in the data due to missing values, with some respondents answering only certain questions and not others, resulting in incomplete data.

This limitation could affect the reliability of the data and limit its usefulness for analysis. Fourthly, respondents often provided broad ranges instead of exact values, which can result in imprecise data. For instance, when reporting the age of a building, some respondents may report a range of years instead of the exact year of construction or renovation. This can make it difficult to accurately determine the age of a facility and may impact the reliability of the data. Finally, due to the data coming from different geographic regions and countries with varying currencies and metric

systems, the data analysis for correlations may not be reliable due to conversion and purchasing power parity issues. It may be challenging to compare and draw conclusions from data that is not standardized across regions and countries. Overall, these limitations highlight the importance of considering the quality and reliability of data sources and being cautious when interpreting results. It is essential to be aware of the potential biases and limitations in the data to make informed decisions and conclusions.

Summary Statistics

1. Location

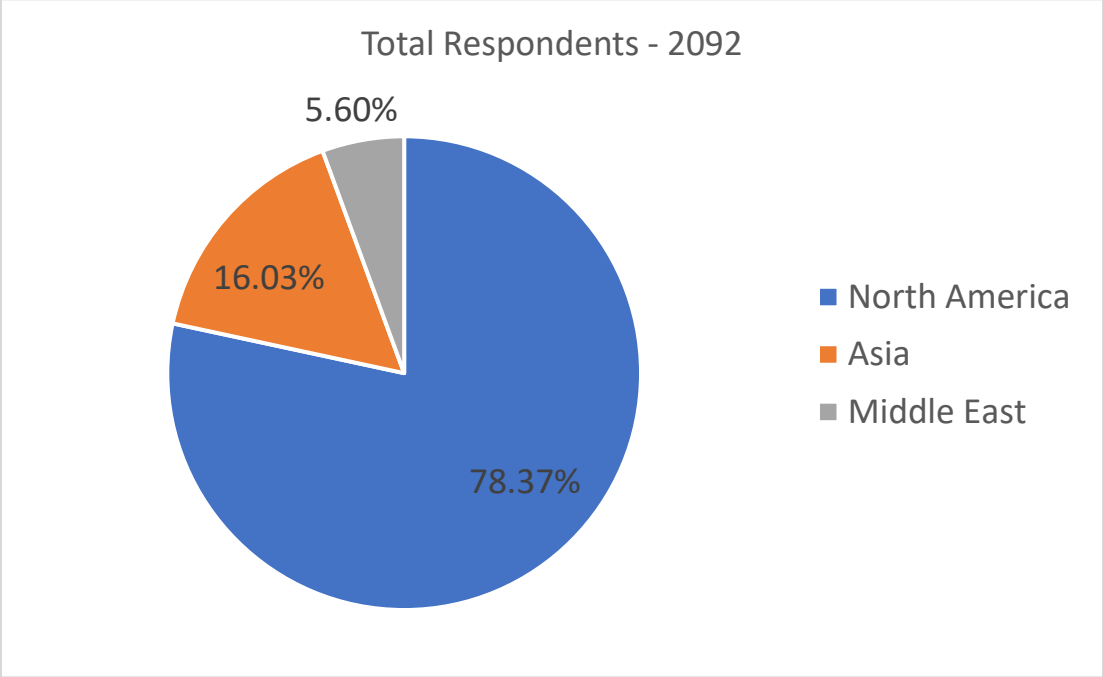

Figure 3 – Distribution of Respondents across regions

The data from the Facilities Management Operations and Benchmarking Survey by IFMA indicates that the FM industry in North America is more advanced compared to Asia and the Middle East. This is evident from the higher percentage of respondents from North America (78.37%) as compared to Asia (16.03%) and the Middle East (5.60%). The higher

number of respondents in North America is likely because the FM industry in North America recognizes the importance of this survey in day-to-day FM practices, and therefore, is more proactive in participating in such surveys. It is also possible that the FM industry in Asia and the Middle East is still growing as the markets in Asia and the Middle East are upgrading and developing.

Table 8 – Total respondents country-wise

Region	Number of responses
North America	**1721**
Canada	107
Mexico	7
United States	1607
Asia	**300**
Australia	1
Australia	8
Bangladesh	1
China	38
China	13
Hong Kong	36
India	157
India	2
Indonesia	2
Korea	2
Macau	3
Malaysia	2
Philippines	4
Singapore	7
Sri Lanka	3
Thailand	1
Vietnam	3
Middle East	**71**
Bahrain	3
Egypt	7
Jordan	1
Kuwait	2
Qatar	14
Saudi Arabia	27
Turkey	1

United Arab Emirates	16
Grand Total	**2092**

A total of 2092 responses from various regions. North America had the highest number of responses, with 1721, with the United States being the major contributor with 1607 responses. In Asia, India had the maximum number of responses with 157, followed by China with 38, and Hong Kong with 36 responses. The Middle East had a total of 71 responses, with Saudi Arabia being the major contributor with 27 responses, followed by Qatar with 14 responses. These responses from the major countries in each region provide insights into the FM industry's practices and benchmarks in these areas.

2. Facility type

Table 9 – Distribution of facility types across different geographical regions

Facility Type	**North America**	**Asia**	**Middle East**
	# of total facilities		
Assembly			
Community/Recreation Center	15	6	-
Religious	8	2	-
Stadium/Auditorium	11	1	-
Convention Center/Exhibit Hall	-	3	-
Other Assembly Use	-	5	-
Office	-	-	-
Branch/Regional Office	161	66	-
Headquarters	220	37	-
Mixed Use office	882	38	-
Other Office Use	-	34	-
Industrial	-		-
Manufacturing	68	12	-
Warehouse	77	1	-
Other Industrial Use	-	3	2

Other Facility	-	-	-
Biosciences	7	-	-
Correctional	4	-	-
Data Center	10	-	-
Education	81	20	12
Health Care	44	-	-
Judicial	-	8	-
Lodging & Hospitality	-	1	-
Library	6	3	-
Military	1	-	-
Multi-family Housing	8	4	-
Museum	6	-	-
Other Facility Uses	1	19	25
Recreational	16	-	6
Research & Development	36	3	-
Senior Housing	-	1	-
Sports & Entertainment	5	-	-
Transportation	10	4	-
Grand Total = 2017	**1677**	**271**	**69**

The dataset provides information on facility types and the number of facilities in North America, Asia, and the Middle East. North America has the highest number of facilities (1677), out of which 882 are mixed-use offices, 220 are headquarters, and 161 are branch/regional offices. The industrial sector has 68 manufacturing and 77 warehouse facilities. Asia has 271 facilities, out of which 66 are branch/regional offices, and 38 are mixed-use offices. The education sector has 20 facilities, and the research and development sector has 3 facilities. In the Middle East, there are a total of 69 facilities, out of which 25 have other facility uses, 24 are offices, and 12 are for educational purposes.

3. Industry Sector

Table 10 – Total Respondents as per Industry Sector

Industry Sector	North America	Asia	Middle East
	# of total facilities		
Services	**390**	**166**	**48**
Banking	65	14	4
Financial	10		
Health Care	50	13	4
Hospitality	17	13	6
Information Services	24	40	10
Insurance	30	5	2
Investment Services	19	4	-
Media	21	6	-
Other Services		2	-
Professional Services	58	25	8
Research	16	2	-
Telecommunications	22	6	1
Trade	14	12	3
Transportation	15	10	3
Utilities	29	14	7
Manufacturing	**154**	**42**	**13**
Aircraft	10	4	-
Building	14	10	4
Chemical/Pharma	45	7	3
Computer	14	5	-
Consumer Products	24	3	-
Electronics	25	5	2
Energy	6	5	2
Manufacturing	9	-	-
Motor Vehicles	7	3	2
Institutional	**1150**	**79**	**22**
Association	34	3	2
Charitable Foundation	14	1	-
City /County	121	3	-
Corrections	5	8	-
Cultural	16	2	-
Educational	76	16	3
Federal Government	814	1	-
Military	7	1	1

Other Institution		38	15
Quasi-government	8		-
Religious	24	3	1
State	31	3	-
Grand Total = 2064	**1694**	**287**	**83**

The data provided in the table lists the number of facilities falling under different industry sectors for three different geographical regions - North America, Asia, and the Middle East. In North America, most facilities belong to the institutional sector, with 1150 facilities falling under this category, followed by services (390 facilities) and manufacturing (154 facilities). The services sector includes industries such as banking, financial, and health care, among others. The manufacturing sector consists of industries such as aircraft, building, chemical/pharma, and electronics, among others. In Asia, the services sector has the most facilities, with 166 facilities falling under this category, followed by institutional (79 facilities) and manufacturing (42 facilities). The services sector includes industries such as banking, health care, and hospitality, among others. The manufacturing sector consists of industries such as aircraft, building, and chemical/pharma, among others. In the Middle East, the services sector has the most facilities, with 48 facilities falling under this category, followed by institutional (22 facilities) and manufacturing (13 facilities). The services sector includes industries such as banking, health care, and information services, among others. The manufacturing sector consists of industries such as building, chemical/pharma, and electronics, among others. Overall, the institutional sector has the most facilities in North America and Asia, whereas the services sector has the most facilities in the Middle East. The manufacturing sector has a significant presence in all three geographical regions but with a relatively smaller number of facilities compared to the other sectors.

4. Facility Age

Table 11 – Statistics of Facility Age and Average Size across different regions

	North America		Asia		Middle East	
Region	**# of facilities**	**Average of Facility Size in sq. ft**	**# of facilities**	**Average of Facility Size in sq. ft**	**# of facilities**	**Average of Facility Size in sq. ft**
Less than 5 years	39	505294	5	181841	9	326457
5-10 years	52	371708	5	1093551	19	1001830
11-20 years	112	482775	6	367160	22	3127177
21-30 years	129	249281	2	1679168	10	218186
31-50 years	242	939778	1	10000	9	10669438
51-100 years	392	531697	1	1500	1	807300
More than 100 years	130	380224	-	-	-	-
TOTAL	**1096**	**542595**	**20**	**573069**	**70**	**2753499**

The data provided is about the number of facilities and their average size in square feet for different regions and their age ranges. The region-wise data shows that North America has the highest number of facilities with 1096, followed by the Middle East with 70 and Asia with 20. For North America, most of the facilities are between 31-50 years old (242), followed by 51-100 years old (392) and then 21-30 years old (129). On the other hand, for the Middle East, most facilities fall into the age range of 11-20 years (22), followed by 5-10 years (19), and then less than 5 years (9). For Asia, most facilities are less than 5 years old (5), followed by 5-10 years (5) and then 11-20 years (6). The average size of the facilities in North America is 542,595 square feet, while in Asia, it is 573,069 square feet, and in the Middle East, it is 2,753,499 square feet. The data shows that the average facility size is highest in the Middle East and lowest in Asia.

Space per Occupant

Table 12 - Statistics of Average space per occupant in different industries, different size groups across different regions

Region/Industry Sector	Average of Space per occupant in sq. ft		
	North America	Asia	Middle East
Services	**460.59**	**186.88**	**306.8**
50 or less	26.27	18.3	24.29
51-250	171.2	135.35	130.72
251-500	367.57	364.68	401.41
501-750	601.11	530	615.09
750 or more	1185.82	1455.24	919.72
Manufacturing	**575.11**	**215.95**	**883.04**
50 or less	15.2	17.01	-
51-250	161.95	137.73	-
251-500	371.95	310.19	427.56
501-750	606.58	-	-
750 or more	1281.5	968.19	1794
Institutional	**503.28**	**324.13**	**400.97**
50 or less	23.24	23.25	46.64
51-250	165.58	116.31	134.55
251-500	373.88	352.94	357.35
501-750	618.48	644.99	608.17
750 or more	1210.52	1318.31	1004.64
The average across the Region	**496.71**	**222.7**	**380.41**

The North American region has the highest average space per occupant, with 496.71 SF, followed by the Middle East with an average of 380.41 SF, and Asia with an average of 222.70 SF. In terms of industry sectors, manufacturing has the highest average space per occupant, with 575.11 SF in North America and 883.04 SF in the Middle East. The services sector has the lowest average space per occupant, with 460.59 SF in North America, 186.88 SF in Asia, and 306.80 SF in the Middle East. For all regions and industry sectors, the average space per occupant increases as the range of space per occupant increases. The highest range of more than 750 SF per occupant has the highest

average space per occupant in all regions and industry sectors, with the highest being 1794.00 SF in the Middle East for the manufacturing industry sector.

Relation between Space per occupant and janitorial cost per square footage

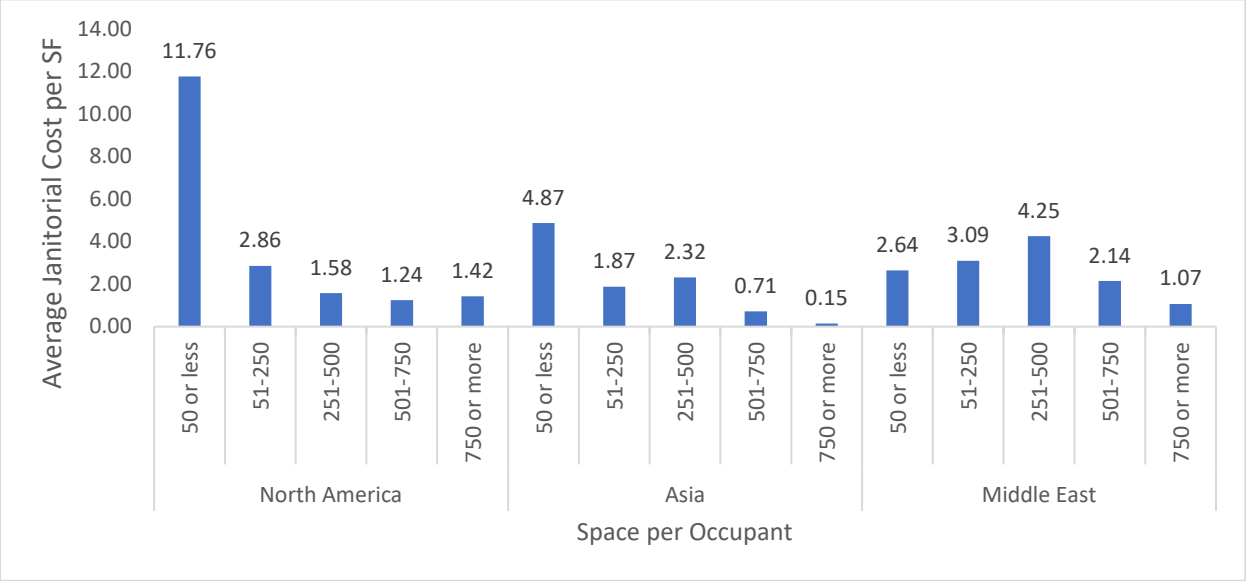

Figure 4 – Space per occupant vs Janitorial Cost per sq. ft across different sizes and Regions

The average total maintenance cost per square foot (SF) for different facility uses in three regions as per space per occupant categories ranging from 50 or less to 750 or more occupants per SF was analyzed. The results showed that North America had the lowest average maintenance cost per SF across all categories at 12.83, while Asia had the highest average maintenance cost per SF at 19.85. For North America, the highest maintenance cost was observed in facilities with 50 or fewer occupants per SF at 25.92, while the lowest maintenance cost was observed in facilities with 251-500 occupants per SF at 6.14. In Asia, facilities with 50 or fewer occupants per SF had the highest maintenance cost at 29.80, while facilities with 750 or more occupants per SF had the lowest maintenance cost at 1.03. The Middle East had an average maintenance cost per SF of 8.53, with

the highest cost observed in facilities with 50 or fewer occupants per SF at 11.58, and the lowest cost observed in facilities with 750 or more occupants per SF at 2.13

Relation between Space per occupant and total maintenance cost per square footage

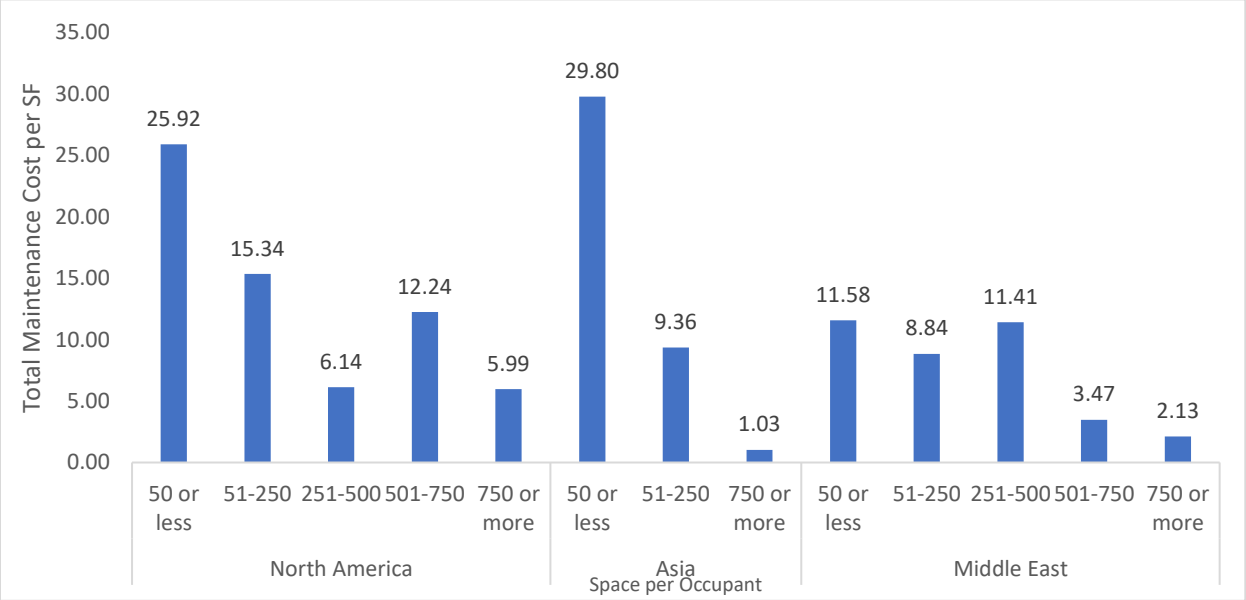

Figure 5 - Space per occupant vs Total Maintenance Cost per sq. ft across different sizes and Regions

The average total maintenance cost per Rentable Square Foot (RSF) is a crucial metric for building owners and managers. This study presents data on the average maintenance cost per RSF for different regions and size categories of buildings. The data reveals that the maintenance cost per RSF varies significantly by region and size category of the building. North America has an average maintenance cost of $12.83 per RSF, while Asia has a higher average cost of $19.85 per RSF. The Middle East has the lowest average maintenance cost per RSF among all regions at $8.53. Furthermore, the space per occupant also affects the maintenance cost per RSF, with the smaller range (50 or fewer occupants per SF) having higher maintenance costs than the larger range (750 or more occupants per SF). In

summary, the data suggest that the maintenance cost per SF varies significantly by region and Occupancy density.

Relationship between the Janitorial costs and Total maintenance cost with space density for different facility uses –

Table 13 – Average Janitorial and Maintenance cost per sq ft for different facility types and sizes across regions

Region/Facility Use/Space per Occupant	North America		Asia		Middle East	
	Janitorial Cost/ SF	**Average of Total maintenance cost per SF**	**Janitorial Cost/ SF**	**Average of Total maintenance cost per SF**	**Janitorial Cost/ SF**	**Average of Total maintenance cost per SF**
North America	-	-	-	-	-	-
Assembly	-	-	-	-	-	-
50 or less	-	-	1.02	43.64	-	-
51-250	1.42	5.48	-	-	-	-
Office	-	-	-	-	-	-
50 or less	8.83	2.67	2.22	9.65	-	-
51-250	0.69	10.97	5.23	9.36	1.43	0.81
251-500	2.42	24.8	-	-	3.77	1.62
501-750	1.13	6.84	-	-	4.34	9.91
750 or more	0.7	5.02	-	-	0.15	1.82
Industrial	-	-	-	-	-	-
51-250	-	-	-	-	9.91	4.21
750 or more	2.25	14.71	-	-	-	-
Other Facility	-	-	-	-	-	-
50 or less	2.98	49.48	0.37	3.68	2.64	11.58
51-250	7.46	39.43	-	-	1.27	2.04
251-500	5.47	13.36	-	-	5.68	23.29
501-750	0.65	41.43	-	-	1.98	1.86
750 or more	-	-	-	-	1.99	2.43
Average per Region	**2.39**	**18.96**	**2.82**	**15.14**	**2.89**	**6.5**

The average Janitorial cost per square foot (SF) for different facility types in three regions, categorized by space per occupant ranging from 50 or fewer occupants to 750 or more occupants. The results indicate that the average Janitorial cost per SF varies considerably by facility type, region, and space per occupant category. In North America, the overall average Janitorial cost per SF is $2.39, with Office facilities having the highest average cost of $8.83 for 50 or fewer occupants per SF and $0.69 for 51-250 SF. In Asia, the average cost per SF is $2.82, with Office facilities having an average cost of $2.22 for 50 or fewer occupants per SF and $5.23 for 51-250 occupants per SF. In the Middle East, the average cost per SF is $2.89, with Office facilities having an average cost of $1.43 for 51-250 occupants per SF, $3.77 for 251-500 occupants per SF, $4.34 for 501-750 occupants per SF, and $0.15 for 750 or more occupants per SF. Office facilities generally have higher Janitorial costs per SF, while Assembly facilities have the lowest. North America and the Middle East have similar average Janitorial costs per SF, while Asia has slightly higher average costs.

The average Total Maintenance cost per square foot (SF) for different facility types in three regions, categorized by space per occupant ranging from 50 or fewer occupants per SF to 750 or more occupants per SF. The results indicate that the average Total Maintenance cost per SF varies considerably by facility type, region, and space per occupant category. In North America, the overall average Total Maintenance cost per SF is $18.96, with Office facilities having the highest average cost of $2.67 for 50 or fewer occupants per SF and $10.97 for 51-250 occupants per SF, and 251-500 occupants per SF having the highest cost of $24.80. In Asia, the average cost per SF is $15.14, with Assembly facilities having the highest average cost of $43.64 for 50 or fewer occupants per SF, and other facilities having the lowest cost of $3.68 for 50 or fewer occupants per SF. In the Middle East, the average cost per SF is $6.50, with Office facilities having the

highest average cost of $0.81 for 51-250 occupants per SF and 501-750 occupants per SF having the highest cost of $9.91.

Correlation between the Janitorial costs, Interior Maintenance Costs, and Total maintenance cost with space density for different Industry Sector –

Table 14 - Average Janitorial cost (JC), Maintenance cost(TMC), and Interior Maintenance cost(IMC) per sq ft for different industry sectors and sizes across regions

Industry Sector Space per Occupant Category	North America			Asia			Middle East		
	Avg. JC / sf	Avg. TMC/ sf	Avg. IMC/ sf	Avg. JC / sf	Avg. TMC/sf	Avg. IMC/sf	Avg. JC / sf	Avg. TMC/ sf	Avg. IMC/sf
Services	**2.45**	**20.07**	**1.51**	**2.92**	**22.65**	**1.42**	**3.39**	**10.06**	**1.79**
50 or less	12.89	30.19		5.75	35.94	2	1.46	15.14	3.16
51-250	3.3	20.29	2.28	2.1	9.36	0.7	4.43	14.63	1.86
251-500	1.58	32.1	0.24	0.93		0.41	4.14	2.71	1.06
501-750	1.24	11.04	1.83				4.34	9.91	
750 or more	0.9	1.78	0.44				1.07	2.13	1.11
Manufacturing	**1.46**	**16.24**	**4.12**	**3.26**		**2.49**	**1.2**	**0.3**	
50 or less				5.09					
51-250	1.92	10.97		1.69		1.44			
251-500	1.52	15.16	5.37	9.82		3.53	1.2	0.3	
501-750	0.88	18.72							
750 or more	1.84		0.38	0.15					
Institutional	**2.94**	**11.75**	**7.68**	**1.97**	**16.11**		**4.3**	**19.11**	**2.55**
50 or less	11.35	23.35	13.01	3.18	23.66				
51-250	2.33	9.82	1.04	1.17			2.15		1.46
251-500	1.61	2.74	5.26	1.48			6.29	34.78	3.38
501-750	1.41	9.33	26.67	0.71			3.45	3.45	2.27
750 or more	1.84	12.29			1.03				
Average cost	**2.46**	**15.85**	**4.79**	**2.76**	**19.85**	**1.73**	**3.47**	**11.45**	**2.09**

CHAPTER 5. RESULTS

Linear Regression Model

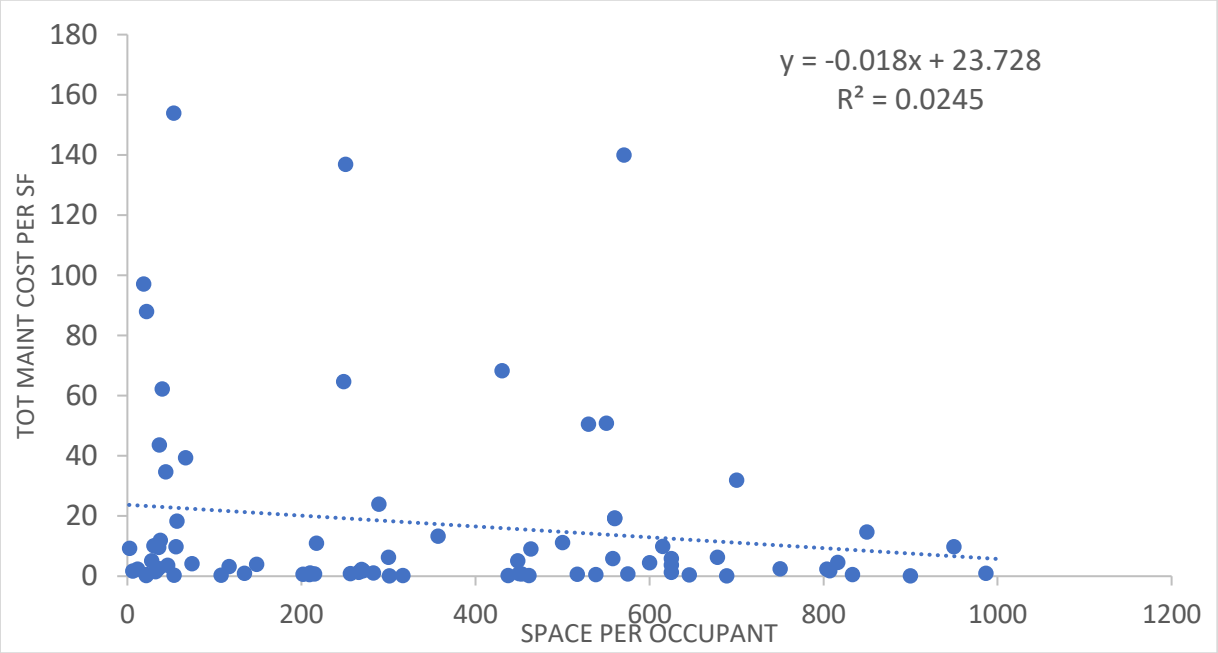

Figure 6 – Liner Regression model between Total Maintenance cost per sq. ft and Space per occupant

The equation y = -0.018x + 23.728 is a linear regression equation that shows the relationship between two variables, y, and x. In this case, y represents the Total maintenance cost per square foot and x represents the space per occupant. The equation suggests that as the space per occupant decreases by one unit, the total maintenance cost per square foot increases by 0.018 units, given that all other factors remain constant. The intercept of 23.728 means that the total maintenance cost per square foot would be approximately 23.728 when the space per occupant is zero.

The coefficient of determination, $R^2 = 0.0245$, tells us how well the data points fit the regression line. R^2 is a measure of the proportion of the variance in the dependent variable, y, that is explained

by the independent variable, x. In this case, the R^2 value of 0.0245 indicates that only 2.45% of the variation in the total maintenance cost per square foot can be explained by the variation in the space per occupant. This suggests that there may be other factors that influence the total maintenance cost per square foot besides the space per occupant.

Overall, the equation and R^2 value suggest that there is a weak negative relationship between space per occupant and total maintenance cost per square foot in this dataset, but it is important to consider other factors that may affect the maintenance cost in practice.

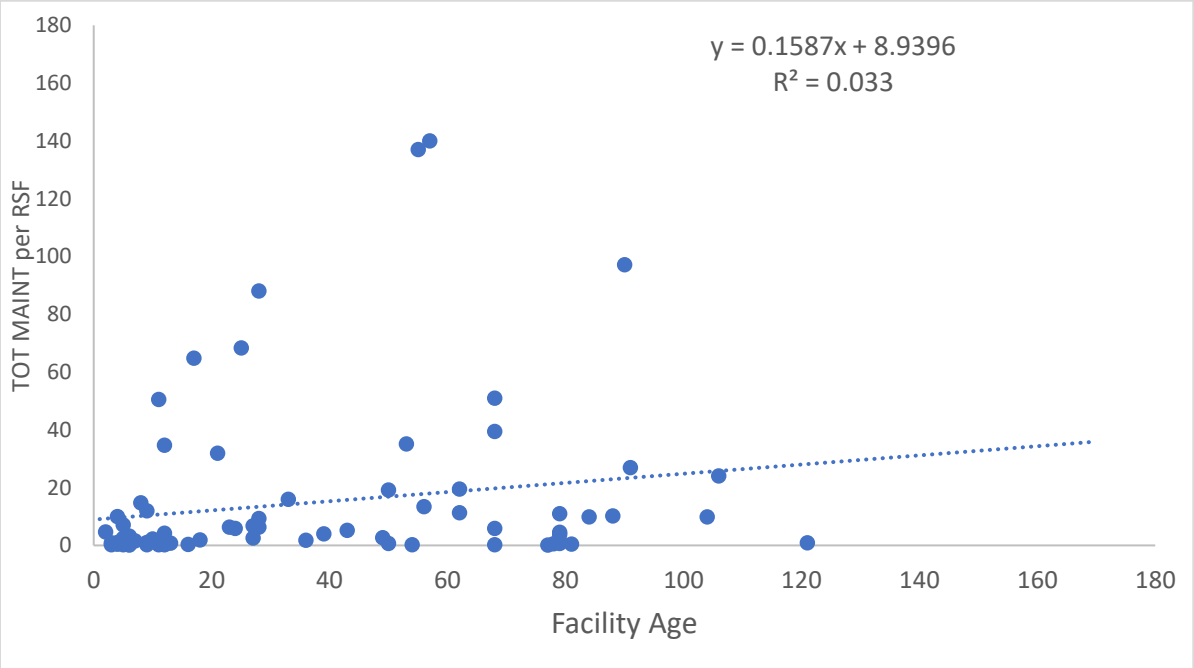

Figure 7 - Liner Regression model between Total Maintenance cost per sq. ft and Facility age

The equation y = 0.1587x + 8.9396 means that for every one-unit increase in facility age (x), the total maintenance cost per square foot (y) will increase by 0.1587 units.

The R^2 value of 0.033 tells us that only 3.3% of the variability in total maintenance cost per square foot can be explained by changes in facility age. This suggests that there may be other factors, beyond facility age, that are influencing the total maintenance cost.

Overall, the equation and R^2 value suggest a weak positive correlation between facility age and total maintenance cost per square foot. However, due to the low R^2 value, we cannot make strong conclusions about the relationship between these variables.

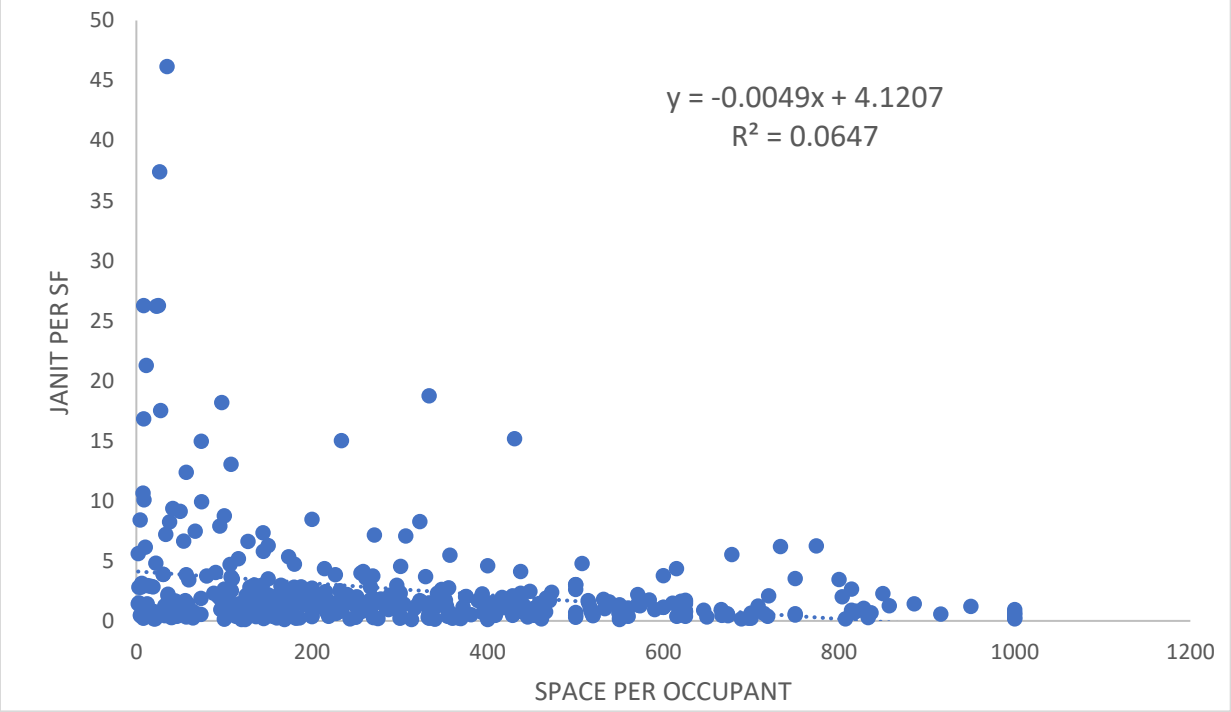

Figure 8 - Liner Regression model between Janitorial cost per sq. ft and Space per occupant

The equation given here is a linear equation that describes the relationship between two variables: janitorial cost per square feet (y) and space per occupant (x). The equation tells us that for every

unit increase in space per occupant, there is a decrease of 0.0049 units in janitorial cost per square foot. The constant term 4.1207 is the y-intercept, which means when space per occupant is 0, the janitorial cost per square foot is 4.1207.

The R^2 value is a measure of how well the equation fits the data points. It ranges from 0 to 1, with 1 indicating a perfect fit. Here, the R^2 value is 0.0647, which means that only 6.47% of the variation in janitorial cost per square foot can be explained by the variation in space per occupant. The low R^2 value suggests that there may be other factors that affect the janitorial cost per square foot, which are not accounted for in the equation.

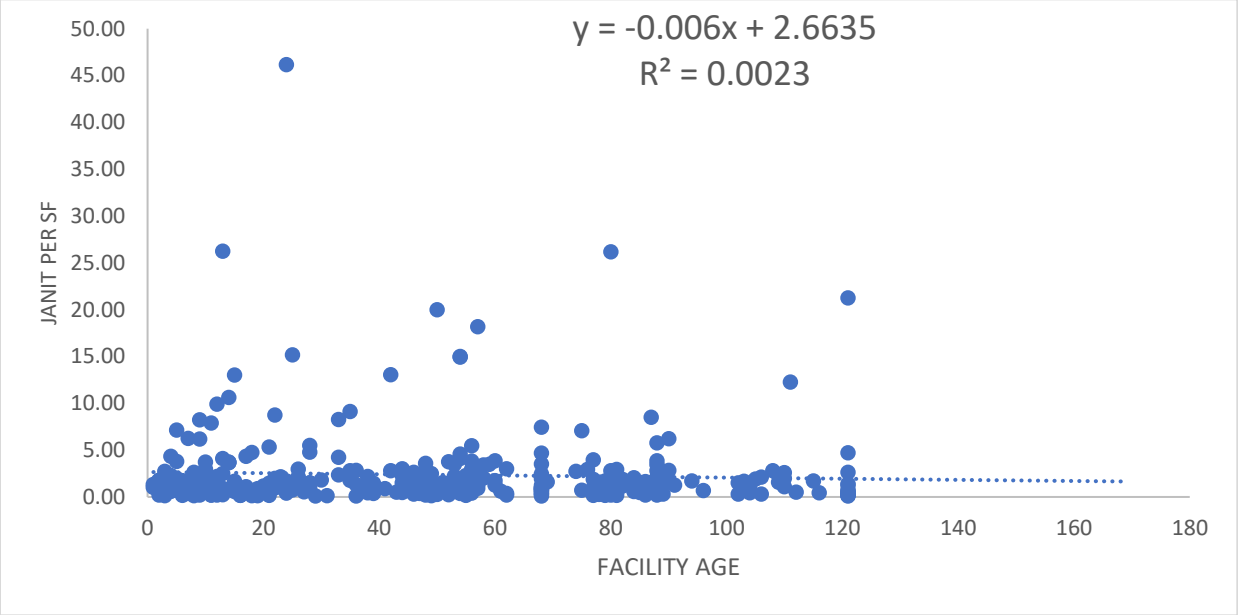

Figure 9 - Liner Regression model between Janitorial cost per sq. ft and Facility age

The equation, y = -0.006x + 2.6635, is a linear equation that represents the relationship between two variables: y (Janitorial cost per square feet) and x (facility age). The equation shows that as the facility age (x) increases, the Janitorial cost per square foot (y) decreases, and vice versa. The

coefficient of x (-0.006) indicates that for every increase of one unit in facility age, the Janitorial cost per square foot decreases by 0.006 units.

The R^2 value of 0.0023 suggests a very weak relationship between the two variables. In other words, only 0.23% of the variation in Janitorial cost per square foot can be explained by the variation in facility age. This means that facility age alone cannot be used to predict Janitorial cost per square foot with a high degree of accuracy.

Overall, the equation and R^2 value suggest that facility age is not a strong predictor of Janitorial cost per square foot. Other factors may have a stronger influence on the cost of janitorial services, such as the size and type of facility, location, and the frequency and scope of cleaning services required.

Pearson Correlation for all three regions

Table 15 – Pearson Correlation for All regions

Regions	**All regions - North America, Asia, Middle East**		
Pearson Correlation	**Space per occupant - Janitorial cost per sq. ft**	**Space per occupant-Total Maintenance cost per sq. ft**	**Facility age- Total maintenance cost per sq. ft**
Co eff (r)	-0.254	-0.086	-0.061
N	477	100	100
T Statistic	-5.734	-0.852	-0.604
DF	475	98	98
p Value	<0.01	0.39	0.54

1.The Pearson correlation coefficient (r) between Janitorial cost per square foot and Space per occupant is -0.254. This suggests that there is a weak negative relationship between the two variables. In other words, as the Space per occupant increases, the Janitorial cost per square foot tends to decrease slightly. The sample size (N) is 477, which is a relatively large sample size. This

provides more confidence in the accuracy of the correlation coefficient. The T statistic is -5.734, which suggests that the correlation coefficient is statistically significant. This means that it is unlikely that the correlation coefficient occurred by chance. The degree of freedom (DF) is 475, which is calculated as N minus 2. This tells us the number of independent observations in the sample.

The p-value less than 0.01, which is less than the typical alpha level of 0.05. This indicates that the correlation coefficient is statistically significant and provides strong evidence against the null hypothesis that there is no correlation between the two variables.

The fact that the samples are from three regions - North America, Asia, and the Middle East - is important because it suggests that the correlation may be held across different geographic areas. However, it is also possible that there are regional differences that affect the relationship between the Janitorial cost per square foot and Space per occupant. Further research would be needed to determine the extent to which the relationship varies by region.

2.The Pearson correlation coefficient (r) between Total Maintenance cost per square foot and Space per occupant is -0.086. This suggests that there is a very weak negative relationship between the two variables. In other words, as the Space per occupant increases, the Total Maintenance cost per square foot tends to decrease slightly, but the correlation is not strong. The sample size (N) is 100, which is relatively small. This reduces the precision of the estimate of the correlation coefficient and reduces the confidence in the accuracy of the correlation coefficient. The T statistic is -0.852, which suggests that the correlation coefficient is not statistically significant. This means that it is likely that the correlation coefficient occurred by chance. The degree of freedom (DF) is

98, which is calculated as N minus 2. This tells us the number of independent observations in the sample.

The p-value is 0.396, which is greater than the typical alpha level of 0.05. This indicates that the correlation coefficient is not statistically significant and provides little evidence against the null hypothesis that there is no correlation between the two variables.

The fact that the samples are from three regions - North America, Asia, and the Middle East - is important because it suggests that the correlation may be held across different geographic areas.

However, it is also possible that there are regional differences that affect the relationship between Total Maintenance cost per square foot and Space per occupant. Further research would be needed to determine the extent to which the relationship varies by region.

3.The Pearson correlation coefficient (r) between Total Maintenance cost per square foot and Facility age is -0.061. This suggests that there is a very weak negative relationship between the two variables. In other words, as the Facility age increases, the Total Maintenance cost per square foot tends to decrease slightly, but the correlation is not strong. The sample size (N) is 100, which is relatively small. This reduces the precision of the estimate of the correlation coefficient and reduces the confidence in the accuracy of the correlation coefficient. The T statistic is -0.604, which suggests that the correlation coefficient is not statistically significant. This means that it is likely that the correlation coefficient occurred by chance. The degree of freedom (DF) is 98, which is calculated as N minus 2. This tells us the number of independent observations in the sample.

The p-value is 0.547, which is greater than the typical alpha level of 0.05. This indicates that the correlation coefficient is not statistically significant and provides little evidence against the null hypothesis that there is no correlation between the two variables.

The fact that the samples are from three regions - North America, Asia, and the Middle East - is important because it suggests that the correlation may be held across different geographic areas. However, it is also possible that there are regional differences that affect the relationship between Total Maintenance cost per square foot and Facility age. Further research would be needed to determine the extent to which the relationship varies by region.

Pearson Correlation for North America

Table 16 - Pearson Correlation for North America

Region	**North America Only**		
Pearson Correlation	**Space per occupant - Janitorial cost per sq. ft**	**Space per occupant-Total Maintenance cost per sq. ft**	**Facility age- Total maintenance cost per sq. ft**
Co eff (r)	-0.333	-0.012	0.026
N	314	87	87
T Statistic	-6.239	-0.111	0.237
DF	312	85	85
p Value	<0.01	0.91	0.81

1.The Pearson correlation coefficient of -0.333 suggests that there is a moderate negative relationship between janitorial cost per square foot and space per occupant in North America. This means that as the space per occupant increases, the janitorial cost per square foot tends to decrease, and vice versa. The T statistic of -6.239 indicates that the correlation is statistically significant, which means that it is unlikely to have occurred by chance alone. The p-value less than 0.01 further confirms this, as it is less than the typical threshold of 0.05 used to determine statistical significance.

However, it is important to note that correlation does not necessarily imply causation. Other factors beyond space per occupant may also be influencing janitorial costs in North America, and further

analysis is needed to determine the causal relationship. Nonetheless, this correlation coefficient provides valuable insight and a starting point for further investigation into the relationship between janitorial costs and space per occupant in North America.

2. The Pearson correlation coefficient of -0.012 between Total Maintenance cost per square foot and Space per occupant in North America indicates a weak and negative relationship between these two variables. This suggests that as the space per occupant increases, there is a slight tendency for the total maintenance cost per square foot to decrease, but the effect is very small. The T-statistic of -0.110 and p-value of 0.912 suggest that this relationship is not statistically significant, meaning that we cannot confidently say that this relationship exists in the population. This may be due to a variety of factors, such as variations in building design, maintenance practices, or regional differences.

In summary, this data suggests that in North America, there is little to no relationship between Total Maintenance cost per square foot and Space per occupant, and other factors may need to be considered to explain variations in maintenance costs.

3.The data provided shows the Pearson correlation between the Total Maintenance cost per square foot and Facility age in North America. The coefficient of correlation, r, is 0.025659558 which suggests a very weak positive linear relationship between these two variables. The sample size, N, is 87, indicating that there were 87 observations or data points used to calculate this correlation. The T statistic, which is used to test the significance of the correlation, is 0.236647353 with a p-value of 0.813499748. This p-value is greater than the commonly used threshold of 0.05, indicating that there is no significant correlation between these two variables in North America.

In simpler language, the data tells us that there is no significant relationship between the Total Maintenance cost per square foot and Facility age in North America. Therefore, Facility age alone may not be a good predictor of Total Maintenance cost per square foot in this region, and other factors may need to be considered. However, it's important to note that this conclusion is based on the given data and may not necessarily apply to other regions or populations.

Pearson Correlation for Asia

Table 17 - Pearson Correlation for Asia

Region	**Asia Only**		
Pearson Correlation	**Space per occupant - Janitorial cost per sq. ft**	**Space per occupant- Total Maintenance cost per sq. ft**	**Facility age- Total maintenance cost per sq. ft**
Co eff (r)	-0.169	-0.277	-0.010
N	122	5	13
T Statistic	-1.89	-0.51	-0.034
DF	120	3	11
p Value	0.061	0.66	0.97

1.The Pearson correlation coefficient of -0.169 indicates a weak negative relationship between Janitorial cost per square foot and Space per occupant in the sample of 122 facilities in Asia. The p-value of 0.061 suggests that there is a 6.1% chance that this correlation was due to random chance, which is just above the commonly used threshold of 0.05 for statistical significance. In other words, there may be a slight tendency for the Janitorial cost per square foot to decrease as Space per occupant increases in Asia, but the evidence is not strong enough to conclude this relationship with confidence.

It is worth noting that the sample size of 122 is relatively small, which may limit the statistical power and increase the uncertainty of the results. Further studies with larger sample sizes or different methods may be needed to confirm or refute the findings.

2. Pearson correlation coefficient of -0.277 and a p-value of 0.651 for the relationship between Total Maintenance cost per square foot and Space per occupant in Asia.

The correlation coefficient indicates a weak negative correlation between the two variables, suggesting that as the space per occupant increases, the total maintenance cost per square foot may decrease slightly, but the relationship is not strong enough to draw any significant conclusions.

The p-value of 0.651 suggests that the correlation coefficient is not statistically significant, meaning that we cannot reject the null hypothesis that there is no correlation between the two variables. However, it's worth noting that the sample size is quite small (n=5), so the results may not be entirely reliable.

3. The Pearson correlation coefficient of -0.010 suggests a very weak negative relationship between the total maintenance cost per square foot and the facility age in the Asian region. The correlation coefficient is very close to zero, indicating that there is almost no linear association between the two variables.

The p-value of 0.973 suggests that this correlation coefficient is not statistically significant, meaning that any observed correlation could be due to random chance rather than a true relationship between the two variables. Therefore, based on this data, we cannot conclude that there is a significant relationship between the total maintenance cost per square foot and the facility age in the Asian region.

Pearson Correlation for Middle East

Table 18 - Pearson Correlation for Middle East

Region	Middle East Only		
Pearson Correlation	**Space per occupant - Janitorial cost per sq. ft**	**Space per occupant- Total Maintenance cost per sq. ft**	**Facility age- Total maintenance cost per sq. ft**
Co eff (r)	-0.123	No value	No value
N	41		
T Statistic	-0.777		
DF	39		
p Value	0.441	No Value	No Value

The Pearson correlation coefficient of -0.12355 indicates a weak negative relationship between Janitorial cost per square foot and Space per occupant in the sample of 41 facilities in the Middle East. The p-value of 0.4415 suggests that there is a 44.15% chance that this correlation was due to random chance, which is higher than the commonly used threshold of 0.05 for statistical significance. In other words, there is little evidence to support a relationship between Janitorial cost per square foot and Space per occupant in the Middle East, and any observed correlation may be due to chance. The small sample size of 41 facilities may also limit the statistical power and increase the uncertainty of the results. Further studies with larger sample sizes or different methods may be needed to confirm or refute the findings.

CHAPTER 6. DISCUSSIONS AND KEY FINDINGS

The study aimed to investigate the relationship between space and janitorial costs compared to maintenance costs in the FM industry. The findings showed a significant correlation between space and janitorial costs, where larger facilities incurred higher janitorial costs. However, there was only a weak correlation between space and maintenance costs, implying that size alone did not lead to higher maintenance costs.

These findings have important implications for FM practitioners as they highlight the need for effective space utilization strategies to control janitorial costs. FM practitioners must prioritize optimizing space utilization to reduce costs associated with janitorial services. Furthermore, customized maintenance plans must be developed to address the specific needs of the facility.

In contrast to the correlation between space and janitorial costs, the study did not find a significant relationship between maintenance costs, facility age, industry sector, and facility use. This implies that maintenance costs are determined by the specific needs of the facility rather than external factors like the age of the building or industry sector.

Moreover, the study identified a new relationship between space per occupant and janitorial costs. This new relationship implies that more significant space per person either means more building space or fewer people in the office.

In conclusion, this thesis provides FM professionals with insights into how workplace changes impact building operations. FM practitioners must prioritize effective space utilization strategies and customized maintenance plans to optimize the performance of their facilities and reduce operational costs. Understanding the relationship between space per occupant and janitorial costs

is crucial to resolving the ongoing debate regarding workplace changes and their impact on building operations.

Limitations in the research

This study on facility management costs has identified several limitations in the data used. These limitations could affect the reliability of the data and limit its usefulness for analysis. Firstly, the variation in the number of responses across different regions could impact the reliability of the results as it may not represent the population accurately. Secondly, the data was self-reported by FM professionals, raising questions about the accuracy and validity of the data. Thirdly, incomplete data was observed due to missing values, which could affect the reliability of the results. Fourthly, respondents often provided broad ranges instead of exact values, which can result in imprecise data, making it difficult to accurately determine the age of a facility and may impact the reliability of the data. Finally, the data from different geographic regions and countries with varying currencies and metric systems may not be reliable due to conversion and purchasing power parity issues.

These limitations are crucial to consider when interpreting the results of this study. FM professionals need to be aware of the potential biases and limitations in the data to make informed decisions and conclusions. Despite these limitations, the study provides valuable insights into the relationships between facility management costs and space utilization, as well as the identification of a new relationship between space per occupant and janitorial costs. Future research could consider addressing these limitations by collecting data from a larger and more representative sample, using standardized measures, and verifying self-reported data to improve the reliability and validity of the data.

Future Research

1. A future research study can target FM industry giants like JLL, CBRE, and Cushman and Wakefield to conduct a survey-based study. The survey would include questions about building demographics, janitorial, and all maintenance costs. The surveys can be distributed to 40-50 clients per FM company. This study can analyze the data to investigate the relationship between space per occupant and janitorial and maintenance costs. The study can also analyze the differences in FM practices and costs between different industries, facility uses and regions as well as the impact of building design and layout on FM costs and performance. The results of this study can provide insights into the effectiveness of data-driven decision-making in FM and can help organizations optimize their FM costs and practices.
2. Identifying and analyzing the factors that affect janitorial costs in facilities beyond space per occupant, facility size, age, and geographical region, such as the type of cleaning products used, frequency of cleaning, and the type of surfaces that need to be cleaned.
3. Examining the relationship between facility maintenance costs and other factors that were not studied in this research, such as the type of equipment used, maintenance schedule and frequency, and quality of maintenance.
4. Investigating the impact of other facility management practices on costs, such as energy management and sustainability practices, and how they relate to janitorial and maintenance costs.
5. Comparing the results of this study to previous IFMA O&M benchmarking surveys to identify trends in space allocation and management practices, as well as changes in maintenance and janitorial costs over time.

6. Conducting a case study analysis of specific facilities to understand how facility management practices impact janitorial and maintenance costs in different types of buildings and facilities.
7. Investigating the impact of the COVID-19 pandemic on facility management practices and costs, particularly with respect to cleaning and maintenance practices.

CHAPTER 7. CONCLUSION

Facilities Management (FM) is an essential function for organizations to ensure that their buildings and infrastructure are well-maintained, efficient, and safe for occupants. The FM industry incurs significant costs, and optimizing these costs is critical to achieving organizational goals. This study investigated the correlation between space and janitorial cost compared to maintenance costs in the FM industry. The findings showed that there is a strong correlation between space and janitorial costs, indicating that larger facilities incur higher janitorial costs. In contrast, there was a weak correlation between space and maintenance costs, indicating that the size of the facility does not necessarily increase maintenance costs.

These findings have significant implications for FM practitioners as they highlight the need for effective space utilization strategies to control janitorial costs. By optimizing space utilization, FM practitioners can reduce the costs associated with janitorial services.

Moreover, the study found no significant correlation between maintenance costs and facility age, industry sector, or facility use. This indicates that maintenance costs may be determined by the specific needs of the facility, and not by external factors such as the age of the building or industry sector. Considering these findings, FM practitioners can design customized maintenance plans that address the specific needs of the facility.

However, data limitations from this study can be identified in several areas. Firstly, the number of responses varied across different regions, which could impact the reliability of the results as it may not represent the population accurately. Secondly, the data was self-reported by FM professionals, which raises questions about the accuracy and validity of the data. Thirdly, there was inconsistency in the data due to missing values, with some respondents

answering only certain questions and not others, resulting in incomplete data. Fourthly, respondents often provided broad ranges instead of exact values, which can result in imprecise data. Finally, due to the data coming from different geographic regions and countries with varying currencies and metric systems, the data analysis for correlations may not be reliable due to conversion and purchasing power parity issues.

To address these limitations, future studies can identify and analyze the factors that affect janitorial costs in facilities beyond space per occupant, facility size, age, and geographical region. They can also examine the relationship between facility maintenance costs and other factors that were not studied in this research. For instance, the type of equipment used, maintenance schedule and frequency, and quality of maintenance. Additionally, investigating the impact of other facility management practices on costs, such as energy management and sustainability practices, and how they relate to janitorial and maintenance costs can provide more insights into FM practices.

Furthermore, future studies can compare the results of this study to previous IFMA O&M benchmarking surveys to identify trends in space allocation and management practices, as well as changes in maintenance and janitorial costs over time. Conducting a case study analysis of specific facilities can also help understand how facility management practices impact janitorial and maintenance costs in different types of buildings and facilities.

Finally, the impact of the COVID-19 pandemic on facility management practices and costs, particularly with respect to cleaning and maintenance practices, is an important area for future research. By addressing these future research areas, FM practitioners can adopt a data-driven approach to optimize the performance of their facilities and reduce operational costs.

REFERENCES

1. Adewunmi, Y. A., R. Iyagba, and M. Omirin. 2017. "Multi-sector framework for benchmarking in facilities management." *BIJ*, 24 (4): 826–856. https://doi.org/10.1108/BIJ-10-2015-0093.
2. Agha-Hossein, M. M., S. El-Jouzi, A. A. Elmualim, J. Ellis, and M. Williams. 2013. "Post-occupancy studies of an office environment: Energy performance and occupants' satisfaction." *Building and Environment*, 69: 121–130. https://doi.org/10.1016/j.buildenv.2013.08.003.
3. Babapour, M., M. Karlsson, and A.-L. Osvalder. 2018. "Appropriation of an Activity-based Flexible Office in daily work." *NJWLS*, 8. https://doi.org/10.18291/njwls.v8iS3.105277.
4. de Bakker, C., M. Aries, H. Kort, and A. Rosemann. 2017. "Occupancy-based lighting control in open-plan office spaces: A state-of-the-art review." *Building and Environment*, 112: 308–321. https://doi.org/10.1016/j.buildenv.2016.11.042.
5. Bradley, S., and C. Hood. 2003. "Delivering minimalist workplaces that improve corporate agility." *Journal of Facilities Management*, 2 (1): 68–84. https://doi.org/10.1108/14725960410808122.
6. Bueno, S., G. Rodríguez-Baltanás, and M. D. Gallego. 2018. "Coworking spaces: a new way of achieving productivity." *Journal of Facilities Management*, 16 (4): 452–466. https://doi.org/10.1108/JFM-01-2018-0006.
7. de, L. J. 1991. "The Ernst & Young approach to facilities management." *Property Management*, 9 (1): 24–31. https://doi.org/10.1108/02637479110029793.

8. De Sanctis, G., J. Kohler, and M. Fontana. 2014. “Probabilistic assessment of the occupant load density in retail buildings.” *Fire Safety Journal*, 69: 1–11. https://doi.org/10.1016/j.firesaf.2014.07.002.
9. Dedesko, S., B. Stephens, J. A. Gilbert, and J. A. Siegel. 2015. “Methods to assess human occupancy and occupant activity in hospital patient rooms.” *Building and Environment*, 90: 136–145. https://doi.org/10.1016/j.buildenv.2015.03.029.
10. “Desk ownership in the workplace: The effect of non-territorial working on employee workplace satisfaction, perceived productivity and health | Elsevier Enhanced Reader.” n.d. Accessed December 11, 2022. https://reader.elsevier.com/reader/sd/pii/S036013231630138X?token=2FA6FEFD22CE3A3338267ECDCA3229389727B5F22BD276D303A987BAC27B61EDF9C91FEA3A74AF3921A612AF4B163C35&originRegion=us-east-1&originCreation=20221211205754.
11. Dibley, M., H. Li, Y. Rezgui, and J. Miles. 2013. “Software agent reasoning supporting non-intrusive building space usage monitoring.” *Computers in Industry*, 64 (6): 678–693. https://doi.org/10.1016/j.compind.2013.03.008.
12. “Elsevier Enhanced Reader.” n.d. Accessed December 11, 2022. https://reader.elsevier.com/reader/sd/pii/S0360132317305176?token=361C6CD403539330D3F8BD515550921D949498E64BDB052E06A7F53A462E404AD52AE7999C77E00ED2A07FB4FE69AC8A&originRegion=us-east-1&originCreation=20221211212305.
13. Espinoza, L., H. Espinoza, and W. Feng. 2013. “Modeling a Facilities Management and Information System by UML.” *2013 10th International Conference on Information Technology: New Generations*, 65–70.

14. Finch, E., and X. Zhang. 2013. “Facilities Management.” *Design and Management of Sustainable Built Environments*, R. Yao, ed., 305–326. London: Springer London.
15. Gocer, O., C. Candido, K. Gocer, A. Brambilla, L. Thomas, N. Billoria, M. Mackey, T. Alizadeh, and S. Sarkar. 2022. “Overlaps in space utilisation patterns and IEQ conditions observed in Activity-Based Working supportive office.” *Building and Environment*, 220: 109273. https://doi.org/10.1016/j.buildenv.2022.109273.
16. Harris, W. 2011. “Budgeting Academic Space.” *Planning for Higher Education*, 40 (1): 29–41.
17. Ho, D. C. W., E. H. W. Chan, N. Y. Wong, and M. Chan. 2000. “Significant metrics for facilities management benchmarking in the Asia Pacific region.” *Facilities*, 18 (13/14): 545–556. https://doi.org/10.1108/02632770010358088.
18. Hugh Fawcett, W. 2009. “Optimum capacity of shared accommodation: yield management analysis.” *Facilities*, 27 (9/10): 339–356. https://doi.org/10.1108/02632770910969595.
19. Ibrahim, I., W. Z. W. Yusoff, and N. S. S. Sidi. 2011. “A Comparative Study on Elements of Space Management in Facilities Management at Higher Education Institutions.”
20. Ilozor, B. D., and D. B. Ilozor. 2006. “Open-planning concepts and effective facilities management of commercial buildings.” *Engineering, Construction and Architectural Management*, 13 (4): 396–412. https://doi.org/10.1108/09699980610680199.
21. Ilozor, B. D., and J. O. Oluwoye. 1999a. “Open-plan measures in the determination of facilities space management.” *Facilities*, 17 (7/8): 237–245. MCB UP Ltd. https://doi.org/10.1108/02632779910270195.

22. Kang, H., M. Lee, T. Hong, and J.-K. Choi. 2018. “Determining the optimal occupancy density for reducing the energy consumption of public office buildings: A statistical approach.” *Building and Environment*, 127: 173–186. https://doi.org/10.1016/j.buildenv.2017.11.010.
23. Kung-Jen, T., and L. Chen- Hong. 2012. “Benchmarking Energy Efficiency by ′Space Type′: An Energy Management Tool for Individual Departments Within Universities.” *Journal of Asian Architecture and Building Engineering*. Accessed December 12, 2022. https://www.tandfonline.com/doi/epdf/10.3130/jaabe.11.299?needAccess=true&role=button.
24. Kwok, S. S. K., R. K. K. Yuen, and E. W. M. Lee. 2011. “An intelligent approach to assessing the effect of building occupancy on building cooling load prediction.” *Building and Environment*, 46 (8): 1681–1690. https://doi.org/10.1016/j.buildenv.2011.02.008.
25. Mesthrige, J. W., and Y. H. Chiang. 2019. “The impact of new working practices on employee productivity: The first exploratory study in Asia.” *Journal of Facilities Management*, 17 (2): 122–141. https://doi.org/10.1108/JFM-03-2018-0020.
26. Nielsen, S. B., and R. Brinkø. 2018. “Access over ownership: meeting facilities in Lyngby-Taarbæk Knowledge City.” *Facilities*, 36 (1/2): 13–23. https://doi.org/10.1108/F-01-2017-0001.
27. Pereira, S. M. C., and G. Leslie. 2010. “Testing differences between two samples of continuous data.” *Australian Critical Care*, 23 (3): 160–166. https://doi.org/10.1016/j.aucc.2010.06.002.

28. Pitt, M., and J. Bennett. 2008. “Workforce ownership of space in a space sharing environment.” *Journal of Facilities Management*, 6 (4): 290–302. https://doi.org/10.1108/14725960810908154.
29. “Post-occupancy studies of an office environment: Energy performance and occupants’ satisfaction | Elsevier Enhanced Reader.” n.d. Accessed December 11, 2022. https://reader.elsevier.com/reader/sd/pii/S0360132313002217?token=DE7C39625D8ECC65971654E80E6C00BEE0EAD90CDD0E7E1040895A292B0261F409AC2982EBB2525044875EFC31274526&originRegion=us-east-1&originCreation=20221211210052.
30. Rikke, B., and S. B. Nielsen. 2018. “Multiplying the use of space and what it implies in practice: a cross-case analysis.” *Journal of Facilities Management*, 16 (2): 197–216. https://doi.org/10.1108/JFM-09-2017-0045.
31. Rusek, R., J. Colomer Llinas, and J. Melendez Frigola. 2018. “A comparison study on space-use analysis techniques and proposal of a novel method for determining space needs in public facilities.” *Sustainable Cities and Society*, 39: 326–334. https://doi.org/10.1016/j.scs.2018.02.032.
32. Rusek, R., J. Melendez Frigola, and J. Colomer Llinas. 2022. “Influence of occupant presence patterns on energy consumption and its relation to comfort: a case study based on sensor and crowd-sensed data.” *Energ Sustain Soc*, 12 (1): 13. https://doi.org/10.1186/s13705-022-00336-6.
33. Sheikh Khan, D., J. Kolarik, C. Anker Hviid, and P. Weitzmann. 2021. “Method for long-term mapping of occupancy patterns in open-plan and single office spaces by using passive-infrared (PIR) sensors mounted below desks.” *Energy and Buildings*, 230: 110534. https://doi.org/10.1016/j.enbuild.2020.110534.

34. “Space Charging Model: Cost Analysis On Classrooms In Higher Education Institutions | Elsevier Enhanced Reader.” n.d. Accessed January 25, 2023. https://reader.elsevier.com/reader/sd/pii/S1877042811024876?token=A20FEC0C5012F70DFA5912643E202C2D27AE3883C9B02B53C65A6DCA2B2EBCB9E95A5DB2955FC22AFEEF2F3874DBAAF5&originRegion=us-east-1&originCreation=20230125232748.
35. Steiner, J. 2005. “The art of space management: Planning flexible workspaces for people.” *Journal of Facilities Management*, 4 (1): 6–22.
36. *The certified facility manager: study guide*. 2004. Houston, Tex.: International Facility Management Association.
37. Udrea, I., T. Trita, and R. T. Popa. 2017. “Energy efficiency increasing through space management. Case study in an office building *.” *Revista Romana de Inginerie Civila*, 8 (4): 28–36.
38. Wauters, B. 2005. “The added value of facilities management: benchmarking work processes.” *Facilities*, 23 (3/4): 142–151. https://doi.org/10.1108/02632770510578511.
39. Yang, J., M. Santamouris, S. E. Lee, and C. Deb. 2016. “Energy performance model development and occupancy number identification of institutional buildings.” *Energy and Buildings*, 123: 192–204. https://doi.org/10.1016/j.enbuild.2015.12.018.
40. Yu, R., M. Burke, and N. Raad. 2019. “Exploring impact of future flexible working model evolution on urban environment, economy and planning.” *Journal of Urban Management*, 8 (3): 447–457. https://doi.org/10.1016/j.jum.2019.05.002.
41. Zhou, Y., T. R. Lin, Y. Sun, Y. Bian, and L. Ma. 2015. “An effective approach to reducing strategy space for maintenance optimisation of multistate series–parallel systems.”

Reliability Engineering & System Safety, 138: 40–53. https://doi.org/10.1016/j.ress.2015.01.018.

42. Harris, W. 2011. "Budgeting Academic Space." *Planning for Higher Education,* 40 (1): 29–41.
43. Udrea, I., T. Trita, and R. T. Popa. 2017. "Energy efficiency increasing through space management. Case study in an office building *." *Revista Romana de Inginerie Civila*, 8 (4): 28–36.
44. *IFMA North America Operation and Maintenance Benchmarking Report 2022, IFMA* https://www.ifma.org/
45. *IFMA Asia Operation and Maintenance Benchmarking Report 2021 IFMA,* https://www.ifma.org/
46. *IFMA Middle East Operation and Maintenance Benchmarking Report 2023, IFMA,* https://www.ifma.org/
47. Currency Conversion Details (Xe Currency Converter - Live Exchange Rates Today. (n.d.). https://www.xe.com/currencyconverter/)
48. United States Environmental Protection Agency- EPA. (2021). Indoor air quality, from https://www.epa.gov/indoor-air-quality-iaq
49. ASHRAE. (2021). Standard 62.1-2019: Ventilation for acceptable indoor air quality, from https://www.ashrae.org/technical-resources/bookstore/standard-62-1
50. OSHA. (2021). Indoor air quality. Retrieved May 7, 2023, from https://www.osha.gov/indoor-air-quality-iaq
51. American Society for Quality (ASQ), 2021 https://asq.org/