A STUDY OF BUILDING INFORMATION MODELING USAGE THROUGH THE

PERCEIVED UTILIZATION OF FACILITIES MANAGEMENT TRAINING,

BUILDING INFORMATION MODELING TECHNICAL SPECIFICATIONS, AND A

QUALITY BUILDING INFORMATION MODEL FOR FACILITIES

MANAGEMENT AT HIGHER EDUCATIONAL INSTITUTIONS IN TEXAS

A Dissertation

by

DARRELL ERNEST THOMPSON

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Chair of Committee,	Edelmiro Escamilla
Committee Members,	Mark Clayton
	Wei Yan
	Boong-Yeol Ryoo
Head of Department,	Ward Wells

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ABSTRACT

The research for this study investigated the correlation between the perceived usage of Building Information Modeling in Facilities Management and; the perceived training level of the FM personnel, the perceived specification requirement and the influence of it by FM personnel, and the perceived quality of the building information model to be used by FM personnel, by the respective institution.

The study began, Phase I, with a diligent review of literature and a scrutinous selection of case studies that provided an identifying mechanism for those elements that possessed the potential to impact the perceived usage of BIM for facilities management in a contained environment. Upon the completion of Phase I, the pilot study and interview process began in Phase II. The interview coupled with the Fault Tree Analysis tool obtained in the literature review derived the conceptual model of the study that ultimately acted as the driver for the generation of the general hypothesis and the subset hypotheses of the study. Once the conceptual model and hypotheses were established, the methodology of the study was outlined. The methodology implemented consisted of both qualitative and quantitative processes. It was in Phase II where the survey instrument was developed. This was manufactured in part by the pilot study interview and research associated with the literature review and the case studies. The population sampling was conducted through a series of targeting techniques in the effort to isolate the highest qualified candidates for the execution of the survey instrument. The survey

instrument was distributed and implemented and through a diligent effort the data was collected and prepared for analyses.

The analysis consisted of descriptive and inferential statistics. The analysis of the data was organized in a methodical fashion and structure of the data was characteristic of placeholders and identifiers using a binary coded procedure that allowed the use of the 'R' statistical software tool. ANOVA and MANOVA testing was utilized with interpretations of F-values and P-values indicating the outcomes.

The outcomes indicated that the perceived Usage of BIM was impacted by its subsets of hypotheses; FM Training (H2) and a Quality BIM (H4) with Specifications (H3) not indicating any significance on the perceived usage of BIM.

The subsets of hypotheses concerning the perceived FM Training, the perceived Specifications, and the perceived Quality BIM were found to exhibit significance independently.

DEDICATION

To my Dad.

ACKNOWLEDGEMENTS

Much in life is not what you earn, but rather, what you negotiate. Proceed confidently and trust no one.

NOMENCLATURE

AIA	American Institute of Architects
ANOVA	Analysis of Variance
BAS	Building Automation System
BIM	Building Information Modeling
CAD	Computer Aided Design
CAFM	Computer Aided Facilities Management
CI	Confidence Interval
CM	Construction Management \ Manager
CM@R	Construction Management at Risk
CMMS	Computerized Maintenance Management System
COAA	Construction Owners Association of America
COBie	Construction Operations Building Information Exchange
CSI	Construction Specifications Institute
DMS	Document Management Software
FAMIS	Facilities Asset Management Information System
FM	Facilities Management
FTA	Fault Tree Analysis
FTP	File Transfer Protocol
GC	General Contractor
GSF	Gross Square Feet

GUI	Graphical User Interface
H0	Primary Hypothesis, Hypothesis 0
H1	Subset Hypothesis, Hypothesis 1
H2	Subset Hypothesis, Hypothesis 2
H3	Subset Hypothesis, Hypothesis 3
H4	Subset Hypothesis, Hypothesis 4
HVAC	Heating, Ventilation, and Air Conditioning
IFC	Industry Foundation Classes
IFMA	International Facility Management Association
IPD	Integrated Project Delivery
IRB	Institutional Review Board
LCCA	Life Cycle Cost Analysis
LOD	Level of Development
MEP	Mechanical, Electrical, Plumbing
NBIMS	National Building Information Modeling Standard
POR	Program of Requirements
RFI	Request for Information
RFID	Radio Frequency Identification
VAK	Visual Auditory Kinesthetic
VARK	Visual Auditory Read-Writing Kinesthetic
2D	Two Dimensional
3D	Three Dimensional

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CHAPTER I

INTRODUCTION

This dissertation shall serve as a study of perceived building information modeling usage and the perceived utilization of facilities management training, perceived building information modeling technical specifications, and perceived quality building information models for facilities management at higher educational institutions in Texas. The attempt of the study is to acquire a relationship between the perceived increased use of building information modeling in facilities management with perceived BIM training, perceived FM influenced technical specifications, and perceived accurately assembled building information models. This investigation was guided through supportive literature reviews, derived conceptual models and hypotheses, intentional methods, and conclusions drawn through carefully analyzed findings. The study began by introducing the basic parameters of the study including; background, needs and objectives, research questions, significance, the outline and scope of the study, and the problem statement and subproblems.

Research Background

There are more than 4,100 universities and colleges in the United States, enrolling approximately 15 million students. These institutions account for more than five billion square feet in nearly 240,000 buildings (Rose, R., 2007). And these approximations for higher educational institutions alone are most likely going to

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increase. As this study shall reveal, the amount of money spent on the life-cycle of a structure is roughly 20% on the design and build, and 80% on the maintenance and operation. The general understanding and acceptance among industry players is that there is ample information in the building information models generated; the problem is identifying the proper information needed to properly and efficiently management a facility using BIM. Through literature, it is clear to analyze the adoption of an innovation and its predictability. What is not clear, are the multifaceted barriers that contribute to the lack of use of BIM for facilities management.

Research Needs and Objectives

In order for the research hypotheses to be addressed, three key objectives were developed for this study. These objectives were centered on the needs of the Facilities Management team and personnel. The objectives include the following:

1. Establish a baseline of facility managers' perception of Building Information Modeling usage for Facilities Management through the administered survey instrument

2. Determine learning style outcomes of facility managers for recommended training of BIM for FM through the administered survey instrument

3. Report the correlations of perceived usage of BIM for FM to the findings of the analyzed collected data

Research Questions

There are several questions associated with this study and the steps that were taken to derive those inquiries. This process began with a literature review that provided support for the fault tree analysis and the conceptual model, detailed and illustrated in Chapter III. A series of inquiries were run through the fault tree analysis. This process was continually repeated until trending questions were formulated. Ultimately, this process evolved into the hypotheses of the study, also discussed and outlined in Chapter III. The primary hypothesis is inclusive of a practical and theoretical assumption that Building Information Modeling (BIM) can increase its use for Facilities Management (FM) if the following items are implemented; a BIM trained facilities manager, a BIM technical specification is influenced by a trained facilities manager, and an accurate, quality building information model exists. The implementation of these aforementioned items also contains some contingencies and impacts the primary inquiry. The questions surrounding the assumptions related to a BIM trained facilities manager, a BIM technical specification influenced by a trained facilities manager, and an accurate, quality building information model for the facility manager each rely on the outcome of the other. Consider the following; if the facility manager lacks training to the point that they cannot efficiently extract information out of the BIM model, then they are unable to accurately and effectively influence the BIM technical specification. In turn, if the BIM technical specification is not influenced properly by the facilities manager, then the produced building information model will not be inclusive of the influenced items needed by the facilities manager for more efficient and accurate maintenance and

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operation. This inaccurate BIM model increases the reluctance for the facilities manager to utilize the BIM model for FM. The relationship between the increased use of BIM for FM and its current usage can be tested utilizing three different metrics; the actual data depicting its usage increase, the perception of its usage increase, and statistical inference. These three metrics are further analyzed and summarized in Chapters V and VI, respectively.

Research Significance

The purpose of this study is to determine the perceived building information modeling usage and the perceived utilization of facilities management training, a perceived building information modeling technical specifications, and a perceived quality building information model for facilities management at higher educational institutions in Texas. Through reviewed literature and the composition of the study conceptual model, the significance of this study has been drawn and illustrated (Figure 1). Much of the focus of implementing BIM in FM has been on the transferring of information from design and construction to that of operations (Akcamete, A., Akinci, B., & Garrett, J. H., 2010). The building information model can contain almost any information desired; however, it is import to note that select information is what the FM operator needs to properly manage and interface with FM software.
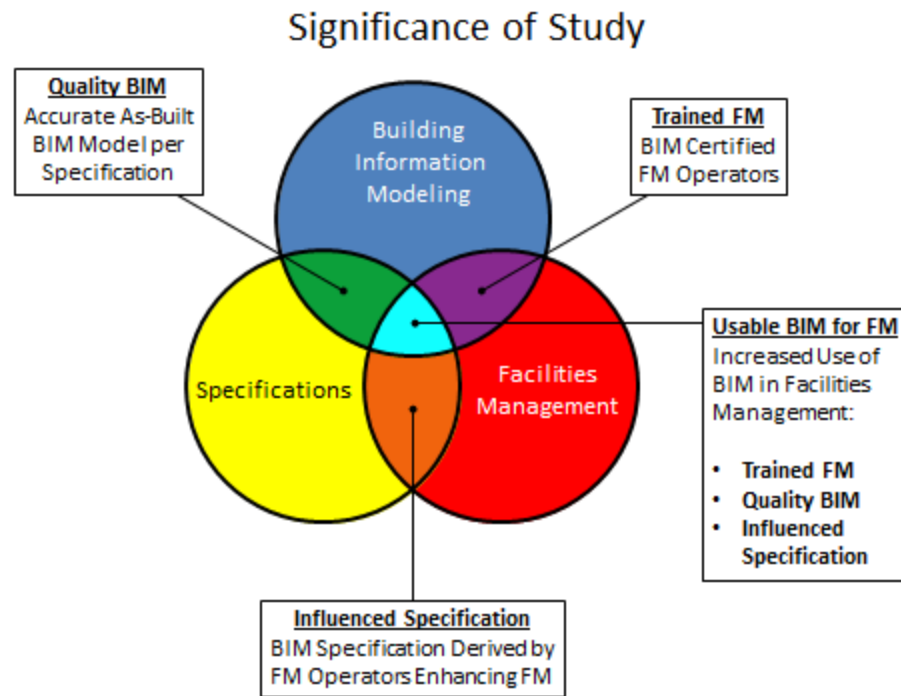
Figure 1, Significance of Study Model

Research Outline and Scope

The outline and scope of this study consists of the following elements and is organized

in six chapters. Chapter one introduced the study and put forth some basic background of

the research, needs and objectives, questions of the study, significance, outline and

scope, and the problem statements and subproblems. Chapter two focused on the

literature review and was comprised of seven sectors, including; building information

modeling, facilities management, BIM technical specifications, case studies,

communication and implementation, adoption, and a summary. Chapter three discussed

the conceptual model and hypotheses of the study, as well as the theoretical framework.

Chapter four addressed the methodology of the study. This included research design and

assumptions, procedure, targeted interest population and sample size, limitations,

delimitations, development of the survey instrument, composition of the questionnaire,

institutional review board, sampling methodology and data collection, classifying the

data, and applying statistical tools. Chapter five consisted of the analysis and results.

And finally, Chapter six was devoted to the summary and conclusions of the study.

The Problem Statement and Subproblems

Many players in the built environment are in agreement that BIM is a tool that will most

likely remain and continue to gain traction in its use. However, from an operations

perspective, few have adopted BIM and are unsure how it can be used in FM. There

have been steps in the industry to increase the interoperability of data transfer and

organizations supporting that effort (East, W. E., & Brodt, W., 2007); including

Construction Operations Building Information Exchange (COBie), Industry Foundation Classes (IFC), and National Building Information Modeling Standard (NBIMS) (Motamedi, A., & Hammad, A., 2009). These standards are key elements to the success of BIM, as it provides structure and means to categorize. These current standards are the precursors to a unique BIM technical specification.

And as it is estimated the BIM can achieve nearly 20% Capital Expenditure savings, "the largest prize for BIM lies in the operational stages of the project life-cycle" (BIM Task Group, 2013). This has tremendous impact as the project life-cycle cost breakdown is a 20 / 80 split; design and build accounting for 20%, while operations and maintenance account for 80% of the overall cost (Eastman, C., Teicholz, P., Sacks, R., & Liston, K., 2008; Teicholz, E. (Ed.)., 2012).

Much of the problem associated with FM and the implementation of BIM is not whether the technology is available or whether the information is attainable; but rather, what is done with the technology and information. In addition to that dilemma is the on-going balance of justifying the expense associated with an implementation that may or may not work. The real expense associated with implementation is the on-going costs of salaries and people. In order for FM to successfully utilize BIM, a balance of people, process, and technology must occur. This balance of people, process, and technology is further analyzed in the Facilities Management literature review in Chapter II.

CHAPTER II

REVIEW OF RELATED LITERATURE

The literature review sets forth and establishes a base for what is happening in the built environment as related to Building Information Modeling (BIM), Facilities Management (FM), and BIM Technical Specifications. A number of impacting factors are investigated as well and include communication, implementation, and adoption of processes. The use of several case studies possessing similar features and parameters to this study are reviewed and considered additional legitimate benchmarks for the investigation.

Building Information Modeling

Building Information Modeling (BIM) as defined by the National Building Information Modeling Standards as the following: *Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition* (NBIMS – United States, 2014). A Building Information Model (BIM), as conveyed in the BIM Handbook, is when completed, the computer-generated model contains precise geometry and relevant data needed to support the construction, fabrication, and procurement activities needed to realize the building (Eastman, C., Teicholz, P., Sacks, R., & Liston, K., 2008).

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The BIM process is basically made up of a building geometrical component and a nongraphic structured information component. Both of these components can be segregated by a designated class or feature that falls into a unique category. A building information model (BIM) that is missing one of these components is technically not classified a BIM. This is important because the collaboration of the two components is the real power of a three dimensional model with an enriched data application. Three dimensional computer aided design (3D CAD) applications have been in existence for over 20 years and are very capable of producing a 3D model, however, the technology is not sophisticated enough to provide significant data of the components of the model or the relationships between objects (Sabol, L., 2008). BIM is a virtual building simulation computer aided parametric technology with relational databases between varied independent building components (Woo, J. H., 2006).

Building information models vary in their degree of detail. This is referred to as Level of Development (LOD). It is essentially arranged in five progressive sectors beginning with level 1, the least amount of detail, to level 5, the greatest amount of detail (Figure 2). Note that Level 5 is often coined an as-built level model.

Level of Development (LOD)
for Building Information Models

Level	Description	BIM Document Phase
100	Conceptual Geometry	Schematic Design
200	Approximate Geometry	Design Development
300	Precise Geometry	Construction Documents
400	Fabrication	Construction Model
500	As-Built	As-Built Model

Figure 2, Level of Development (LOD) for Building Information Models

Determining the level of detail within a building information model has been based
on a descriptive matrix. This matrix is documented on the American Institute of
Architects (AIA) document E202-2008, and contains the following descriptions
(Teicholz, P. (Ed.)., 2013).

- Level 100: Overall building massing, including area, height, volume, location,
  and orientation

- Level 200: Generalized systems and assemblies with approximate quantities,
  size, location, and orientation

- Level 300: Specific systems and assemblies with accurate information for
  quantities, size, location, and orientation

- Level 400: Specific systems and assemblies with accurate size, shape, location, quantity, and orientation that will allow fabrication, assembly, and detailing to be completed

- Level 500: As-constructed assemblies with accurate size, shape, location, quantity, and orientation information

The Level of Development (LOD) is also found as a specifications tool in the American Institute of Architects Building Information Modeling Protocol Form, AIA G202-2013. This LOD Specification protocol form was organized by the Construction Specifications Institute, CSI Uniformat 2010, defining and illustrating characteristics of modeling elements for different building systems at different levels of development (Reinhardt, J. and Bedrick, J., 2013). These designations are important to facilities managers because the process offers another opportunity to segregate information and elements of a building information model in the effort to enhance usability of a BIM for FM. Additionally, the LOD is a great communication tool for designers, constructors and facilities managers to establish the appropriate level of detail for any given element, or aspect of a building information model.

The standards for building information modeling are governed and hold two primary guidelines; IFC established in 1994 (Figures 5, 6, 7, 8, and 9) and COBie established in 2007 (Figure 10). A third standard exists, the National Building Information Modeling Standards (NBIMS) established in 1995, but it essentially follows the same guidelines set forth by the Industry Foundation Classes (IFC). These guidelines

and functions are further elaborated later in the literature review in the BIM Technical Specifications section.

Building Information Modeling (BIM) possesses many potential beneficial attributes in the design, construction, and operations of facilities. Some of these benefits include the integration of multiple discipline plans, sections, details, graphics, and data. These benefits are shown in cost and time reduction as well as a usable platform for tracking associated with operations. However, Building Information Modeling (BIM) also faces some barriers to its full implementation and usage penetration with the primary obstacle being people. Social and habitual resistance to change contributes to the slow adoption rates as well as tedious training associated with relatively difficult learning curves that result in the allocation of vast time and resources (Yan, H., & Damian, P., 2008).

Facilities Management

As defined by the International Facility Management Association (IFMA), facilities management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process, and technology (IFMA, 2014). The integration of people, place, process, and technology plays a significant role in the successful functionality of the built environment and is graphically supported in Figure 3.

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People, Process, Technology
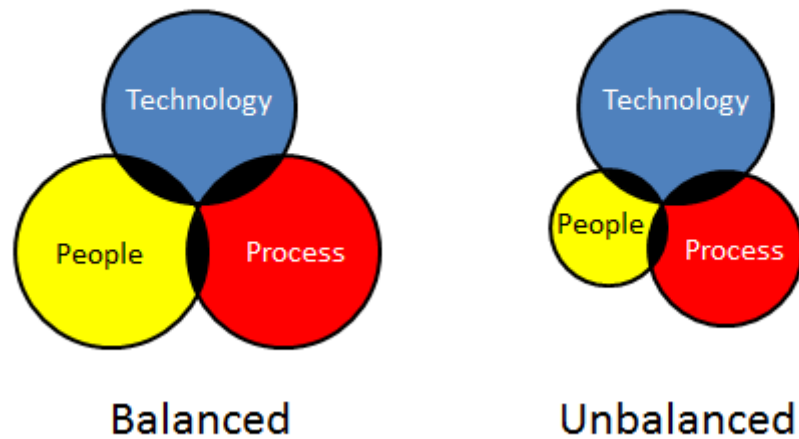
Figure 3 (Teicholz, E. (Ed.)., 2012), Balanced and Unbalanced FM Implementation Model

Currently, the FM operations are unbalanced with a unique problem. There is an abundance of technology and adequate people. The FM process is tried and true, but for a system that is pre-BIM. And, so the challenge continues to harness the technology, continue the stream of quality and knowledgeable people, while implementing a process that includes BIM.

The usage of BIM continues to increase and gain traction in the design and construction of the built environment; and its use in FM and operations & maintenance is not keeping pace.

Life-cycle cost analysis (LCCA) is an important component of facilities management. The life cycle of a structure begins with the programming and ends with the demolition of the structure. As shown in Figure 4, it is clear the lop-sided percentage of cost associated with the operations and maintenance of a structure versus the design and construction; 20% of costs designated for design and construction, while 80% of costs are allocated for operations and maintenance (Eastman, C., Teicholz, P., Sacks, R., & Liston, K., 2008; Teicholz, E. (Ed.)., 2012).

Life Cycle Cost Analysis

Programming   Demolition

100%

20%   80%

❏ Design   ❏ Operations
❏ Construction   ❏ Maintenance

(Cost analysis is based on a life cycle of approximately 40-50 years)
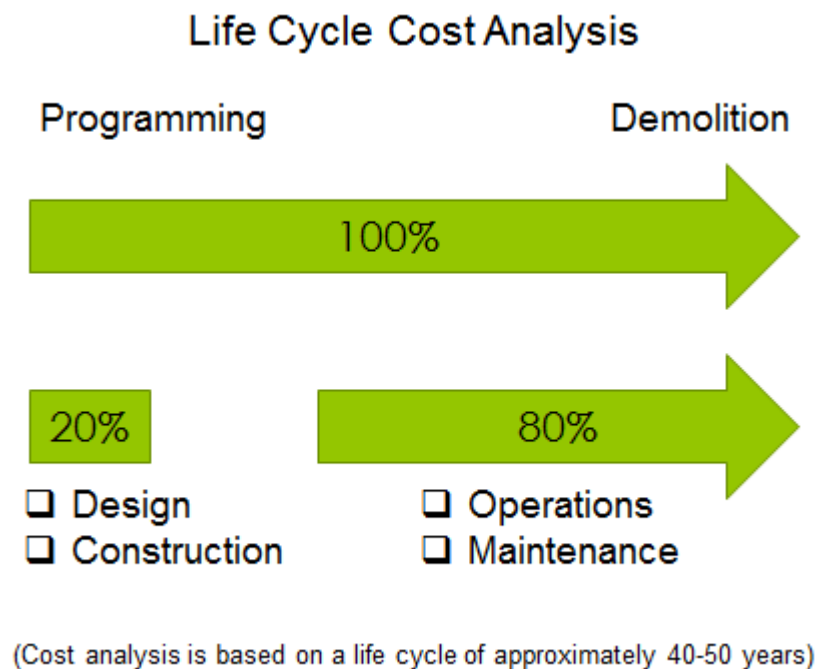
Figure 4, Life Cycle Cost Analysis (LCCA)

Much, if not all, of the focus for Facilities Management and FM personnel is the cost associated with performing the necessary tasks of maintaining a facility. FM teams

worldwide have deep resources available to perform the tracking of such tasks, but the programs are generic in nature and are not specific to each individual facility. The building information model is specific to its facility. And over time, BIM will support data collection on all aspects of building operations with a platform that will optimize those operations (Valentine, E., & Zyskowski, P., 2009). However, the only way for this to occur is if the FM team has the BIM in place with personnel that know how to properly use it. Additionally, the availability of FM applications based on BIM is already in operation internationally and show excellent prospects for implementation (Innovation, C. C., 2007).

Due to the focus on the amount of time and resources dedicated to the life cycle of a facility, the demand for Facilities Management is higher than ever. A relatively recent case study confirms in its findings; that a structured and organized FM has the potential to improve the physical performance and appearance of a building and its systems, as well as to increase the users' level of satisfaction, and to improve the efficiency with which the building is maintained and operated (Lavy, S., 2008). This type of confirmation reiterates the need for a more sophisticated means of managing facilities.

BIM Technical Specifications

By definition, technical specifications are requirements stated in terms suitable to form the basis for the actual design development and production processes of an item having the qualities specified in the operational characteristics, usually with specific

acceptance criteria (Farlex, I., 2001). Currently, technical specifications for BIM are primarily lead by the Industry Foundation Classes (IFC), the National Building Information Modeling Standards (NBIMS), and the Construction Operations Building Exchange (COBie).

The standards for building information modeling are governed and hold two primary guidelines; IFC established in 1994 (Figures 5, 6, 7, 8, and 9) and COBie established in 2007 (Figure 10). A third standard exists, the National Building Information Modeling Standards (NBIMS) established in 1995, but it essentially follows the same guidelines set forth by the Industry Foundation Classes (IFC).
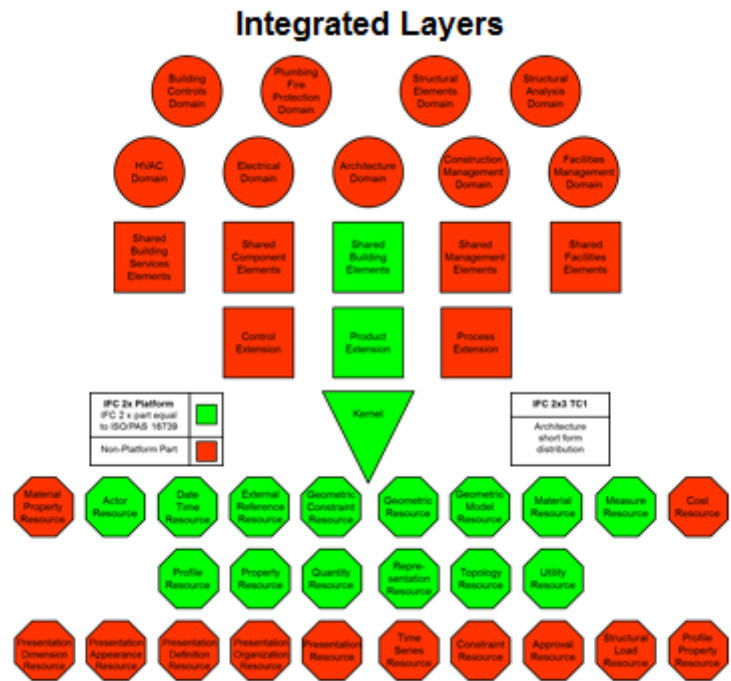
Figure 5, Industry Foundation Classes (IFC); Integrated Layers

The integrated layers (Figure 5) represented for the Industry Foundation Classes (IFC) include the domain layer, the inter-operability layer, the core layer, and the resource layer. These layers are ranked from high to low with the domain layer being the highest, the inter-operability layer being the next to the highest, the core layer being the next to the lowest, and the resource layer being the lowest. The Building Information Modeling (BIM) data that is exchanged and shared among the various participants in a construction project or a facilities management process is represented in an open specification format by the Industry Foundation Classes (IFC) (Liebich, T., Adachi, Y., Forester, J., Hyvarinen, J., Richter, S., Chipman, T., Weise, M., Wix, J., 2013).
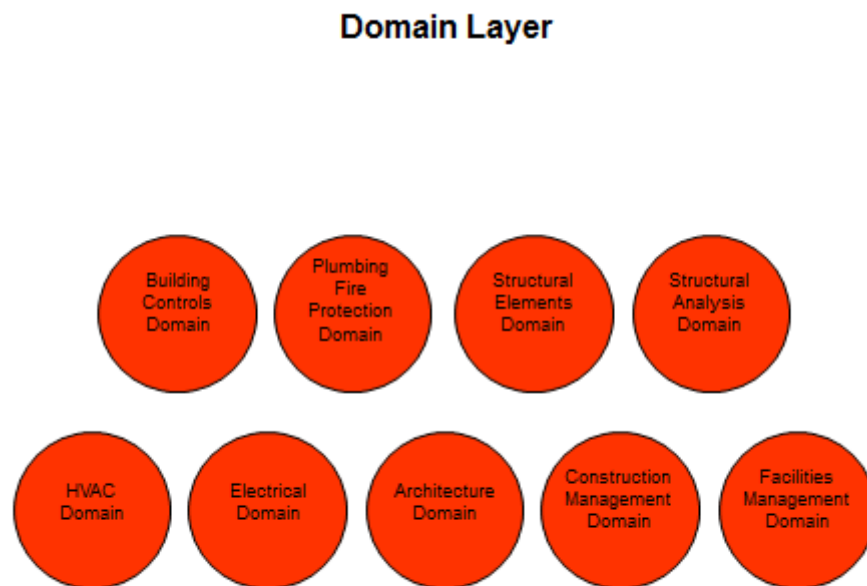
Domain Layer

Figure 6, Industry Foundation Classes (IFC); Domain Layer

The domain layer (Figure 6) consists of nine separate elements including the following: Building Controls Domain; Plumbing, Fire Protection Domain; Structural Elements Domain; Structural Analysis Domain; Heating, Ventilation, and Air Conditioning (HVAC) Domain; Electrical Domain; Architecture Domain; Construction Management Domain; and Facilities Management Domain. The domain layer is the highest ranking layer and includes schemas that contain entity definitions that are specialized pertaining to products, processes, or resources specific to a unique discipline; the definitions are typically used for intra-domain exchange and sharing of information (Liebich, T., Adachi, Y., Forester, J., Hyvarinen, J., Richter, S., Chipman, T., Weise, M., Wix, J., 2013).

Inter-Operability Layer

| Shared Building Services Elements | Shared Component Elements | Shared Building Elements | Shared Management Elements | Shared Facilities Elements |
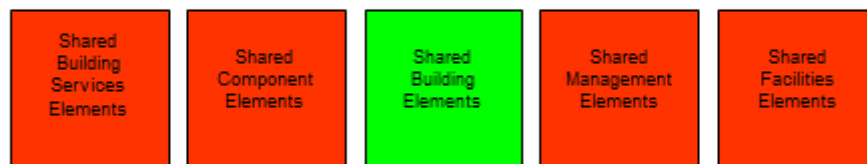
Figure 7, Industry Foundation Classes (IFC); Inter-Operability Layer

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The inter-operability layer (Figure 7) consists of five separate elements including the following: Shared Building Services Elements; Shared Component Elements; Shared Building Elements; Shared Management Elements; and Shared Facilities Elements. The inter-operability layer is the next to the highest ranking layer and includes schemas that contain entity definitions that are specific to a general product, process, or resource specialization used across several disciplines; the definitions are typically utilized for inter-domain exchange and the sharing of construction information (Liebich, T., Adachi, Y., Forester, J., Hyvarinen, J., Richter, S., Chipman, T., Weise, M., Wix, J., 2013).
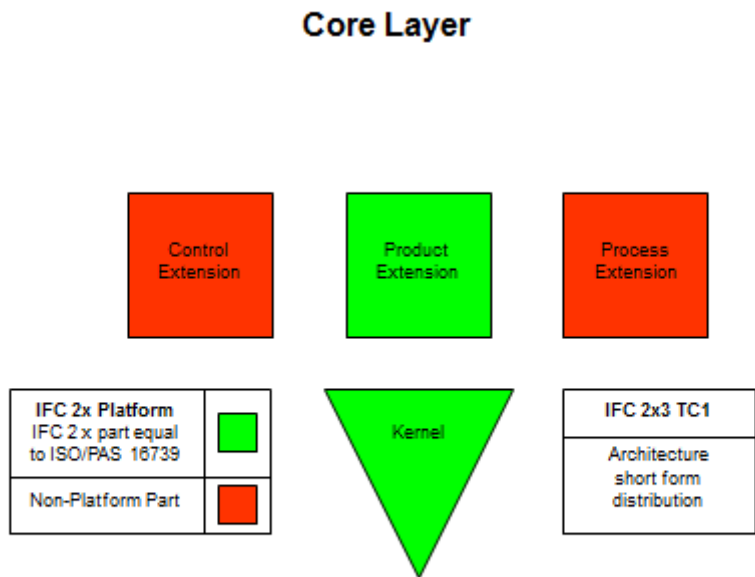
Core Layer

Figure 8, Industry Foundation Classes (IFC); Core Layer

The core layer (Figure 8) consists of three separate elements including the following: Control Extension; Product Extension; Process Extension; and the Kernel.

The core layer is the next to the lowest ranking layer and includes the kernel schema and the core extension schemas that contain the most general entity definitions. All entities defined at the core layer or above carry a globally unique identification with optional owner and historical information (Liebich, T., Adachi, Y., Forester, J., Hyvarinen, J., Richter, S., Chipman, T., Weise, M., Wix, J., 2013).
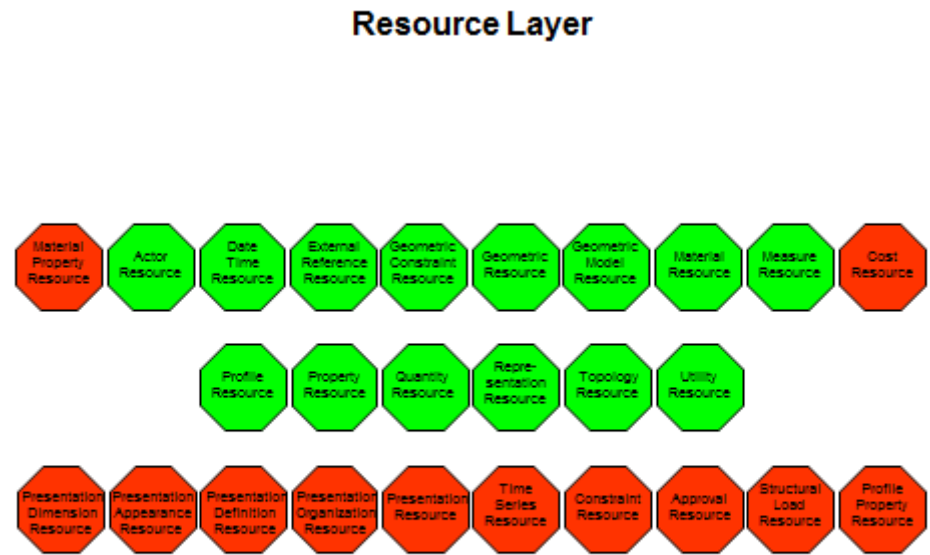
Figure 9, Industry Foundation Classes (IFC); Resource Layer

The resource layer (Figure 9) consists of twenty six separate elements including the following: Material Property Resource; Actor Resource; Measure Resource; Cost Resource; Date and Time Resource; External Reference Resource; Geometric Constraint Resource; Geometric Resource; Geometric Model Resource; Material Resource; Profile

Resource; Property Resource; Quantity Resource; Representation Resource; Topology

Resource; Utility Resource; Presentation Definition Resource; Presentation Organization

Resource; Presentation Resource; Time Series Resource; Constraint Resource; Approval

Resource; Presentation Dimension Resource; Presentation Appearance Resource;

Structural Load Resource; and Profile Property Resource. The resource layer is the

lowest ranking layer and includes all individual schemas that contain resource

definitions; the definitions do not include a globally unique identifier and are not to be

used independently of a definition declared at a higher layer (Liebich, T., Adachi, Y.,

Forester, J., Hyvarinen, J., Richter, S., Chipman, T., Weise, M., Wix, J., 2013).
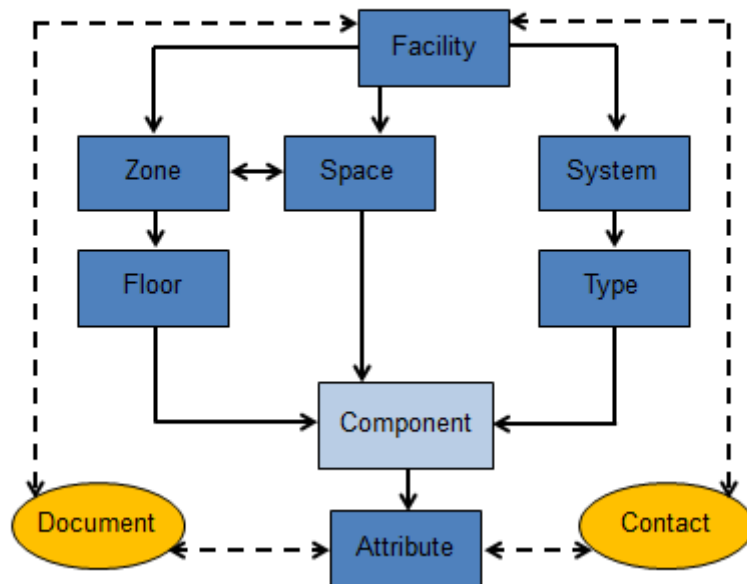
Figure 10, Construction Operations Building Information Exchange (COBie)

The origin of Construction Operations Building Information Exchange (COBie) is tied to Bill East of the United States Army Corps of Engineers in 2007. The COBie process follows the design and construction process of a given project. As the design process progresses, information related to those early stages of a project are conveyed through graphical and written means; plans and specifications. Designers often begin this process by developing designated spaces or groups of spaces that support the activities of the end design. The hierarchy of COBie follows this same process. As depicted in Figure 10, the facility is segregated into zone, space and system. These categories are further segregated by floor and type that support the facility components. These components are directly linked to the attributes of the facility which is the main function or purpose of the facility. This information process continues accounting of every piece of information for the project in this categorized manner (design through construction completion). Post the delivery of the facility asset, a compiled, segregated information file is transmitted to the owner \ operations team to load into their respective Computer Maintenance Management System (CMMS) for the use and application of the comprehensive formatted information file (East, B., & Carrasquillo-Mangual, M., 2012).

Case Studies

In most BIM FM integration efforts, there appears to be a common theme echoing that the approach to achieving better than average results is not standard. Six examples of previously conducted case studies were selected for review (see appendices A, B, C, D, E, and F) and with each case studied, procedures of technology,

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collaboration, guidelines and standards, and other varied aspects of the integration were analyzed. And at the end of each study a section labeled "lessons learned" reflected the findings and insights of each case. These case studies are used as a baseline to establish support linked to the use, or lack thereof, of Facility Manager Influenced Specifications. Each case study was independently evaluated and compiled in the text book; BIM for Facility Managers by Paul Teicholz (Teicholz, P. (Ed.)., 2013).

The first case study, Case Study 1: MathWorks, the leading developer for mathematical software company planned to add a new building on their corporate campus to accommodate their growing needs. For the construction of their new facility, they chose to use BIM as a key component in the selection process of awarding contracts and to place complete and accurate information in the hands of the owner prior to occupancy. MathWorks soon learned the complexity of the fragmented nature of BIM and its use, and hired a BIM consultant to assist with the coordination of the modeling for their project. This study concluded two main barriers for integrating BIM and FM. The first being the transition from traditional two-dimensional construction to three-dimensional, information enriched processes. The second barrier was the determination of data detail for the FM model. This second barrier derived a need to outline the steps or guidelines required to implement FM integration with BIM technology (Teicholz, P. (Ed.)., 2013; Bernardi, C., and Donahue, B., 2012; Butler, B., 2009; Khemlani, L., 2011).

The findings of this study support the baseline theory of applying the involvement of Facility Managers in the process of generating BIM Technical

Specifications. This case study makes no direct link to the application of involving the Facility Manager in the influencing process of the BIM Technical Specifications prior to, or post the study.

The second case study, Case Study 2: Texas A&M Health Science Center – A Case Study of BIM and COBie for Facility Management, focused on the implementation of Construction Operations Building Information Exchange (COBie) at one of their nine locations in Bryan, Texas. The intent of this study was to evaluate and validate the long-term predicted benefits and return on investment of the enriched facilities management data process. Broaddus & Associates, an Austin, Texas based consultant, coupled with key Texas A&M Health Science Center personnel and other BIM and FM experts oversaw the study. The collaboration of training was very active among the players and the use of multiple technologies was required for this case study. Ultimately, the team was able to integrate the COBie data to the facility management team's Computerized Maintenance Management System (CMMS), AiM, via EcoDomus. There were many lessons learned with this study, however, there were three aspects that appear to be most significant. The first outcome was that the BIM Program of Requirements (POR) was not itemized in such a manner that the COBie integration responsibilities for the work scopes could be tied to the contract. The second notable outcome was quality control related. There unauthorized changes being made to the record COBie data set and it became evident that one party, or "gatekeeper", needed to be responsible for the configuration management of the COBie data. The third outcome was that the

specifications (found in the BIM POR) for the FM data were essentially an as-built of the COBie data specification and format.

Much like that of Case Study 1, the findings of this study support the baseline theory of applying the involvement of Facility Managers in the process of generating BIM Technical Specifications. This case study makes an indirect link to the application of involving the Facility Manager in the influencing process of the BIM Technical Specifications prior to, or post the study with the use of the BIM POR. However, the outcomes stated in the lessons learned section of this study indicate an opportunity for improvement, which the study recognized prior to conclusion.

The third case study, Case Study 3: USC School of Cinematic Arts, was a six building complex, constructed in three phases, beginning in 2007 and continuing to the present. These three phases had different focused areas concerning BIM and FM; phase one focused on BIM in a construction centric manner, phase two focused on BIM in a design centric application, and phase three focused on BIM in a facilities management centric. This was an extensive study and as a result, the lessons learned section of the study was broken into key sectors categorized in the following: overall lessons learned, technology, technology users, information from models, and BIM FM processes. The most critical overall lesson learned from this study was the importance for facility managers to understand what they want to achieve, what resources are available, and what the vital functions are of the facility management team. This take-away is important because it reiterates the need for quality influence from the facility management team on the specifications that apply to BIM for FM. Lessons learned for

technology begin with the use of existing tools. Many existing tools are not utilized to capacity and careful examination should be considered when evaluating whether a new tool should be implemented. However, if a new tool is going to implemented, it is important not to reengineer the current facility management software or system that is in place. The final lesson for technology was that for a facility manager to keep pace with all of the licenses and software available for the many trades and practices for a complete BIM package is not feasible; hence, it is imperative to focus on the end user needs for the required BIM record models that support the facility management. Lessons learned from technology users are relatively brief, but impactful. Simply stated, FM teams must clearly define the requirements for BIM deliverables in order receive the information that they are seeking. This is the crux of the idea of an influenced specification by facilities managers, and this action takes place well before the design of a project. This allows the FM team continuous involvement in the design, construction, and operation of the project with limited interruption. Lessons learned about information from models are closely related to the lessons learned from the technology users. Determining what data should be in the model differs from the viewpoints of the designers, the constructors, and the facilities managers. Ultimately, these decisions are going to have a range of needs and will be tailored to the use of the building and the vision of the FM team. Finally, the lessons learned about BIM FM processes suggest that BIM FM is not an "out-of-the-box" plug and play solution. The BIM FM process is a dynamic ideology that requires champions, leaders, resources, adaptable tools and

people, buy-in, and influence from facilities managers of all rank (Teicholz, P. (Ed.)., 2013; ASHRAE., 2010; Standish., 1995; USC., 2012).

This case study was a prime example of taking steps toward an implementation that truly integrates BIM with FM, yet, there remains a plethora of challenges ahead. Similar to Case Studies 1 and 2, the findings of this study support the baseline theory of applying the involvement of Facility Managers in the process of generating and influencing BIM Technical Specifications. This case study makes a larger stride toward the application of involving the Facility Manager in the influencing process of the BIM Technical Specifications prior to, or post the study. This was most evident with the guidelines put forth by USC and the phased analysis pertaining to BIM in a design centric, BIM in a construction centric, and BIM in a facilities management centric. This study was most effective due to its vision of starting with the end in mind and its unwavering support.

The fourth case study, Case Study 4: Implementation of BIM and FM at Xavier University, was the largest and most costly expansion to the university to date. It consisted of four new campus buildings and accounted for a twenty five percent increase in the portfolio of usable and managed facility. For this endeavor, it was the first time that Xavier University was utilizing BIM. But, more noteworthy, the facility management department was not involved in the early stages of the project, which lead to costly expenditures associated with model revisions for the support of the FM integration. Similar to the other case studies analyzed, there were a variety of players involved in the study, as well as technology types used for the collaboration of the

undertaking. There were six key lessons learned from this case study that echo some of the lessons learned from other case studies. The first lesson learned was that all future contracts for general contractors, architects, and engineers will have specific BIM requirements. This lesson proved critical due to the volume of data generated by each player that, when compiled, contributed to extended schedules and cost overruns. Additionally, much of the data from different players was fragmented due to non-conforming BIM platforms. The second lesson learned was the need to track and properly identify university specified materials for the project using unique code identifiers. These identifiers were not distributed at the beginning of the project and created tremendous confusion and inaccurate data for the BIM models that were ultimately used for the FM system. Again, the result of this led to additional time and expense. The third lesson learned was realization that the FM team and staff should have been involved in the early stages of the project. The insight of the FM team would have provided items that were missing from the models, as well as items provided in the models that were not necessary. This lesson learned establishes a trend and common theme among case study outcomes. The fourth lesson learned was that all project team members should be required to utilize BIM tools and workflows. Ultimately, this is a training related issue and hinders project progress. Projects are a collaborative effort, which would imply that the sum of the parts of the project would equal its whole. Quite the opposite is debated, stemming from Aristotle's "the whole is greater than the sum of its parts". The debate continues; however, it is supported by the notion that it is the fact that a system contains within itself the possibility of becoming something different, of

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'adapting', of evolving, that makes the 'parts' less than the 'whole' (Allen, P. M., 1988).

This holds true for successful projects in that each contributor provides a portion of an

evolving whole. It is imperative that each player of the project team provide a usable

piece, hence, a project team player not using a BIM tool detracts from the overall goal of

using the BIM for FM. The fifth learned lesson was that detailed BIM data can assist the

FM team with strategic goals; a 100-year comprehensive facilities plan. Not only does

the BIM require detail, but it must also be accurate. At Xavier, this is an on-going

evolving effort. And finally, the sixth lesson learned for this case study was the use of

reverse phase scheduling and its value in expediting the schedule. Simply stated, this is a

schedule that works backwards from a constrained end date to all of those activities that

precede it. This process helps team players truly identify the impact of finishing their

portion on time. This case study was the first step for Xavier University to recognize the

potential and value of integrating BIM and FM data with benefits already surfacing

(Teicholz, P. (Ed.)., 2013; FM:Systems., 2012; Xavier University., 2011).

The key outcomes of this case study were iterated in the first, third, and fourth

lessons learned summaries. By acknowledging the need for a refined and specific set of

BIM requirements (first lesson learned); realizing the impact of FM team and staff in the

beginning of a project (third lesson learned); and implementing BIM savvy, or BIM

trained players to their project team (fourth lesson learned), Xavier now has the ability to

alter future outcomes associated with BIM and FM integration.

The fifth case study, Case Study 5: State of Wisconsin Bureau of Facilities

Management, Division of State Facilities, Department of Administration, was

implementing a BIM FM pilot program that began in 2011. This was a unique case study in that the State of Wisconsin had a clear mission and vision of BIM FM with a guideline and standard that supported that mission and vision, prior to the implementation of the pilot. These guidelines and standards were written to accommodate IFC compliance interoperability standards as well as open the use of open standards for interoperability. Detailed lists of those elements that should be modeled were also included in these guidelines and were specific to each discipline. Additionally, this study was conscious of the BIM handover process from construction to facility management and involved the FM team to clearly request the type of information desired within the BIM models. The mission of this case study was to advance the quality, timeliness, and cost effective aspect of facility information at the time of transition from construction completion to building operation using technology (BIM) for FM. The vision for BIM FM is simple; timely and accurate access to information. This case study consisted of two projects and the lessons learned were specific to each project. The analysis will review each project separately; Pilot Project 1, and Pilot Project 2. The lessons learned and challenges for Pilot Project 1 were centered on the impacts to designers, the impacts to facility management, and the impact to both designers and facility managers. The first lesson learned for designers was that the technology tool utilized, Revit, was perceived only as a graphic tool, and not as an information tool. The future goal is to change this view for the technology tool to be viewed and used as both a graphic and an information tool. The second lesson learned for designers was that as BIM for FM evolves, the role of the designer will also need to adapt. This will include

services of design; as well as, information management, and data entry services. And the final lesson learned for designers was that many designers are accustomed to designing in a 2-dimensional (2D) manner, which focuses on a point-to-point single plane element. A 3-dimensional (3D) design takes place in multi-plane setting and is a more challenging effort for designers, especially in the schematic design phase of a project. The first lesson learned for the facility management was the management of the volume of data that was available for use. This will most likely be resolved through training that will show technicians and managers how to efficiently discern information and rapidly determine its importance. The second lesson learned for facility management was the nomenclature associated with life cycle information as depicted from construction terms to facility management terms. This outcome further supports the philosophy of involving the FM team from the very beginning of a project. The final lesson learned for the facility management was the importance placed on the ability to test the vast amount of information on a separate site of the chosen FM software of a given team. This allows for experimentation of the data without interrupting or "crashing" the main FM software, or system. There were several lessons learned concerning the impact to both the designer and the facility management team, and the following focuses on two key aspects. The first key lesson learned for designers and facility management was that the needs of the two players differ greatly and the recognition of that early in the project effort is critical to its success. The players need to be understanding of the desired outcomes of each other's requirements and goals. The second key lesson learned for designers and facility management was that overall data population standards and equipment\software of the

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varied players is critical to the efficiency and the desired outcomes of the BIM for FM integration. In summary, Pilot Project 1 and the use of BIM for the integration of BIM for FM was a success. The outcomes and the lessons learned will be great tools for future studies. The lessons learned and challenges for Pilot Project 2 were focused on the construction process and the data source of the BIM FM handover from the completion of construction to facility management. The outcomes for this case study were categorized in three areas of concentration; the FM lessons learned, the construction-focused lessons learned, and the overall project lessons learned. The first FM lesson learned was qualifying and filtering the data received from the construction BIM models. This process is similar in nature to when the constructor receives the design BIM models and determines what is relevant and usable for that given application. This step cannot successfully occur unless the FM team has determined the data needed that is pertinent to the life cycle operations of the project. The next FM lesson learned was that unless data providers (subcontractors and general contractors) are contractually bound to provide the required FM data desired, then the data was not generally provided. The importance of specifying the correct data desired along with its format is paramount to the anticipated success to the life cycle FM operation. This issue has been a common theme among the multiple case studies analyzed. The final FM lesson learned was closely related to the previous lesson learned, but addresses the contractual obligations concerning relationships and levels of modeled details between the construction team and the FM team. The construction-focused lessons learned had two key elements. The first learned lesson was conveyance challenge for current as-built conditions in the BIM

model in real time. The ability to accomplish this offers better, more accurate communication with reduced response time for Requests for Information (RFI's). This real time problem solver increases efficiencies in the field. Additionally, written and verbal explanations of these changes in the model sought the opportunity to provide team members a clearer understanding of the real time changes to the as-built BIM model. The second learned lesson for the construction-focused outcome was closely related to the first with the implementation of two effective strategies to support real time coordination. The use of GoToMeeting to assist with the resolution of RFI's and the Newforma File Transfer Protocol (FTP) site to allow automated exchange between the BIM model of the designer and the BIM model of the constructor proved moderately successful. The latter experienced added confusion when a portion of the design update was incomplete. Again, additional written and verbal communication appeared to be a potential solution to improve the process. The overall project lessons learned for this case study included the use of well-defined and clearly written requirements associated with software type usage and project deliverables among the disciplines and teams. This application holds true for both software type and project deliverables of 2D and 3D applications. There were a number of findings that were of parallel nature among the two case studies, Pilot Project1 and Pilot Project 2; however, the most prominent finding was the importance to clearly and concisely define the quality and the level of detail for the populated BIM model used for the FM operation. This heightens the awareness of the impact of BIM guidelines and standards that are intentionally influenced by the FM team. These studies in conjunction with other works are contributing to the

establishment of a foundation dedicated to moving the industry forward with the implementation of the BIM FM vision (Teicholz, P. (Ed.)., 2013; Beck, K., 2011a; Beck, K., 2011b; Division of State Facilities., 2011; Napier, B., 2008; Napier, B., 2009).

The implementation of an influenced guideline and standard (specifications) by the FM team was the strongest outcome of these two independent studies. Although they were comprised of different team members, disciplines, and administrators; the consensus of a strongly influenced guideline and standard was consistent. These arguments support better training, better communication, more accurate models, and FM influenced guidelines and standards as key factors towards successfully implementing BIM and FM.

The sixth, and final case study, Case Study 6: University of Chicago Administration Building, was focused on the information handover between construction and facility management. This case study addressed three primary challenges including; the determination concerning what level of information detail should be collected in order to support the facility management processes, the understanding of 3D BIM use for FM and the software choice for that platform, and the alignment and leverage of the varying skill sets possessed by different team members concerning valuable and useable deliverables for the FM process. This case study was unique in that no specific requirements for BIM FM were established from the start of the project. Additionally, the contract structure, a construction management at risk (CM@R) contract, with the construction manager did not require the use of BIM, or the turnover of the BIM information to the FM team upon completion of the project. The University of Chicago

felt that these requirements were not necessary based on the small nature of the

renovation project. This was the first project for the University of Chicago to utilize BIM

for a small renovation project. The key to this case study was the small project size

allowed for easier modifications to the BIM data and the communication among a

smaller team proved positive. Also, the contract type allowed for more vertical and

lateral movement of the construction manager and the design team. Even though BIM

was not required for this project, both the design team and the construction manager

were dedicated and committed to using BIM for the project. Another unique feature of

this case study was the subcontractor prequalification requirement by the construction

manager. That prequalification process included the subcontractors to demonstrate a

basic BIM skill set; and for those subcontractors with limited BIM skills, the

construction manager offered training to assist with the BIM usage for the project. The

outcomes for this project hinged on the committed use of BIM by the designer and the

construction manager. The lessons learned for this case study were centered on people,

process, and technology (software). There were a number of challenges and lessons

obtained within these aforementioned categories. The most basic lesson learned

concerning people was the contingent success as related to the effort put forth by the

leaders of each respective department involved with the project. Just like a large project,

small projects require (in no specific order) the collaboration of planning, design,

construction, operations, inventory, procurement, maintenance management, contracts,

information systems, and coordination at all levels. Every person should be considered a

stakeholder and their promotion of collaboration from each leader was vital to the

success of this project. These champions proved pivotal and much of this success was

due to the small nature of the project. Concerning process lessons learned, it was

concluded (similar to other case studies previously analyzed) that a designated BIM FM

gatekeeper proved most beneficial to the synergy of data collection and integration into

the FM operation system. Additionally, the ability of the FM executive to properly

communicate the needs of the FM team to the BIM model providers continues to remain

a priority. Because there are so many technology (software) options, the key lesson

learned for this topic was not focused on which technology to use, but rather how that

technology was used. This case study found that how the information was stored, where

the information was stored, and who had rights to access that information and data was

the importance of the database management within any BIM FM strategy (Teicholz, P.

(Ed.)., 2013; American Institute of Architects., 2008; Black, B., Wilson, P., Lobello, A.,

and Stapleton, A., 2011).

This case study has been the initial ground work for future studies at the

University of Chicago. There are currently two studies that are already being pursued

based on the findings of this initial case study. In summary, there were four key lessons

learned for this case study. The first was the opportunities created by the use of small

projects for the analysis to advance the use of BIM and its contents for the transition

from completed construction to the operations of facilities management. This finding

sets the stage for other entities with small projects that are interested in BIM FM

implementation. The second lesson learned was the use of laser scanning for the creation

of accurate as-built drawings for the project. This technique was a tremendous time

saver and proved quite accurate for the as-built models. The third lesson learned for this case study was the need to clearly define the data desired that impact FM decisions. Data driven FM decision making has very little historical data / findings. Therefore, much of the analysis related to data driven FM decisions is unknown. Because of this, future case studies potentially need to focus on this topic for better understanding and more efficient use of the data driven FM decision process. And the final lesson learned from this case study was the education / training of BIM for construction and FM members. Success levels, for implementing BIM for FM, rely on the knowledge base of its members concerning BIM. This final lesson learned has been seen in the outcomes of other case studies analyzed and appears to be a common area of focus. This case study used COBie as its guideline standard and found that regardless of the use of BIM, the developed transitional tool from completed construction to facilities management reported true signs of value to the University of Chicago FM team.

The six case studies previously analyzed were pivotal in the generation of the conceptual model and the formed hypotheses for this study. The conceptual model and hypotheses are discussed and illustrated in Chapter III.

Communication and Implementation

For centuries, communication has been the keystone of successful and unsuccessful outcomes of nearly every societal endeavor. Accurate communication is often taken for granted and is only a topic of concern when it fails. The existence, or absence, of content from the transmitter via the channel to the receiver is the result of

implementation; hence, the channel, or carrier, is associated with one, and only one,

content (Al-Fedaghi, S., 2012). This concept is further supported by the following:

Obviously, Shannon's theory requires that the transmitter and receiver both be

capable of handling the message. In describing the components in the communication

process, the ability of the transmitter and receiver to operate effectively together (i.e. for

the transmitter to successfully read a primary message and transmit a corresponding

signal and for the receiver to successfully receive that signal and construct a message

closely corresponding to that handled by the transmitter) fundamentally depends upon

the transmitter and receiver having identical copies of the code (Blackburn, P.L., 2007).
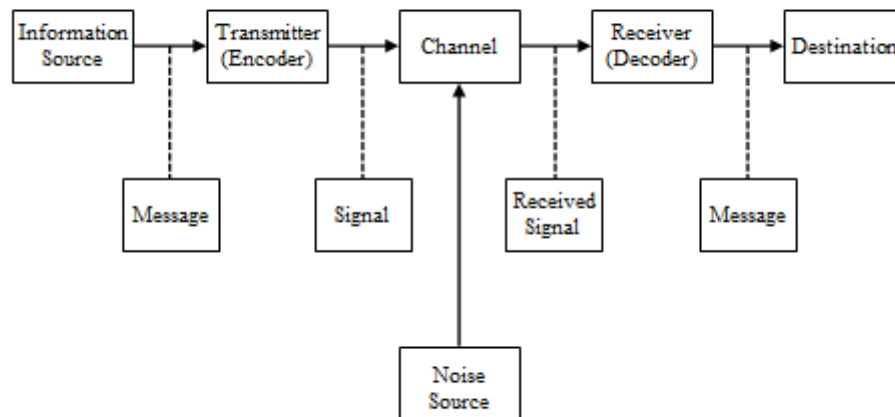
Figure 11 (Shannon, C.E. and W Weaver, 1949), Shannon-Weaver Communication
Model

This communication model is the basis for BIM standards associated with interoperability of shared data. Interoperability is a highly debated topic with many opinions and means of attempting to eliminate the communication breakdown so commonly experienced. The BIM Technical Specifications section of this literature review exposed the primary industry accepted guidelines. These guidelines have been functioning and evolving for decades, yet there remain issues associated with clear and accurate lines of communication. The Shannon-Weaver Communication Model shown in Figure 11 illustrates the most basic of transmission and receiver communication descriptions and are the most commonly used at the technology level. Communication falters as a result of assumption, interpretation, and miscues associated with transmissions and receivers. And the anecdote for communication breakdown is a call for increased structure to diminish the variables contributing to the possible breakdown. The more structured and explicitly designed communication forms or systems reduce ambiguity, enhance clarity, and transmit \ receive unequivocal signals for unique and individual communication requirements (Dayton, E., & Henriksen, K., 2007). This gyration is continuous for any system, which explains why communication and its failure is forever a topic of concern.

When examining the implementation of technologies in virtually every industry, the success rates are historically low. There are a number of contributing factors including champions, user training and education, performance expectations, and dedicated resources that impact the success, or failure, of an implementation plan (Somers, T. M., & Nelson, K., 2001). The dedicated resources often times proves critical

for an organization if it fails to commit the required human, financial, or other crucial resources required to support the effort of the implementation (Grover, V., Jeong, S.R., Kettinger, W.J., and Teng, J.T., 1995).

Strategic Planning and Implementation

1	Assessment
2	Develop Alternatives
3	Evaluate Alternatives
4	Alternative Decision
5	Plan for Implementation
6	Implementation
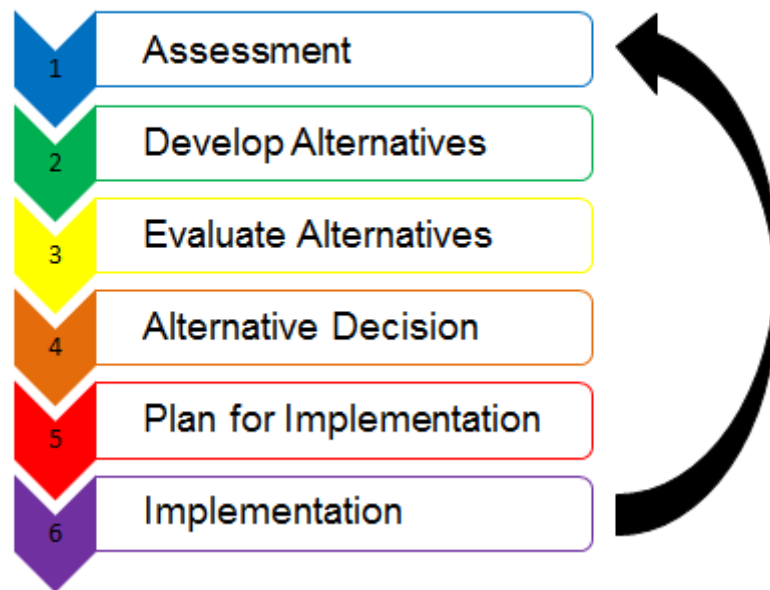
Figure 12 (Smith, James C., 2012), Strategic Planning and Implementation Model

As seen in Figure 12, this strategic planning and implementation cycle illustrates a six step process. The process repeats itself following the last implementation step in an effort to continually improve the process until a level of improved saturation is achieved. Historically, organizations report tremendous success with steps one through five and typically record approximately an 80% failure rate associated with step six.

This implementation model is a typical path for many organizations implementing a plan, strategy, technology, culture, or other instrument. Jack Welch, former CEO of General Electric from 1981 to 2001, asserted that any idea, however worthwhile, not implemented has no value; a million dollar idea multiplied by 0 percent implementation has zero value (Stevens, M., 2012).

<div align="center">**Adoption**</div>

Through literature, it is clear to analyze the adoption of an innovation and its predictability. There are a multitude of determinates responsible for the adoption of a given innovation. However, it is the benefits and the costs of adoption that ultimately prevail as the obvious determinates of new technology adoption (Hall, B. H., & Khan, B., 2003). If we examine the relative recent events of transition from hand drawn documents to Computer Aided Design documents, we can see the migration of industry players eventually embrace the technology. The replacement of hand drawing to CAD took nearly twelve (12) years, while current trends are indicating an adoption time for BIM of almost half that of CAD (Era-Users, 2009). The illustration depicting the adoption of CAD is shown in Figure 13.

The rate at which innovation \ technology is adopted is contingent upon the attributes of persuasion; these variables include relative advantage, compatibility, complexity, trialability, and observability (Rogers, E.M., 2010). BIM is being adopted at a much faster rate than its predecessor, CAD. The diagram shown in Figure 1 indicates a much shorter interval of adoption with BIM than CAD. Of the five aforementioned

attributes of persuasion, the two most likely responsible for this reduced adoption time

frame is compatibility and complexity. The compatibility component for BIM adoption

is related to its longevity and ties to CAD. Although there remains a number of

interoperability issues associated with BIM, the basis of a three-dimensional modeling

system has been a natural transition from CAD. Hence, the compatibility of this

technology has been successful from an attribute of persuasion perspective. The

complexity piece of this puzzle has diminished in recent years for BIM. Consumer

familiarity, coupled with ongoing updates of user-friendlier software, continue to erode

the complexity issues linked to the adoption of an arguably difficult technology.

BIM Era-Users

Most technological changes (telephone, railroads, airplanes, computers) take multiple generations from introduction to acceptance. CAD took 12 years to replace hand drawing, BIM will less than half that time.

BIM Products: Revit, ArchiCAD, Digital project (Catia), Bentley, VectorWorks, Tekla

CAD versus BIM adoption chart. BIM has been adopted twice as quickly as CAD. *Dennis Neeley, AIA*

Figure 13 (Era-Users, 2009), CAD versus BIM Adoption Chart

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Currently, designers and contractors have been aggressive in their efforts to adopt the emerging technology of BIM, while FM and FM operators have been extremely reluctant in embracing the use of BIM shown in Figure 2. What is surprising about the percentages of adoption (designers near 70% and constructors at 74%) is the overall usage of BIM in such a short interval. The percentage of companies using BIM is now 71%, which is a jump when comparing previous statistics; 17% in 2007 and 49% in 2009 (BLOG J., 2013).
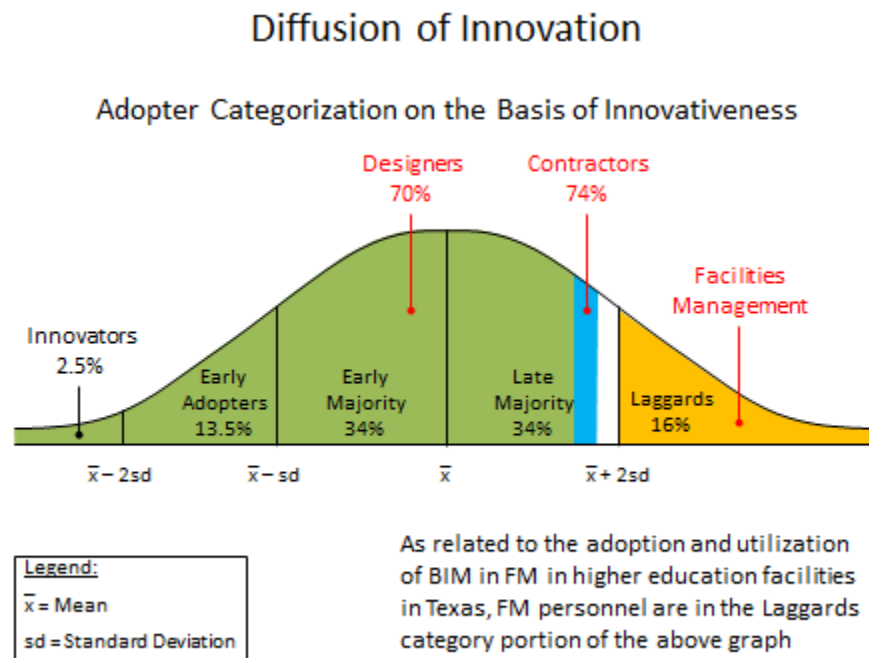
Figure 14 (Rogers, E.M., 2010; BLOG J., 2013), Adopter Categorization Curve

This rapid adoption of BIM creates, both, roadblocks and opportunity. Like many other adoptions of technological innovation, BIM is highly sought after, due to its

tremendous potential. Users and implementers are discovering the problems associated with BIM, such as interoperability and model compliance issues. There are a number of modeling standards that are applicable to the consistency and compatibility of any given model. The Industry Foundation Classes (IFC), the National Building Information Modeling Standard (NBIMS), and Construction Operations Building Information Exchange (COBie) are the most recognized standards associated with BIM currently (Motamedi, A., & Hammad, A., 2009).

So, with the current trends among designers and contractors, it appears that the adoption of BIM would be a clear and logical decision for all involved in the built environment. Yet, few FM operators are utilizing the technology that industry leaders argue is the path of the future. Because BIM has been present in the designing and building phase for such a long time (nearly a decade, identified as BIM, and over two decades as identified as a 3-D tool), it is possible that the diffusion system has experienced a "bottle-neck" in its adoption among FM owners and operators (Eastman, C., Teicholz, P., Sacks, R., & Liston, K., 2008). To further expand on this notion, consider the two types of diffusion directly connected to the adoption of a technology; Centralized and Decentralized Diffusion Systems (Figures 4 and 5). Centralized Diffusion Systems are linear in nature and tend to be more directional, while its counterpart, Decentralized Diffusion Systems, follow an integrated \ convergence mode of communication. Also, note the presence of the Change Agent displayed in the Centralized Diffusion System and the direct impact on the Opinion Leaders. This element is missing in the Decentralized Diffusion System, but does not hinder the

effectiveness of the system. Additionally, it is possible to combine the two systems to create a hybrid that might require elements of both systems for a particular situation or need.
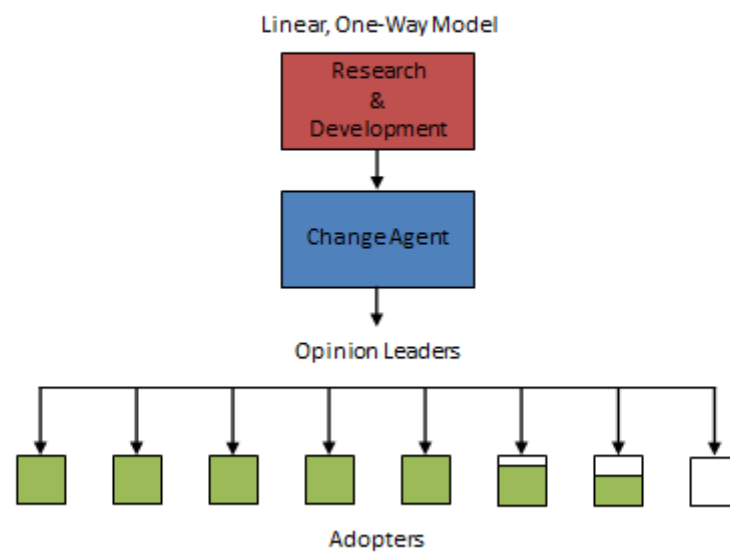
Figure 15 (Rogers, E.M., 2010), Centralized Diffusion Model

It is important to recognize that decentralized diffusion is not geared, historically, for diffusing innovations involving high levels of technical expertise among the potential adopters (Rogers, E.M., 2010). Therefore, the diffusion of implementing BIM for FM will most likely utilize the Centralized Diffusion System. In many instances, the designers and the contractors will be playing the role of the Change Agent in this model. The research and development for BIM is highly evolved, however, continuous and on-

going; hence, the Change Agent must remain diligent in continuing education while steady in influencing the Opinion Leaders. This diffusion system is sensible and fits the mold for adopters of BIM.

Decentralized Diffusion System
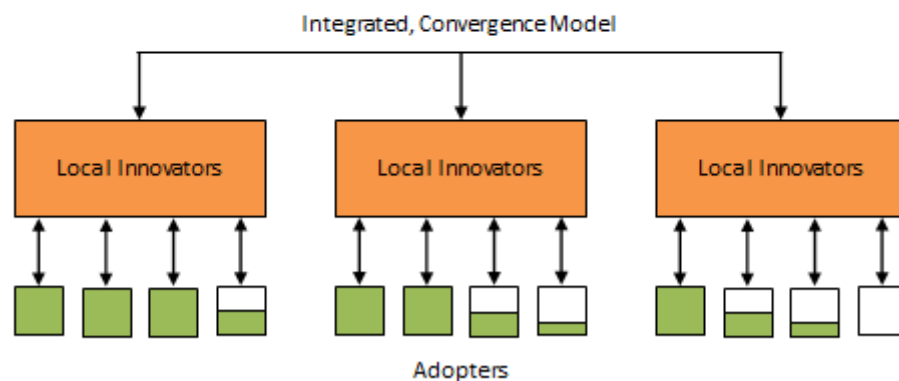
Figure 16 (Rogers, E.M., 2010), Decentralized Diffusion Model

Technology adoption is difficult and the time frames are typically long. It has been documented that BIM and its players (designers and contractors) in the built environment have made tremendous strides in embracing the technology. The inquiry surrounding the question of why FM owners and operators are slow to adopt is lingering.

Facilities Management Owners and Operators have not adopted BIM into the FM process because the following: specifications are not written into working models that support the adoption of BIM into working and usable building information models; the

FM operators are not functionally trained for the use of BIM; and the models being produced for the management of the facility are not a high quality BIM model, as a result of a misguided specification.

Therefore, the adoption of BIM for FM owners and operators will not gain traction until the owners and operators are fully engaged in the writing of the specifications of the built environment, training of BIM for FM personnel, and the level of BIM models improve.

As mentioned earlier in this review, there are many determining factors that contribute to this outcome. Technology adoption and the diffusion of new technology is a slow process by nature. Typically, it is not a matter of whether a technology will be adopted, but rather at what rate will it occur. And the speed of that adoption can be impacted by the ongoing improvements of both old and new technologies alike; hence, the need to develop and enhance complementary skills and capital goods for systemic technologies remains key to the success of a more rapid adoption process (Hall, B. H., & Khan, B., 2003).

Summary of Literature

The literature review accomplishes several important objectives for the basis of research. Primarily, it generates the context of the study by clearly demarcating what is included and what is not included in the scope of the investigation while justifying those decisions associated with the study (Boote, D. N., & Beile, P., 2005). Not only does it report the claims of existing literature, it also discriminates the methods used to allow for

judgment of the literature and whether or not its claims are warranted (Boote, D. N., &

Beile, P., 2005). The literature review acts as a benchmark and embodies the "state of

the field" that allows the researcher to establish a baseline (Webster, J., & Watson, R. T.,

2002).

     The literature review for this study focused on the current trends and practices

associated with Building Information Modeling (BIM), Facilities Management (FM),

and BIM Technical Specifications. In support of Building Information Modeling (BIM),

Facilities Management (FM), and BIM Technical Specifications; there were multiple

topic applied cases studies reviewed with outcomes pertinent to the specifics of this

study. Additional reviews examined communication, implementation, and adoption

processes that outlined current practices that directly impact the investigation of the

study.

CHAPTER III

CONCEPTUAL MODEL AND HYPOTHESES

The primary focus of this study is to determine the relationship between a perceived BIM trained FM operator, a perceived influenced BIM technical specification, a perceived quality BIM, and a perceived increased use of BIM for facilities management. The impact of a perceived BIM trained FM operator, a perceived influenced BIM technical specification, and a perceived quality BIM make up the variables that will be tested to ascertain each of the respective influences on the perceived increased use of BIM for facilities management. The inferential statistical testing methods for this examination will include an Analysis of Variance (ANOVA) and an Ordinary Least Square Regression. The conceptual model and the formed hypotheses are derivatives of the Fault Tree Analysis and are sanctioned by the literature review that supports the relationship between the increased use of BIM for FM in higher education institutions and the BIM trained facility managers influencing BIM technical specifications that generate a higher quality BIM model.

Theoretical Framework of the Study

Fault Tree Analysis (FTA) is a tool originally developed by H.A. Watson in 1962 at Bell Laboratories under a US Air Force Ballistics Division Systems Division contract (Ramamoorthy, C. V., Ho, G. S., & Han, Y. W., 1977). It is a top down, deductive failure analysis in which an undesired state of a system is analyzed using Boolean Logic

to combine a series of lower level events. The fundamental concept of Fault Tree

Analysis is the translation of the failure behavior of a physical system into a visual

diagram and logic model. The diagram segment provides a visual model that very easily

portrays system relationships and root cause fault paths. The logic segment of the model

provides a mechanism for qualitative and quantitative evaluation (Ericson, C. A. II,

1999). A generic Fault Tree Analysis template is illustrated in Figure 17.
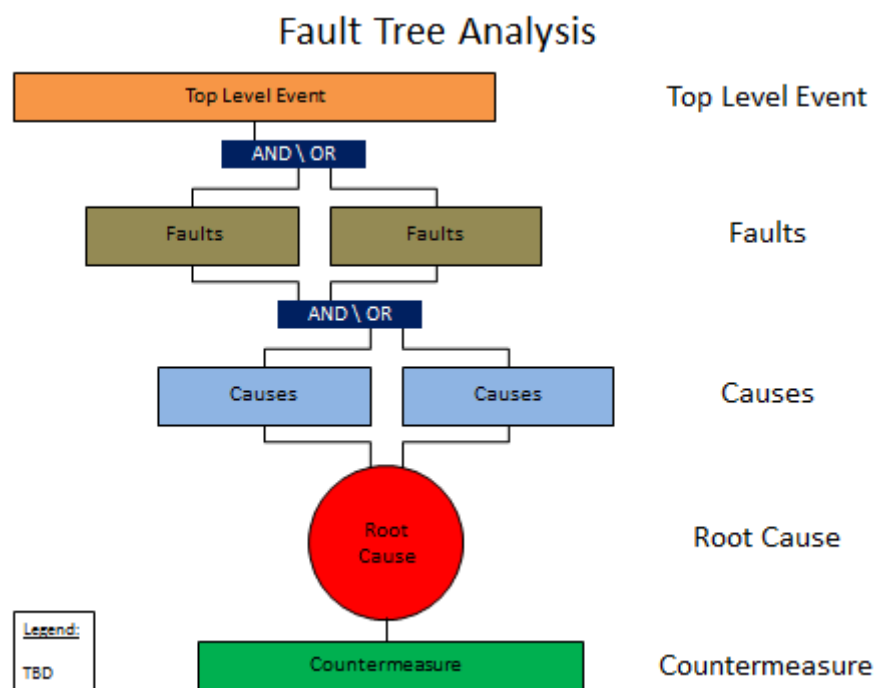
Figure 17, Fault Tree Analysis Template

The Fault Tree Analysis consists of five hierarchical categories that are

illustrated in top-down order; the top level event, identifiable faults, causes, the root of

those causes, and a countermeasure.

Fault Tree Analysis – Sample Problem

Technician Cannot Locate Pump Valve	Top Level Event
AND \ OR	
Does Not Know How to Use BIM / Not In BIM	Faults
AND \ OR	
Technician Has No BIM Training / BIM Provider Did Not Know To Put In Model	Causes
To Be Determined	Root Cause
To Be Determined	Countermeasure

Legend:

BIM
Building
Information
Modeling

FM
Facilities
Management
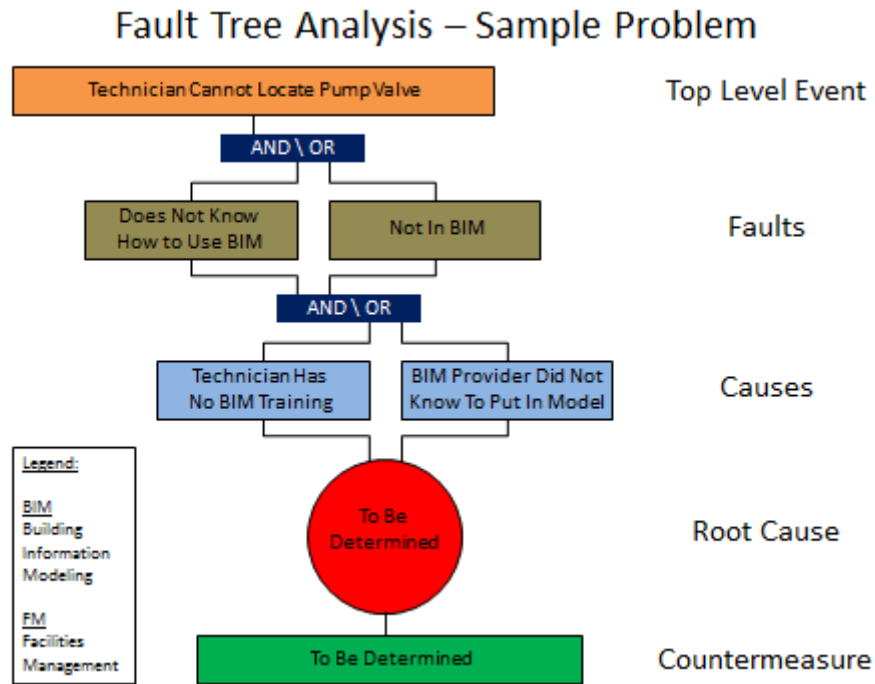
Figure 18, Fault Tree Analysis Sample Problem

A Fault Tree Analysis sample problem for an FM operator is staged in Figure 18. There are optional paths that can be deduced with different outcomes for each path. The top level event represents a common problem for a facilities manager of not being able to locate a specific item in need of managing. There are two faults associated with the top level event. The first fault is a training related item inferring that the FM operator cannot locate the item based on the inability to use a building information modeling tool (first cause). The second fault infers that the item being sought is not in the building information model at all, indicating that the model is not of high quality (second cause). Three scenarios have been created, based on this sample problem (Figure 18), that illustrates gaps identified in the literature review.

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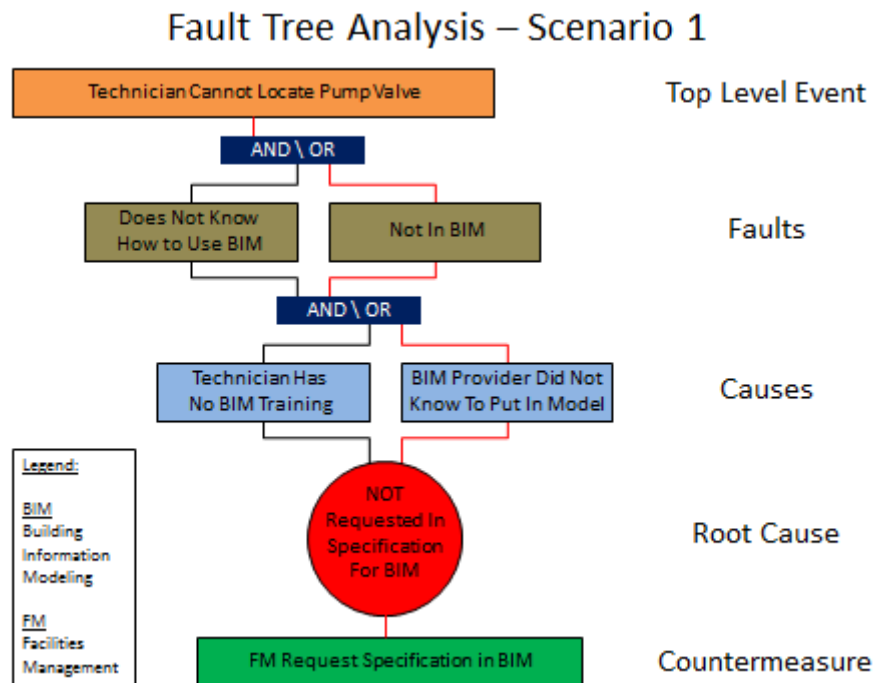
Figure 19, Fault Tree Analysis Sample Problem; Scenario 1

The first scenario (Figure 19, Scenario 1) indicates that the FM operator cannot find the item identified in the top level event as a result of it not being in the building information model. The cause is identified as the BIM provider not knowing to place the item in the BIM model. The derived root cause deduces that this occurred because the item was not requested to be placed in the BIM model specification. The countermeasure for this scenario is for the FM operator to request in the BIM specification for the item in the top level event to be placed in the BIM model. This example supports an Influenced BIM Technical Specification and a Quality BIM.
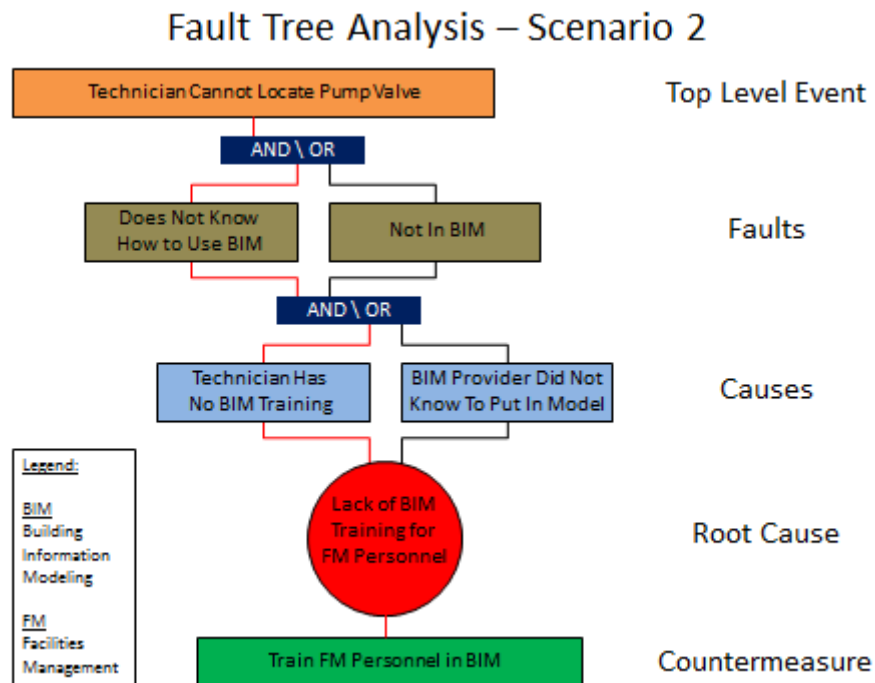
Figure 20, Fault Tree Analysis Sample Problem; Scenario 2

The second scenario (Figure 20, Scenario 2) indicates that the FM operator cannot find the item identified in the top level event as a result of the FM operator not knowing how to use building information modeling tools or software. The cause is identified as the FM operator having no BIM training. The derived root cause deduces that this occurred because there has been a lack of BIM training for the FM personnel. The countermeasure for this scenario is to train FM personnel in BIM \ BIM tools. This example supports BIM Trained FM personnel.
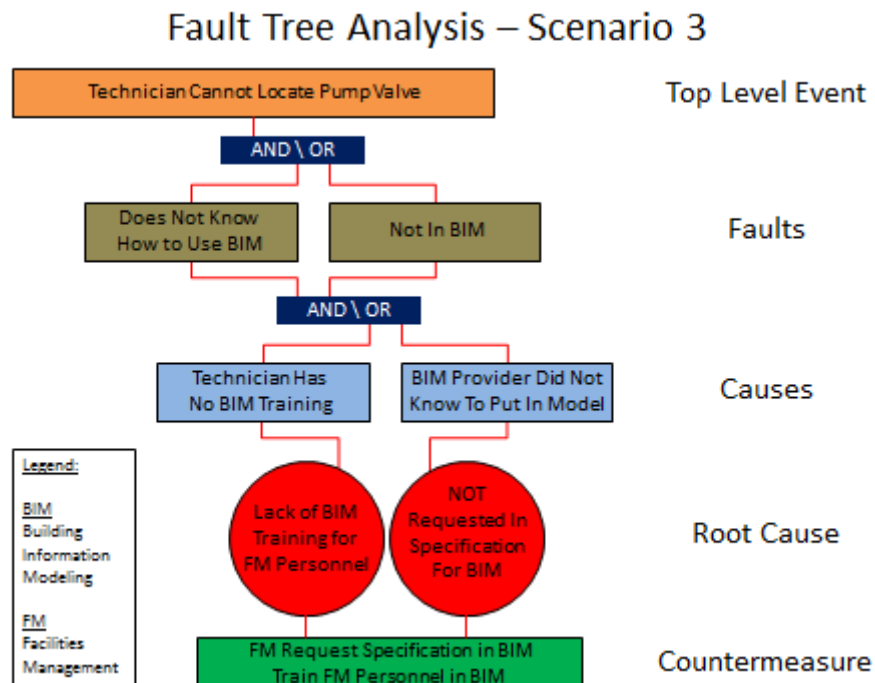
Figure 21, Fault Tree Analysis Sample Problem; Scenario 3

The third scenario (Figure 21, Scenario 3) indicates that the FM operator cannot find the item identified in the top level event as a result of it not being in the building information model and the FM operator not knowing how to use building information modeling tools or software. The cause is identified as the BIM provider not knowing to place the item in the BIM model and the FM operator having no BIM training. The derived root cause deduces that this occurred because the item was not requested to be placed in the BIM model specification and there has been a lack of BIM training for the FM personnel. The countermeasure for this scenario is for the FM operator to request in the BIM specification for the item in the top level event to be placed in the BIM model

and to train FM personnel in BIM \ BIM tools. This example supports an Influenced

BIM Technical Specification, a Quality BIM, and BIM Trained FM personnel.

Conceptual Model

The conceptual model (Figure 22) is derived from the aforementioned Fault Tree

Analysis. This model explains the contingency of each orbiting factor and its required

contribution to the purpose of the study to increase the use of BIM in FM. The

conceptual model is also supported and is directly linked to the line of survey

questioning and the interview processes.
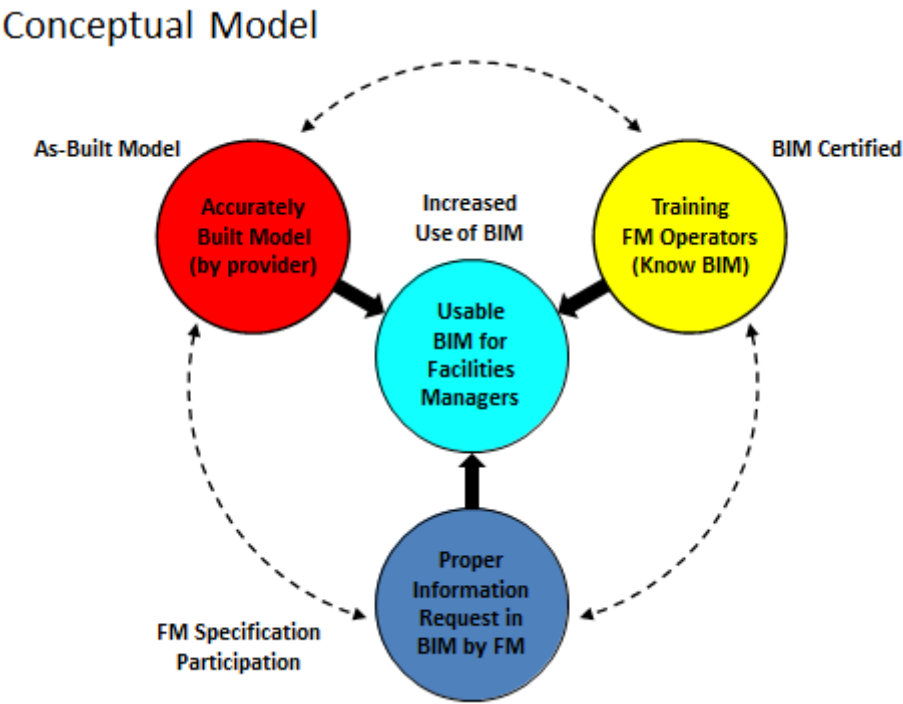
Figure 22, Conceptual Model

As the literature review indicated, there is a consensus surrounding the current status associated with the three independent variables; a BIM Trained FM operator, an Influenced BIM Specification by facilities managers, and a Quality BIM Model. The dependent variable is the increased use of Building Information Modeling (BIM) for Facilities Management (FM).

Hypotheses

There are multiple hypotheses associated with this study. The conceptual model, derived by the Fault Tree Analysis, is supported by these hypotheses. The development of a research hypothesis was created to examine the relationship between the increased use of a usable building information model for facilities managers and the external impacts of facility manger training, influenced specifications, and accurately built models.

The developed primary null hypothesis and the primary hypothesis, respectively, are the following:

H_0

If a Trained FM, an Influenced Specification, and a Quality BIM are not implemented; then a Usable BIM for FM will not increase the use of BIM in FM.

H₁

If a Trained FM, an Influenced Specification, and a Quality BIM are

implemented; then a Usable BIM for FM will increase the use of BIM in FM.

The study investigated three subsequent phases in an effort to establish a

relationship between the perceived usage of BIM in FM and the increased use of a

usable building information model for facilities managers and the external impacts of

facility manger training, influenced specifications, and accurately built models. These

three subsequent phases were also analyzed for their perceived implementation and

included the following subset of research hypotheses:

H₂

If the appropriate BIM training occurs for Facilities Managers \ FM Technicians;

then the Facilities Managers \ FM Technicians will have a better knowledge base for

operating a building information model.

H₃

If the proper Facilities Management information is implemented into the

specifications for the BIM model; then the Facilities Manager \ FM Technician will have

a more Quality BIM model from which to operate.

H₄

If the FM influenced specification for the BIM model is enforced to the creator of the model; then a higher quality BIM model exists for the Facilities Manager \ FM Technician in which to utilize for facilities management.

The focus of the study via the aforementioned hypotheses was to establish a relationship between the independent variable and the dependent variable; independent variable, a usable building information model for facilities managers, and the dependent variable, the external impacts of facility manger training, influenced specifications, and accurately built models. The basis to develop the hypotheses was derived from the conceptual model, which in turn, was spawned from the theoretical framework of the fault tree analysis. The conceptual model and the theoretical framework of the study are supported by components of the literature review.

CHAPTER IV

METHODOLOGY AND PROCEDURE

The research methodology encompasses those elements directly impacting the course of this study. The integration of qualitative and quantitative data for this study, by definition, categorizes the process as a mixed-method analysis. The reasoning behind this selected mixed-method analysis within a single study is conducted for the purpose of gaining a better understanding of the research problem (Teddlie & Tashakkori, 2003; Creswell, 2005).

Research Design and Assumptions

This study was comprised of a two phased process with the organization adhering to mixed-method explanatory design. In cases of human behavioral studies, mixed-method designs with both qualitative and quantitative elements often provide a more complete picture of a particular phenomenon than either approach could provide alone (Leedy, P. D., Ormrod, J., 2009). Qualitative and quantitative methods, utilized in combination, complement each other and allow for a more rigorous analysis, preying on the advantages of the strengths of each method (Greene, Caracelli, & Graham, 1989; Miles & Huberman, 1994; Greene & Caracelli, 1997; Tashakkori & Teddlie, 1998).

This study consists of three independent variables and one dependent variable as related to the investigation of the study. The three independent variables are represented by the following: a BIM Trained FM operator, an Influenced BIM Specification by

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facilities managers, and a Quality BIM Model. The dependent variable is the increased use of Building Information Modeling (BIM) for Facilities Management (FM), which is affected by the independent variables.

The study was conducted in two phases, Phase I and Phase II, and the tests of the hypotheses for the study was based on the methodologies of both qualitative and quantitative analysis. The analysis included in Phase I contained a thorough literature review of the specified dependent variables those topics directly impacting the dependent variables, including communication, implementation, and adoption processes. Also included in Phase I was a review of six selected cases studies with similar parameters of this research; a study of perceived building information modeling usage and the utilization of building information modeling technical specifications for facilities management at higher educational institutions in Texas. The analysis for Phase I was conducted with the use of descriptive and the Analysis of Variance (ANOVA) methods. Phase II consisted of a distributed survey among competent participants directly involved in the facilities management. Phase II was conducted with the use of descriptive analysis and the statistical analysis of Ordinal Least Squares for Multiple Regression methods.

The qualitative methodology utilized in Phase I analyzed six case studies and investigated the relationship that each case study contained pertaining to the application of a BIM Trained FM operator, an Influenced BIM Specification by facilities managers, and a Quality BIM Model. It was not the focus of every case study to emphasize the use of all three components; however, each of the case studies did contain an element of

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each of the three components. Each of the case studies indicated the varied outcomes and the impact of how Building Information Modeling (BIM) was being exercised with Facilities Management at each of the respective institutions. It is typical practice for case studies to utilize a variety of evidence from different sources such as documents, artifacts, interviews, and observations that go beyond the range of evidence sources available in historical study; hence, case study research methodology is useful when posing a 'why' or 'how' inquiry (Rowley, J., 2002).

A quantitative methodology approach was utilized in Phase II of the study. This was portion of the study was distributed to competent Facilities Management participants through the use of an online survey instrument. The survey instrument was segregated into four sectors; demographics, technology usage, learning styles, and implementation. This tool was geared to identify specific measures, as related to the dependent variables, and investigate the impact on the independent variable; an increased use in BIM for FM.

The assumptions applicable for the study surrounded the case study efforts and included the following (Rowley, J., 2002):

1. The case studies used contained an acceptable level of generalization; the case study design has been appropriately informed by theory, and can therefore be seen to add to the established theory. This generalization is analytical in which a previously developed theory is used as a template with which to compare the empirical results of the case study.

2. The case studies used contained an acceptable level of construct validity; the case study establishes correct and accurate operational measures for the concepts being studied. The goal is to expose and reduce subjectivity by linking data collection inquiries and measures to research questions and propositions.

3. The case studies used contained an acceptable level of internal validity; the case study design establishes a causal relationship whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships.

4. The case studies used contained an acceptable level of external validity; the case study design establishes the domain to which the generalization of the study can be deemed as generalized; and is based on replication logic.

5. The case studies used contained an acceptable level of reliability; the case study design establishes that the operations of the study can be repeated with the same results. This function relies heavily on the proper and accurate documentation of procedural tasks and record keeping of the study.

Procedure

The procedure, graphically illustrated in Figure 23, consists of the stages of research and the outputs of research. The stages of research represented all of the

necessary and required components of the study that assisted in achieving the anticipated

benefits of the research. The outputs of research represented the deliverables that were

derived from the stages of research. The deliverables were then honed for the inferential

statistical analysis conducted in the analytical stage of the study. The solid lined arrows

indicate direct procedural process and the dashed lined arrows indicate refined influence

reverting back to the original stage of research in the effort of generating a higher quality

deliverable.
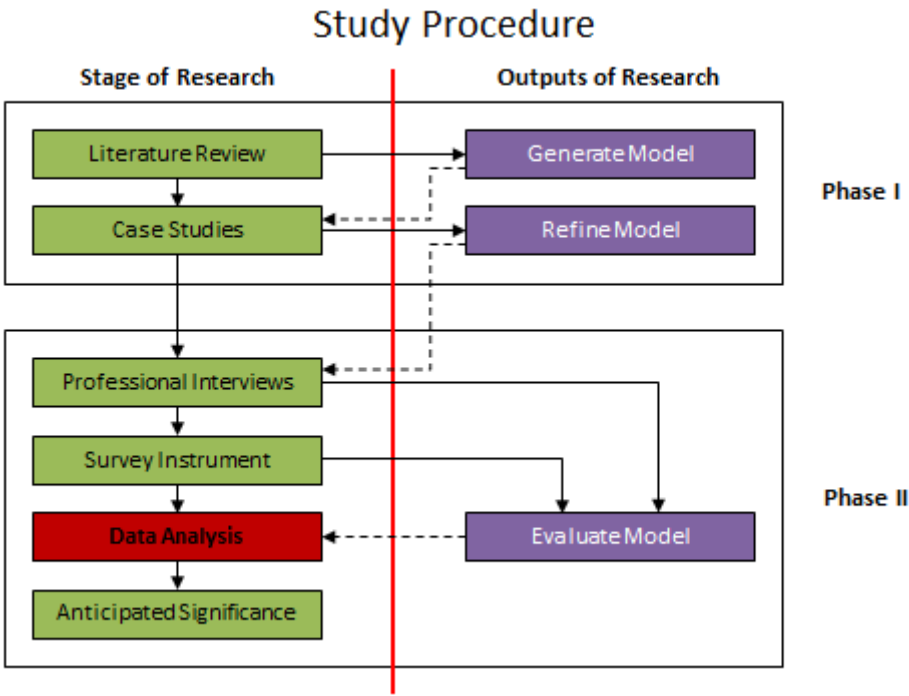
Figure 23, Research Study Procedure

The procedure was phased into two parts, Phase I and Phase II. Phase I primarily

consisted of the literature review and case studies that initiated the generation of models

used for the study including the Fault Tree Analysis, the conceptual model, and the hypotheses used for the study. Phase II utilized the models created in Phase I to generate the interview questions (pilot study) and the survey instrument for the study. Phase I allowed for refinement of the models and concepts of the study, while Phase II served as an evaluation mechanism for the tools used in the study.

Procedure - Phase I

Phase I began with the literature review that initiated the drawn conclusions associated with the gaps identified in the conceptual model in Chapter III. Additionally, the literature review initiated the use of the Fault Tree Analysis as a tool in refining and further defining the gaps in the study (the precursor to the design of the conceptual model). In a chronological manner, the hypotheses were developed from the conceptual model.

Study Procedure – Phase I
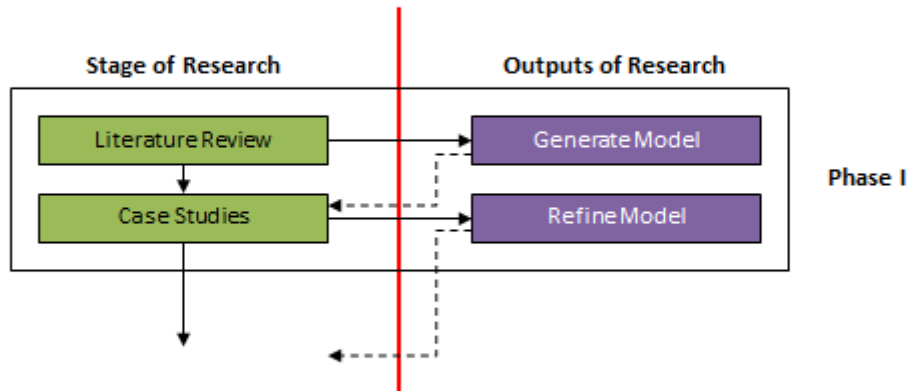
Figure 24, Research Study Procedure – Phase I

As depicted in Figure 24, Phase I of the study gathered critical information of the current state of Building Information Modeling (BIM), Facilities Management (FM), and BIM Technical Specifications through the literature review and case studies. The importance of this current state was that it established a benchmark and allowed for a comparison and categorization metric used in identifying both gaps and opportunities. The refinement process began and lists were generated focusing on the impact of the influence that the identified gaps held for Building Information Modeling (BIM), Facilities Management (FM), and BIM Technical Specifications. This process was accomplished through three objectives:

1. Building Information Modeling (BIM); identify the state of use for BIM in the built environment arena for designers (Design Consultants), constructors (Construction \ Builders), and operations (Facilities Management), to explore the usage among the respective players.

2. Facilities Management (FM); identify the state of use for FM in the built environment arena, to explore how facilities management practices were being conducted and the tools used to do it.

3. BIM Technical Specifications; identify the state of use for BIM Technical Specifications in the built environment arena, to explore how the models were governed and who or what was generating the specification.

Following these generated lists, continued refinement ensued by discovering and denoting the target group that would best be suited for the study. This refinement process through phase I yielded the pilot study interview, described in the procedure of Phase II.

Procedure - Phase II

Phase II began with conducting an interview for the pilot study of the research. The data produced by the interview served as a marker for the perceived and actual happenings of BIM usage for FM at a higher educational institution in Texas. The participants for the interview were randomly selected from the pool of facilities managers with ranging roles and experience levels. The interviews followed Institutional Review Board (IRB) protocol as outlined later in Chapter III. Contact with the perspective participants was conducted via telephone, using the designed script (Appendix K). The results of the pilot

interview were part of the initial beginnings of the survey instrument (Appendix M) that

was later administered per Institutional Review Board (IRB) protocol. The participants

in the interview process shared a common ilk with that of the facilities management

community; hence, generating a homogeneous pool of informants with varied roles and

experience levels. It is also noteworthy that the process was conducted at a large public

categorized higher educational institution in Texas. The approach of case analysis used

in Phase I, or grounded theory methodology, is now among one of the most influential

and widely used modes of executing qualitative research when the aim of the research is

to generate theory (Strauss, A., & Corbin, J. M. (Eds.)., 1997). The importance of this

lies with the generated resulted of the literature review and the case studies in Phase I;

conveying the extracted theories into demonstrative inquiries for the interviews and the

implemented survey instrument that created a quality data set for analysis.
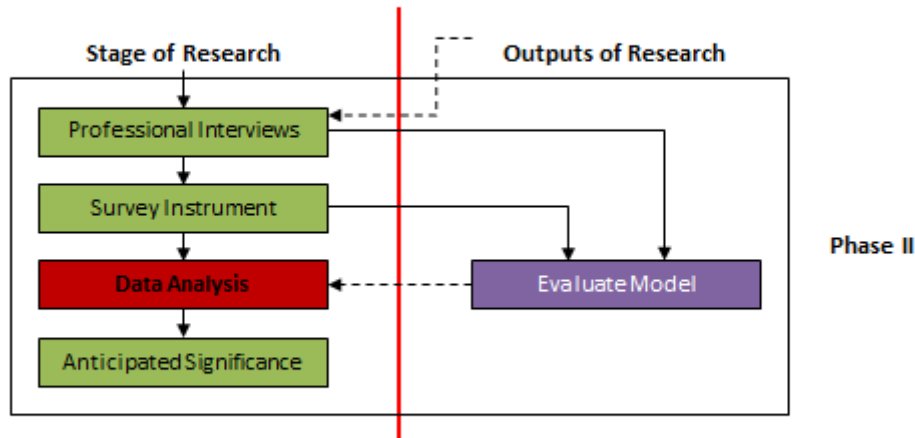
Figure 25, Research Study Procedure – Phase II

The survey instrument (Appendix M) was developed through a series of evolving

inquiries that were originated, in part, by the pilot interviews. This was implemented in

an effort to collect data pertinent to the hypotheses of the study in a current setting of

higher educational institutions in Texas. The survey instrument was conducted in an

online manner for efficiency and convenience for the participant; this format also

provided accurate and rapid retrieval of the data gathered for the researcher. The

generated data from the interview and the survey instrument underwent a series of

discriminated evaluations (Figure 25) that resulted in a comprehensive analysis of the

data, conveyed in Chapter V. Ultimately, the aim of the sequential progression of the

research was to determine the anticipated significance of the study; deriving the supported or refuted status of the given hypotheses.

Targeted Interest Population and Sample Size

The targeted interest population for this study consisted of facilities management personnel in higher educational institutions in the state of Texas. The facilities management personnel categories included executives, managerial positions, office technicians, field technicians, and support staff. The study was able to discern the gender of facilities management personnel, as well as experience and employment structure. The experience levels of all personnel targeted ranged from one year of experience to more than twenty years. Additionally, the personnel were categorized into two employment sectors; direct higher educational institution employees and outsourced personnel.

The higher educational institutions varied greatly with segregation occurring in the following categories; public or private institution; amount of square footage managed by the facilities management team. The amount of managed square footage ranged from under one million square feet to exceeding twenty million square feet. The targeted interest population and sample size differed from Phase I to Phase II and are examined separately.

Population and Sample Size - Phase I

Phase I of the study consisted of literature review and case study analysis; therefore, the population and sample size for Phase I of the study is applicable to the six (6) case studies selected for analysis. These case studies were purposefully selected due to the common themes of the anticipated research drawn from the literature review.

Population and Sample Size - Phase II

The population and sample size for the interview portion of Phase II of the study consisted primarily of facilities management personnel ranging in varied roles and experience levels; all were associated with the facilities management operations of higher educational institutions in Texas, and consisted of nine (9) participants. As a result of the affiliation to facilities management of higher educational institutions in Texas, the targeted audience was considered a homogeneous selection. Following the interview portion of the study, a targeted audience through a selection process anticipating a high percentage of participants reached a sample size of fifty-three (53) active facilities management personnel for the survey instrument. Of this targeted group, there were fifty-two (52) actual participants for the study. Similar to that of the interview process, the roles, experience levels, and size of the institutions managed varied; yet all of the participants were active in their respective roles directly involved in facilities management in higher educational institutions in Texas. These criteria generated an extremely well qualified sample selection for the study. All of phase II was conducted utilizing the guidelines and regulatory rules established by the Institutional Review

Board (IRB). The sample size for the study was considered small by standards, however, the quality of the participants proved valuable.

Limitations

This study recognizes and acknowledges that there are a multitude of factors contributing to the results and outcomes. Because of this, it is virtually impossible to account for every factor or contributing nuance. The following include, but are not limited to, some of the controlled and non-controlled limitations particular to this study. Controlled Limitations:

- The status of the higher educational institution; public or private. The importance of this limitation addresses higher educational institution funding and its sources. The study solely identifies the category of being public or private, but does investigate the actual amount of funding received, nor the source.

- The study is limited to higher educational institutions in the state of Texas. The impact of this limitation is supported by differing means and methods applied to manage facilities other than that of higher educational purposes. For example, the requirements for a healthcare facility that is similar in size to an educational institution are different and, hence, will generate unique findings. Data findings from one to the other may be used to fabricate an educated inference, however, it is important to recognize the distinction and segregate the usage of the facility.

Non-Controlled Limitations:

- The educational levels of the facilities management personnel prove to be a factor beyond the control of the observer. Each higher educational institution uses their own discretion when hiring and implores metrics unique to their system. It is feasible, and quite plausible, to have formally and informally educated personnel performing similar tasks.

Delimitations

The delimitations of this study also need to be addressed. This study is not 100% inclusive in that the study is based on higher educational facilities specific to the state of Texas. Although the findings may be applied to other studies similar in nature, it is imperative to consider the type of institution (specific to higher educational institutions), and the varying geographic location of each study (higher educational institutions outside the state of Texas).

Development of the Survey Instrument

The survey instrument used for this study was an online web-based surveying tool; survey monkey (www.surveymonkey.com). There are several reasons for utilizing online web-based surveys which include reduced cost, reduced time, ease of analysis, and human error avoidance as related to data entry (Solomon, D. J., 2001). The design of the instrument was deliberate concerning the layout of the questions with the intention of creating a survey that was fast and easy to expedite. This design was centered on the

basis of the conceptual model directing inquiries for the optimum coverage of sampling

with a streamlined path of ease. By using Dillman's tailored design method, the study

was able to achieve a decreased rate of non-response, as well as an increased avoidance

in measurement error (Dillman, D. A., 2011). The objective of the study was to obtain

information about those elements impacting the increased use of BIM in FM and the

survey instrument was the vehicle allowing the progression. The design and

development of the survey instrument proved to accomplish the aforementioned

objective.

Composition of the Questionnaire

Directly related to the development of the survey instrument was the composition

of the questionnaire. The questionnaire was developed through a series of evolving

inquiries that ultimately resulted in a 32 question survey, segregated into four categories

(Appendix M). The categories include demographics, technology usage, learning styles,

and implementation. The first category of demographics focused on gender, FM role,

FM experience, institution and type (public, private), employment status (direct,

outsourced), and size of the facility managed. The purpose of this category was to

establish the interpretation of the varied players in the Facilities Management arena. The

second category was the technology usage which focused on types of technology and

levels of familiarity and understanding. This section was comprised of a series of

questions designed to extract the use of current technology and the potential difficulties

associated with the interpretation of how information from the BIM models was being

used, or not used. The purpose of this section was to gage the technology benchmark of the varied players in Facilities Management, as well as to view the perception of BIM and its role in FM. This section also served as a precursor to the last section of perceived implementation. The third category addressed learning styles among the participants. This series of questions was directed specifically to establish the type of learning style that each participant possessed. These learning styles are segregated into three sectors; visual, auditory, and kinaesthetic. The purpose of this category was to address the issue centered on how different participants actual learn a new skill. This is vital information in the adoption process of implementation. How people learn impacts the acceptance or rejection of an implementation. And finally, the last category was the perceived interpretation of the implementation of BIM and FM through the participants. Although this section was brief, it proved quite significant in what Facilities Management teams think they are doing and what they are actually doing. The analysis of this survey is dissected in detail in Chapter V.

Institutional Review Board

Texas A&M University complies with federally mandated legislation requiring monitored guidelines addressing interaction with human subjects and the assurance of protection for human research participants. Any such research conducted at or by Texas A&M faculty, staff, or students is subject to the review and approval prior to any initiated research (Texas A&M University, 2014). This study was completely compliant with the protocol and did not collect any data until the formal letter of approval was

received (Appendix G). The application was comprehensive and rigorous requiring a myriad of documents including the assent letter form (Appendix H), the interview consent for (Appendix I), the survey consent form (Appendix J), the phone script (Appendix K), the sample email to the facilities management director for the survey (Appendix L), and the survey (Appendix M). Additionally, signatures from the committee chair and the department head were obtained for authenticity of the submitted documents, including the proper storage and security of the collected data. As part of the application, an online training course was conducted via the Collaborative Institutional Training Initiative (CITI). This certification was issued April 1, 2014 and expires March 31, 2017 supported by the IRB training status report (Appendix N), the IRB training completion report number (Appendix O), and the IRB training completion report (Appendix P).

Sampling Methodology and Data Collection

As mentioned previously, the targeted interest population for this study consisted of facilities management personnel in higher educational institutions in the state of Texas. Specifically, this population consisted of executives, facilities managers, facilities technicians, facilities staff, and 'other' category option. The 'other' category option was utilized in 11 of the 52 sampled Facility Management surveyed participants. This is significant, in that it made up more than 21% of the sample with job descriptions falling outside of the perceived normal titles. Selection of the targeted interest population was accomplished by identifying Facilities Management directors for higher educational

institutions in Texas with an inquiry of interest in the study. Upon the response indicating a high level of interest, the FM director was placed on a priority list of receiving the anticipated survey. This process was conducted via email, with contacts found on higher educational institution websites, accessible to all of the public. The incentive to the directors and their respective teams was the results of the study. This particular strategy generated a relatively low number of participants; however, of those participants deemed highly interested in the study, the response rate was tremendous. Careful diligence was implored with retaining the interested respondents. Dillman's Tailored Design Method was instituted for the survey implementation phase (Dillman, D. A., 2011). The initial contact of each director was a combination of a telephone call and an email, both scripted. Following the initial contact, email was the primary source of communication, with occasional phone calls for convenience and clarity of the study. The following steps were conducted:

1. Initial scripted phone call and scripted email introducing the study and gaging the level of interest as a potential participant

2. A follow up scripted email introducing the study and gaging the level of interest as a potential participant

3. A follow up email confirming the high level of interest in the study with anticipated dates surrounding the release of the survey

4. The initial email sent with the consent forms, assent letter templates, the Institutional Review Board (IRB) approval code and contact information, and the link to the survey

5. A follow up email as a reminder, and importance, of completing the survey (sent approximately 7 calendar days from the initial email containing the survey link)

6. A follow up email as a reminder, and importance, of completing the survey (sent approximately 14 calendar days from the initial email containing the survey link)

7. A follow up email as a reminder, and importance, of completing the survey (sent approximately 21 calendar days from the initial email containing the survey link)

8. A final follow up email as a reminder, and importance, of completing the survey (sent approximately 28 calendar days from the initial email containing the survey link)

Although Dillman's process was a five step recommendation, the diligence on targeting the interested population coupled with the ability to communicate rapidly via email resulted in a successful response rate.

Classifying the Data

Each of the respondents of the study was tagged with an alphanumeric code. This code was keyed and could then correlate responses as related to the four sectors of the questionnaire; demographic, technology usage, learning styles, and implementation. This classification technique proved efficient and accurate.

In order for data to become useful, the captured data from a source needs to be converted into information and knowledge from the recorded data set (Kantardzic, M., 2011). The data collection process for this study followed this train of thought using coding systems, mainly binary, to measure the impact of a given response and convert those responses into information and knowledge. Each question response from each respondent was entered into an electronic spreadsheet. Prior to entering the coded matrix data into the statistical generator, all of the respondent identifiers were removed, creating an aggregated analysis. All of the statistical data for this study were conducted with the statistics software, R. Additionally, the handling of all data and outcomes were compliant with Texas A&M University and the Institutional Review Board; specifically, confidentiality related to any and all data that could potentially identify any participant was not published in this study.

Descriptive and inferential statistical methods were utilized to analyze the research hypotheses of the study. An analysis of variance (ANOVA) and an ordinal least squares of multiple regressions were included in the inferential method. These descriptive and inferential methodologies are illustrated and discussed in Chapter V, Analysis and Results.

Applying Statistical Tools

The principal statistical analysis tool utilized for the study was the 'R' statistical software, 'car' package. 'R' is a free, open-source implemented tool that acts as an interpreter for the 'S' statistical computing language and is command driven; meaning

that it does not use Graphical User Interface (GUI) that is a visual way of interacting with computers by the use of icons and menus and windows, commonly found in most computer operating systems (Fox, J., 2005).

Additionally, survey monkey provided good usable analysis that was the main functional tool used in the descriptive analysis for the survey instrument. The survey monkey provided data was illustrated graphically, in part, by the use of column charts generated in the Microsoft Excel program of Microsoft Office (version 2010). These generated tables for the descriptive analysis also allowed for a numerical metric associated with the graphical depiction.

CHAPTER V

ANALYSIS AND RESULTS

The collected data in Phases I and Phase II of the study (procedure phases illustrated in Chapter IV) are analyzed in two sections; descriptive and inferential. The initial section exercises the descriptive analysis of the study. This five step process includes; the organization of the data into frequency distributions, the display of the data in a graph, a description of what is average or typical of the distributions, the description of variability within the distributions, and the descriptions of the relationships between the variables (Frankfort-Nachmias, C., and Leon-Guerrero, A.Y., 2009). The second section analyzes the results as related to the inferential statistical analysis of the responses of the participants for the survey instrument of the study.

Descriptive Statistical Analysis

The survey was segregated into four sectors; demographics, technology usage, learning styles, and implementation. Every question for the survey was classified as one of the four question types; Dichotomous, Likert Scale, Open Ended, and Filtered. A dichotomous inquiry is one that has only two choices; it can be mathematically convenient for interpretation in which a variable occurring or not occurring is assigned a binary code, 0 or 1 (Amemiya, T., 1981). The Likert Scale questioning is a method in which the responses have a range of answers, typically as follows; *strongly disagree, disagree, neither, agree, or strongly agree*. The responses of 'strongly disagree' or

'disagree' may be equated to a 'no' response, while a 'strongly agree' or an 'agree' response is equated to a 'yes' response. The confidence or strength measurement in this format is assessed as the distance away from the neutral response (Maurer, T. J., & Pierce, H. R., 1998). The Open Ended question is simply posing a question and having the survey participant respond in their own words. The Open Ended questions offers a way of providing qualitative depth in survey based research with the advantage of allowing respondents to answer in their own frame of reference, reducing the influences of researcher suggested alternatives (Mossholder, K. W., Settoon, R. P., Harris, S. G., & Armenakis, A. A., 1995; Allen, B.P. & Potkay, C.R., 1983; Salancik. G.R., 1979). The Filtered questioning method is when a given question has multiple available answers that have been provided by the researcher. These questions are in no certain order and have no ranking associated with them; simply, multiple options for response. This method is common practice in research and it has been determined that in most instances, the filtering process has no little to no impact on the distribution of substantive responses (Bishop, G. F., Oldendick, R. W., & Tuchfarber, A. J., 1983). The results from each sector generated the drawn summaries of the depictions in the figures. Each question was analyzed into three parts; a description of the inquiry, the purpose or reasoning for the inquiry, and a summary of the question with the description of its outcome.

Inferential Statistical Analysis

This study utilized one-way Analysis of Variance (ANOVA) and Multivariate Analysis of Variance (MANOVA) for testing the collected data. The analysis of variance

(ANOVA) is founded on a core of assumptions that need to be met in order to rely on

the validity of the analysis; these assumptions include the score within the group to be

normally or independently distributed, the score must be within the mean or the variance

of the distribution, and the score variances within the group maintain homogeneity, or

are equal (Keselman, H. J., Huberty, C. J., Lix, L. M., Olejnik, S., Cribbie, R. A.,

Donahue, B., ... & Levin, J. R., 1998). This type of conformation of the assumptions

ensures a higher probability of validity among the tests associated with the hypotheses.

The research also instituted the use of a multivariate analysis of variance (MANOVA)

tool for the inferential statistical portion of the study. This is typically utilized when one

or more grouping variables are present and the anticipated outcomes are variable, as

well. The validity assumptions for the multivariate analysis of variance (MANOVA)

include multivariate normality, homogeneity of the P x P covariance matrices (variances

within the groupings of P-values are equal), and independence of observations are

maintained (Keselman, H. J., Huberty, C. J., Lix, L. M., Olejnik, S., Cribbie, R. A.,

Donahue, B., ... & Levin, J. R., 1998). As iterated with ANOVA, this type of

conformation of the assumptions using MANOVA ensures a higher probability of

validity among the tests associated with the hypotheses. The criteria for utilizing both of

these analyses were met for the inferential statistical examinations of this study.

The obtained data from the distributed survey instrument was collected and

organized in a categorized fashion, segregating the Demographic, the perceived FM

Training, the perceived Specifications, the perceived Quality BIM, and the perceived

BIM Usage questions (Table 1).

| Participant Status | Hypothesis 1 | Hypothesis 2 | Hypothesis 2 | Hypothesis 3 | Hypothesis 4 |
Demographic	BIM Usage	Training	Training - Learning Styles	Specification	Quality BIM
Q1. Gender	Q8. BIM Usage	Q9D. Training	Q21. Training	Q9B. Specification	Q9A. Quality BIM
Q2. Role	Q32. BIM Usage	Q10A. Training	Q22. Training	Q12A. Specification	Q9C. Quality BIM
Q3. Experience		Q10B. Training	Q23. Training	Q12B. Specification	Q19. Quality BIM
Q4. Classification		Q10C. Training	Q24. Training	Q12C. Specification	Q20. Quality BIM
Q5. Classification		Q10D. Training	Q25. Training	Q13. Specification	Q31C. Quality BIM
Q6. Classification		Q10E. Training	Q26. Training	Q14. Specification	
Q7. Size		Q11. Training	Q27. Training	Q15. Specification	
		Q31A. Training	Q28. Training	Q16. Specification	
			Q29. Training	Q17. Specification	
			Q30. Training	Q18. Specification	
				Q31B. Specification	

Table 1, Questionnaire Analysis Matrix

Each question was assigned a binary coded identifier for analysis generating an efficient means to evaluate the data. The data was then implemented into the 'R' statistical software tool where the outcomes were then interpreted categorically by each given hypothesis; hypothesis 2 (H_2), hypothesis 2 (H_2), hypothesis 3 (H_3), and hypothesis 1 (H_1).

Demographics Descriptive Analysis

The intent of the questions pertaining to demographics was to establish the nature of the players in the facilities management arena. There were seven questions in this section, of which, are individually described. As mentioned earlier, the analysis consists of three parts; a description of the inquiry, the purpose or reasoning for the inquiry, and a summary of the question with the description of its outcome.
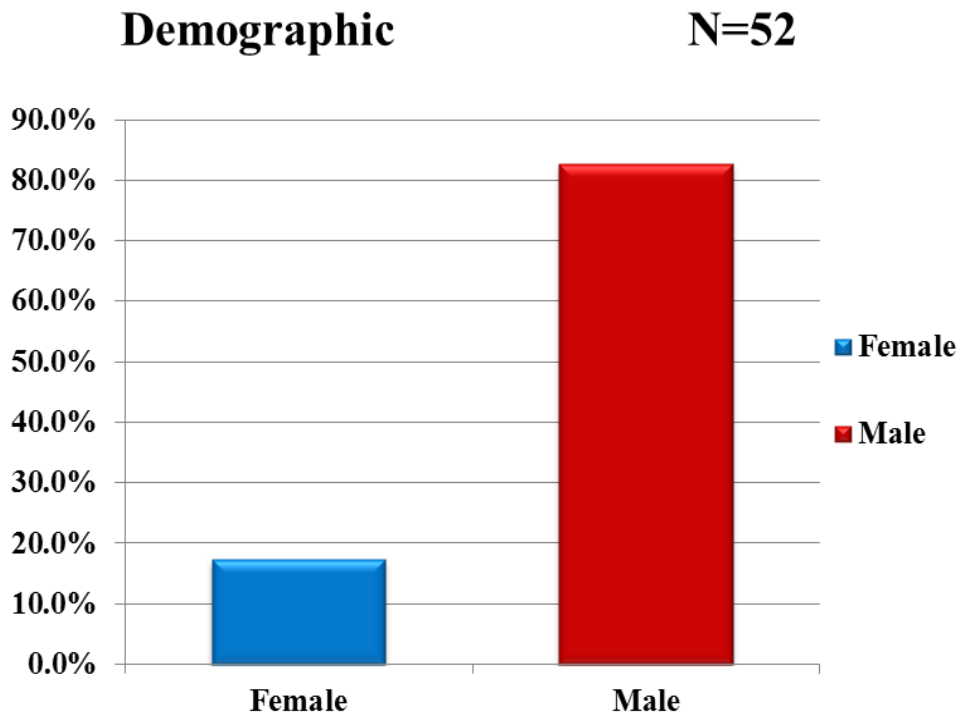
Figure 26, Demographic Results for Q1. What is your gender?

Question one (Q1) asked the gender of the survey participant in a dichotomous

structured inquiry, resulting in a male \ female response (Figure 26). The purpose of this

inquiry was to identify whether the survey participant was male or female and to

compare which gender held a greater presence in the study. The results indicate that of

the 52 survey participants, 9 were female and 43 were male, accounting for 17.3% and

82.7%, respectively. The potential of determining any impact or significance to the study

of participants being male or female was not feasible due to the size of the sample.
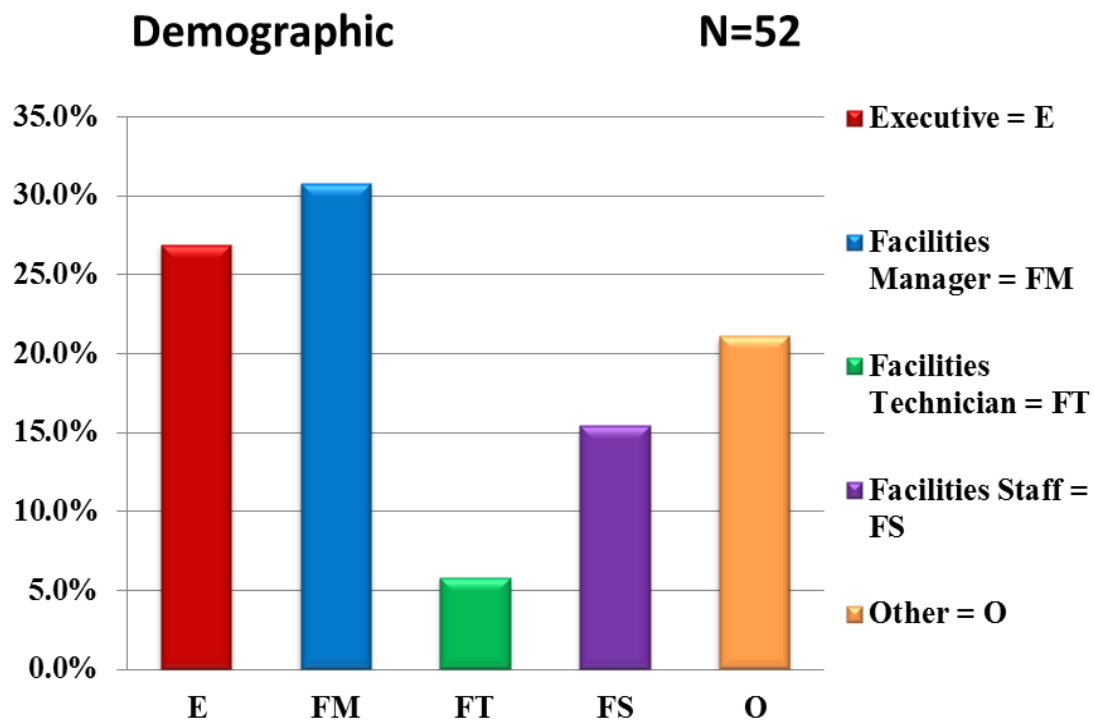
Figure 27, Demographic Results for Q2. What best describes your role in Facilities Management?

Question two (Q2) focused on the role of the Facilities Management survey participant (Figure 27). The purpose of this filtered \ open ended inquiry was to establish the varied tiers of the participants. Four typical roles were described with the fifth option category of 'other'. The 'other' category gave the participant and an opportunity to define that role and this option was exercised in 11 of the 52 instances and accounted for 21.1% of the study. These responses primarily consisted of a general or specific type of project manager, but also included inspectors, analysts, supervisors, and coordinators. The responses reported that 14 of the 52 participants were executives, accounting for 26.9%; 16 of 52 responses were facilities managers, accounting for 30.8%; 3 of the 52

responders were facilities technicians, accounting for 5.8%; and facilities staff held 8 of the 52 responses, accounting for 15.4%. Depending on the exact job description, the respondents in the 'other' category that identified themselves as project managers might very well fallen in the facilities manager or facilities technician description. Also, the respondents in the 'other' category that classified themselves as coordinators could have been in the facilities staff response. This study did not report or make any of these assumptions; only the exact responses of the participants were used. From the received data, executives and facilities managers accounted for more than half of the respondents of the study. The facilities staff and facilities technicians represented the lowest stakes in the study. These demographic results for roles in FM are not significant due to the size of the sample; however, nearly all of the typical associated roles in FM were present in the study. It was also interesting to observe the relatively high percentage (26.9%) of executives in the study.
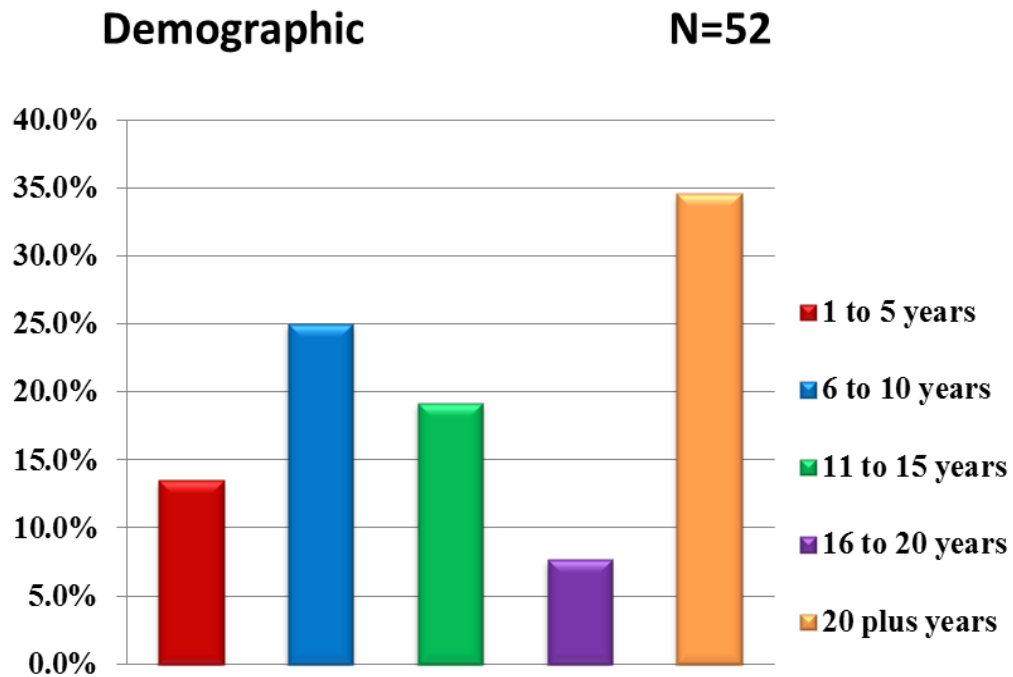
Figure 28, Demographic Results for Q3. What is your Facilities Management experience level?

Question three (Q3) targeted the experienced level of the survey participant (Figure 28). The purpose of this filtered question was to gain insight to FM exposure of each individual and to illustrate the varied levels of experience for each participant. The experience levels were segregated into five categories; 1-5 years, 6-10 years, 11-15 years, 16-20 years, and 20 or more years of experience. Those participants with 1-5 years of experience consisted of 7 of the 52 respondents, accounting for 13.5% of this inquiry. Those answering 6-11 years of experience were nearly twice as much as those with 1-5 years, making up 13 of the 52 participants at 25.0%. Respondents answering 11-15 years of experience were slightly fewer than those with 6-11 years, accounting for

10 out of the 52 participants at 19.2%. The next category of 16-20 years accounted for

the least amount of this inquiry at 4 of the 52 surveyed resulting in 7.7% of the

respondents. And the last category of 20 or more years of experience was quite high. It

consisted of 18 of the 52 polled, representing 34.6% of this inquiry. Those participants

with 16 or more years of experience accounted for 42.3%, nearly half of those polled. As

iterated prior, the significance of this is limited to the size of the participants in the
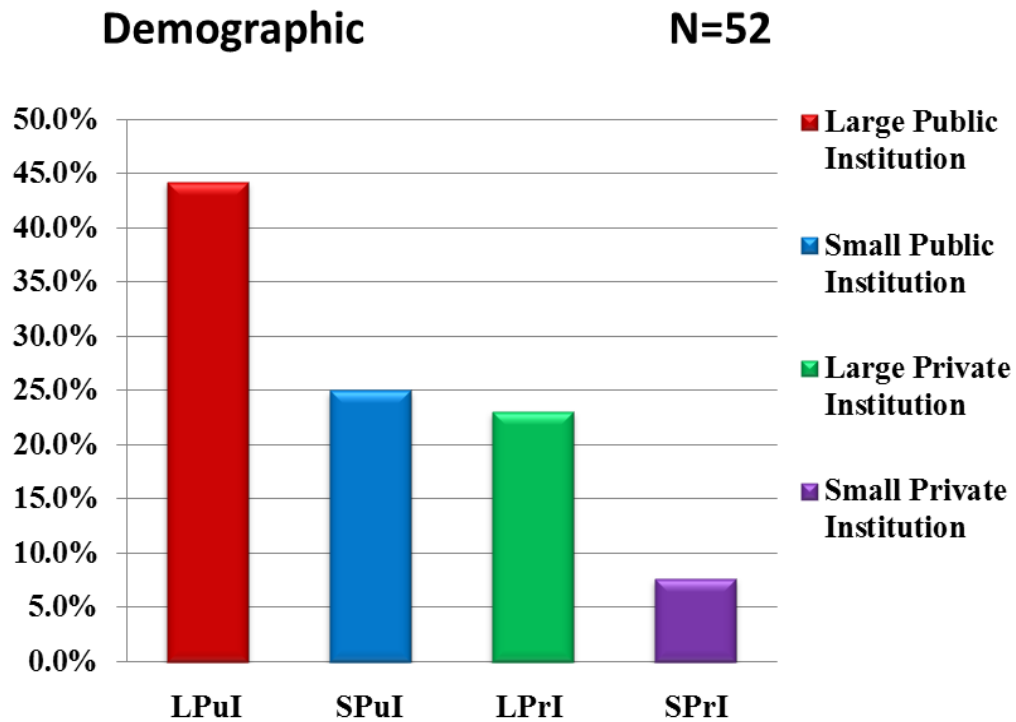
study.

Figure 29, Demographic Results for Q4. What is the name of your institution?

Question four (Q4) addressed the classification of the institution. This open

ended question posed the inquiry of identifying their respective institutions (Figure 29).

The purpose of this query was to gain insight of the type of institutions participating in the study. After the data was received, it was placed into a coded spreadsheet that generated a metric that would segregate each of the responses into one of four categories; a small public institution, a large public institution, a small private institution, and a large private institution. The first category found there to be 23 of the 52 participants to be affiliated with a large public institution, accounting for 44.2% of the participants. The next category associated participants with small public institutions at 13 of the 52 polled, making up 25.0% of the responses. The large private institutions held 12 responses to the query and accounted for 23.1% of those polled. And the last category of participants was affiliated with the smallest sector of the inquiry, at 4 of the 52 surveyed, accounting for 7.7%. The generator utilized for the indicator of each institution being public or private was confirmed by the responses in question five (Q5, Figure 28); outcomes were the same for the counts and the percentages. The size of the study limited any significance for this inquiry.
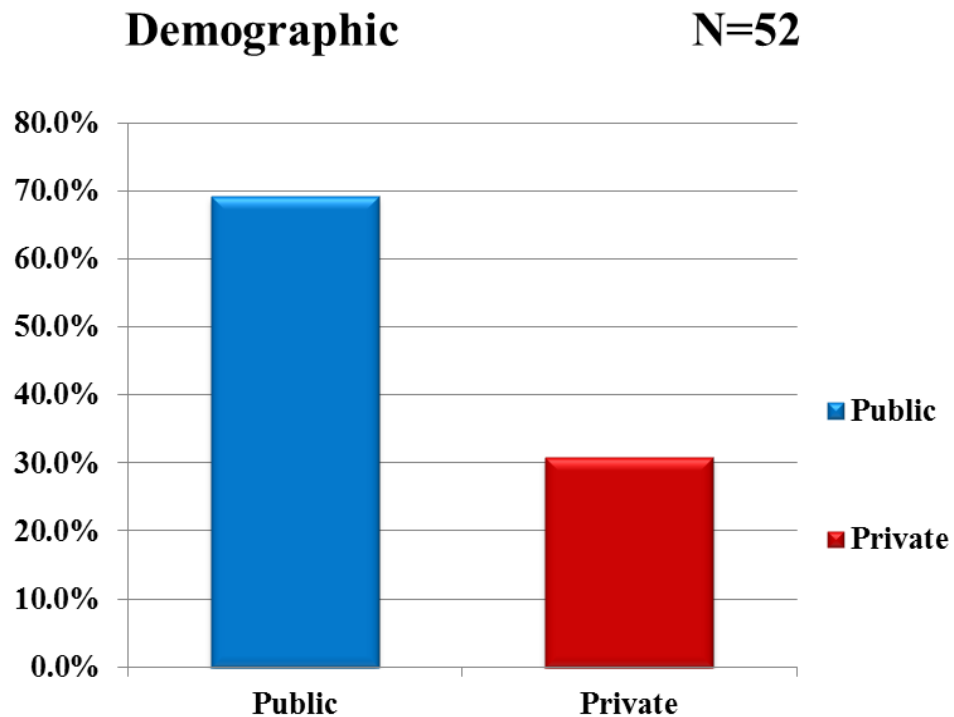
Figure 30, Demographic Results for Q5. Your institution is classified as the following: Public \ Private.

Question five (Q5) addressed the classification of the institution in a dichotomous structured inquiry; public, or private (Figure 30). The purpose of this question was to confirm the status of the institution concerning its public or private nature and to compare which status held a greater presence in the study. The results indicate that of the 52 survey participants, 36 were public and 16 were private, accounting for 69.2% and 30.8%, respectively. The potential of determining any impact or significance to the study of participants being public or private was not feasible due to the size of the sample.
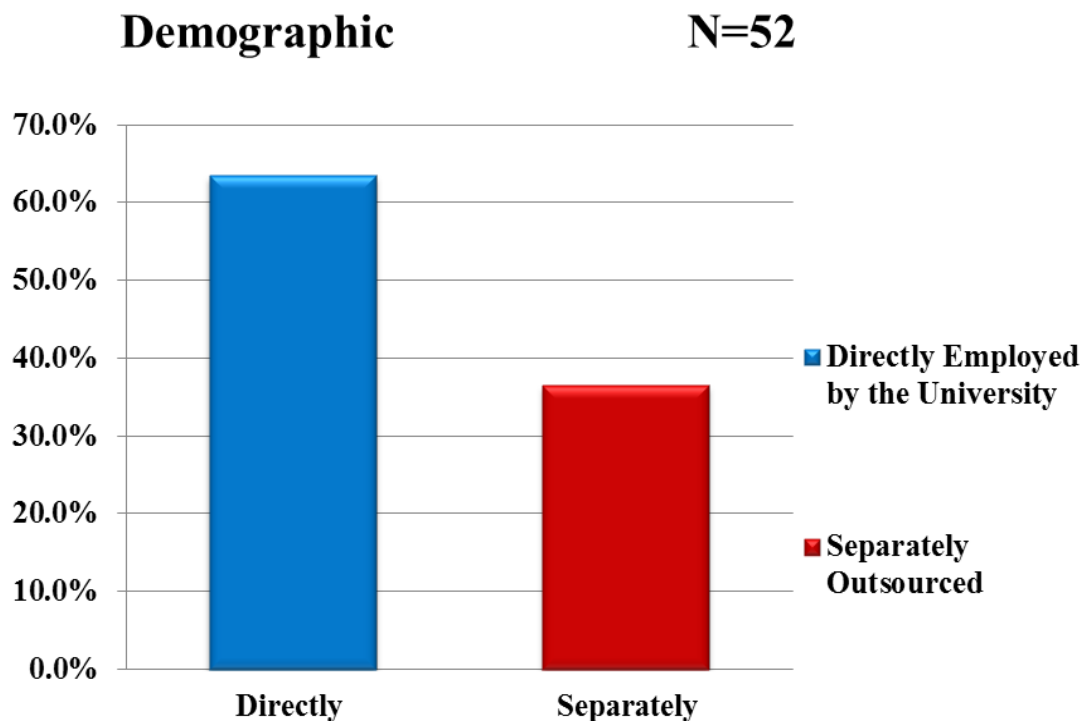
Figure 31, Demographic Results for Q6. What best describes your employment status?

Question six (Q6) posed the employment status of the survey participant in a dichotomous structured inquiry, resulting in a directly employed by the institution \ separately outsourced response (Figure 31). The purpose of this inquiry was to identify whether the survey participant was directly employed by the institution or separately outsourced and to compare which status held a greater presence in the study. The results indicate that of the 52 survey participants, 33 were directly employed by the institution and 19 were separately outsourced, accounting for 63.5% and 36.5%, respectively. The potential of determining any impact or significance to the study of participants being directly employed by the institution or separately outsourced was not feasible due to the size of the sample.
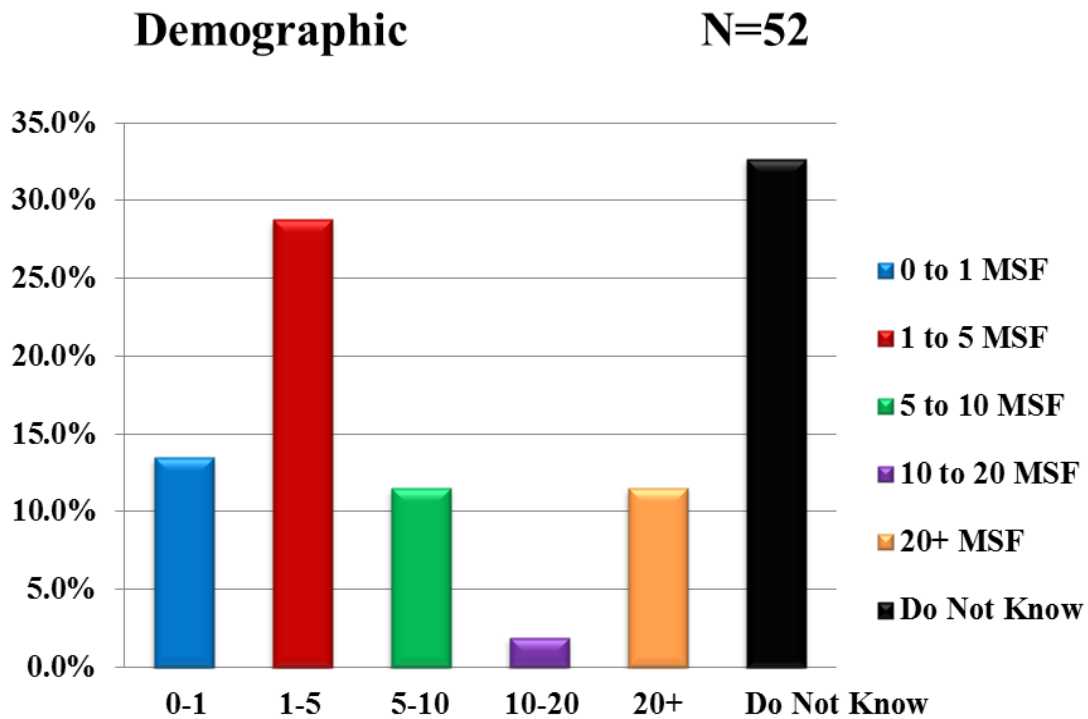
Figure 32, Demographic Results for Q7. How many square feet of facility are managed by your team?

Question seven (Q7) targeted the amount of square feet of facility that was managed by the teams of each participant (Figure 32). The purpose of this filtered inquiry was to gage the capacity of the Facilities Management team for each respective institution of the surveyed participants. Those participants in the 0 to 1 million square feet of managed facility made up 7 of the 52 surveyed, accounting for 13.5% of the inquiry. The next category containing participants that managed 1 to 5 million square feet of facility accounted for 15 of the 52 polled, holding 28.8% of the query. Those participants managing 5 to 10 million square feet of facility held 6 of the 52 surveyed, accounting for 11.5%. The category representing those participants managing 10 to 20

million square feet of facility held the lowest count of those polled with 1 of the 52 participants accounting for only 1.9% of the inquiry. The following participants managed facilities that held the category of more than 20 million square feet, containing 6 of the 52 polled for 11.5% of the inquiry. And the last category addressed those participants that did not know how many square feet of facility that their FM team managed; this consisted of 17 of the 52 participants and accounted for 32.7% of the responses to the question. The outcome of this question indicated that nearly a third of those polled were not aware of how many square feet of facility that their teams managed. Additionally, teams that managed 10 to 20 million square feet of facility was extremely low with less than 2% making up that placeholder.

Technology Usage Descriptive Analysis

It was the intent of the study to establish the current and perceived use of technology among varied FM personnel. The technology usage section contained the majority of the questioning for the survey with thirteen inquiries, of which, several had multiple parts. These questions were analyzed in a three part process; a description of the inquiry, the purpose or reasoning for the inquiry, and a summary of the question with the description of its outcome.
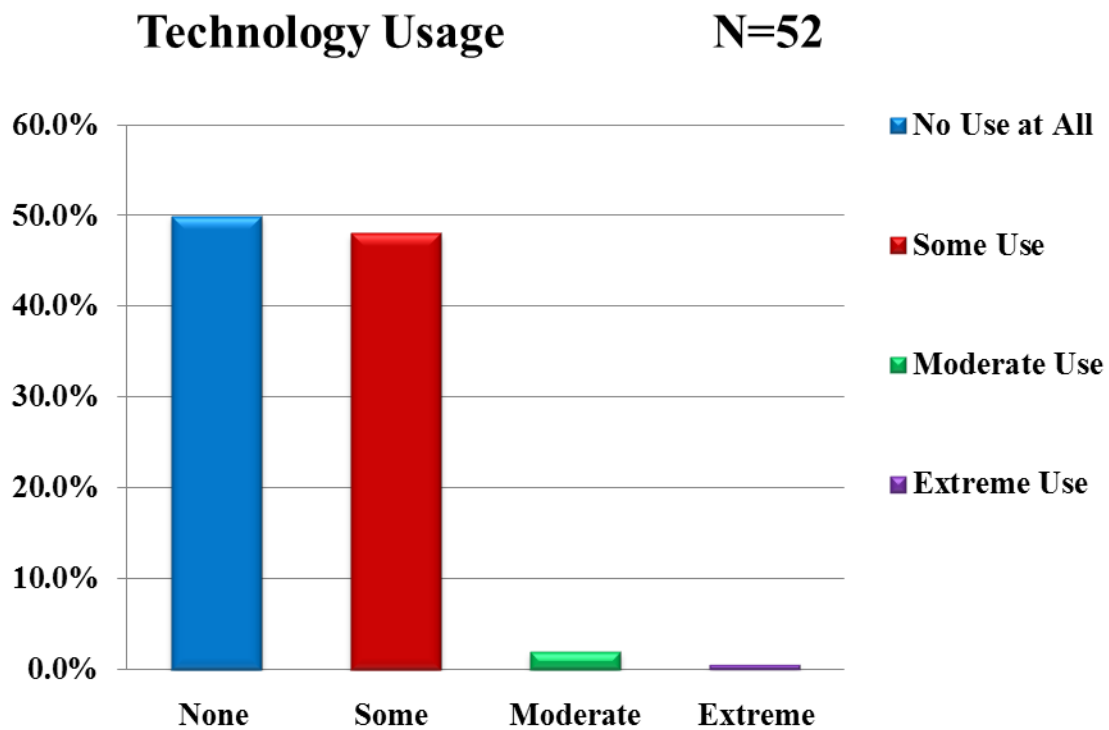
Figure 33, Technology Usage Results for Q8. Rate your usage of BIM in your Facilities Management process.

Question eight (Q8) began the technology usage section of the study that posed a rated usage of BIM in each of the participant's FM process (Figure 33). This was a filtered inquiry and produced some interesting data. The question was scripted with four possible outcomes; no use at all, some use, moderate use, and extreme use. The purpose of this question was to confirm the rate of usage of BIM in the facilities management process and to compare which status held a greater presence in the study. The first response category of no use at all held 26 of the 52 participants and accounted for 50.0% of the responses. The category associated with some use acquired 25 of the 52 surveyed and accounted for 48.1% of the responses. The moderate use of BIM in the facilities

management process held only 1 of 52 surveyed participants and accounted for 1.9% of

the question. The last category of extreme use had 0 of the 52 polled, resulting in 0% of

the responses for this inquiry. The outcome indicating no use at all of BIM in the

facilities management process made up half of those polled for this question, while some

use represented nearly the remaining half of the inquiry. Only one participant found their

process to contain moderate use of BIM in the facilities management process.
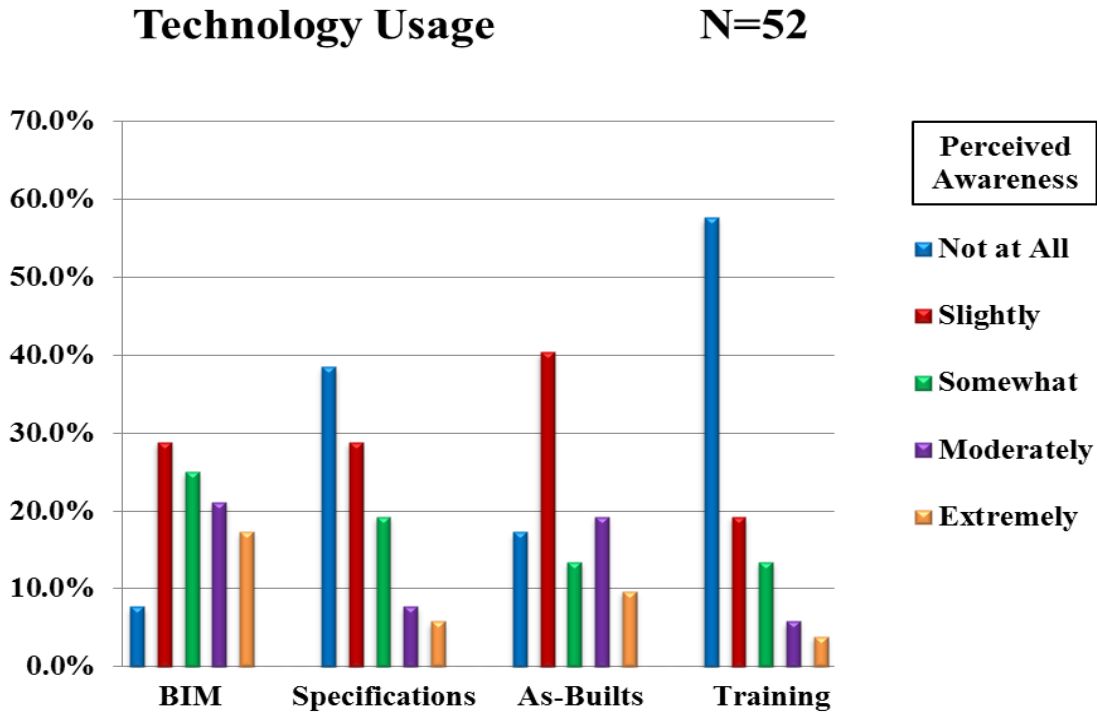

Figure 34, Demographic Results for Q9. What is your perceived awareness of the following: Building Information Modeling (BIM); BIM Technical Specifications; BIM As-Built-Models; Available BIM Training and Certifications?

Question nine (Q9) targeted the perceived awareness of four separate categories;

Building Information Modeling (BIM); BIM Technical Specifications; BIM As-Built-

Models; Available BIM Training and Certifications (Figure 34). The inquiry presented

five levels of awareness, in a filtered inquiry, for the participants to choose. The purpose

of this filtered inquiry was to establish what the surveyed participants believed their

position to be as related to the aforementioned four categories. Concerning the first

category of Building Information Modeling (BIM), the surveyed participants perceived

their awareness to be the following: not at all aware, 4 of the 52 responses, accounting

for 7.7% of the inquiry; slightly aware, 15 of the 52 responses, accounting for 28.8% of

the inquiry; somewhat aware, 13 of the 52 responses, accounting for 25.0% of the

inquiry; moderately aware, 11 of the 52 responses, accounting for 21.2% of the inquiry;

and extremely aware, 9 of the 52 responses, accounting for 17.3% of the inquiry.

Concerning the second category of BIM Technical Specifications, the surveyed

participants perceived their awareness to be the following: not at all aware, 20 of the 52

responses, accounting for 38.5% of the inquiry; slightly aware, 15 of the 52 responses,

accounting for 28.8% of the inquiry; somewhat aware, 10 of the 52 responses,

accounting for 19.2% of the inquiry; moderately aware, 4 of the 52 responses,

accounting for 7.7% of the inquiry; and extremely aware, 3 of the 52 responses,

accounting for 5.8% of the inquiry. Concerning the third category of BIM As-Built-

Models, the surveyed participants perceived their awareness to be the following: not at

all aware, 9 of the 52 responses, accounting for 17.3% of the inquiry; slightly aware, 21

of the 52 responses, accounting for 40.4% of the inquiry; somewhat aware, 7 of the 52

responses, accounting for 13.5% of the inquiry; moderately aware, 10 of the 52

responses, accounting for 19.2% of the inquiry; and extremely aware, 5 of the 52

96

responses, accounting for 9.6% of the inquiry. And concerning the fourth category of Available BIM Training and Certifications, the surveyed participants perceived their awareness to be the following: not at all aware, 30 of the 52 responses, accounting for 57.7% of the inquiry; slightly aware, 10 of the 52 responses, accounting for 19.2% of the inquiry; somewhat aware, 7 of the 52 responses, accounting for 13.5% of the inquiry; moderately aware, 3 of the 52 responses, accounting for 5.8% of the inquiry; and extremely aware, 2 of the 52 responses, accounting for 3.8% of the inquiry. The overall outcomes for this inquiry indicated that awareness for Building Information Modeling (BIM) appeared moderate, while the awareness for BIM Technical Specifications was low. Also, the awareness for BIM As-Built-Models appeared to be moderate, while the awareness for Available BIM Training and Certifications was low.
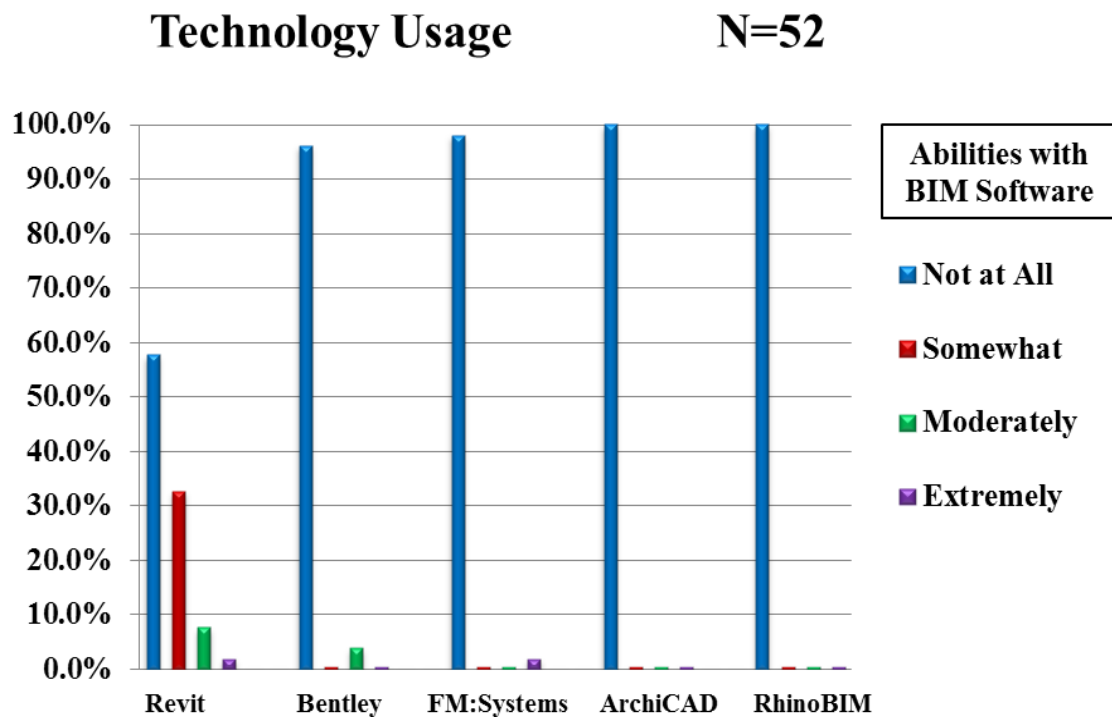
Technology Usage   N=52

Figure 35, Technology Usage Results for Q10. Describe your ability to manipulate a Building Information Model using the following BIM software.

Question ten (Q10) focused on the ability to manipulate a building information model using software from five potential categories; Autodesk Revit, Bentley Architecture, FM:Systems \ FM:Interact, Graphisoft ArchiCAD, and RhinoBIM. In a filtered inquiry, the question presented four levels of ability to manipulate each of the given software options for the participants to select (Figure 35). The purpose of this filtered inquiry was to establish what the surveyed participants believed their position to be as related to their ability to manipulate each of the given five categories; not at all, somewhat, moderately, and extremely. Pertaining to the first category of Autodesk Revit, the surveyed participants perceived their ability to manipulate the software to be

the following: not at all able, 30 of the 52 responses, accounting for 57.7% of the inquiry; somewhat able, 17 of the 52 responses, accounting for 32.7% of the inquiry; moderately able, 4 of the 52 responses, accounting for 7.7% of the inquiry; and extremely able, 1 of the 52 responses, accounting for 1.9% of the inquiry. Pertaining to the second category of Bentley Architecture, the surveyed participants perceived their ability to manipulate the software to be the following: not at all able, 50 of the 52 responses, accounting for 96.2% of the inquiry; somewhat able, 0 of the 52 responses, accounting for 0% of the inquiry; moderately able, 2 of the 52 responses, accounting for 3.8% of the inquiry; and extremely able, 0 of the 52 responses, accounting for 0% of the inquiry. Pertaining to the third category of FM:Systems FM:Interact, the surveyed participants perceived their ability to manipulate the software to be the following: not at all able, 51 of the 52 responses, accounting for 98.1% of the inquiry; somewhat able, 0 of the 52 responses, accounting for 0% of the inquiry; moderately able, 0 of the 52 responses, accounting for 0% of the inquiry; and extremely able, 1 of the 52 responses, accounting for 1.9% of the inquiry. Pertaining to the fourth category of Graphisoft ArchiCAD, the surveyed participants perceived their ability to manipulate the software to be the following: not at all able, 52 of the 52 responses, accounting for 100% of the inquiry; somewhat able, 0 of the 52 responses, accounting for 0% of the inquiry; moderately able, 0 of the 52 responses, accounting for 0% of the inquiry; and extremely able, 0 of the 52 responses, accounting for 0% of the inquiry. Pertaining to the final category of RhinoBIM, the surveyed participants perceived their ability to manipulate the software to be the following: not at all able, 52 of the 52 responses, accounting for

100% of the inquiry; somewhat able, 0 of the 52 responses, accounting for 0% of the inquiry; moderately able, 0 of the 52 responses, accounting for 0% of the inquiry; and extremely able, 0 of the 52 responses, accounting for 0% of the inquiry. The overall outcome for this inquiry indicated that close to half of the surveyed participants' ability to manipulate Autodesk Revit appeared to be somewhat able; while the ability to manipulate Bentley Architecture, FM:Systems \ FM:Interact, Graphisoft ArchiCAD, and RhinoBIM was essentially non-existent.
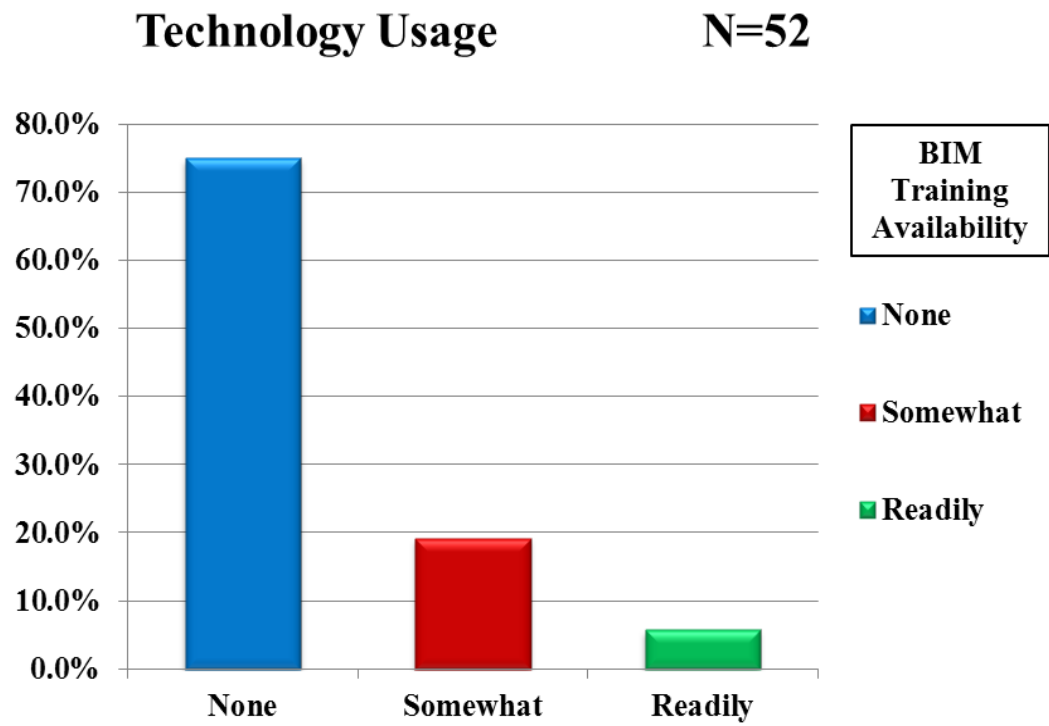

Figure 36, Technology Usage Results for Q11. Is any BIM software training available at your institution?

Question eleven (Q11) was centered on the availability of BIM software training at each of the participants respective institutions (Figure 36). This filtered inquiry presented three potential options of BIM software training availability; none, somewhat, and readily. The purpose of this question was to gain insight concerning the status of the availability of BIM software training and to compare which status held a greater presence in the study. Of the 52 respondents, 39 indicated that there was no available training at their institution, accounting for 75% of those polled. Of the 52 respondents, 10 indicated that there was somewhat available training at their institution, accounting for 19.2% of those polled. And finally, 3 of the 52 respondents surveyed indicated that there was readily available training at their institution, accounting for 5.8% of those polled. The overall outcome for this inquiry illustrated that three quarters the surveyed participants confirmed that there was no available BIM software training at their respective institutions, while the remaining quarter indicated that there was somewhat to readily available BIM software training accessible at their respective institutions.
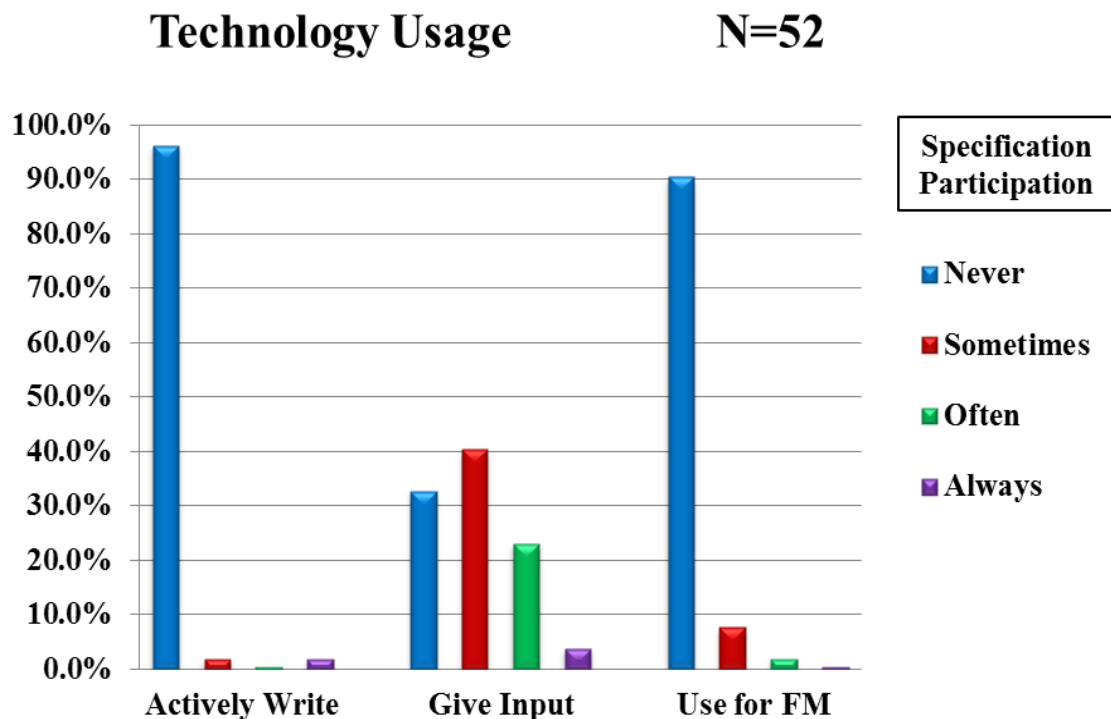
Technology Usage   N=52

Figure 37, Technology Usage Results for Q12. Describe your participation in the following: I actively participate in writing BIM Technical Specifications for FM; Given the chance would you give input for BIM Technical Specification writing; I use written BIM Technical Specification to perform my FM tasks.

Question twelve (Q12) addressed the participation of actively writing BIM Technical Specifications for FM, giving input for BIM Technical Specification writing, and the use of written BIM Technical Specifications to perform FM tasks (Figure 37). The inquiry presented four levels of participation, in a filtered inquiry, for those polled to select. The purpose of this filtered inquiry was to establish the involvement of writing, influencing, and using BIM Technical Specifications for FM. The optional responses presented to the surveyed participants included never, sometimes, almost every time, and every time. Concerning the first category of actively writing BIM Technical

Specifications for FM, the surveyed participants signaled their respective participation to be the following: never, 50 of the 52 responses, accounting for 96.2% of the inquiry; sometimes, 1 of the 52 responses, accounting for 1.9% of the inquiry; almost every time, 0 of the 52 responses, accounting for 0% of the inquiry; and every time, 1 of the 52 responses, accounting for 1.9% of the inquiry. Concerning the second category of giving input for BIM Technical Specification writing, the surveyed participants signaled their respective participation to be the following: never, 17 of the 52 responses, accounting for 32.7% of the inquiry; sometimes, 21 of the 52 responses, accounting for 40.4% of the inquiry; almost every time, 12 of the 52 responses, accounting for 23.1% of the inquiry; and every time, 2 of the 52 responses, accounting for 3.8% of the inquiry. And concerning the last category of using written BIM Technical Specifications to perform FM tasks, the surveyed participants signaled their respective participation to be the following: never, 47 of the 52 responses, accounting for 90.4% of the inquiry; sometimes, 4 of the 52 responses, accounting for 7.7% of the inquiry; almost every time, 1 of the 52 responses, accounting for 1.9% of the inquiry; and every time, 0 of the 52 responses, accounting for 0% of the inquiry. The overall outcome for this inquiry indicated that the participation among those surveyed for actively writing BIM Technical Specifications for FM was extremely low. The outcome for the participation among those surveyed for giving input for BIM Technical Specification writing was relatively high, showing nearly two thirds of the participants responding sometimes, almost every time, and every time for this query. And the outcome for the participation among those

surveyed for using written BIM Technical Specifications to perform FM tasks was very

low with a vast majority indicating no participation for this category.
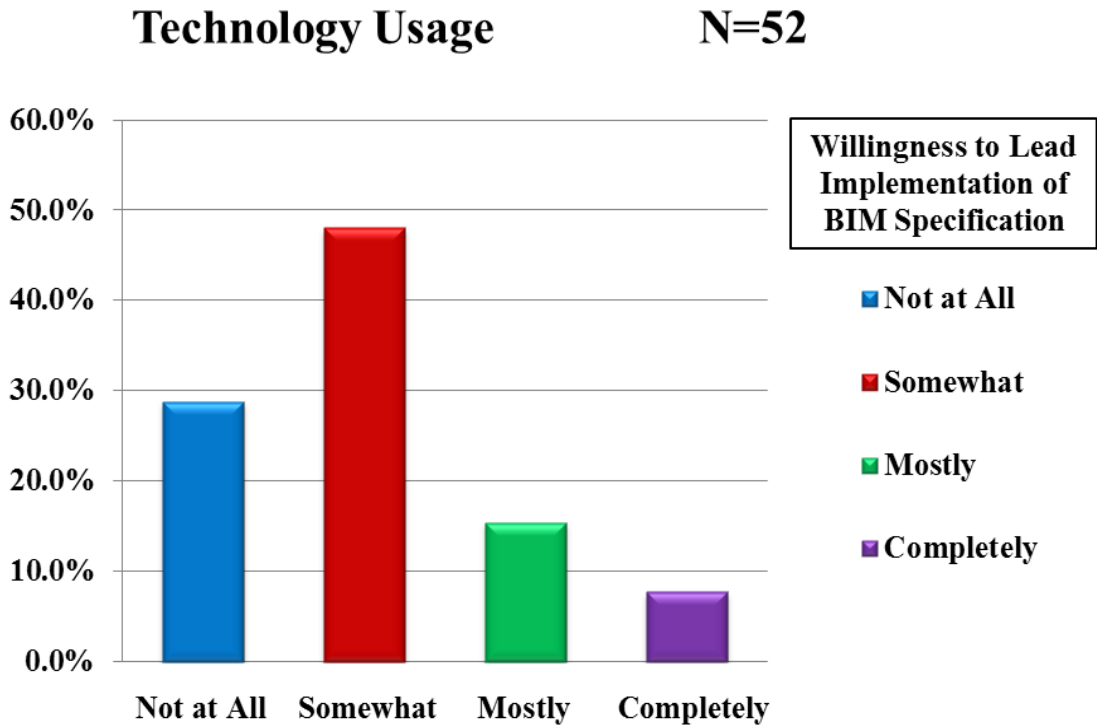
Technology Usage   N=52

Figure 38, Technology Usage Results for Q13. What would be your willingness to lead
the implementation of a better BIM Technical Specification for Facilities Management?

Question thirteen (Q13) was focused on the willingness to lead the

implementation of a better BIM Technical Specification for Facilities Management

(Figure 38). This filtered inquiry presented four possible options of the inquired

willingness; not at all, somewhat, mostly, and completely. The purpose of this question

was to establish the status concerning the willingness to lead the implementation of a

better BIM Technical Specification for Facilities Management and to compare which

status held a greater presence in the study. Of the 52 respondents, 39 indicated that there was no willingness to lead the implementation of a better BIM Technical Specification for Facilities Management, accounting for 28.8% of those polled. Of the 52 respondents, 25 indicated that there was a somewhat likelihood of willingness to lead the implementation of a better BIM Technical Specification for Facilities Management, accounting for 48.1% of those polled. Of the 52 respondents, 8 indicated that there was a mostly likelihood of willingness to lead the implementation of a better BIM Technical Specification for Facilities Management, accounting for 15.4% of those polled. And finally, 4 of the 52 respondents surveyed indicated that there was a completely likelihood of willingness to lead the implementation of a better BIM Technical Specification for Facilities Management, accounting for 7.7% of those polled. The overall outcome for this inquiry illustrated that less than a third of the surveyed participants confirmed that there was no willingness to lead the implementation of a better BIM Technical Specification for Facilities Management, while the remaining two thirds indicated that there was somewhat, mostly, or completely responses for the willingness to lead the implementation of a better BIM Technical Specification for Facilities Management.

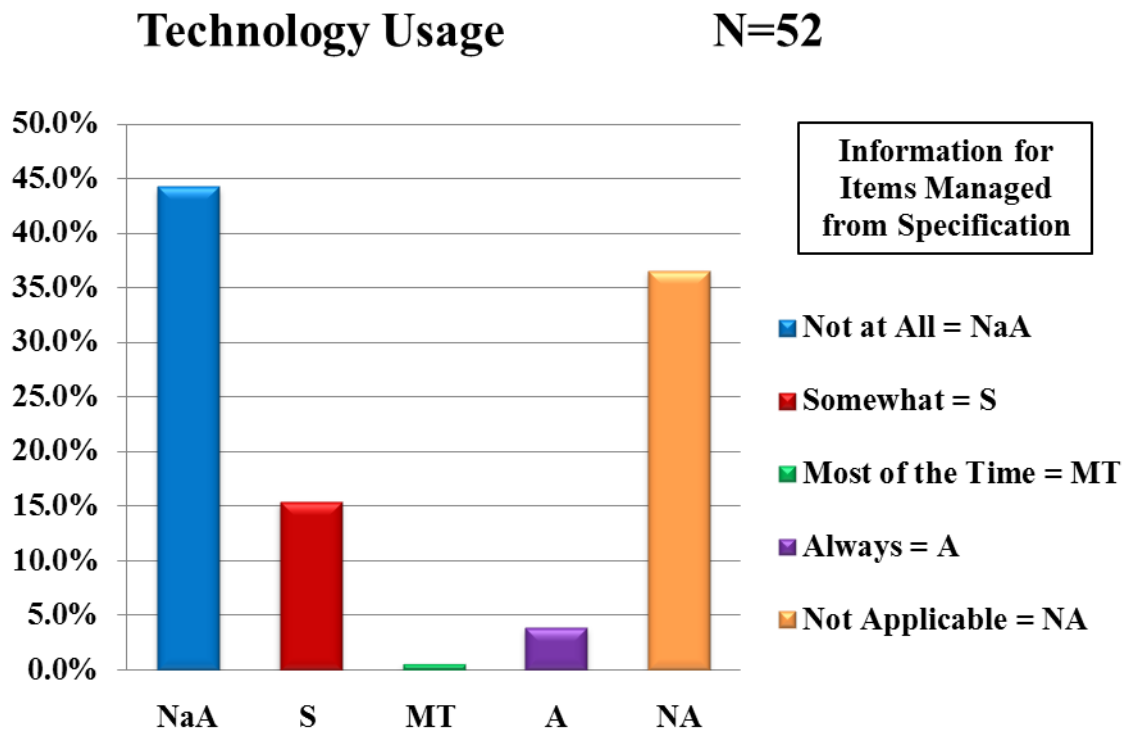**Technology Usage   N=52**

Figure 39, Technology Usage Results for Q14. Does your BIM Technical Specification provide detailed information about items you manage?

Question fourteen (Q14) addressed the inquiry focused on the ability of BIM Technical Specification to provide detailed information about the items managed in facilities management (Figure 39). The filtered question was scripted with five possible outcomes; not at all, somewhat, most of the time, always, and not applicable. The purpose of this question was to establish the status concerning the ability of BIM Technical Specification to provide detailed information about the items managed in facilities management and to compare which status held a greater presence in the study. Of the 52 respondents, 23 indicated that the BIM Technical Specification did not provide detailed information about the items managed in facilities management, accounting for

44.2% of those polled. Of the 52 respondents, 8 indicated that the BIM Technical

Specification somewhat provided detailed information about the items managed in

facilities management, accounting for 15.4% of those polled. Of the 52 respondents, 0

indicated that the BIM Technical Specification provide detailed information most of the

time about the items managed in facilities management, accounting for 0% of those

polled. Of the 52 respondents, 2 indicated that the BIM Technical Specification always

provided detailed information about the items managed in facilities management,

accounting for 3.8% of those polled. And of the 52 respondents, 19 indicated that the

BIM Technical Specification was not applicable for providing detailed information

about the items managed in facilities management, accounting for 36.5% of those polled.

The outcome of the inquiry of the ability of BIM Technical Specification to provide

detailed information about the items managed in facilities management found that more

than a third of the surveyed signaled that it was not applicable to the FM process. Less

than 20% found that BIM Technical Specifications provided detailed information about
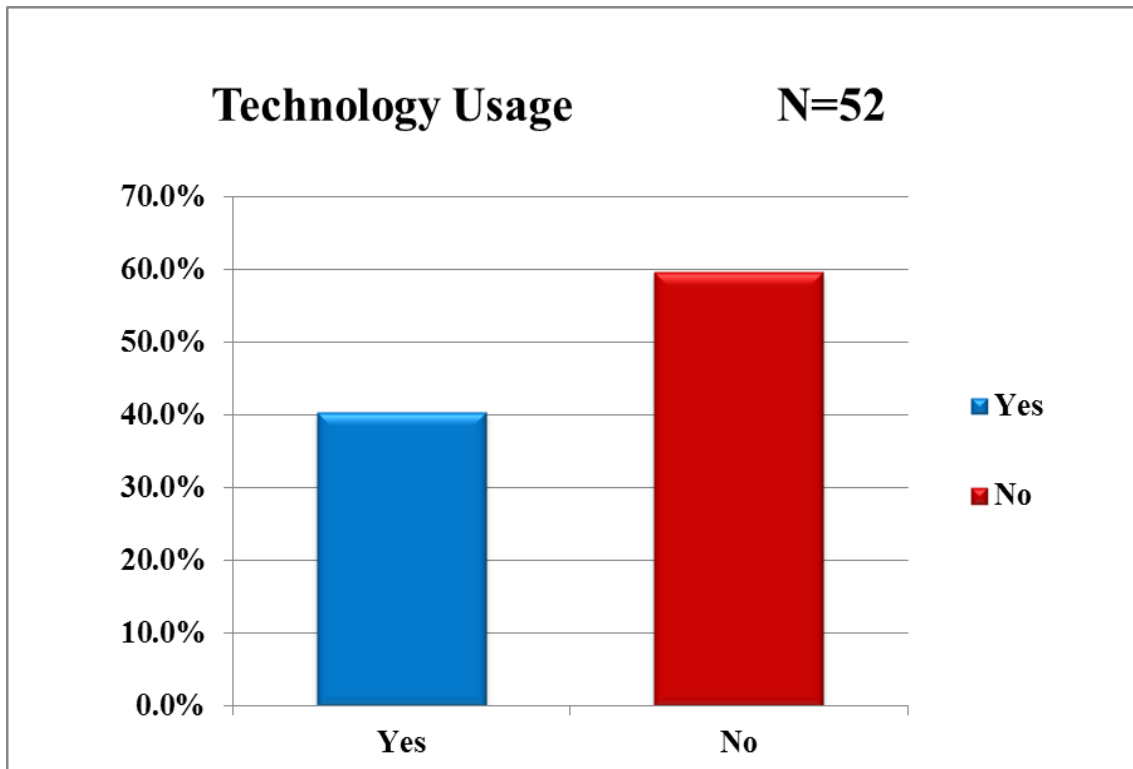
the items managed in facilities management.

Figure 40, Technology Usage Results for Q15. Are you familiar with Construction Operations Building Information Exchange (COBie)?

Question fifteen (Q15) posed the familiarity with Construction Operations Building Information Exchange (COBie). This dichotomous structured inquiry presented a yes \ no response option for the surveyed participant (Figure 40). The purpose of this inquiry was to identify whether the survey participant was familiar with COBie and to compare which status held a greater presence in the study. The results indicate that of the 52 survey participants, 21 responded yes and were familiar with COBie, while 31 responded no and were not familiar with COBie, accounting for 40.4% and 59.6%, respectively. The potential of determining any impact or significance to the study of

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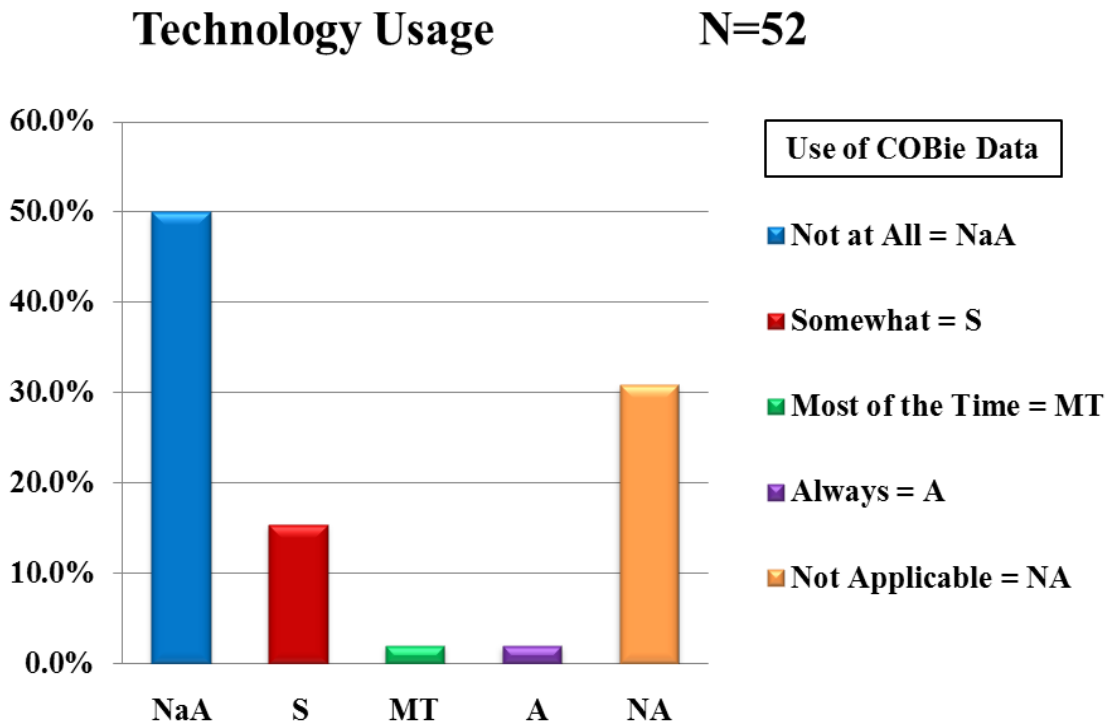participants being familiar or not familiar with COBie was not feasible due to the size of the sample.

Figure 41, Technology Usage Results for Q16. Does your facilities software use COBie data?

Question sixteen (Q16) addressed the inquiry focused on the use of COBie data in facilities management (Figure 41). The filtered question was scripted with five possible outcomes; not at all, somewhat, most of the time, always, and not applicable. The purpose of this question was to establish the status concerning the use of COBie data in facilities management and to compare which status held a greater presence in the study. Of the 52 respondents, 26 indicated that the use of COBie data in facilities

management was not used at all, accounting for 50.0% of those polled. Of the 52

respondents, 8 indicated that the use of COBie data in facilities management was used

somewhat, accounting for 15.4% of those polled. Of the 52 respondents, 1 indicated that

the use of COBie data in facilities management was used most of the time, accounting

for 1.9% of those polled. Of the 52 respondents, 1 indicated that the use of COBie data

in facilities management was always used, accounting for 1.9% of those polled. And of

the 52 respondents, 16 indicated that the use of COBie data in facilities management was

not applicable, accounting for 30.8% of those polled. The outcome of the inquiry of the

use of COBie data in facilities management found that nearly a third of the surveyed

signaled that it was not applicable to the FM process. Additionally, less than 20% found

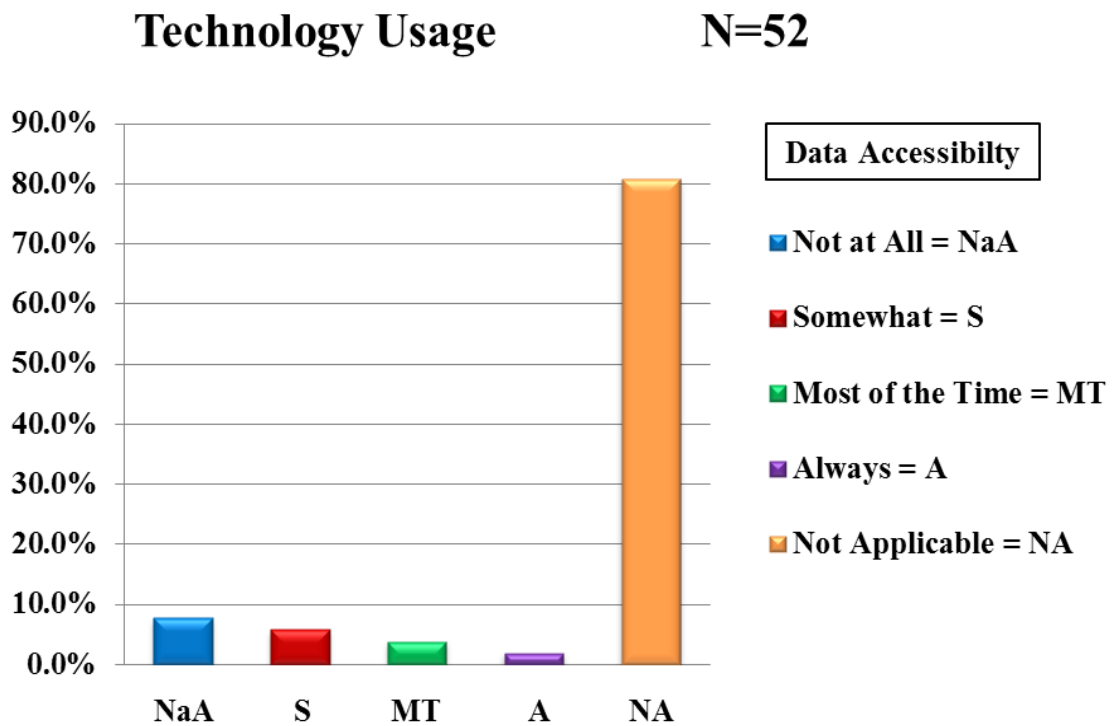that the use of COBie data in facilities management was being utilized.

Figure 42, Technology Usage Results for Q17. If you use COBie, is the data easily accessible for FM tasks?

Question seventeen (Q17) addressed the inquiry centered on the use of COBie data and the ease of data access for facilities management tasks (Figure 42). The filtered question was scripted with five possible outcomes; not at all, somewhat, most of the time, always, and not applicable. The purpose of this question was to establish the status concerning the use of COBie data and the ease of data access for facilities management tasks and to compare which status held a greater presence in the study. Of the 52 respondents, 4 indicated that the use of COBie data and the ease of data access for facilities management tasks was not used at all, accounting for 7.7% of those polled. Of the 52 respondents, 3 indicated that the use of COBie data and the ease of data access for

facilities management tasks was used somewhat, accounting for 5.8% of those polled. Of the 52 respondents, 2 indicated that the use of COBie data and the ease of data access for facilities management tasks were used most of the time, accounting for 3.8% of those polled. Of the 52 respondents, 1 indicated that the use of COBie data and the ease of data access for facilities management tasks was always used, accounting for 1.9% of those polled. And of the 52 respondents, 42 indicated that the use of COBie data and the ease of data access for facilities management tasks was not applicable, accounting for 80.8% of those polled. The outcome of the inquiry of the use of COBie data and the ease of data access for facilities management tasks found that over three quarters of the surveyed signaled that it was not applicable to the FM process. Additionally, only 6 of the 52 respondents, 11.5%, found that the use of COBie data and the ease of data access for facilities management tasks were being utilized.
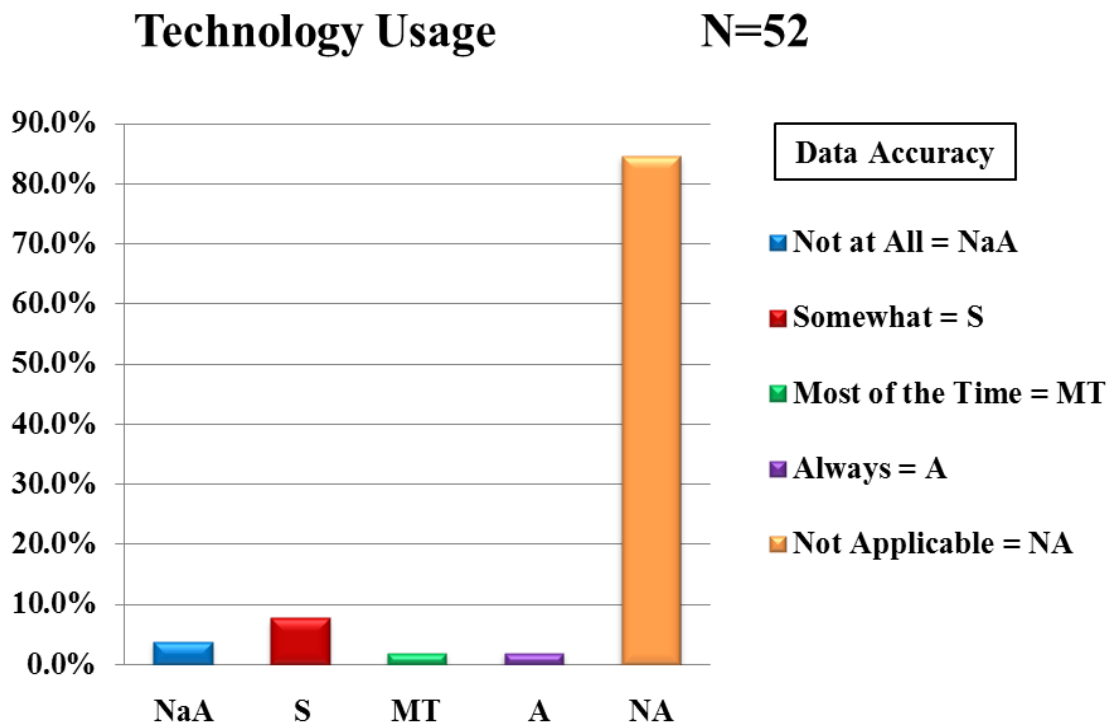
Figure 43, Technology Usage Results for Q18. If you use COBie, is the accessible data accurate?

Question eighteen (Q18) addressed the inquiry concentrated on the use of COBie data and the accuracy of the accessible data for facilities management tasks (Figure 43). The filtered question was scripted with five possible outcomes; not at all, somewhat, most of the time, always, and not applicable. The purpose of this question was to establish the status concerning the use of COBie data and the accuracy of the accessible data for facilities management tasks and to compare which status held a greater presence in the study. Of the 52 respondents, 2 indicated that the use of COBie data and the accuracy of the accessible data for facilities management tasks was not used at all, accounting for 3.8% of those polled. Of the 52 respondents, 4 indicated that the use of

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COBie data and the accuracy of the accessible data for facilities management tasks was used somewhat, accounting for 7.7% of those polled. Of the 52 respondents, 1 indicated that the use of COBie data and the accuracy of the accessible data for facilities management tasks were used most of the time, accounting for 1.9% of those polled. Of the 52 respondents, 1 indicated that the use of COBie data and the accuracy of the accessible data for facilities management tasks was always used, accounting for 1.9% of those polled. And of the 52 respondents, 44 indicated that the use of COBie data and the accuracy of the accessible data for facilities management tasks was not applicable, accounting for 84.6% of those polled. The outcome of the inquiry of the use of COBie data and the accuracy of the accessible data for facilities management tasks found that well over three quarters of the surveyed signaled that it was not applicable to the FM process. Additionally, only 6 of the 52 respondents, 11.5%, found that the use of COBie data and the accuracy of the accessible data for facilities management tasks were being utilized.

Technology Usage   **N=52**

Legend:
- Photographic Images
- 2D Paper Blueprints
- 2D Electronic Files
- 3D Electronic Building Models
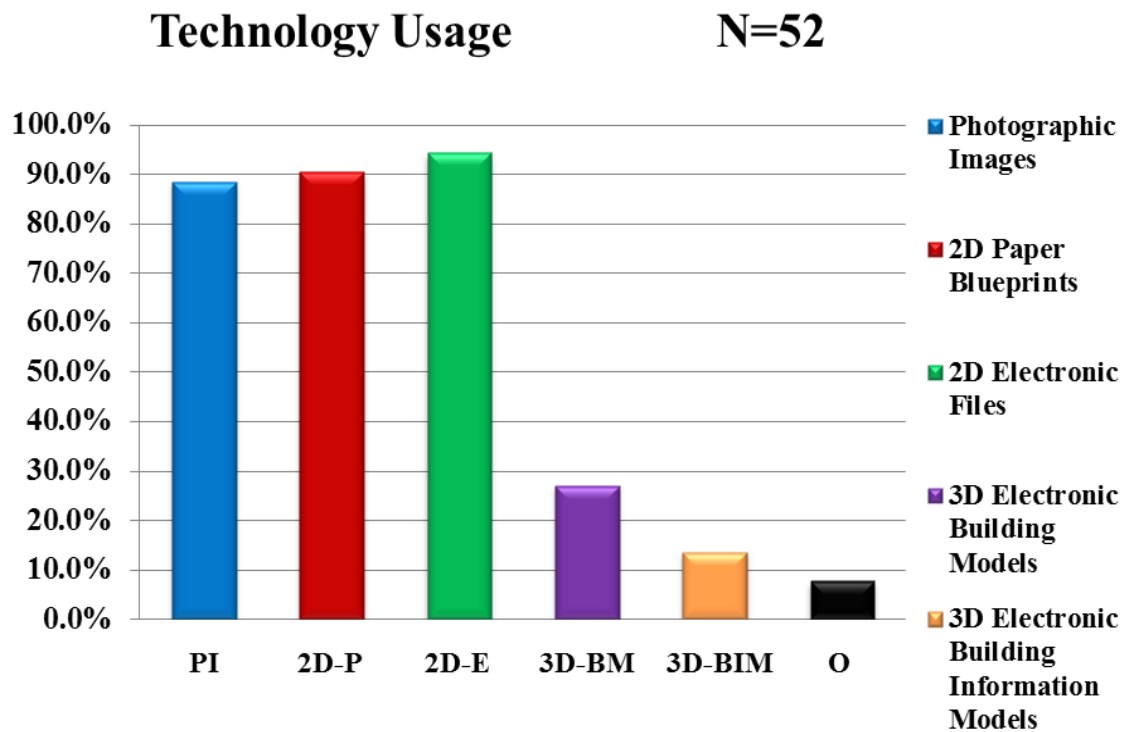- 3D Electronic Building Information Models

Figure 44, Technology Usage Results for Q19. What kind of documents do you utilize for Facilities Management (answer all that apply)?

Question nineteen (Q19) addressed the inquiry focused on the type of documents utilized for facilities management (Figure 44). The filtered \ open ended question was scripted with six possible outcomes; photographic images, 2D paper blueprints, 2D electronic files, 3D electronic building models, 3D electronic building information models, and other (an open ended description). This inquiry gave the respondent the option to check all of the presented options that apply to each participant's usage; with the last option being an open ended response. The purpose of this inquiry was to establish the type of documents utilized for facilities management among the surveyed participants and to compare which type of documents were commonly used for facilities

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management processes at the varied institutions. Of the 52 respondents, 46 indicated that the type of documents utilized for facilities management included the use of photographic images, accounting for 88.5% of the surveyed participants. Of the 52 respondents, 47 indicated that the type of documents utilized for facilities management included the use of 2D paper blueprints, accounting for 90.4% of the surveyed participants. Of the 52 respondents, 49 indicated that the type of documents utilized for facilities management included the use of 2D electronic files, accounting for 94.2% of the surveyed participants. Of the 52 respondents, 14 indicated that the type of documents utilized for facilities management included the use of 3D electronic building models, accounting for 26.9% of the surveyed participants. Of the 52 respondents, 7 indicated that the type of documents utilized for facilities management included the use of 3D electronic building information models, accounting for 13.5% of the surveyed participants. Of the 52 respondents, 4 indicated that the type of documents utilized for facilities management included the use of other, accounting for 7.7% of the surveyed participants. The other option consisted of a range that included; work order sheets, small format operations & maintenance manuals, specifications, and GIS mapping. The outcome of the inquiry of the type of documents utilized for facilities management indicated that over 90% of those polled utilized photographic images, 2D paper blueprints, and 2D electronic files. Another outcome of the inquiry found that over a quarter of those polled used 3D building models, while less than 14% were using 3D building information models. The category associated with the other types of documents utilized for facilities management only accounted for 4 of the 52 surveyed participants.
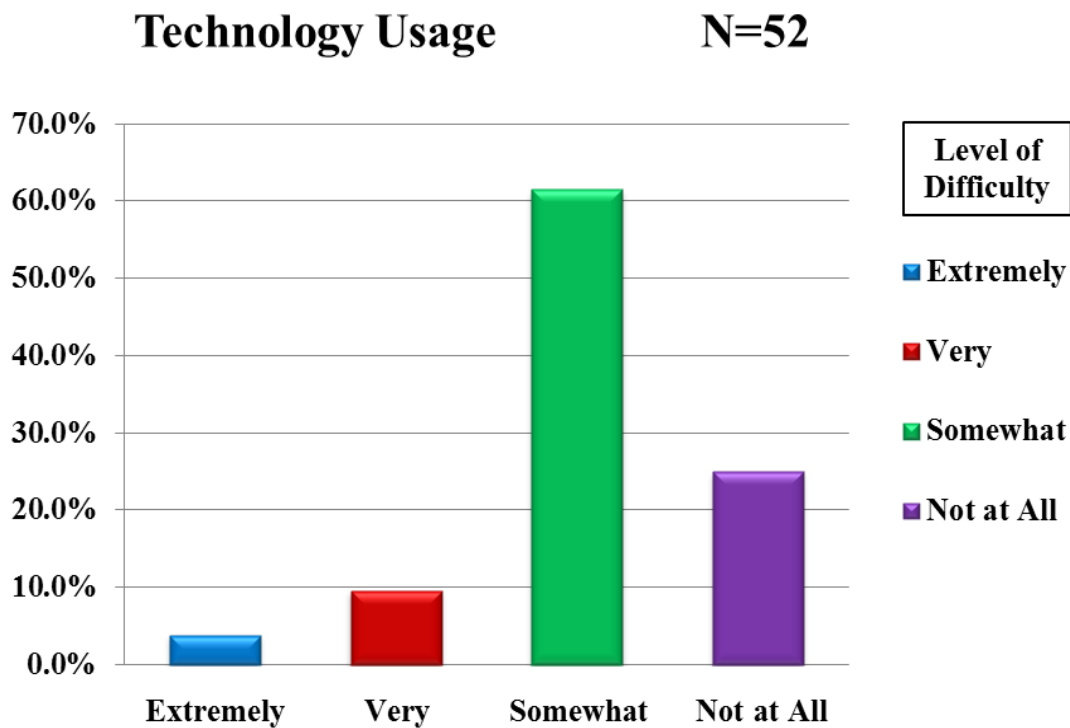
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Figure 45, Technology Usage Results for Q20. Based on the documents you currently use, describe the level of difficulty to extract information for Facility Management?

Question twenty (Q20) targeted the level of difficulty to extract information for facilities management based on the current use of the documents utilized at the varied institutions (Figure 45). This filtered inquiry presented four possible options of the inquired level of difficulty of information extraction; extremely, very, somewhat, and not at all. The purpose of this inquiry was to establish the level of difficulty to extract information for facilities management based on the current use of the documents utilized and to compare those utilized among the responses of the participants of the varied institutions. Of the 52 respondents, 2 indicated that the level of difficulty to extract information for facilities management based on the current use of the documents utilized

was extremely difficult, accounting for 3.8% of those polled. Of the 52 respondents, 5 indicated that the level of difficulty to extract information for facilities management based on the current use of the documents utilized was very difficult, accounting for 9.6% of those polled. Of the 52 respondents, 32 indicated that the level of difficulty to extract information for facilities management based on the current use of the documents utilized was somewhat difficult, accounting for 61.5% of those polled. And finally, 13 of the 52 respondents indicated that the level of difficulty to extract information for facilities management based on the current use of the documents utilized was not at all difficult, accounting for 25.0% of those polled. The overall outcome for this inquiry illustrated that exactly one quarter of the surveyed participants confirmed that there was no level of difficulty associated with the extraction of information for facilities management based on the current use of the documents utilized. Additionally, the outcomes found that three quarters of those polled did find difficulty associated with the extraction of information for facilities management based on the current use of the documents utilized.

Learning Styles Descriptive Analysis

The intent of the questions pertaining to learning styles was to establish the means and methods of how the participants learn. This knowledge is critical for training curriculums and can assist with building a better understanding of steps necessary to establish a more efficient training program among Facilities Management teams. There were ten questions in this section, of which, are individually described. The analysis

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consists of three parts; a description of the inquiry, the purpose or reasoning for the inquiry, and a summary of the question with the description of its outcome.

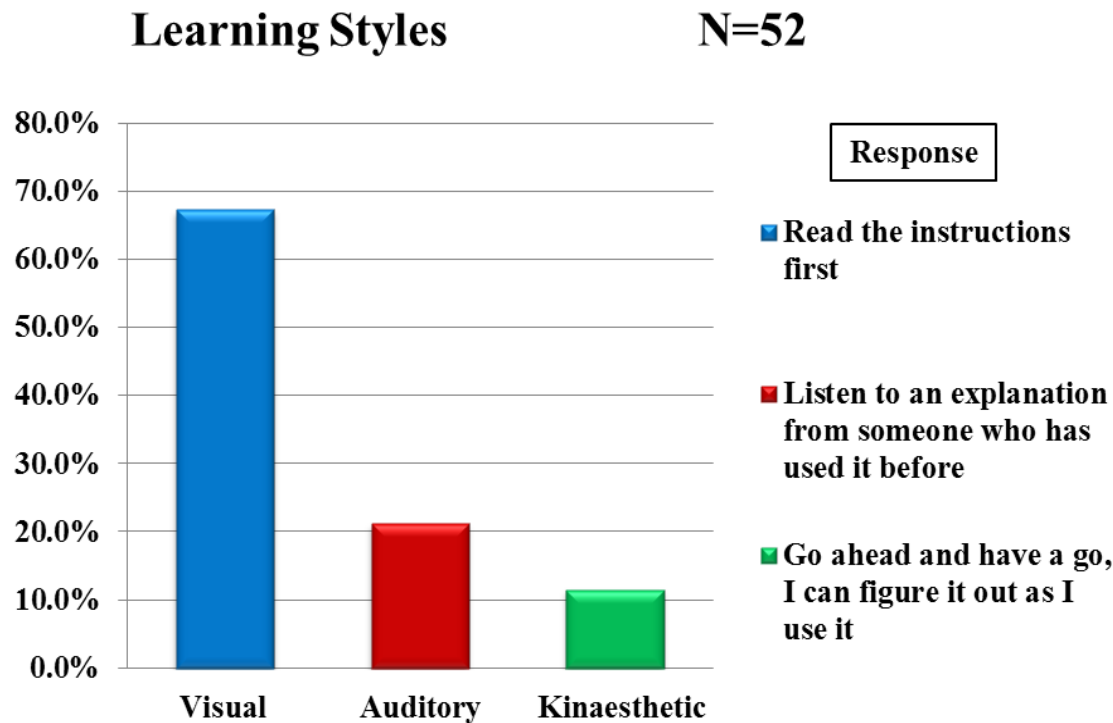**Learning Styles**   **N=52**

Figure 46, Learning Styles Results for Q21. When I operate new equipment I generally:

Question twenty one (Q21) was focused on the learning style of the surveyed participant. The question was not targeted towards activities specific to facilities management, but designed to create a scenario that triggered a comfortable and natural reaction to the inquiry for each participant. This filtered inquiry presented three options for the participant to select; a reading or writing option, a talking or listening option, and a doing or demonstrating option (Figure 46). The responses were matched to a categorized outcome that served as an indicator which characterized the learning style of

the participant. The purpose of this inquiry was to determine what type of learning category the surveyed participant was best suited; visual, auditory, and kinaesthetic. Of the 52 surveyed participants, 35 responded with a visual learning style outcome, representing 67.3% of the respondents for this inquiry. Of the 52 surveyed participants, 11 responded with an auditory learning style outcome, representing 21.2% of the respondents for this inquiry. And of the 52 surveyed participants, 6 responded with a kinaesthetic learning style outcome, representing 11.5% of the respondents for this inquiry. The overall outcome of this question indicated that nearly two thirds of those polled were in the visual learning style category. The auditory learning style consisted of over 20% of those polled, while the kinaesthetic learning style held just over 10% of those polled for this inquiry. This particular scenario appeared to be dominated by the visual learning style.
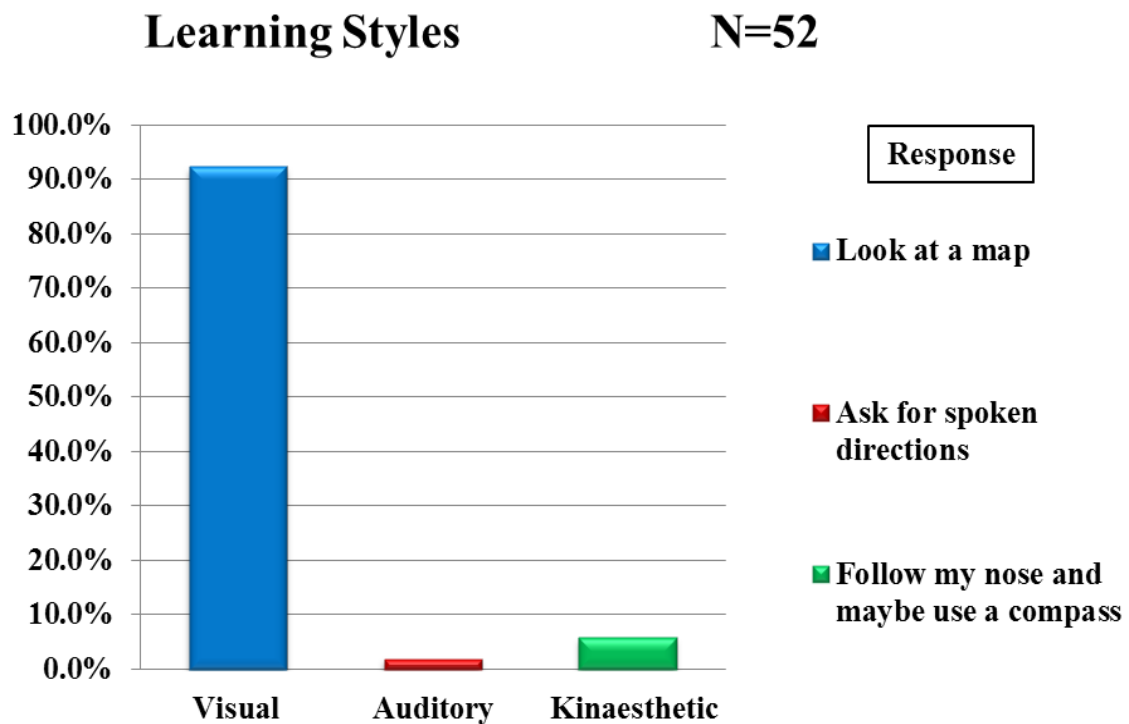
Learning Styles N=52

Figure 47, Learning Styles Results for Q22. When I need directions for traveling I usually:

Question twenty two (Q22) was focused on the learning style of the surveyed participant. The question was not targeted towards activities specific to facilities management, but designed to create a scenario that triggered a comfortable and natural reaction to the inquiry for each participant. This filtered inquiry presented three options for the participant to select; a reading or writing option, a talking or listening option, and a doing or demonstrating option (Figure 47). The responses were matched to a categorized outcome that served as an indicator which characterized the learning style of the participant. The purpose of this inquiry was to determine what type of learning category the surveyed participant was best suited; visual, auditory, and kinaesthetic. Of

the 52 surveyed participants, 48 responded with a visual learning style outcome, representing 92.3% of the respondents for this inquiry. Of the 52 surveyed participants, 1 responded with an auditory learning style outcome, representing 1.9% of the respondents for this inquiry. And of the 52 surveyed participants, 3 responded with a kinaesthetic learning style outcome, representing 5.8% of the respondents for this inquiry. The overall outcome of this question indicated that over 90% of those polled were in the visual learning style category. The auditory learning style consisted of only 1 of the 52 surveyed participants, while the kinaesthetic learning style held just over 5% of those polled for this inquiry. This particular scenario was dominated by the visual learning style.
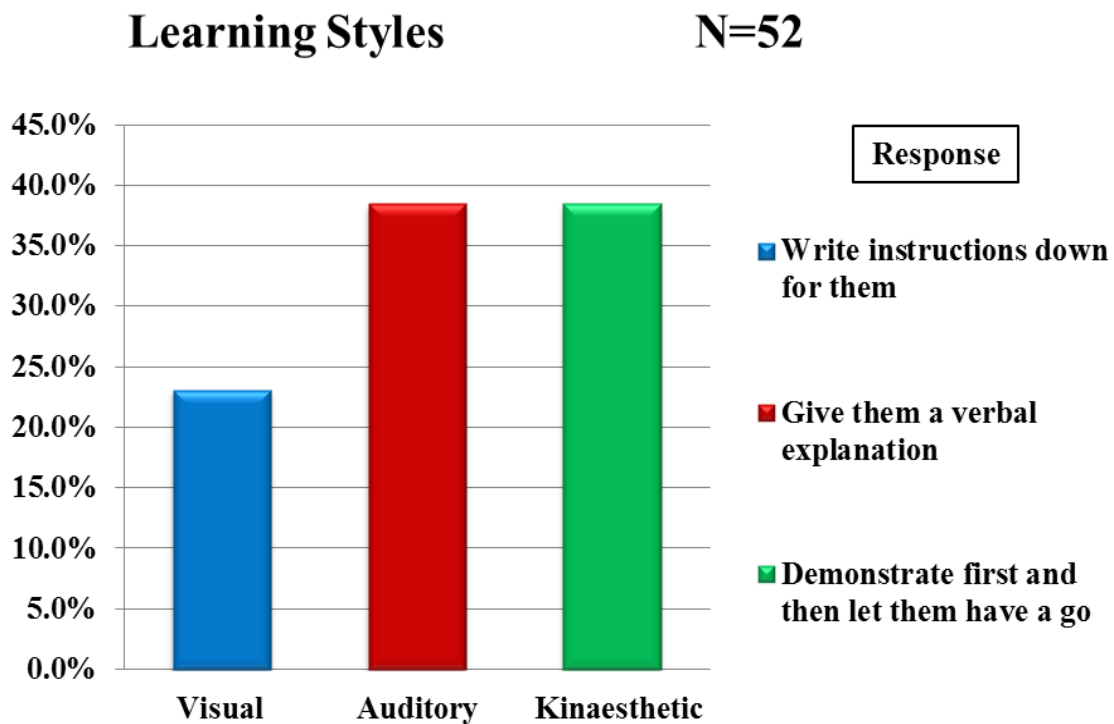
Learning Styles N=52

Figure 48, Learning Styles Results for Q23. If I am teaching someone something new, I tend to:

Question twenty three (Q23) was focused on the learning style of the surveyed participant. The question was not targeted towards activities specific to facilities management, but designed to create a scenario that triggered a comfortable and natural reaction to the inquiry for each participant. This filtered inquiry presented three options for the participant to select; a reading or writing option, a talking or listening option, and a doing or demonstrating option (Figure 48). The responses were matched to a categorized outcome that served as an indicator which characterized the learning style of the participant. The purpose of this inquiry was to determine what type of learning category the surveyed participant was best suited; visual, auditory, and kinaesthetic. Of

the 52 surveyed participants, 12 responded with a visual learning style outcome, representing 23.1% of the respondents for this inquiry. Of the 52 surveyed participants, 20 responded with an auditory learning style outcome, representing 38.5% of the respondents for this inquiry. And of the 52 surveyed participants, 20 responded with a kinaesthetic learning style outcome, representing 38.5% of the respondents for this inquiry. The overall outcome of this question indicated that less than one quarter of those polled was in the visual learning style category. The auditory learning style consisted of 20 of the 52 surveyed participants, while the kinaesthetic learning style held the exact number of responses as the auditory learning style of those polled for this inquiry. This particular scenario appeared to give a slight edge to the auditory and kinaesthetic learning styles over the visual learning style.

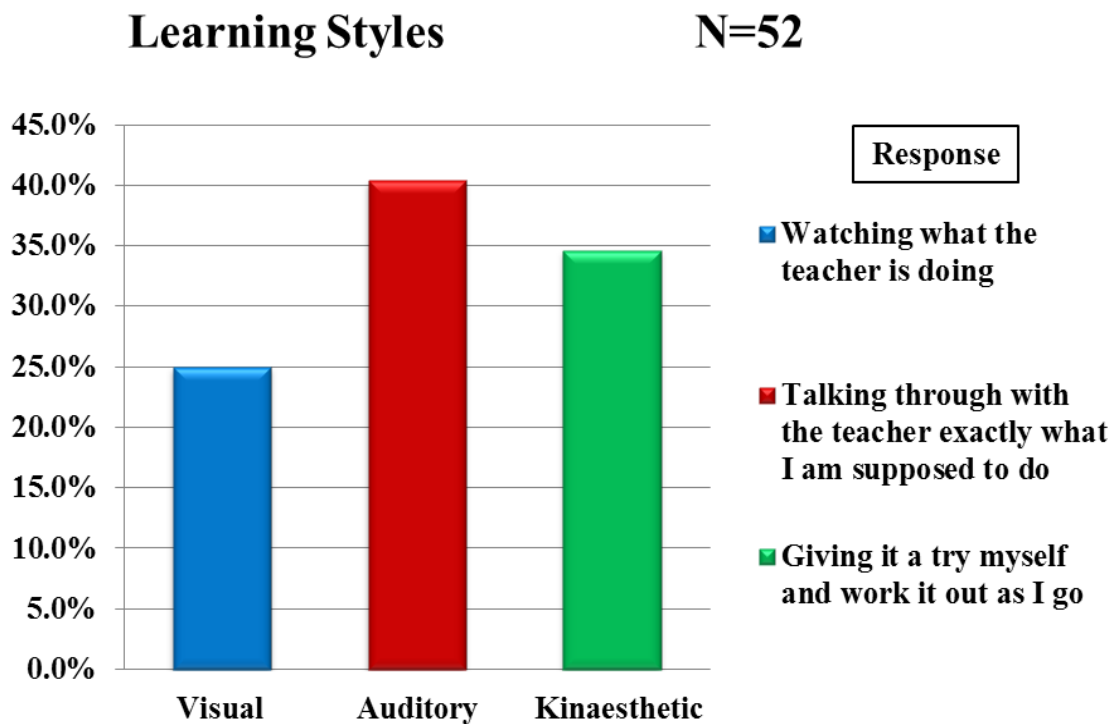## Learning Styles   N=52

Figure 49, Learning Styles Results for Q24. When I am learning a new skill, I am most comfortable:

Question twenty four (Q24) was focused on the learning style of the surveyed participant. The question was not targeted towards activities specific to facilities management, but designed to create a scenario that triggered a comfortable and natural reaction to the inquiry for each participant. This filtered inquiry presented three options for the participant to select; a reading or writing option, a talking or listening option, and a doing or demonstrating option (Figure 49). The responses were matched to a categorized outcome that served as an indicator which characterized the learning style of the participant. The purpose of this inquiry was to determine what type of learning category the surveyed participant was best suited; visual, auditory, and kinaesthetic. Of

the 52 surveyed participants, 13 responded with a visual learning style outcome, representing 25.0% of the respondents for this inquiry. Of the 52 surveyed participants, 21 responded with an auditory learning style outcome, representing 40.4% of the respondents for this inquiry. And of the 52 surveyed participants, 18 responded with a kinaesthetic learning style outcome, representing 34.6% of the respondents for this inquiry. The overall outcome of this question indicated that one quarter of those polled were in the visual learning style category. The auditory learning style consisted of over 40% of those polled, while the kinaesthetic learning style held just under 35% of those polled for this inquiry. This particular scenario appeared to illustrate a slight edge by the auditory learning style.
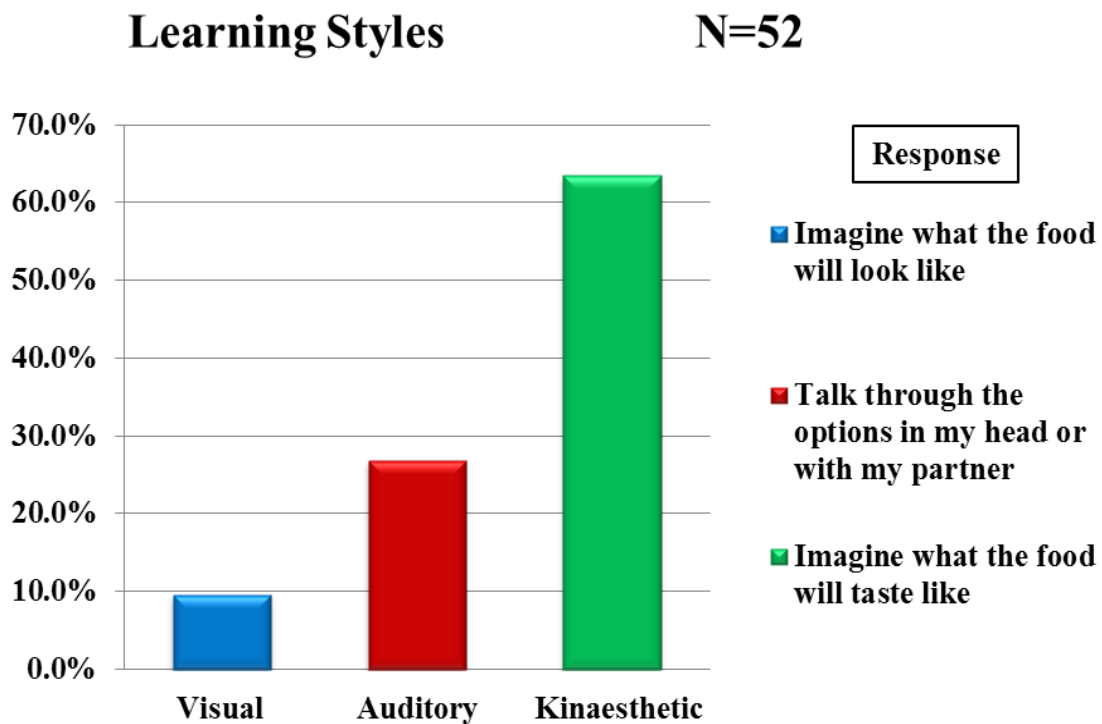
Learning Styles   N=52

Figure 50, Learning Styles Results for Q25. If I am choosing food off a menu, I tend to:

Question twenty five (Q25) was focused on the learning style of the surveyed participant. The question was not targeted towards activities specific to facilities management, but designed to create a scenario that triggered a comfortable and natural reaction to the inquiry for each participant. This filtered inquiry presented three options for the participant to select; a reading or writing option, a talking or listening option, and a doing or demonstrating option (Figure 50). The responses were matched to a categorized outcome that served as an indicator which characterized the learning style of the participant. The purpose of this inquiry was to determine what type of learning category the surveyed participant was best suited; visual, auditory, and kinaesthetic. Of the 52 surveyed participants, 5 responded with a visual learning style outcome,

representing 9.6% of the respondents for this inquiry. Of the 52 surveyed participants, 14 responded with an auditory learning style outcome, representing 26.9% of the respondents for this inquiry. And of the 52 surveyed participants, 33 responded with a kinaesthetic learning style outcome, representing 63.5% of the respondents for this inquiry. The overall outcome of this question indicated that less than 10% of those polled were in the visual learning style category. The auditory learning style consisted of just over one quarter of those polled, while the kinaesthetic learning style held nearly two thirds those polled for this inquiry, with 33 of the 52 surveyed participants. This particular scenario appeared to be dominated by the kinaesthetic learning style.
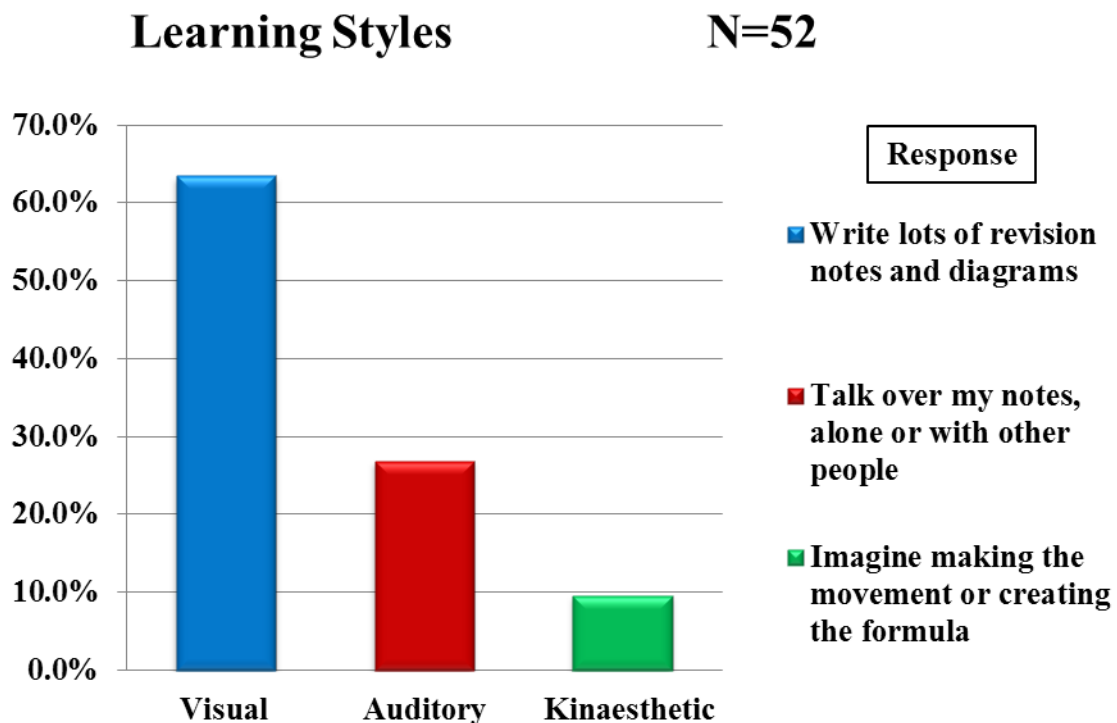

Figure 51, Learning Styles Results for Q26. When I have to revise for an exam, I generally:

Question twenty six (Q26) was focused on the learning style of the surveyed participant. The question was not targeted towards activities specific to facilities management, but designed to create a scenario that triggered a comfortable and natural reaction to the inquiry for each participant. This filtered inquiry presented three options for the participant to select; a reading or writing option, a talking or listening option, and a doing or demonstrating option (Figure 51). The responses were matched to a categorized outcome that served as an indicator which characterized the learning style of the participant. The purpose of this inquiry was to determine what type of learning category the surveyed participant was best suited; visual, auditory, and kinaesthetic. Of the 52 surveyed participants, 33 responded with a visual learning style outcome, representing 63.5% of the respondents for this inquiry. Of the 52 surveyed participants, 14 responded with an auditory learning style outcome, representing 26.9% of the respondents for this inquiry. And of the 52 surveyed participants, 5 responded with a kinaesthetic learning style outcome, representing 9.6% of the respondents for this inquiry. The overall outcome of this question indicated that nearly two thirds of those polled were in the visual learning style category. The auditory learning style consisted of more than one quarter of those polled, while the kinaesthetic learning style held just under 10% of those polled for this inquiry. This particular scenario appeared to be dominated by the visual learning style.
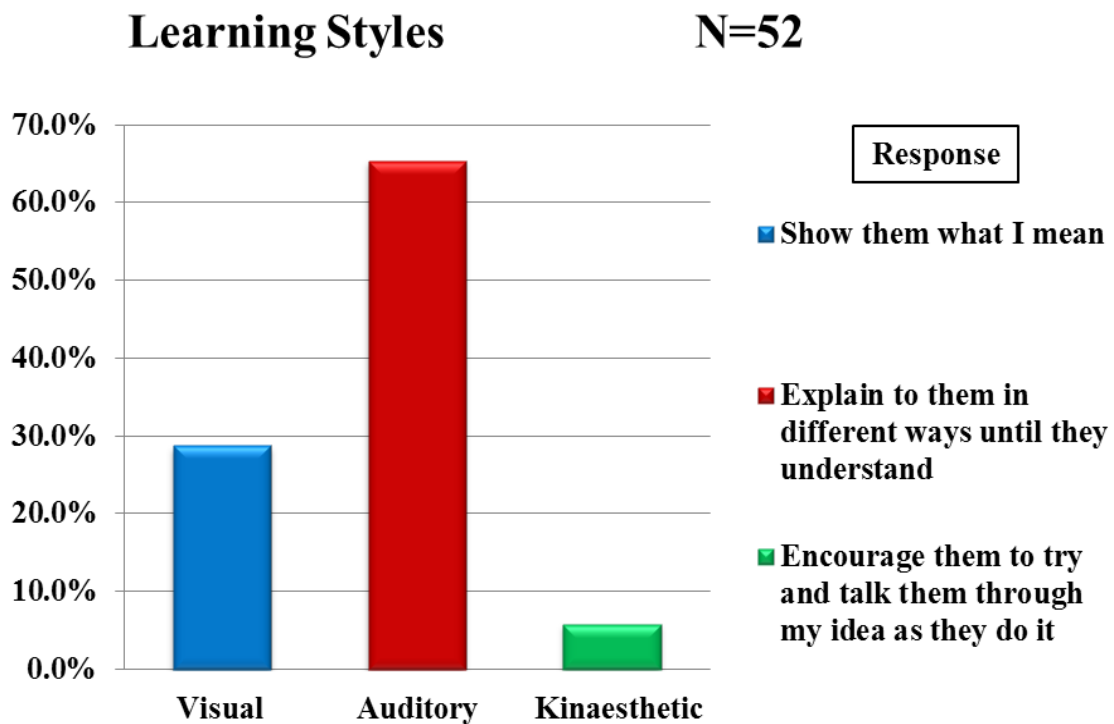
Learning Styles   **N=52**

Figure 52, Learning Styles Results for Q27. If I am explaining to someone I tend to:

Question twenty seven (Q27) was focused on the learning style of the surveyed

participant. The question was not targeted towards activities specific to facilities

management, but designed to create a scenario that triggered a comfortable and natural

reaction to the inquiry for each participant. This filtered inquiry presented three options

for the participant to select; a reading or writing option, a talking or listening option, and

a doing or demonstrating option (Figure 52). The responses were matched to a

categorized outcome that served as an indicator which characterized the learning style of

the participant. The purpose of this inquiry was to determine what type of learning

category the surveyed participant was best suited; visual, auditory, and kinaesthetic. Of

the 52 surveyed participants, 15 responded with a visual learning style outcome,

representing 28.8% of the respondents for this inquiry. Of the 52 surveyed participants, 34 responded with an auditory learning style outcome, representing 65.4% of the respondents for this inquiry. And of the 52 surveyed participants, 3 responded with a kinaesthetic learning style outcome, representing 5.8% of the respondents for this inquiry. The overall outcome of this question indicated that just over one quarter of those polled were in the visual learning style category. The auditory learning style consisted of nearly two thirds of those polled, while the kinaesthetic learning style held only 3 of the 52 surveyed participants for this inquiry. This particular scenario illustrated that the auditory learning style appeared to be the majority choice.
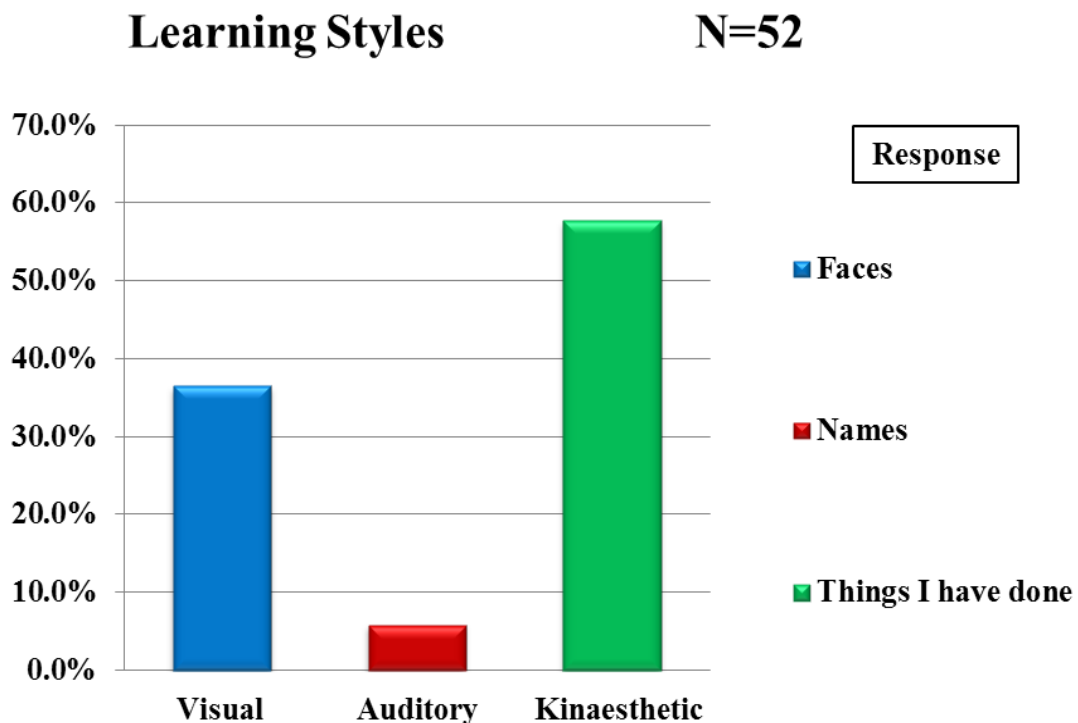

Figure 53, Learning Styles Results for Q28. I find it easiest to remember:

Question twenty eight (Q28) was focused on the learning style of the surveyed participant. The question was not targeted towards activities specific to facilities management, but designed to create a scenario that triggered a comfortable and natural reaction to the inquiry for each participant. This filtered inquiry presented three options for the participant to select; a reading or writing option, a talking or listening option, and a doing or demonstrating option (Figure 53). The responses were matched to a categorized outcome that served as an indicator which characterized the learning style of the participant. The purpose of this inquiry was to determine what type of learning category the surveyed participant was best suited; visual, auditory, and kinaesthetic. Of the 52 surveyed participants, 19 responded with a visual learning style outcome, representing 36.5% of the respondents for this inquiry. Of the 52 surveyed participants, 3 responded with an auditory learning style outcome, representing 5.8% of the respondents for this inquiry. And of the 52 surveyed participants, 30 responded with a kinaesthetic learning style outcome, representing 57.7% of the respondents for this inquiry. The overall outcome of this question indicated that over a third of those polled were in the visual learning style category. The auditory learning style consisted of only 3 of the 52 surveyed participants, while the kinaesthetic learning style accounted for over half of those polled for this inquiry. This particular scenario presented an edge for the majority of those polled by the kinaesthetic learning style.
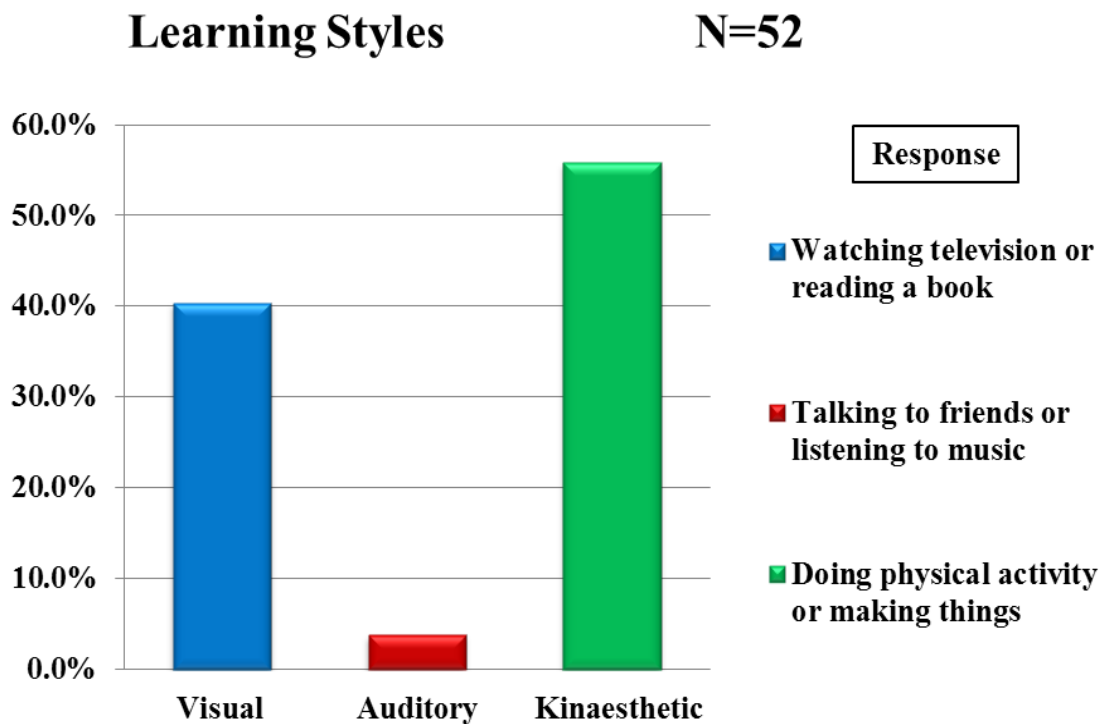
Learning Styles   N=52

Figure 54, Learning Styles Results for Q29. Most of my free time is spent:

Question twenty nine (Q29) was focused on the learning style of the surveyed

participant. The question was not targeted towards activities specific to facilities

management, but designed to create a scenario that triggered a comfortable and natural

reaction to the inquiry for each participant. This filtered inquiry presented three options

for the participant to select; a reading or writing option, a talking or listening option, and

a doing or demonstrating option (Figure 54). The responses were matched to a

categorized outcome that served as an indicator which characterized the learning style of

the participant. The purpose of this inquiry was to determine what type of learning

category the surveyed participant was best suited; visual, auditory, and kinaesthetic. Of

the 52 surveyed participants, 21 responded with a visual learning style outcome,

representing 40.4% of the respondents for this inquiry. Of the 52 surveyed participants, 2 responded with an auditory learning style outcome, representing 3.8% of the respondents for this inquiry. And of the 52 surveyed participants, 29 responded with a kinaesthetic learning style outcome, representing 55.8% of the respondents for this inquiry. The overall outcome of this question indicated that over 40% of those polled were in the visual learning style category. The auditory learning style consisted of just 2 of the 52 surveyed participants, while the kinaesthetic learning style held over half of those polled for this inquiry. This particular scenario appeared to be dominated by the kinaesthetic learning style; however, the visual learning style also represented a vast number of those polled.
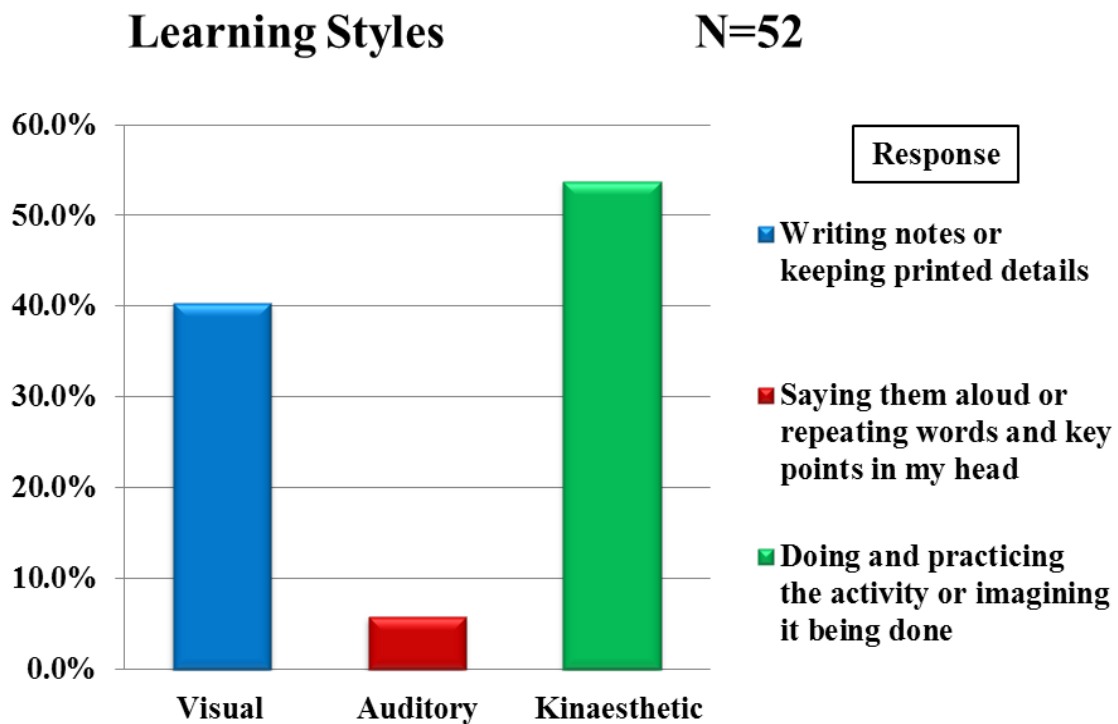
Learning Styles   N=52

Figure 55, Learning Styles Results for Q30. I remember things best by:

Question thirty (Q30) was focused on the learning style of the surveyed

participant. The question was not targeted towards activities specific to facilities

management, but designed to create a scenario that triggered a comfortable and natural

reaction to the inquiry for each participant. This filtered inquiry presented three options

for the participant to select; a reading or writing option, a talking or listening option, and

a doing or demonstrating option (Figure 55). The responses were matched to a

categorized outcome that served as an indicator which characterized the learning style of

the participant. The purpose of this inquiry was to determine what type of learning

category the surveyed participant was best suited; visual, auditory, and kinaesthetic. Of

the 52 surveyed participants, 21 responded with a visual learning style outcome,

representing 40.4% of the respondents for this inquiry. Of the 52 surveyed participants, 3 responded with an auditory learning style outcome, representing 5.8% of the respondents for this inquiry. And of the 52 surveyed participants, 28 responded with a kinaesthetic learning style outcome, representing 53.8% of the respondents for this inquiry. The overall outcome of this question indicated that over 40% of those polled were in the visual learning style category. The auditory learning style consisted of just 3 of the 52 surveyed participants, while the kinaesthetic learning style held over half of those polled for this inquiry. Similar to question twenty nine (Q29), this particular scenario appeared to be dominated by the kinaesthetic learning style; however, the visual learning style also represented a vast number of those polled.

Implementation Descriptive Analysis

It was the intent of the implementation section of the study to establish the levels of importance and the perceived current status of technology implementation for the use of technology in facilities management among varied FM personnel. For the surveyed participants, the implementation section contained only two questions, one of which had several sections. These questions were analyzed in a three part process; a description of the inquiry, the purpose or reasoning for the inquiry, and a summary of the question with the description of its outcome.
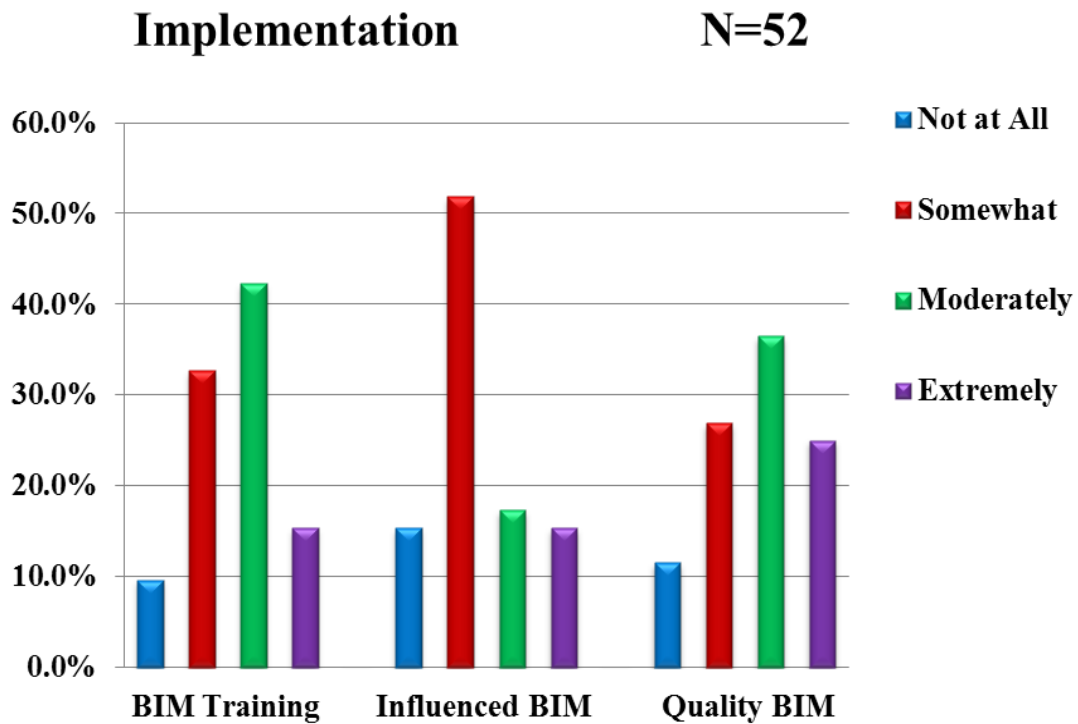
Figure 56, Implementation Results for Q31. Whether you are doing so now, or possibly in the future, rate the importance of the following: BIM Training; Influenced BIM Technical Specification; Quality BIM Model.

Question thirty one (Q31) addressed the importance rating among those polled for the following categories; BIM Training, an Influenced BIM Technical Specification, and a Quality BIM Model (Figure 56). The inquiry presented four levels of participation, in a filtered inquiry, for those polled to select. The purpose of this filtered inquiry was to establish the importance of each of the presented categories and compare those importance ratings among the responses of the participants of the varied institutions. The optional responses presented to the surveyed participants included not at all, somewhat, moderately, and extremely. Concerning the first category of BIM Training, the surveyed participants indicated their respective importance rating to be the following: not at all

important, with 5 of the 52 responses, accounting for 9.6% of the inquiry; somewhat important, with 17 of the 52 responses, accounting for 32.7% of the inquiry; moderately important, with 22 of the 52 responses, accounting for 42.3% of the inquiry; and extremely important, with 8 of the 52 responses, accounting for 15.4% of the inquiry. Concerning the second category of an Influenced BIM Technical Specification, the surveyed participants indicated their respective importance rating to be the following: not at all important, with 8 of the 52 responses, accounting for 15.4% of the inquiry; somewhat important, with 27 of the 52 responses, accounting for 51.9% of the inquiry; moderately important, with 9 of the 52 responses, accounting for 17.3% of the inquiry; and extremely important, with 8 of the 52 responses, accounting for 15.4% of the inquiry. And concerning the last category of a Quality BIM Model, the surveyed participants indicated their respective importance rating to be the following: not at all important, with 6 of the 52 responses, accounting for 11.5% of the inquiry; somewhat important, with 14 of the 52 responses, accounting for 26.9% of the inquiry; moderately important, with 19 of the 52 responses, accounting for 36.5% of the inquiry; and extremely important, with 13 of the 52 responses, accounting for 25.0% of the inquiry. The overall outcome for this inquiry indicated that the importance rating among those surveyed for BIM Training was extremely high, with less than 10% stating that this category was not important. The outcome for the importance rating among those surveyed for an Influenced BIM Technical Specification was also quite high with well over three quarters of those polled signaling this item to be important for this query. And the outcome for the importance rating among those surveyed for a Quality BIM Model

was also quite high with a vast majority deeming this category to be important. Additionally, exactly one quarter of those polled stated that a Quality BIM Model was considered extremely important.
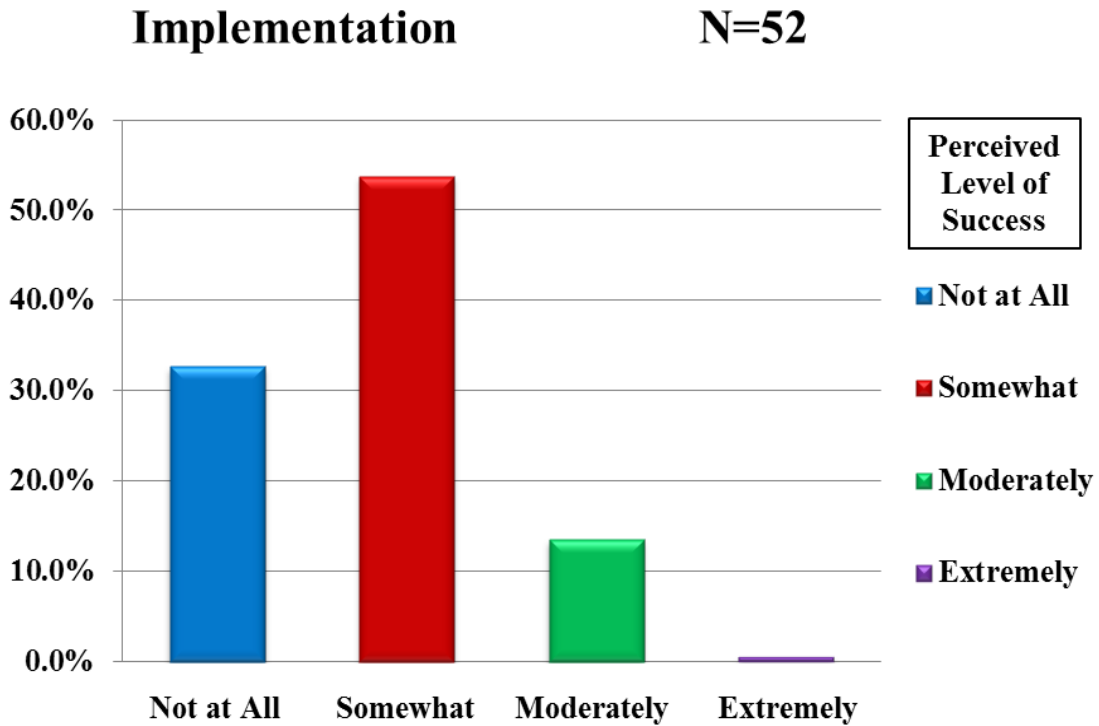

Figure 57, Implementation Results for Q32. Do you perceive that FM Managers \ FM Technicians in your company are successfully using BIM for Facilities Management?

Question thirty two (Q32) targeted the perceived successful usage of BIM for Facilities Management among those polled by FM Managers \ FM Technicians in the respective institutions of the surveyed participants (Figure 57). This filtered inquiry presented four possible options of the inquired perceived level of success associated with the usage of BIM for Facilities Management by FM Managers \ FM Technicians; not at

all, somewhat, moderately, and extremely. The purpose of this inquiry was to establish the level of perceived success associated with the usage of BIM for Facilities Management by FM Managers \ FM Technicians based on the current use of BIM for Facilities Management and to compare those perceptions among the responses of the participants of the varied institutions. Of the 52 respondents, 17 indicated that the perceived level of success associated with the usage of BIM for Facilities Management by FM Managers \ FM based on the current use of BIM for Facilities Management was not at all successful, accounting for 32.7% of those polled. Of the 52 respondents, 28 indicated that the perceived level of success associated with the usage of BIM for Facilities Management by FM Managers \ FM based on the current use of BIM for Facilities Management was somewhat successful, accounting for 53.8% of those polled. Of the 52 respondents, 7 indicated that the perceived level of success associated with the usage of BIM for Facilities Management by FM Managers \ FM based on the current use of BIM for Facilities Management was moderately successful, accounting for 13.5% of those polled. And finally, 0 of the 52 respondents indicated that the perceived level of success associated with the usage of BIM for Facilities Management by FM Managers \ FM based on the current use of BIM for Facilities Management was extremely successful, accounting for 0% of those polled. The overall outcome for this inquiry illustrated that nearly one third of the surveyed participants confirmed that the perceived level of success associated with the usage of BIM for Facilities Management by FM Managers \ FM based on the current use of BIM for Facilities Management was not at all successful. Additionally, the outcomes found that two thirds of those polled did find the

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perceived level of success associated with the usage of BIM for Facilities Management by FM Managers \ FM based on the current use of BIM for Facilities Management to be somewhat to moderately successful. None of those polled found the perceived level of success associated with the usage of BIM for Facilities Management by FM Managers \ FM based on the current use of BIM for Facilities Management to be extremely successful.

Descriptive Statistical Analysis Summary

The use of the descriptive statistical analysis provided the state of being for the collected results of the study. The intent was to simply convey the accurate state of the responses to the inquiries and report them in a manner that is easily understood and clearly depicted. The graphical portions of the descriptive analysis proved most beneficial for a clear visual illustration of the inquiry and its outcomes. It is imperative to convey the information in a high level of accuracy and consistency with proper sequence of the described events in an effort to maintain acceptable validity (Sandelowski, M., 2000; Maxwell, J.A., 1992). Due to its nature of a pre-structured means of responses, the description analysis of the survey does not require much in the way of interpretation; however, this is not the case with the open ended line of questioning. As stated earlier, it is the intent of the descriptive analysis to provide the state of being of the outcomes for the study; which sets the stage for the analytical testing of the data.

Inferential Analysis of Variance (ANOVA) Testing

The analytical testing of the data for this study was separated into two 'runs' of the data in an effort to explore and exhaust correlations among specific inquiries and the respective responses. The tests were also organized in a manner that allowed for the support, or refute, of the aforementioned hypotheses in Chapter III.

As outlined in Chapter IV, this study consisted of three independent variables and one dependent variable as related to the investigation of the study. The three independent variables are represented by the following: a perceived BIM Trained FM operator, a perceived Influenced BIM Specification by facilities managers, and a perceived Quality BIM Model. The dependent variable is the perceived increased use of Building Information Modeling (BIM) for Facilities Management (FM), which is affected by the independent variables.

The design of the first 'run' of testing was intended to illustrate the impact of the correlations and relationships among the segregated inquiries for each subsequent hypothesis category for the independent variables. The analysis then conducted a second 'run' of testing that examined those correlations and relationships among the subsequent hypotheses of the independent variables as related to the general hypothesis of the dependent variable.

The conducted analysis for the inferential statistical outcomes made use of the information generated by the statistical tool; including Df-values, Sum Sq-values, Mean Sq-values, F-values, and P-values. The Df-values are the Degrees of Freedom and represent the number of values in a study that are free to vary; the number of

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observations to be decreased by the number of unknowns estimated from the data to serve as the divisor in estimating the standard error of a set of observations, depicted in formula by $\sigma^2 = \Sigma x^2/N\text{-r}$ (Walker, H. M., 1940). This original concept was recognized by Carl Friedrich Gauss in his classical works; *Theoria Combinationis Observationum Erroribus Minimis Obnoxiae* and *Erganzung zur Theorie der den kleinsten Fehlern unterworfen Combination der Beobachtungen, 1826* (Walker, H. M., 1940). The Sum Sq-values represent the sum of squares in regression. The sum of squares is the amount each score deviates from the mean, squared and summed, creating a numerical metric with the purpose of determining the variance of a set of values. There are two typical formulas which include Definitional where $SS = \Sigma(X-\mu)^2$, and Computational where $SS = \Sigma X^2 - [((\Sigma X)^2 / N]$. When two categories of scores exist, SS_x and SS_y are used to determine the relationship between the two set of scored categories. The Mean Sq-values are the sum of squares divided by its Degrees of Freedom (Df) (Ott, R. L., & Longnecker, M., 2001). The Mean Sq-values are often referred to as the standard deviation using $\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$ as the expressed formula; which measures the amount of variation or dispersion from the average of a set of values. The F-values are the ratios of 'between-group' variances and the 'within-group' variances in a test of significance of the differences between two or more populations (Clark, P. J., & Evans, F. C., 1954). The F-values for this study consist of two types; $F_{calculated}$ and $F_{critical}$. The calculated F-values ($F_{calculated}$) compared to the critical values of F ($F_{critical}$), indicate significance or rejection at that level of probability. The $F_{critical}$ calculations are typically found in a table format with given respective significance levels designated for each

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table; and is used for the derivation when $F_{calculated}$ is greater than or equal to $F_{critical}$ producing significance for the given hypothesis; illustrated $F_{calculated} \geq F_{critical}$. The P-values are the levels of significance of the statistical test with weights given in terms of probability (Ott, R. L., & Longnecker, M., 2001). The P-values represent a number between 0 and 1 with the following typical interpretations:

- A small P-value of ≤ 0.05, indicates strong evidence against the null hypothesis; hence, rendering the null hypothesis rejected.
- A large P-value of ≥ 0.05, indicates weak evidence against the null hypothesis; hence, rendering the null hypothesis accepted.
- A P-value that is close to 0.05, indicates marginal evidence against the null hypothesis; hence, rendering the null hypothesis either rejected or accepted.

The aforementioned statistical tools were applied in the analysis of each of the tests and the varied 'runs' of the study. Additionally, graphical depictions of the numerical outcomes were provided in the effort to further convey clarity of the results for the study.

Inferential Analysis Outcomes for Hypothesis 2 (H₂)

The second hypothesis (H₂) of the study was dedicated to the FM Training and consisted of six tests. Testing began (Run 1, Test 1) with the examination of the second hypothesis and its relationship to BIM Usage; targeting Q8. It was based on the isolation

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of Q11; which focused on the availability of any BIM software training at the respective

institutions of the participants of the study. The isolated Q11 was tested against the

learning styles (VAK) of the Training hypothesis (H2). The learning styles were

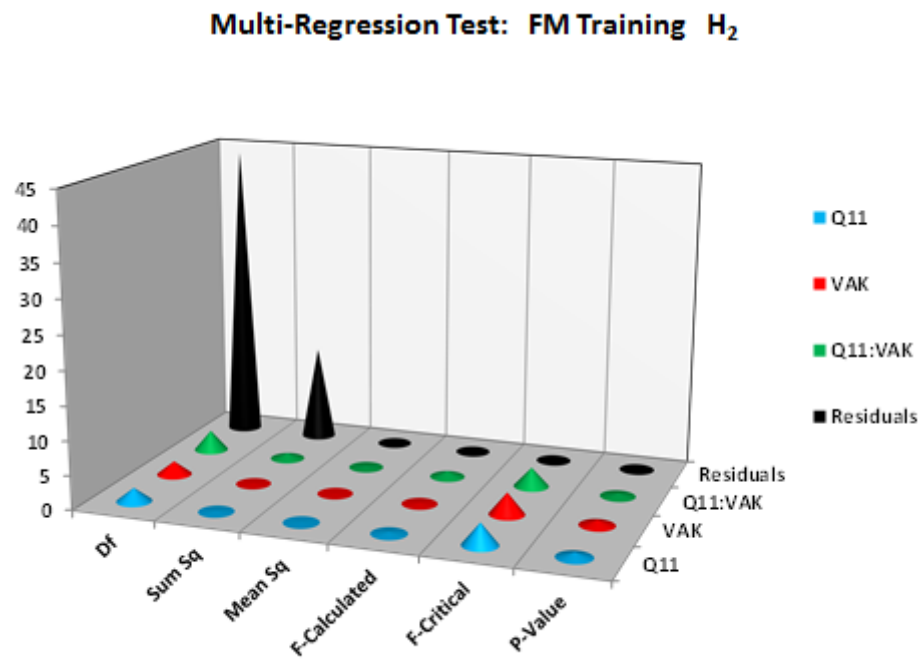categorized by visual, auditory, and kinaesthetic preferences.

Figure 58, Multi-Regression Run 1, Test 1; FM Training H_2

The overall graphical depiction of this test (Figure 58) for the degrees of freedom

(Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values

($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays

90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the

data analysis in relation to the derived p-value. This derived data is displayed in Table 2, and was used in the generation of the graphical illustrations.

Run 1, Test 1	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
Q11	2	0.192	0.09594	0.305	3.21	0.739
VAK	2	0.147	0.07366	0.234	3.21	0.792
Q11:VAK	3	0.786	0.26193	0.832	2.82	0.484
Residuals	44	13.856	0.3149	0	0	0

Table 2, Multi-Regression Run 1, Test 1; FM Training H_2

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicate that the F-values are not significant at the 0.05 level of probability because the $F_{calculated}$ (0.305) $\leq F_{critical}$ (3.21) for Q11, $F_{calculated}$ (0.234) $\leq F_{critical}$ (3.21) for VAK, and $F_{calculated}$ (0.832) $\leq F_{critical}$ (2.82) for Q11:VAK; hence, rejecting the hypothesis (H_2), and accepting the null hypothesis (H_0).
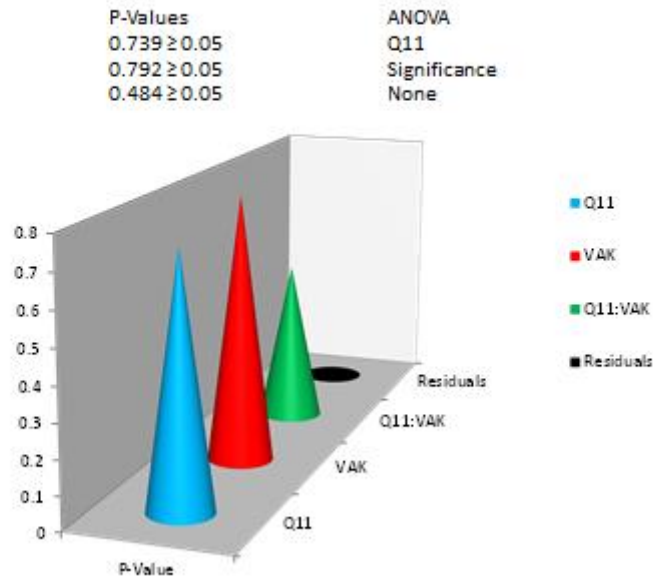
Figure 59, Multi-Regression Run 1, Test 1; FM Training H_2, P-Values

The isolated graphical depictions of this test (Figure 59), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.739 for Q11, P-value = 0.792 for VAK, and P-value = 0.484 for Q11:VAK. All of the P-values for this test are greater than 0.05 which suggests that the hypothesis (H_2) is rejected, and the null hypothesis (H_0) is accepted.

Testing continued (Run 1, Test 2) with the examination of the second hypothesis and its relationship to BIM Usage; targeting Q32. It was based on the isolation of Q11; which focused on the availability of any BIM software training at the respective institutions of the participants of the study. The isolated Q11 was tested against the

learning styles (VAK) of the Training hypothesis (H2). The learning styles were

categorized by visual, auditory, and kinaesthetic preferences.
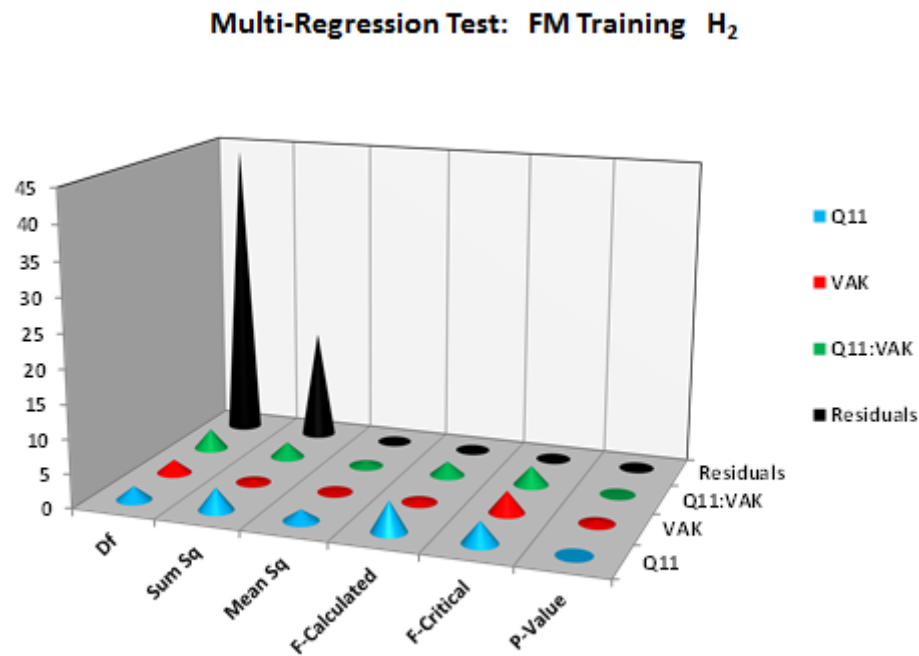

Figure 60, Multi-Regression Run 1, Test 2; FM Training H_2

The overall graphical depiction of this test (Figure 60) for the degrees of freedom

(Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values

($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays

90%, resulting in $\alpha=0.10$ significance level. This α-value indicates the reliability of the

data analysis in relation to the derived p-value. This derived data is displayed in Table 3,

and was used in the generation of the graphical illustrations.

Run 1, Test 2	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
Q11	2	3.302	1.651	4.516	3.21	0.0165
VAK	2	0.42	0.21	0.574	3.21	0.5672
Q11:VAK	3	2.269	0.7562	2.069	2.82	0.1181
Residuals	44	16.086	0.3656	0	0	0

Table 3, Multi-Regression Run 1, Test 2; FM Training H_2

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicate that the F-value for Q11 in this test is significant at the 0.05 level of probability because the $F_{calculated}$ (4.516) $\geq$ $F_{critical}$ (3.21) for Q11 in relation to Q8; hence, supporting the hypothesis (H_2), and rejecting the null hypothesis (H_0). The F-values, $F_{calculated}$ (0.574) $\leq$ $F_{critical}$ (3.21) for VAK, and $F_{calculated}$ (2.069) $\leq$ $F_{critical}$ (2.82) for Q11:VAK are not significant; hence, rejecting the hypothesis (H_2), and accepting the null hypothesis (H_0).
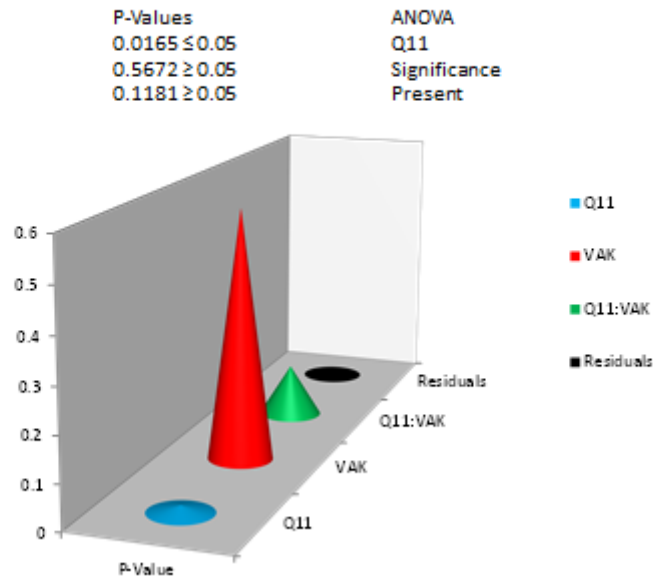
Figure 61, Multi-Regression Run 1, Test 2; FM Training H_2, P-Values

The isolated graphical depictions of this test (Figure 61), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.0165 for Q11, P-value = 0.5672 for VAK, and P-value = 0.1181 for Q11:VAK. The P-value for Q11 in this test in relation to Q8 is not greater than 0.05 which suggests that the hypothesis (H_2) is supported, and the null hypothesis (H_0) is rejected. The remaining P-values are greater than 0.05 which suggests that the hypothesis (H_2) is rejected for VAK and Q11:VAK, and the null hypothesis (H_0) are accepted for those respective comparisons.

Testing continued (Run 1, Test 3) with the examination of the second hypothesis and its relationship to BIM Usage; targeting Q8. It was based on the isolation of Q11;

which focused on the availability of any BIM software training at the respective institutions of the participants of the study. The isolated Q11 was tested solely against the BIM Usage; specific to Q8 without the learning styles (VAK) of the Training hypothesis (H2). The learning styles of visual, auditory, and kinaesthetic preferences were purposefully removed from this test.
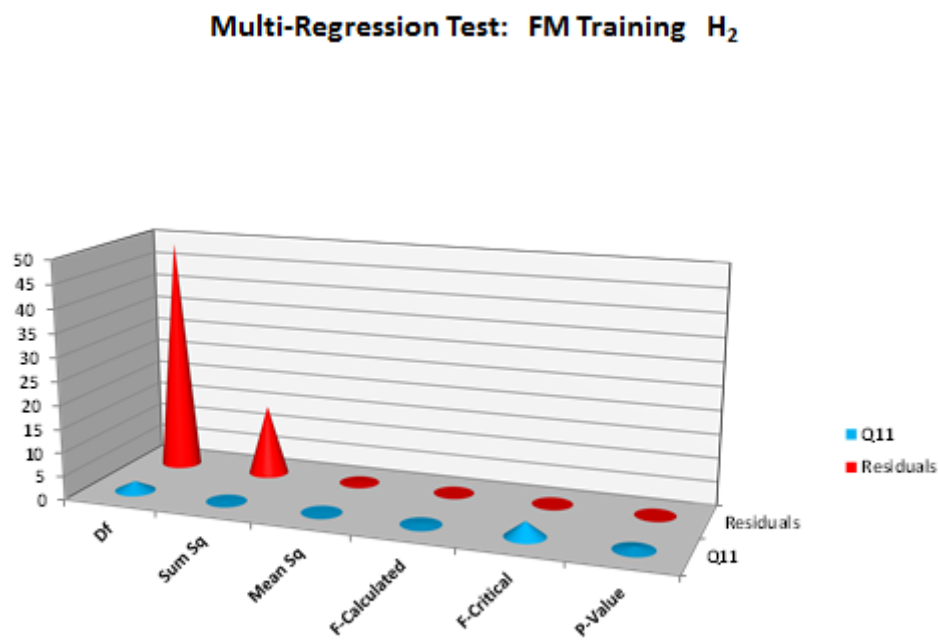
Multi-Regression Test: FM Training H_2

Figure 62, Multi-Regression Run 1, Test 3; FM Training H_2

The overall graphical depiction of this test (Figure 62) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values ($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the

data analysis in relation to the derived p-value. This derived data is displayed in Table 4, and was used in the generation of the graphical illustrations.

Run 1, Test 3	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
Q11	2	0.192	0.09594	0.318	3.19	0.729
Residuals	49	14.789	0.30181	0	0	0

Table 4, Multi-Regression Run 1, Test 3; FM Training H_2

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicate that the F-value for Q11 in this test is significant at the 0.05 level of probability because the $F_{calculated}$ (0.318) $\leq$ $F_{critical}$ (3.19) for Q11 in relation to Q8; hence, rejecting the hypothesis (H_2), and accepting the null hypothesis (H_0). No other results of the F-values were recorded for this test.
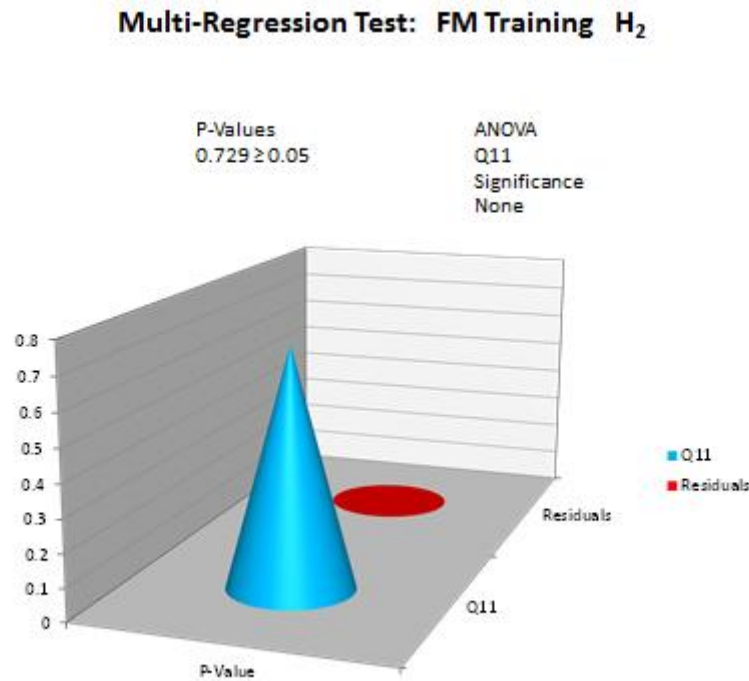
Figure 63, Multi-Regression Run 1, Test 3; FM Training H_2, P-Values

The isolated graphical depictions of this test (Figure 63), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.729 for Q11. The P-value for this test is greater than 0.05 which suggests that the hypothesis (H_2) is rejected, and the null hypothesis (H_0) is accepted. No other results of the P-values were recorded for this test.

Testing continued (Run 1, Test 4) with the examination of the second hypothesis and its relationship to BIM Usage; targeting Q32. It was based on the isolation of Q11; which focused on the availability of any BIM software training at the respective institutions of the participants of the study. The isolated Q11 was tested solely against the BIM Usage; specific to Q32 without the learning styles (VAK) of the Training

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hypothesis (H2). The learning styles of visual, auditory, and kinaesthetic preferences were purposefully removed from this test.
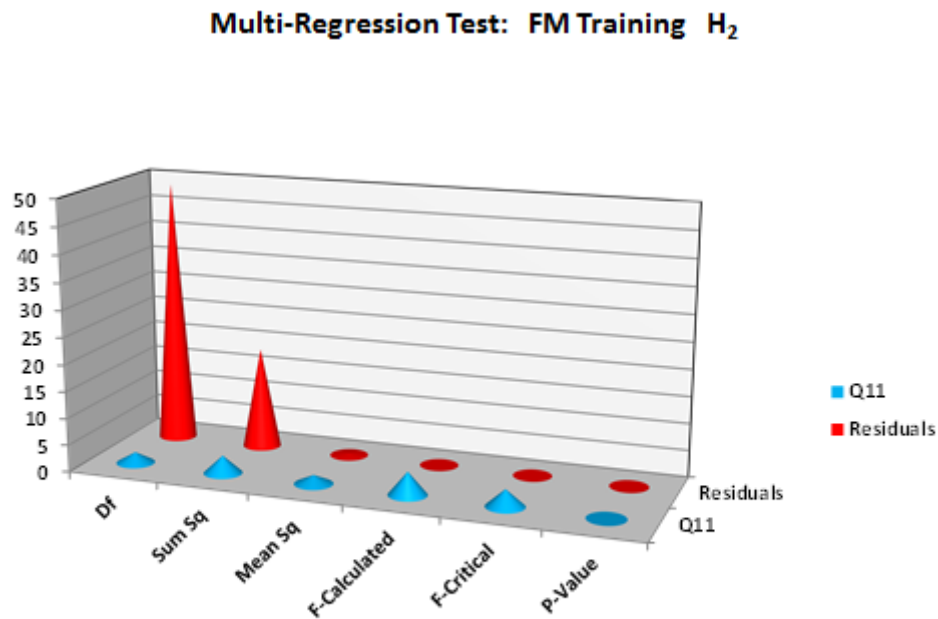

Figure 64, Multi-Regression Run 1, Test 4; FM Training H_2

The overall graphical depiction of this test (Figure 64) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values ($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in $\alpha=0.10$ significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 5, and was used in the generation of the graphical illustrations.

Run 1, Test 4	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
Q11	2	3.302	1.651	4.309	3.19	0.0189
Residuals	49	18.775	0.3832	0	0	0

Table 5, Multi-Regression Run 1, Test 4; FM Training H_2

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicate that the F-value for Q11 in this test is significant at the 0.05 level of probability because the $F_{calculated}$ (4.309) $\geq$ $F_{critical}$ (3.21) for Q11 in relation to Q32; hence, supporting the hypothesis (H_2), and rejecting the null hypothesis (H_0). No other results of the F-values were recorded for this test.
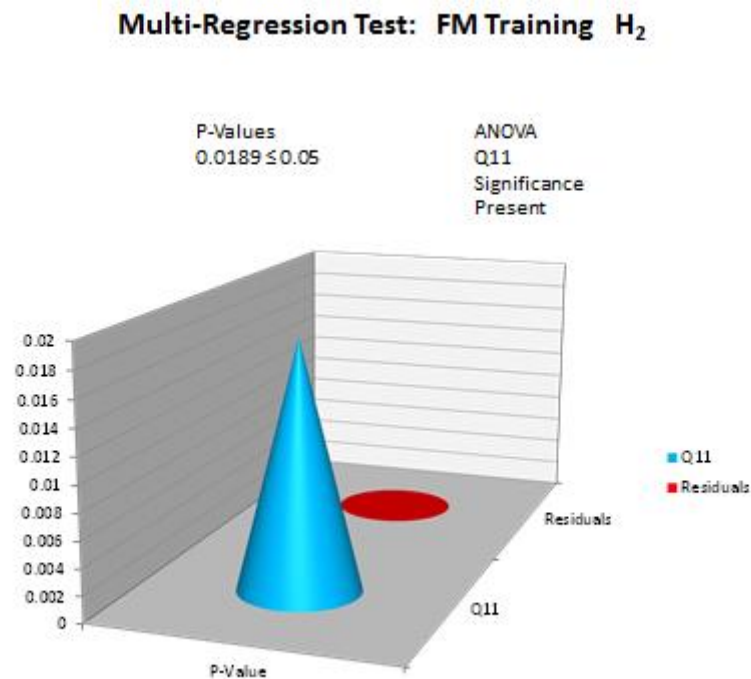

Figure 65, Multi-Regression Run 1, Test 4; FM Training H_2, P-Values

The isolated graphical depictions of this test (Figure 65), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.0189 for Q11. The P-value for this test is not greater than 0.05 which suggests that the hypothesis (H_2) is supported, and the null hypothesis (H_0) is rejected. No other results of the P-values were recorded for this test.

Testing continued (Run 1, Test 5) with the examination of the second hypothesis and its relationship to BIM Usage; targeting Q8. It was based on the isolation of Q11; which focused on the availability of any BIM software training at the respective institutions of the participants of the study. The isolated Q11 was tested against the learning styles (VAK) of the Training hypothesis (H2). The learning styles were categorized by visual, auditory, and kinaesthetic preferences.
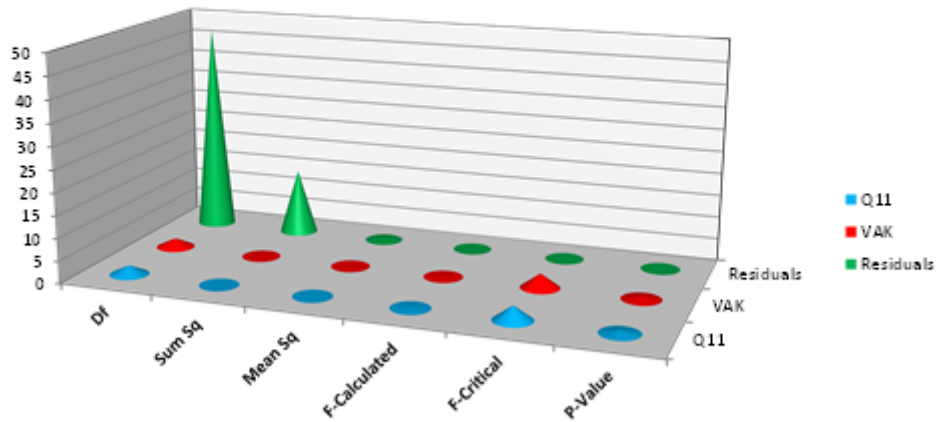
Figure 66, Multi-Regression Run 1, Test 5; FM Training H_2

The overall graphical depiction of this test (Figure 66) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values ($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 6, and was used in the generation of the graphical illustrations.

Run 1, Test 5	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
Q11	2	0.0192	0.09594	0.308	3.2	0.736
VAK	2	0.147	0.07366	0.236	3.2	0.79
Residuals	47	14.642	0.31152	0	0	0

Table 6, Multi-Regression Run 1, Test 5; FM Training H_2

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicate that the F-values are not significant at the 0.05 level of probability because the $F_{calculated}$ (0.308) $\leq F_{critical}$ (3.20) for Q11, and $F_{calculated}$ (0.236) $\leq F_{critical}$ (3.20) for VAK; hence, rejecting the hypothesis (H_2), and accepting the null hypothesis (H_0).
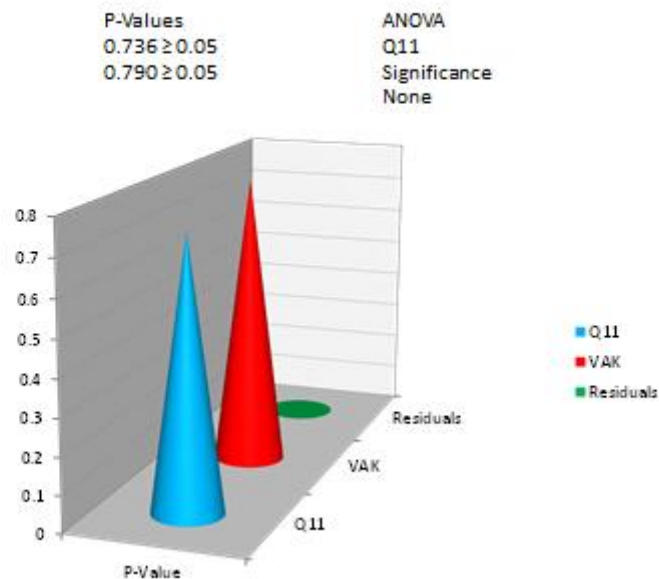

Figure 67, Multi-Regression Run 1, Test 5; FM Training H_2, P-Values

The isolated graphical depictions of this test (Figure 67), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.736 for Q11, and P-value = 0.790 for VAK. All of the P-values for this test are greater than 0.05 which suggests that the hypothesis (H_2) is rejected, and the null hypothesis (H_0) is accepted.

Testing continued (Run 1, Test 6) with the examination of the second hypothesis and its relationship to BIM Usage; targeting Q32. It was based on the isolation of Q11; which focused on the availability of any BIM software training at the respective institutions of the participants of the study. The isolated Q11 was tested against the learning styles (VAK) of the Training hypothesis (H2). The learning styles were categorized by visual, auditory, and kinaesthetic preferences.
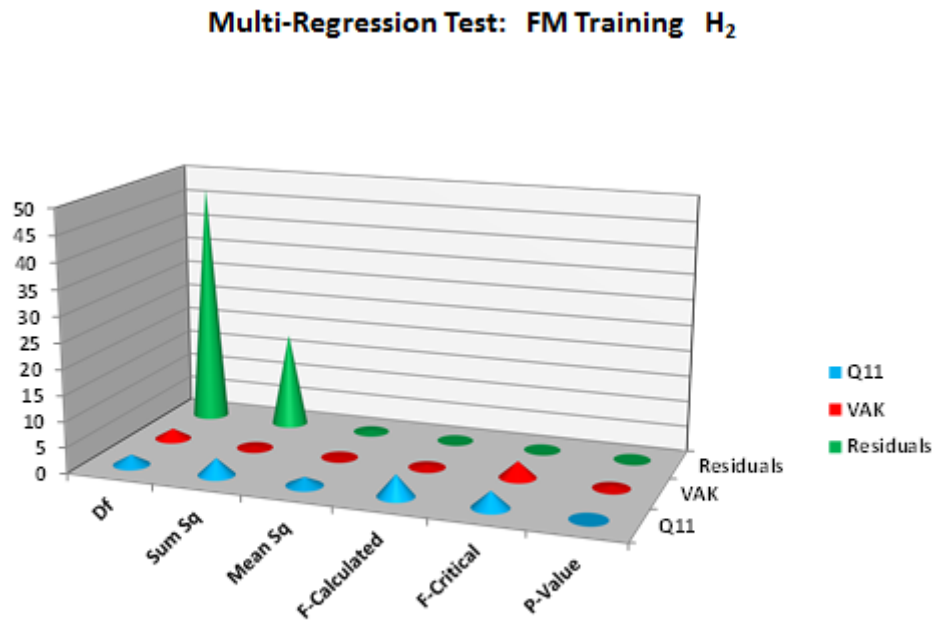
Figure 68, Multi-Regression Run 1, Test 6; FM Training H_2

The overall graphical depiction of this test (Figure 68) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values ($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 7, and was used in the generation of the graphical illustrations.

Run 1, Test 6	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
Q11	2	3.302	1.651	4.227	3.2	0.0205
VAK	2	0.42	0.21	0.538	3.2	0.5876
Residuals	47	18.355	0.3905	0	0	0

Table 7, Multi-Regression Run 1, Test 6; FM Training H_2

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicate that the F-value for Q11 in this test is significant at the 0.05 level of probability because the $F_{calculated}$ (4.227) $\geq$ $F_{critical}$ (3.20) for Q11 in relation to Q32; hence, supporting the hypothesis (H_2), and rejecting the null hypothesis (H_0). The F-values, $F_{calculated}$ (0.538) $\leq F_{critical}$ (3.20) for VAK is not significant; hence, rejecting the hypothesis (H_2), and accepting the null hypothesis (H_0).

Multi-Regression Test: FM Training H_2

P-Values
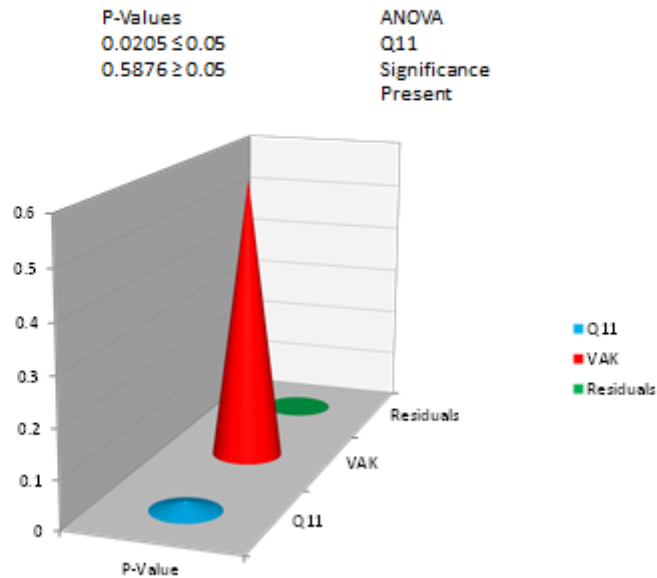0.0205 ≤ 0.05
0.5876 ≥ 0.05

ANOVA
Q11
Significance
Present

Figure 69, Multi-Regression Run 1, Test 6; FM Training H_2, P-Values

The isolated graphical depictions of this test (Figure 69), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.0205 for Q11, and P-value = 0.5876 for VAK. The P-value for Q11 in this test in relation to Q32 is not greater than 0.05 which suggests that the hypothesis (H_2) is supported, and the null hypothesis (H_0) is rejected. The P-value is greater than 0.05 which suggests that the hypothesis (H_2) is rejected for VAK, and the null hypothesis (H_0) is accepted for that respective comparison.

This concluded the testing of the six scenarios for the second hypothesis (H_2) of the study dedicated to the FM Training. The results of this testing is summarized in Chapter VI.

Inferential Analysis Outcomes for Hypothesis 3 (H$_3$)

The third hypothesis (H$_3$) of the study was dedicated to the Specifications and consisted of two tests. Testing began (Run 1, Test 7) with the examination of the third hypothesis (H$_3$) and its relationship to BIM Usage; targeting Q8. It was based on questions 9B, 12A, 12B, 12C, 13, 14, 15, 16, 31B, Q16:Q17, and Q16:Q18. Questions Q17 and Q18 were nested inquiries of Q16, which explains the comparison coupling. Questions Q16, Q17, and Q18 were specific to the use of COBie and its use, its accessibility, and its accuracy. These tests were then tested against the targeted Q8 in the same fashion as the other stand-alone inquiries. The targeted Q8 concerning BIM Usage was tested against all of the questions that were linked to Specifications for the study.
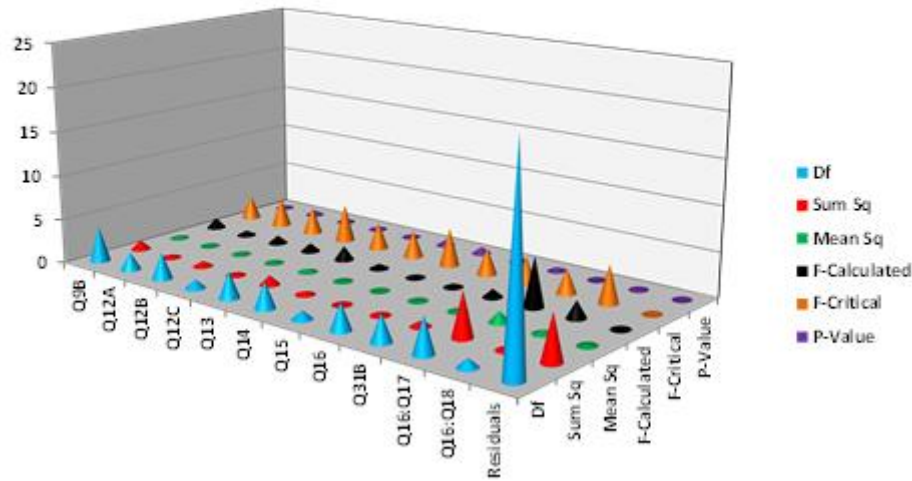
Figure 70, Multi-Regression Run 1, Test 7; Specifications H$_3$

The overall graphical depiction of this test (Figure 70) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values (F$_{calculated}$ and F$_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 8, and was used in the generation of the graphical illustrations.

Run 1, Test 7	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
Q9B	4	1.0585	0.26464	1.1935	2.8	0.340211
Q12A	2	0.25	0.125	0.5638	3.42	0.576733
Q12B	3	0.6146	0.20486	0.9239	3.03	0.444925
Q12C	1	0.2154	0.21537	0.9713	4.28	0.334603
Q13	3	1.0794	0.35981	1.6228	3.03	0.211519
Q14	3	0.3757	0.12523	0.5648	3.03	0.643731
Q15	1	0.0181	0.01811	0.0817	4.28	0.77762
Q16	3	0.2931	0.09769	0.4406	3.03	0.726171
Q31B	3	0.6325	0.21083	0.9509	3.03	0.432471
Q16:Q17	4	4.9163	1.22907	5.5432	2.8	0.002827
Q16:Q18	1	0.4275	0.42749	1.928	4.28	0.178279
Residuals	23	5.0997	0.22173	0	0	0

Table 8, Multi-Regression Run 1, Test 7; Specifications H_3

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicated that the F-values are not significant at the 0.05 level of probability; except for one test with Q16:Q17 indicating that the F-values were significant at the 0.05 level of probability. The F-values included the $F_{calculated}$ (1.1935) $\leq F_{critical}$ (2.80) for Q9B, $F_{calculated}$ (0.5638) $\leq F_{critical}$ (3.42) for Q12A, $F_{calculated}$ (0.9239) $\leq F_{critical}$ (3.03) for Q12B, $F_{calculated}$ (0.9713) $\leq F_{critical}$ (4.28) for Q12C, $F_{calculated}$ (1.6228) $\leq F_{critical}$ (3.03) for Q13, $F_{calculated}$ (0.5648) $\leq F_{critical}$ (3.03) for Q14, $F_{calculated}$ (0.0817) $\leq F_{critical}$ (4.28) for Q15, $F_{calculated}$ (0.4406) $\leq F_{critical}$ (3.03) for Q16, $F_{calculated}$ (0.9509) $\leq F_{critical}$ (3.03) for Q31B, $F_{calculated}$ (5.5432) $\geq F_{critical}$ (2.80) for Q16:Q17, and $F_{calculated}$ (1.928) $\leq F_{critical}$ (4.28) for Q16:Q18. All of the tests indicated a rejection of the hypothesis (H_3) and acceptance of the null hypothesis (H_0); however, the test with Q16:Q17 indicated support for the hypothesis (H_3) and rejection of the null hypothesis (H_0).

Multi-Regression Test: Specifications H_3

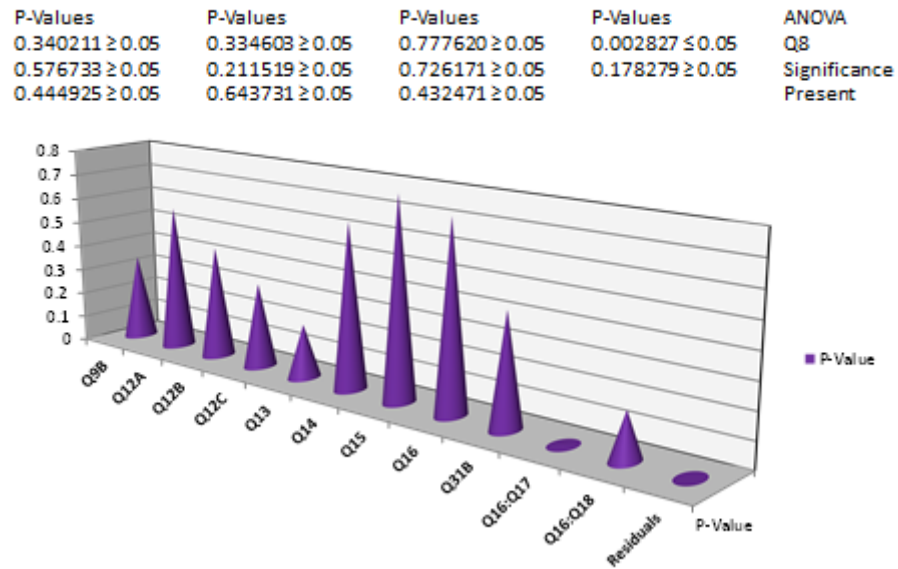| P-Values	P-Values	P-Values	P-Values	ANOVA
$0.340211 \geq 0.05$	$0.334603 \geq 0.05$	$0.777620 \geq 0.05$	$0.002827 \leq 0.05$	Q8
$0.576733 \geq 0.05$	$0.211519 \geq 0.05$	$0.726171 \geq 0.05$	$0.178279 \geq 0.05$	Significance
$0.444925 \geq 0.05$	$0.643731 \geq 0.05$	$0.432471 \geq 0.05$		Present

Figure 71, Multi-Regression Run 1, Test 7; Specifications H_3, P-Values

The isolated graphical depictions of this test (Figure 71), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.340211 for Q9B, P-value = 0.576733 for Q12A, P-value = 0.444925 for Q12B, P-value = 0.334603 for Q12C, P-value = 0.211519 for Q13, P-value = 0.643731 for Q14, P-value = 0.777620 for Q15, P-value = 0.726171 for Q16, P-value = 0.432471 for Q31B, P-value = 0.002827 for Q16:Q17, and P-value = 0.484178279 for Q16:Q18. All of the P-values for this test are greater than 0.05 which suggests that the hypothesis (H_3) is rejected, and the null hypothesis (H_0) is accepted; except for the test of Q16:Q17 which suggests the support of the hypothesis (H_3) and the rejection of the null hypothesis (H_0).

Testing continued (Run1, Test 8) with the examination of the third hypothesis

(H$_3$) and its relationship to BIM Usage; targeting Q32. It was based on questions 9B,

12A, 12B, 12C, 13, 14, 15, 16, 31B, Q16:Q17, and Q16:Q18. Questions Q17 and Q18

were nested inquiries of Q16, which explains the comparison coupling. Questions Q16,

Q17, and Q18 were specific to the use of COBie and its use, its accessibility, and its

accuracy. These tests were then tested against the targeted Q32 in the same fashion as

the other stand-alone inquiries. The targeted Q8 concerning BIM Usage was tested

against all of the questions that were linked to Specifications for the study.
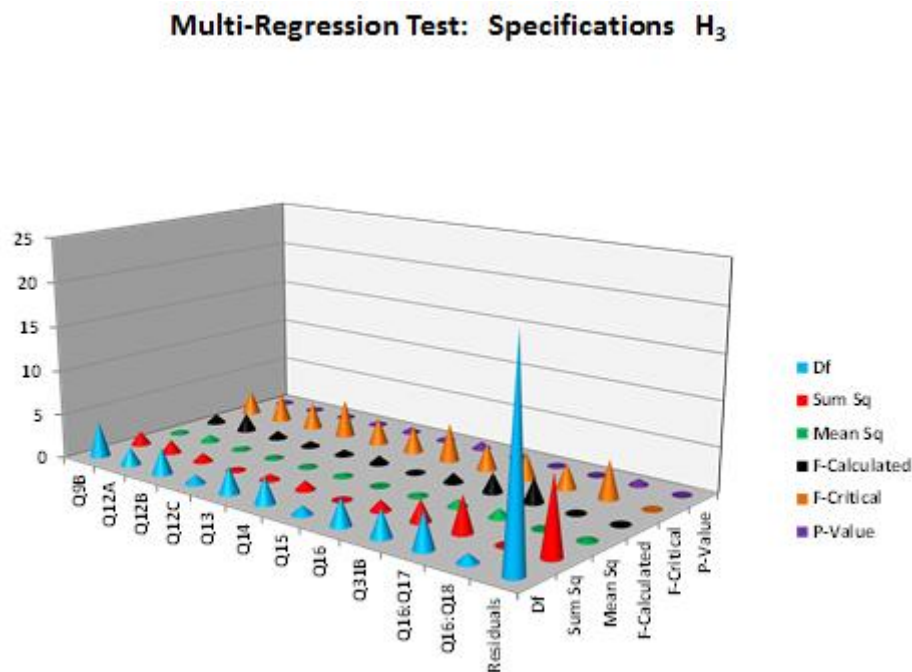

Figure 72, Multi-Regression Run 1, Test 8; Specifications H$_3$

The overall graphical depiction of this test (Figure 72) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values ($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 9, and was used in the generation of the graphical illustrations.

Run 1, Test 8	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
Q9B	4	1.5339	0.38347	1.0472	2.8	0.4047
Q12A	2	1.5	0.75	2.0482	3.42	0.15184
Q12B	3	0.9816	0.3272	0.8935	3.03	0.45938
Q12C	1	0.2281	0.22806	0.6228	4.28	0.43806
Q13	3	0.6878	0.22925	0.6261	3.03	0.60547
Q14	3	1.0489	0.34963	0.9548	3.03	0.43068
Q15	1	0.0169	0.01688	0.0461	4.28	0.83189
Q16	3	1.1978	0.39927	1.0904	3.03	0.37305
Q31B	3	2.3935	0.79783	2.1788	3.03	0.11795
Q16:Q17	4	4.0054	1.00136	2.7346	2.8	0.05365
Q16:Q18	1	0.061	0.06101	0.1666	4.28	0.68692
Residuals	23	8.4221	0.36618	0	0	0

Table 9, Multi-Regression Run 1, Test 8; Specifications H_3

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicated that the F-values are not significant at the 0.05 level of probability; except for one test with Q16:Q17 indicating that the F-values were significant at the 0.05 level of probability. The F-values included the $F_{calculated}$ (1.0472) $\leq F_{critical}$ (2.80) for Q9B, $F_{calculated}$ (2.0482) $\leq F_{critical}$ (3.42) for Q12A, $F_{calculated}$ (0.8935) $\leq F_{critical}$ (3.03) for Q12B, $F_{calculated}$ (0.6228) $\leq F_{critical}$ (4.28) for Q12C, $F_{calculated}$ (0.6261) $\leq F_{critical}$ (3.03) for Q13, $F_{calculated}$ (0.9548) $\leq F_{critical}$ (3.03) for

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Q14, $F_{calculated}$ (0.0461) $\leq F_{critical}$ (4.28) for Q15, $F_{calculated}$ (1.0904) $\leq F_{critical}$ (3.03) for

Q16, $F_{calculated}$ (2.1788) $\leq F_{critical}$ (3.03) for Q31B, $F_{calculated}$ (2.7346) $\leq F_{critical}$ (2.80) for

Q16:Q17, and $F_{calculated}$ (1.666) $\leq F_{critical}$ (4.28) for Q16:Q18. All of the tests indicated a

rejection of the hypothesis (H_3) and acceptance of the null hypothesis (H_0); however, the

test with Q16:Q17 was very close to indicating support for the hypothesis (H_3) and

rejection of the null hypothesis (H_0) with the F-values nearly equaling each other.

Multi-Regression Test: Specifications H_3

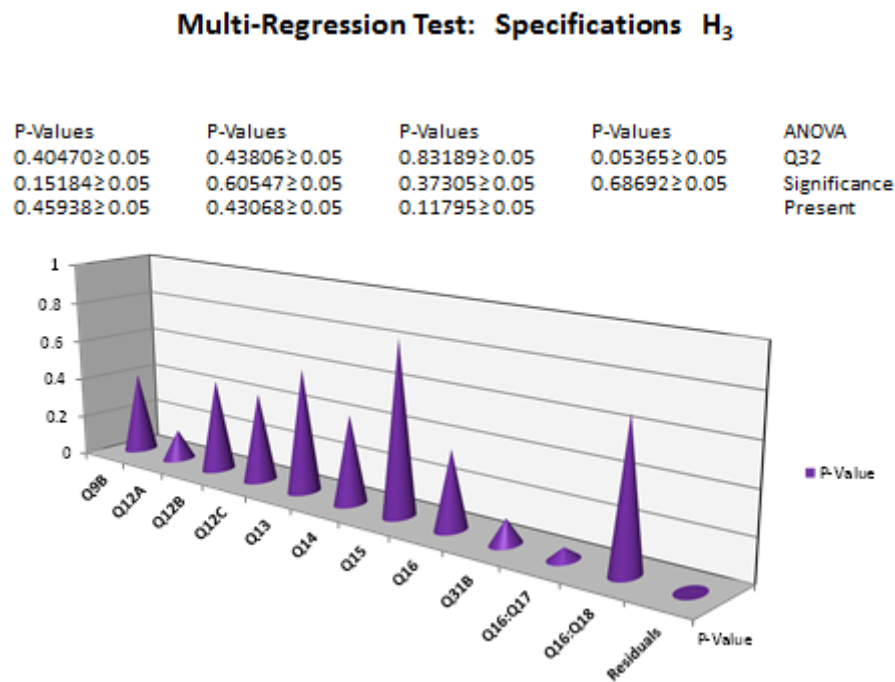| P-Values	P-Values	P-Values	P-Values	ANOVA
0.40470≥0.05	0.43806≥0.05	0.83189≥0.05	0.05365≥0.05	Q32
0.15184≥0.05	0.60547≥0.05	0.37305≥0.05	0.68692≥0.05	Significance
0.45938≥0.05	0.43068≥0.05	0.11795≥0.05		Present

Figure 73, Multi-Regression Run 1, Test 8; Specifications H_3, P-Values

The isolated graphical depictions of this test (Figure 73), for the varied P-values,

are supported by the data. The P-values for this recorded test include a P-value =

0.40470 for Q9B, P-value = 0.15184 for Q12A, P-value = 0.45938 for Q12B, P-value =

0.43806 for Q12C, P-value = 0.60547 for Q13, P-value = 0.43068 for Q14, P-value =

0.83189 for Q15, P-value = 0.37305 for Q16, P-value = 0.11795 for Q31B, P-value =

0.05365 for Q16:Q17, and P-value = 0.68692 for Q16:Q18. All of the P-values for this

test are greater than 0.05 which suggests that the hypothesis (H_3) is rejected, and the null

hypothesis (H_0) is accepted. However, the test of Q16:Q17 was very close to indicating

support for the hypothesis (H_3) and rejection of the null hypothesis (H_0) with the P-value

nearly equaling the level of significance; $P \leq 0.05$.

Inferential Analysis Outcomes for Hypothesis 4 (H_4)

The fourth hypothesis (H_4) of the study was dedicated to the Quality BIM and

consisted of two tests. Testing began (Run 1, Test 9) with the examination of the fourth

hypothesis (H_4) and its relationship to BIM Usage; targeting Q8. It was based on

questions 9A, 9C, 19, 20, and 31C. The targeted Q8 concerning BIM Usage was tested

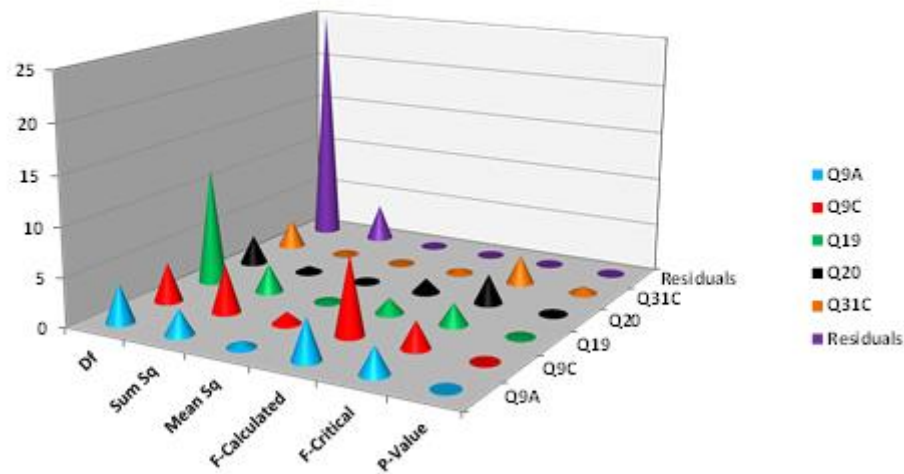against all of the questions that were linked to the Quality BIM for the study.

Figure 74, Multi-Regression Run 1, Test 9; Quality BIM H_4

The overall graphical depiction of this test (Figure 74) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values ($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 10, and was used in the generation of the graphical illustrations.

Run 1, Test 9	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
Q9A	4	2.566	0.6416	4.243	2.76	0.009316
Q9C	4	4.868	1.217	8.048	2.76	0.000259
Q19	12	2.894	0.2411	1.595	2.24	0.157009
Q20	3	0.665	0.2217	1.466	2.99	0.247734
Q31C	3	0.207	0.0692	0.457	2.99	0.714454
Residuals	25	3.78	0.1512	0	0	0

Table 10, Multi-Regression Run 1, Test 9; Quality BIM H_4

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicated that the F-values are not significant at the 0.05 level of probability; except for two tests, Q9A and Q9C, both indicating that the F-values were significant at the 0.05 level of probability. The F-values included the $F_{calculated}$ (4.243) $\geq$ $F_{critical}$ (2.76) for Q9A, $F_{calculated}$ (8.048) $\geq$ $F_{critical}$ (2.76) for Q9C, $F_{calculated}$ (1.595) $\leq$ $F_{critical}$ (2.24) for Q19, $F_{calculated}$ (1.466) $\leq$ $F_{critical}$ (2.99) for Q20, and $F_{calculated}$ (0.457) $\leq$ $F_{critical}$ (2.99) for Q31C. All of the tests indicated a rejection of the hypothesis (H_3) and acceptance of the null hypothesis (H_0); however, the tests with Q9A and Q9C indicated support for the hypothesis (H_4) and rejection of the null hypothesis (H_0).
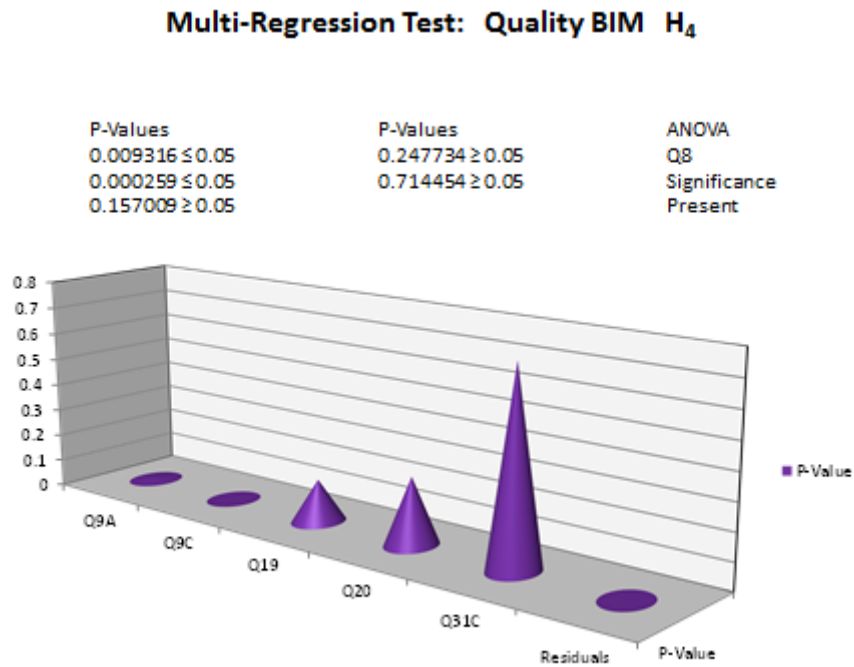
Figure 75, Multi-Regression Run 1, Test 9; Quality BIM H_4, P-Values

The isolated graphical depictions of this test (Figure 75), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.009316 for Q9A, P-value = 0.000259 for Q9C, P-value = 0.157009 for Q19, P-value = 0.247734 for Q20, and P-value = 0.714454 for Q31C. All of the P-values for this test are greater than 0.05 which suggests that the hypothesis (H_4) is rejected, and the null hypothesis (H_0) is accepted; except for the tests of Q9A and Q9C which suggests the support of the hypothesis (H_4) and the rejection of the null hypothesis (H_0).

Testing continued (Run1, Test 10) with the examination of the fourth hypothesis (H_4) and its relationship to BIM Usage; targeting Q32. It was based on questions 9A, 9C,

19, 20, and 31C. The targeted Q32 concerning BIM Usage was tested against all of the questions that were linked to the Quality BIM for the study.
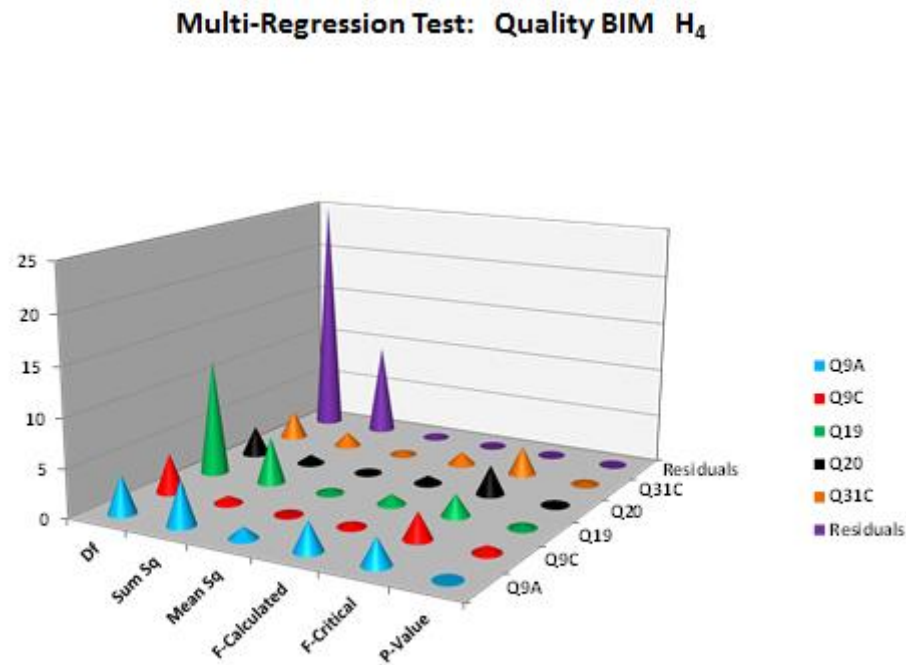

Figure 76, Multi-Regression Run 1, Test 10; Quality BIM H$_4$

The overall graphical depiction of this test (Figure 76) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values (F$_{calculated}$ and F$_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 11, and was used in the generation of the graphical illustrations.

Run 1, Test 10	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
Q9A	4	4.607	1.1517	3.045	2.76	0.0357
Q9C	4	0.761	0.1904	0.503	2.76	0.7336
Q19	12	4.839	0.4033	1.066	2.24	0.4261
Q20	3	0.928	0.3092	0.817	2.99	0.4964
Q31C	3	1.486	0.4952	1.309	2.99	0.2935
Residuals	25	9.456	0.3783	0	0	0

Table 11, Multi-Regression Run 1, Test 10; Quality BIM H_4

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicated that the F-values are not significant at the 0.05 level of probability; except for one test, Q9A, indicating that the F-values were significant at the 0.05 level of probability. The F-values included the $F_{calculated}$ (3.045) $\geq F_{critical}$ (2.76) for Q9A, $F_{calculated}$ (0.503) $\leq F_{critical}$ (2.76) for Q9C, $F_{calculated}$ (1.066) $\leq F_{critical}$ (2.24) for Q19, $F_{calculated}$ (0.817) $\leq F_{critical}$ (2.99) for Q20, and $F_{calculated}$ (1.309) $\leq F_{critical}$ (2.99) for Q31C. All of the tests indicated a rejection of the hypothesis (H_3) and acceptance of the null hypothesis (H_0); however, the test for Q9A indicated support for the hypothesis (H_4) and rejection of the null hypothesis (H_0).

Multi-Regression Test: Quality BIM H₄

P-Values
0.009316 ≤ 0.05
0.000259 ≤ 0.05
0.157009 ≥ 0.05

P-Values
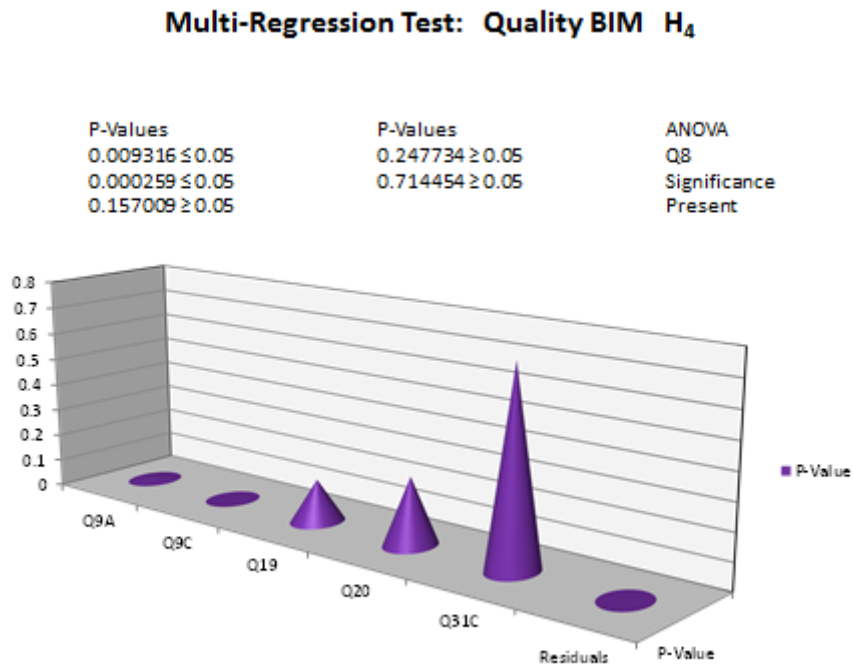0.247734 ≥ 0.05
0.714454 ≥ 0.05

ANOVA
Q8
Significance
Present

Figure 77, Multi-Regression Run 1, Test 10; Quality BIM H_4, P-Values

The isolated graphical depictions of this test (Figure 77), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.0357 for Q9A, P-value = 0.7336 for Q9C, P-value = 0.4261 for Q19, P-value = 0.4964 for Q20, and P-value = 0.2935 for Q31C. All of the P-values for this test are greater than 0.05 which suggests that the hypothesis (H_4) is rejected, and the null hypothesis (H_0) is accepted; except for the test of Q9A which suggests the support of the hypothesis (H_4) and the rejection of the null hypothesis (H_0).

Inferential Analysis Outcomes for Hypothesis 1 (H_1)

The primary hypothesis (H_1) of the study was dedicated to the BIM Usage and consisted of four tests. Testing began (Run 2, Test 11) with the examination of the primary hypothesis (H_1) and its relationship to the second hypothesis (H_2) FM Training, the third hypothesis (H_3) Specifications, and the fourth hypothesis (H_4) Quality BIM; targeting Q8. It was based on a multivariate comparison between the Usage of BIM and the FM Training, the Specifications, and the Quality BIM. The FM Training consisted of all of the compiled and related questions from the study dedicated to FM Training represented in a binary coded format. The Specifications consisted of all of the compiled and related questions from the study dedicated to Specifications represented in a binary coded format. The Quality BIM consisted of all of the compiled and related questions from the study dedicated to Quality BIM represented in a binary coded format. The targeted Q8 concerning BIM Usage was the focus of the test against all of the hypotheses and their respective representation for the study.
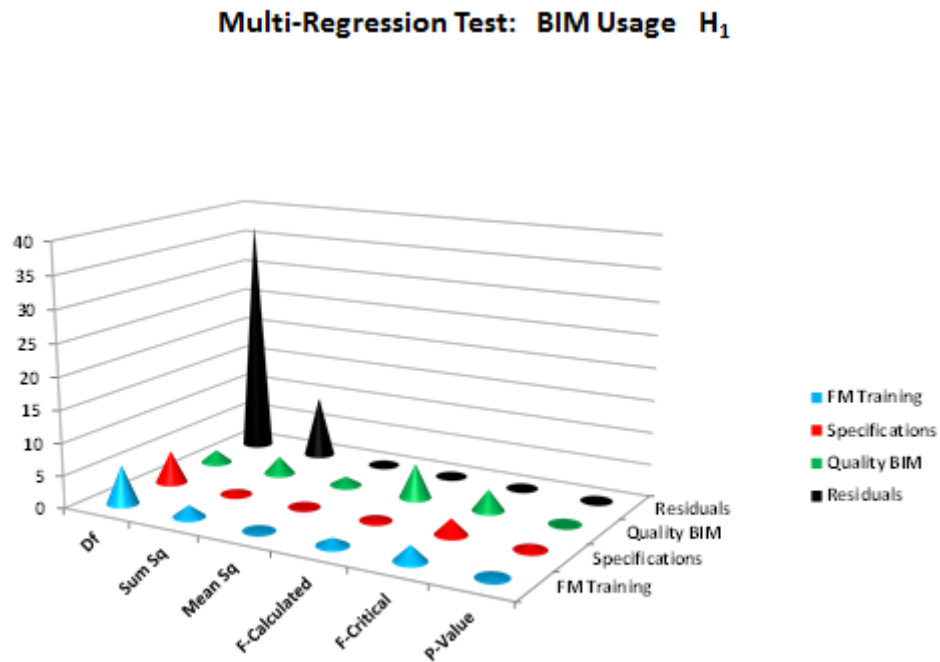
Figure 78, Multi-Regression Run 2, Test 11; BIM Usage H_1

The overall graphical depiction of this test (Figure 78) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values ($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 12, and was used in the generation of the graphical illustrations.

Run 2, Test 11	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
FM Training	6	1.8059	0.30098	1.1703	2.36	0.343034
Specifications	5	0.6563	0.13125	0.5104	2.47	0.766585
Quality BIM	2	2.728	1.36401	5.3037	3.25	0.009435
Residuals	37	9.5157	0.25718	0	0	0

Table 12, Multi-Regression Run 2, Test 11; BIM Usage H_1

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicated that the F-values were not significant at the 0.05 level of probability for the FM Training and the Specifications; however, for the Quality BIM, the F-values were significant at the 0.05 level of probability. The F-values included the $F_{calculated}$ (1.1703) $\leq$ $F_{critical}$ (2.36) for FM Training, $F_{calculated}$ (0.5104) $\leq$ $F_{critical}$ (2.47) for Specifications, and $F_{calculated}$ (5.3037) $\geq$ $F_{critical}$ (3.25) for Quality BIM. The tests for FM Training and Specifications indicated a rejection of the hypothesis (H_1) and acceptance of the null hypothesis (H_0); however, the test for the Quality BIM indicated support for the hypothesis (H_1) and rejection of the null hypothesis (H_0).
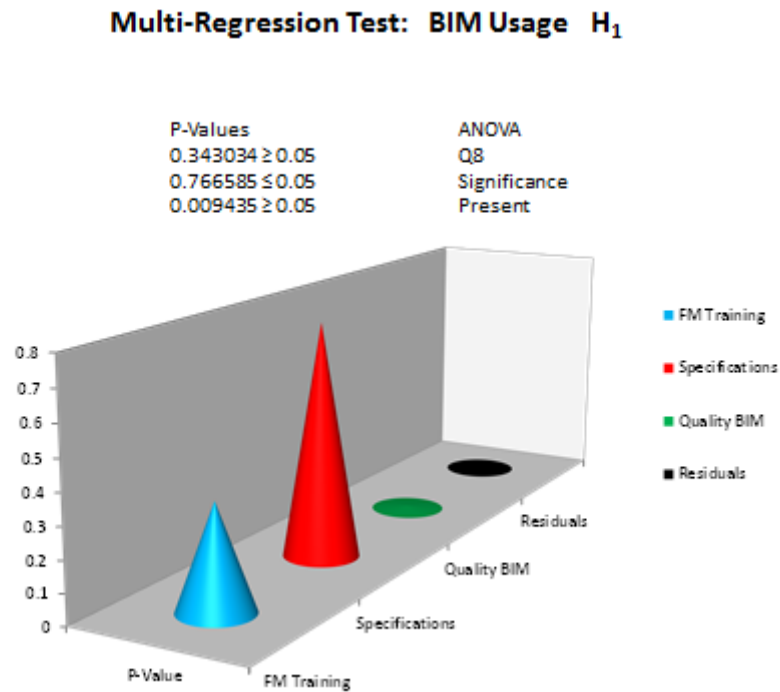
Figure 79, Multi-Regression Run 2, Test 11; BIM Usage H_1, P-Values

The isolated graphical depictions of this test (Figure 79), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.009316 for FM Training, P-value = 0.000259 for Specifications, and P-value = 0.157009 for Quality BIM. The P-values for FM Training and Specifications are greater than 0.05 which suggests that the hypothesis (H_1) is rejected, and the null hypothesis (H_0) is accepted. However, the test for the Quality BIM possessed a P-value less than 0.05 which suggests the support of the hypothesis (H_1) and the rejection of the null hypothesis (H_0) pertaining to Q8 of the study.

Testing continued (Run 2, Test 12) with the examination of the primary hypothesis (H_1) and its relationship to the second hypothesis (H_2) FM Training, the third

hypothesis (H_3) Specifications, and the fourth hypothesis (H_4) Quality BIM; targeting

Q32. It was based on a multivariate comparison between the Usage of BIM and the FM

Training, the Specifications, and the Quality BIM. The FM Training consisted of all of

the compiled and related questions from the study dedicated to FM Training represented

in a binary coded format. The Specifications consisted of all of the compiled and related

questions from the study dedicated to Specifications represented in a binary coded

format. The Quality BIM consisted of all of the compiled and related questions from the

study dedicated to Quality BIM represented in a binary coded format. The targeted Q32

concerning BIM Usage was the focus of the test against all of the hypotheses and their
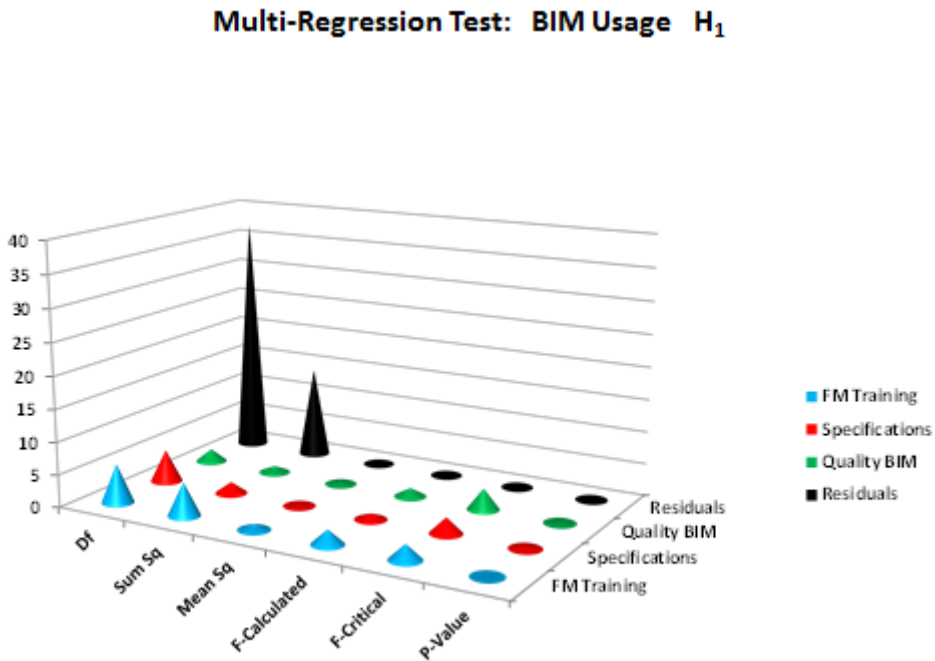
respective representation for the study.

Figure 80, Multi-Regression Run 2, Test 12; BIM Usage H_1

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The overall graphical depiction of this test (Figure 80) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values ($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in $\alpha=0.10$ significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 13, and was used in the generation of the graphical illustrations.

Run 2, Test 12	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
FM Training	6	5.1392	0.85654	2.2441	2.36	0.06027
Specifications	5	1.7642	0.35284	0.9244	2.47	0.47619
Quality BIM	2	1.0137	0.50683	1.3279	3.25	0.27737
Residuals	37	14.1222	0.38168	0	0	0

Table 13, Multi-Regression Run 2, Test 12; BIM Usage H_1

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicated that the F-values were not significant at the 0.05 level of probability for the FM Training, the Specifications, and the Quality BIM. The F-values included the $F_{calculated}$ (2.2441) $\leq F_{critical}$ (2.36) for FM Training, $F_{calculated}$ (0.9244) $\leq F_{critical}$ (2.47) for Specifications, and $F_{calculated}$ (1.3279) $\leq$ $F_{critical}$ (3.25) for Quality BIM. The tests for Training, Specifications, and Quality BIM indicated a rejection of the hypothesis (H_1) and acceptance of the null hypothesis (H_0).

Figure 81, Multi-Regression Run 2, Test 12; BIM Usage H_1, P-Values

The isolated graphical depictions of this test (Figure 81), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.06027 for FM Training, P-value = 0.47619 for Specifications, and P-value = 0.27737 for Quality BIM. The P-values for FM Training, Specifications, and Quality BIM are greater than 0.05 which suggests that the hypothesis (H_1) is rejected, and the null hypothesis (H_0) is accepted pertaining to Q32 of the study.

Testing continued (Run 2, Test 13) with the examination of the primary hypothesis (H_1) and its relationship to the second hypothesis (H_2) FM Training, the third hypothesis (H_3) Specifications, and the fourth hypothesis (H_4) Quality BIM; targeting Q8. It was based on a multivariate comparison between the Usage of BIM and the FM

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Training, the Specifications, and the Quality BIM. The FM Training consisted of all of the compiled and related questions from the study dedicated to FM Training represented in a binary coded format with the added component of the experience level derived from the demographic inquiries. The experience level component, question three (Q3), was segregated into five categories; 1 to 5 years, 6-10 years, 11 to 15 years, 16 to 20 years, and more than 20 years of experience. This added component to the FM Training was assigned a binary code and implemented into the FM Training. The modified FM Training was then placed into the test. The Specifications consisted of all of the compiled and related questions from the study dedicated to Specifications represented in a binary coded format. The Quality BIM consisted of all of the compiled and related questions from the study dedicated to Quality BIM represented in a binary coded format. Additionally, the BIM Usage was tested in relation to the Quality BIM:Specification comparison, the FM Training:Quality BIM comparison, and the FM Training:Specification comparison. The targeted Q8 concerning BIM Usage was the focus of the test against all of the hypotheses and their respective representation for the study.
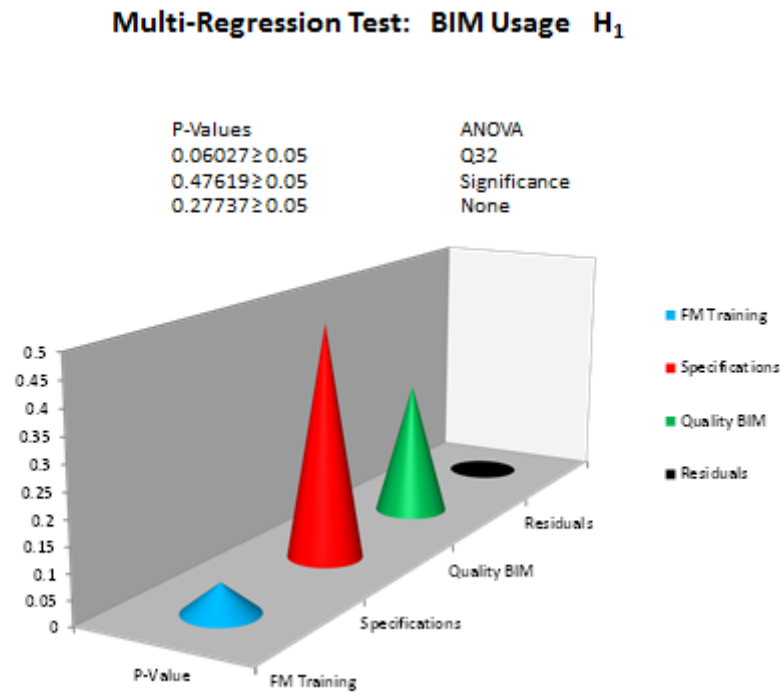
Figure 82, Multi-Regression Run 2, Test 13; BIM Usage H_1

The overall graphical depiction of this test (Figure 82) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values ($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 14, and was used in the generation of the graphical illustrations.

Run 2, Test 13	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
FM Training	6	1.806	0.301	1.186	2.55	0.3498
Specifications	5	0.97	0.1941	0.765	2.66	0.5849
Quality BIM	5	4.461	0.8922	3.515	2.66	0.0174
Quality BIM : Specifications	2	0.906	0.4532	1.786	3.44	0.1911
FM Training : Quality BIM	9	0.774	0.086	0.339	2.34	0.9517
FM Training : Specifications	1	0.205	0.2045	0.806	4.3	0.379
Residuals	22	5.583	0.2538	0	0	0

Table 14, Multi-Regression Run 2, Test 13; BIM Usage H_1

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicated that the F-values were not significant at the 0.05 level of probability for the FM Training, the Specifications, the Quality BIM:Specifications, FM Training:Quality BIM, and the FM Training:Specifications; however, for the Quality BIM, the F-values were significant at the 0.05 level of probability. The F-values included the $F_{calculated}$ (1.186) $\leq F_{critical}$ (2.55) for FM Training, $F_{calculated}$ (0.765) $\leq F_{critical}$ (2.66) for Specifications, $F_{calculated}$ (3.515) $\geq F_{critical}$ (2.66) for Quality BIM, $F_{calculated}$ (1.786) $\leq F_{critical}$ (3.44) for Quality BIM:Specifications, $F_{calculated}$ (0.339) $\leq F_{critical}$ (2.34) for FM Training:Quality BIM, and $F_{calculated}$ (0.806) $\leq F_{critical}$ (4.30) for FM Training:Specifications. The tests for FM Training, the Specifications, the Quality BIM:Specifications, the FM Training:Quality BIM, and the FM Training:Specifications indicated a rejection of the hypothesis (H_1) and acceptance of the null hypothesis (H_0); however, the test for the Quality BIM indicated support for the hypothesis (H_1) and rejection of the null hypothesis (H_0).

Multi-Regression Test: BIM Usage H_1

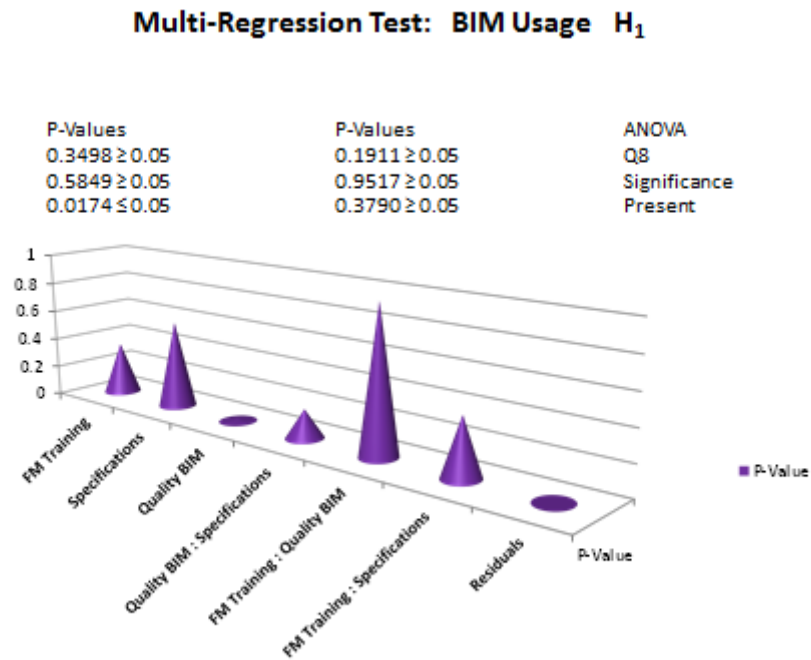| P-Values	P-Values	ANOVA
$0.3498 \geq 0.05$	$0.1911 \geq 0.05$	Q8
$0.5849 \geq 0.05$	$0.9517 \geq 0.05$	Significance
$0.0174 \leq 0.05$	$0.3790 \geq 0.05$	Present

Figure 83, Multi-Regression Run 2, Test 13; BIM Usage H_1, P-Values

The isolated graphical depictions of this test (Figure 83), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.3498 for FM Training, P-value = 0.5849 for Specifications, P-value = 0.0174 for Quality BIM, P-value = 0.1911 for Quality BIM:Specifications, P-value = 0.9517 for FM Training:Quality BIM, and P-value = 0.3790 for FM Training:Specifications. The P-values for FM Training, the Specifications, the Quality BIM:Specifications, the FM Training:Quality BIM, and the FM Training:Specifications are greater than 0.05 which suggests that the hypothesis (H_1) is rejected, and the null hypothesis (H_0) is accepted. However, the test for the Quality BIM possessed a P-value less than 0.05 which suggests

the support of the hypothesis (H_1) and the rejection of the null hypothesis (H_0) pertaining to Q8 of the study.

Testing continued (Run 2, Test 14) with the examination of the primary hypothesis (H_1) and its relationship to the second hypothesis (H_2) FM Training, the third hypothesis (H_3) Specifications, and the fourth hypothesis (H_4) Quality BIM; targeting Q32. It was based on a multivariate comparison between the Usage of BIM and the FM Training, the Specifications, and the Quality BIM. The FM Training consisted of all of the compiled and related questions from the study dedicated to FM Training represented in a binary coded format with the added component of the experience level derived from the demographic inquiries. The experience level component, question three (Q3), was segregated into five categories; 1 to 5 years, 6-10 years, 11 to 15 years, 16 to 20 years, and more than 20 years of experience. This added component to the FM Training was assigned a binary code and implemented into the FM Training. The modified FM Training was then placed into the test. The Specifications consisted of all of the compiled and related questions from the study dedicated to Specifications represented in a binary coded format. The Quality BIM consisted of all of the compiled and related questions from the study dedicated to Quality BIM represented in a binary coded format. Additionally, the BIM Usage was tested in relation to the Quality BIM:Specification comparison, the FM Training:Quality BIM comparison, and the FM Training:Specification comparison. The targeted Q32 concerning BIM Usage was the focus of the test against all of the hypotheses and their respective representation for the study.
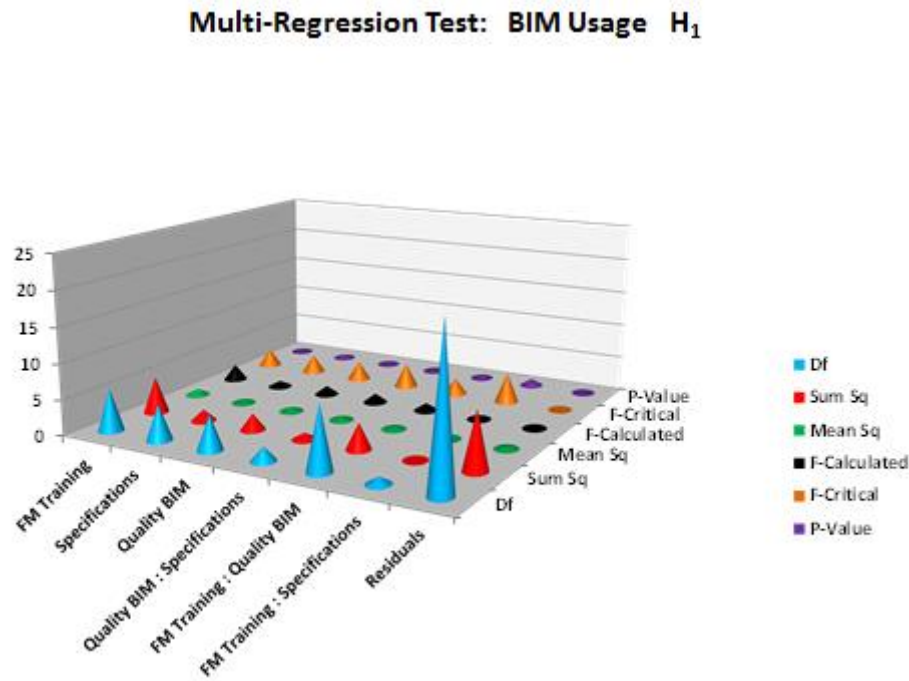
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Figure 84, Multi-Regression Run 2, Test 14; BIM Usage H_1

The overall graphical depiction of this test (Figure 84) for the degrees of freedom (Df), the sum of squares (Sum Sq), the standard deviation (Mean Sq), and the F-values ($F_{calculated}$ and $F_{critical}$) are supported by the data. The confidence interval (CI) displays 90%, resulting in α=0.10 significance level. This α-value indicates the reliability of the data analysis in relation to the derived p-value. This derived data is displayed in Table 15, and was used in the generation of the graphical illustrations.

Run 2, Test 14	Df	Sum Sq	Mean Sq	F-Calculated	F-Critical	P-Value
FM Training	6	5.139	0.8565	2.296	2.55	0.0175
Specifications	5	1.635	0.327	0.876	2.66	0.5129
Quality BIM	5	2.346	0.4691	1.257	2.66	0.3171
Quality BIM : Specifications	2	0.975	0.4876	1.307	3.44	0.2909
FM Training : Quality BIM	9	3.736	0.4151	1.113	2.34	0.3945
FM Training : Specifications	1	0	0	0	4.3	1
Residuals	22	8.208	0.3731	0	0	0

Table 15, Multi-Regression Run 2, Test 14; BIM Usage H_1

The result of the F-values, $F_{calculated}$ and $F_{critical}$, indicated that the F-values were not significant at the 0.05 level of probability for the FM Training, the Specifications, the Quality BIM:Specifications, FM Training:Quality BIM, and the FM Training:Specifications; however, for the Quality BIM, the F-values were significant at the 0.05 level of probability. The F-values included the $F_{calculated}$ (2.296) $\leq F_{critical}$ (2.55) for FM Training, $F_{calculated}$ (0.876) $\leq F_{critical}$ (2.66) for Specifications, $F_{calculated}$ (1.257) $\leq F_{critical}$ (2.66) for Quality BIM, $F_{calculated}$ (1.307) $\leq F_{critical}$ (3.44) for Quality BIM:Specifications, $F_{calculated}$ (1.113) $\leq F_{critical}$ (2.34) for FM Training:Quality BIM, and $F_{calculated}$ (0) $\leq F_{critical}$ (4.30) for FM Training:Specifications. The tests for FM Training, the Specifications, the Quality BIM, the Quality BIM:Specifications, the FM Training:Quality BIM, and the FM Training:Specifications indicated a rejection of the hypothesis (H_1) and acceptance of the null hypothesis (H_0).

Multi-Regression Test: BIM Usage H_1

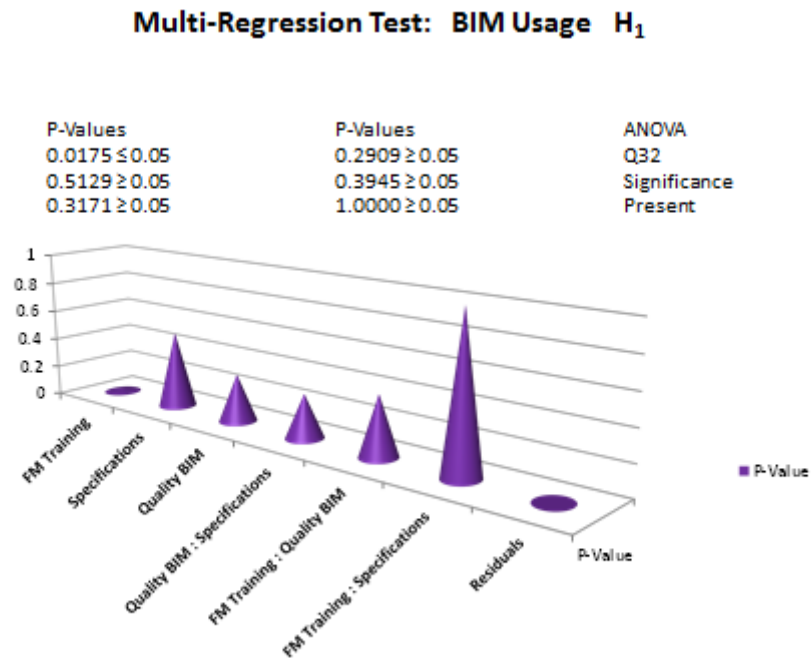| P-Values	P-Values	ANOVA
$0.0175 \leq 0.05$	$0.2909 \geq 0.05$	Q32
$0.5129 \geq 0.05$	$0.3945 \geq 0.05$	Significance
$0.3171 \geq 0.05$	$1.0000 \geq 0.05$	Present

Figure 85, Multi-Regression Run 2, Test 14; BIM Usage H_1, P-Values

The isolated graphical depictions of this test (Figure 85), for the varied P-values, are supported by the data. The P-values for this recorded test include a P-value = 0.0175 for FM Training, P-value = 0.5129 for Specifications, P-value = 0.3171 for Quality BIM, P-value = 0.2909 for Quality BIM:Specifications, P-value = 0.3945 for FM Training:Quality BIM, and P-value = 1.0000 for FM Training:Specifications. The P-values for the Specifications, the Quality BIM, the Quality BIM:Specifications, the FM Training:Quality BIM, and the FM Training:Specifications are greater than 0.05 which suggests that the hypothesis (H_1) is rejected, and the null hypothesis (H_0) is accepted. However, the test for the FM Training possessed a P-value less than 0.05 which suggests

the support of the hypothesis (H_1) and the rejection of the null hypothesis (H_0) pertaining to Q32 of the study.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This study has been a portrayal of the perceived building information modeling usage

and the utilization of building information modeling technical specifications for facilities

management at higher educational institutions in Texas. This final chapter includes the

summary of the research, findings and conclusions, limitations of the study,

contributions and recommendations, future research, and points to ponder concerning the

study.

Summary of the Research

The overall objective of the research was to establish current practices associated

with the usage of building information modeling and compare that state of being to the

perceived usage of building information modeling for facilities management in higher

educational institutions in Texas. In support of the overall objective, there were three

supporting measures that were directly explored through the study including; perceived

FM Training, perceived BIM Technical Specifications, and a perceived Quality BIM.

Each of these subcategories were independently researched in an effort to unveil the

impact, or lack of impact, that each had on the aforementioned overall objective.

The organization of the study began with a review of literature concerning the

usage of building information modeling, as well as the current state of being for FM

Training, BIM Technical Specifications, and a Quality BIM. In conjunction with the

literature review, six case studies were selected that possessed similar attributes of the study and were analyzed in the effort to further support the current state of being for each category. Together, the literature review and the case studies established a baseline for each category and provided direction for the continued research. Through the literature and the case studies, several tools were used and developed to further shape the outline of the study, including the Fault Tree Analysis and the Conceptual Model. The Fault Tree Analysis was used concurrently with the pilot study and through multiple trial and error runs, lead to the development of the Conceptual Model. The Conceptual Model, illustrated in Chapter III, was used in the professional interviews, which directly impacted the development of the survey instrument. It was also during the pilot study that a targeted sample group of facilities management personnel was established. This filtered group would prove crucial to the study in that the range of personnel was specific to facilities management and the quality of the potential participant was high.

The survey instrument, in conformance to Institutional Review Board (IRB) guidelines, was distributed to the pre-qualified participants for completion. The obtained data was then collected and organized in a categorized fashion, segregating the Demographic, the FM Training, the Specifications, the Quality BIM, and the BIM Usage questions with binary coded identifiers for analysis. The segregated questions were then linked to their respective hypothesis and implemented for analysis; the BIM Usage null (H_0), the BIM Usage (H_1), FM Training (H_2), the Specifications (H_3), and the Quality BIM (H_4). The BIM Usage (H_1) was the primary hypothesis of the study with the

remaining hypotheses classified as subsets. The hypotheses for the study were as follows:

H₀

  If a Trained FM, an Influenced Specification, and a Quality BIM are not implemented; then a Usable BIM for FM will not increase the use of BIM in FM.

H₁

  If a Trained FM, an Influenced Specification, and a Quality BIM are implemented; then a Usable BIM for FM will increase the use of BIM in FM.

H₂

  If the appropriate BIM training occurs for Facilities Managers \ FM Technicians; then the Facilities Managers \ FM Technicians will have a better knowledge base for operating a building information model.

H₃

  If the proper Facilities Management information is implemented into the specifications for the BIM model; then the Facilities Manager \ FM Technician will have a more Quality BIM model from which to operate.

H₄

If the FM influenced specification for the BIM model is enforced to the creator

of the model; then a higher quality BIM model exists for the Facilities Manager \ FM

Technician in which to utilize for facilities management.

The data results from the 'R' statistical software tool were then analyzed in a descriptive

manner and an inferential manner. The outcomes of those analyses have been compiled

and established in the findings and conclusions of the study. The rigor of the descriptive

and inferential analyses was conveyed in Chapter V of the study.

Findings and Conclusions

The perceptions of the participants of the study were diverse and expressed a

varied range concerning the usage of BIM for facilities management in higher

educational institutions in Texas. Those perceptions were equally diverse in the findings

related to the identified supporting hypotheses associated with the FM Training, the

Specifications, and the Quality BIM. The analysis was conducted in a descriptive and an

inferential statistical manner and the findings are revealed in the following script,

respectively.

For the descriptive analysis, there were eighteen inquiries in reference to the FM

Training in the survey instrument which consisted of two parts. The first part was

comprised of eight inquiries specific to FM Training. The second part, ten queries,

contained learning styles that were linked to the training process. The inquiries were in

no particular order and were dispersed throughout the survey instrument. The overall

findings for part one regarding the FM Training, revealed 65.7% were not engaging in

FM Training at all and 34.3% were signifying FM Training ranging from some training,

moderate training, and extreme training. The impact of these training findings appears to

be indicating limited engagement for FM Training through this descriptive depiction.

The findings for the learning styles portion of the survey instrument revealed that 43%

were visual learners, 24% were auditory learners, and 34% were kinaesthetic learners.

Overall, it appears that most learn by seeing or doing, while the minority learn through

listening. These learning styles and the impact are explored in the inferential findings.

For the descriptive analysis, there were eleven inquiries in reference to the

Specifications in the survey instrument. The inquiries were in no particular order and

were dispersed throughout the survey instrument. The findings regarding Specifications

revealed 60.3% were not engaging in the use of Specifications at all and 39.7% were

suggesting the use of Specifications ranging from some use, moderate use, and extreme

use. The impact of these Specifications findings appears to be indicating limited

engagement for Specifications usage through this descriptive depiction. The

Specifications and the potential impact are explored in the inferential findings.

For the descriptive analysis, there were five inquiries in reference to the Quality

BIM in the survey instrument. The inquiries were in no particular order and were

dispersed throughout the survey instrument. The findings regarding the Quality BIM

revealed 40% were not engaging in the use of the Quality BIM at all and 60% were

suggesting the use or familiarity of the Quality BIM ranging from some use\awareness,

moderate use\awareness, and extreme use\awareness. However, those truly engaged in utilizing a Quality BIM accounted for 22.1% while the remaining 87.9% were not fully engaged in the use of a Quality BIM. The impact of these Quality BIM findings appears to be indicating limited engagement for the Quality BIM usage with relatively high awareness of the Quality BIM through this descriptive depiction. The Quality BIM and the potential impact are explored in the inferential findings.

For the descriptive analysis, there were two inquiries in reference to the usage of BIM in the survey instrument. The inquiries were strategically placed, following the demographic queries, as the first question and the last question. The findings regarding the usage of BIM for Q8, the first inquiry, revealed 50% not using BIM at all and 50% signifying usage ranging from some use, moderate use, and extreme use. However, for Q32, the last inquiry, the findings revealed 32.7% not using BIM at all and 67.3% signifying usage ranging from some use, moderate use, and extreme use. Theoretically, these percentages should be the same. Perhaps these differing percentages could be explained by the participant feeling more confident about their usage of BIM based on the responses of Q9 through Q31 of the survey instrument. Ultimately, nearly 59% held the perception that the usage of BIM for facilities management was present.

The findings for the inferential statistical analysis regarding the FM Training conveyed that there is evidence supporting its impact as related to the use of building information modeling for facilities management. This was displayed in a series of examinations for the first run of tests producing P-values less than 0.05 (P-value ≤ 0.05) indicating significance. The FM Training testing in the first run of six tests found

validity surrounding the respective P-values for test 1 (P-values ≥ 0.05), test 2 ($0.0165 \leq$ 0.05), test 3 (P-values ≥ 0.05), test 4 ($0.0189 \leq 0.05$), test 5 (P-values ≥ 0.05), and test 6 ($0.0205 \leq 0.05$). These P-values represent significance directly related to the hypothesis (H$_2$) and indicate that FM Training plays a role as a contributing factor as a supporting element of the overall or general hypothesis (H$_1$). It was found that the learning styles, segregated in FM Training, affect training, but do not affect the usage of BIM. However, the FM Training does impact the usage of BIM which, in turn, is impacted by the learning styles. Therefore, the learning styles are indirectly impacting the usage of BIM.

The findings for the inferential statistical analysis regarding the Specifications conveyed that there is evidence supporting its impact as related to the use of building information modeling for facilities management. This was displayed in a series of examinations for the first run of tests producing P-values less than 0.05 (P-value ≤ 0.05) indicating significance. The Specifications testing in the first run of two tests found validity surrounding the respective P-values for test 7 ($0.002827 \leq 0.05$) and test 8 ($0.05365 \geq 0.05$). Note that the P-value for test 2 is greater than 0.05, however, it is approaching an equal numeric value of 0.05 and by definition; it is accepted practice to that this P-value is in contention for significance. These P-values represent significance directly related to the hypothesis (H$_3$) and indicate that Specifications play a role as a contributing factor as a supporting element of the overall or general hypothesis (H$_1$).

The findings for the inferential statistical analysis regarding the Quality BIM conveyed that there is evidence supporting its impact as related to the use of building information modeling for facilities management. This was displayed in a series of

examinations for the first run of tests producing P-values less than 0.05 (P-value ≤ 0.05) indicating significance. The Quality BIM testing in the first run of two tests found validity surrounding the respective P-values for test 9 (0.009316 ≤ 0.05) and test 10 (0.0357 ≤ 0.05). These P-values represent significance directly related to the hypothesis (H_4) and indicate that the Quality BIM plays a role as a contributing factor as a supporting element of the overall or general hypothesis (H_1).

The findings for the inferential statistical analysis regarding the Usage of BIM conveyed that there is evidence supporting its impact as related to the use of the FM Training, the Specifications, and the Quality BIM for building information modeling for facilities management. This was displayed in a series of examinations for the second run of tests producing P-values less than 0.05 (P-value ≤ 0.05) indicating significance. The Quality BIM testing in the second run of four tests found validity surrounding the respective P-values for test 11 (0.009435 ≤ 0.05), test 12 (P-values ≥ 0.05), test 13 (0.0174 ≤ 0.05), and test 14 (0.0175 ≤ 0.05). These P-values represent significance directly related to the hypothesis (H_1) and indicate that the FM Training and the Quality BIM play a role as a contributing factor as a supporting element of the overall or general hypothesis (H_1). However, the Specifications P-values were all greater than 0.05, indicating that there was no significance associated with the Specifications impact on the Usage of BIM for facilities management. Note that when the Specifications was tested independently, it displayed signs of significance; however, its direct impact did not test as a significant role in the overall Usage of BIM.

There was sufficient supporting evidence from the findings that provide a definitive conclusion of the study. The derived conclusion conveys that the Usage of BIM is minimally implemented for Facilities Management because of the limited willingness by facilities management decision makers to risk the adoption of BIM for FM. Facilities managers continue to revert to means and methods that are tried and true in the FM process; and by doing so, avert the risk of implementing BIM for FM practices. Many of the facilities management decision makers are deliberately not implementing BIM for FM because of the stigma associated with early adoption failures. These managers do not want the association of the adoption struggles linked to their tenure and avoid the risk by not embracing the technology that BIM offers the FM community.

As seen by the evidence provided through the pilot study interviews and Q8 and Q32 of the survey instrument, many of the personnel of FM perceive that BIM is being used when, in fact, the Usage of BIM is not actually occurring. This circles back to the risk aversion by FM decision makers and the continued migration towards means and methods of FM that have been functioning in formats pre-BIM. Ultimately, until FM decision makers commit to taking the risk of implementing BIM for FM, the Usage of BIM for FM will remain in a limited state of adoption.

Limitations of the Study

This study was geared towards investigating the usage of building information modeling and the utilization of building information modeling technical specifications

for facilities management in higher educational institutions in Texas. The compass of the research allowed for strategic and calculated hypotheses supporting and/or rejecting anticipated outcomes. The study was also intended to investigate the impact, or lack of impact, that the facilities management training, the specifications, and the quality BIM model held in regard to the overall usage of BIM. With these objectives, the study endured limiting elements through the course of the research.

The study encountered three main limitations. The first limitation was associated with the potential number of variables that may impact the outcomes of the study. Through the literature review and case study analysis, three factors were derived as potential candidates that could impact the usage of BIM for facilities management in higher educational institutions in Texas; however, it is highly probable that other factors exist that were not addressed in this study. The second limitation was obtaining a large enough sample to generate conclusions about the study that could be generalized. This study was specific to higher educational institutions in Texas, and the sampling size was deliberately selected to ensure a high quality of collected data. The third limitation was associated with the impact demographics have, if any, on the derived hypotheses of the study. Limited demographic analysis was conducted concerning its role in supporting or rejecting the hypotheses, as this analysis was not part of the intended purpose of the study. Although demographics were a limiting factor for this study, it would be a legitimate platform for future research.

There are a multitude of factors contributing to the results and outcomes of the research and the study recognizes and acknowledges that characteristic. Because of this,

it is virtually impossible to account for every factor or contributing nuance and is beyond the intended scope of this study.

Contributions and Recommendations

It is the intent of every research study to put forth a measurable and impactful piece of knowledge with the hope that it will become a placeholder in the framework of the given field of study. Albeit minute, this study has exhibited the ever so slight movement of the needle of knowledge. Within the defined parameters of the study, this research has provided valid and meaningful results through a methodical and rigorous process.

Equally important to what has been found in a study is to identify what was not found. This holds true of this study and its outcomes. The sampling population of this study was specific and somewhat small, yet of high quality. However, even though the sampling was small, these characteristics did allow for the findings to be generalized. This is important because that opens the door for further research to begin ways of generating a study that will continue to narrow that gap. Another item that this study did not provide was the continued elaboration on the impression of the learning styles as related to the FM Training portion of the research. This is a very important piece to the success of the training aspect concerning personnel. As this was not investigated thoroughly, it would be a valid aspect to explore and research the impact of its presence.

The contributions of this study possess similar qualities by focusing on isolated aspects of the research; specifically FM Training, Specifications, and Quality BIM. This

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is significant because these components are pieces of the greater whole associated with both building information modeling and facilities management. It is these very components, and like components, that can be further studied in future research.

Future Research

This study has provided a platform for future research with the intention of exploring different means to increase the usage of building information modeling for facilities management. The literature review and the selected cases studies provided a vehicle to derive the chosen elements of FM Training, Specifications, and Quality BIM to investigate the respective impacts on the Usage of BIM for facilities management. As this study was specific to higher educational institutions in Texas, it is quite plausible that a similar study could easily be orchestrated for a new parameter within the realm of facilities management and the usage of BIM. Additionally, this platform sets the stage for future studies to explore other elements, or combinations thereof, to be executed in similar fashion to test new levels of influence.

As mentioned in the previous section, the opportunity to explore and research the learning styles of facilities practitioners presents a tremendous avenue to investigate an item touched on in this study but not fully discovered. Additionally, the fact that this study was not able to be generalized opens the opportunity for future research with methodology that would allow for the frequency and increased population of the future study to allow this to occur.

Points to Ponder

As building information modeling continues to embed itself in the built environment, it is imperative that owners and facilities management personnel recognize and acknowledge the urgency to embrace the usage of BIM for facilities management. It is evident that this sector of the built environment is behind the adoption curve. It will be through research and industry application efforts that solutions will surface and assist with the increased base of knowledge surrounding the issue.

The perceptions of BIM usage and the actual practice on a daily basis appear to differ; however, with every piece of contributed knowledge it is possible to enlighten those that remain skeptical or tentative about making changes towards implementation.

This study derived that the FM Training, the Specifications, and the Quality BIM were potential contributing factors towards increasing the use of BIM for facilities management. To claim definitively that these are the sole impacting factors responsible for generating an increased use of BIM for facilities management would be impossible. Arguably, from the results of the study it would certainly be fair to state that each of these factors are contributors to the usage of BIM for facilities management. And that contribution is worthwhile.

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Case Study 1: MathWorks

Osama Aladham, Jasmin Gonzalez, Iris Grant, Kenyatta Harper, Abe Kruger,

Scott Nannis, Arpan Patel, and Lauren Snedeker

Management Summary

MathWorks, a leading developer of mathematical software for engineers and scientists, planned to add a new building to their corporate campus to accommodate the growth of the company, employees' needs, and increase client satisfaction. In both their procurement and contract language, MathWorks emphasized building information modeling (BIM) as a key factor in awarding contracts for this project. To design and construct the new building, the facilities team at MathWorks worked with Spagnolo, Gisness, & Associates, Inc. (SG&A; Core and Shell Architects), Gensler (Interior Architects), Cranshaw Construction of New England (General Contractor), van Zelm Engineers (MEP Engineers), Vico Software (BIM Consultants), FM:Systems (FM Software), ID Group (Data Center Consultant), and National Development (Developer). The collaboration of this team helped MathWorks realize its vision for a work environment similar to a college campus: fostering a corporate culture focused on innovation, learning, and teamwork. Their design, construction, and facilities

management teams have proven to be effective in achieving their goals, although there are no deliverables yet in terms of quantifiable costs and benefits data.

This project highlights innovation in both the processes and technology required to support the integration of BIM and FM. Although their contract specified only a basic requirement to deliver a BIM model, during the course of the project MathWorks realized that a more detailed definition of deliverables was critical. While the GC and its team of subcontractors were very skilled at their core disciplines, there were various levels of BIM maturity across the firms. This eventually led MathWorks to ask SG&A to help them find a BIM consultant to coordinate modeling among all the parties involved during the construction phase. SG&A found Vico Software and MathWorks retained them to manage coordination. This meant that some team members had to pay Vico to create their part of the BIM model, an investment that MathWorks felt was worth its value in the long run. In total, there were five different BIM models created and linked together. The main BIM software used to coordinate construction was Autodesk Revit and MathWork's space and maintenance management system was FM:Interact, which released a major enhancement to its Revit integration in May 2012. This project was a pilot for the new technology.

New technology paves the way for process improvement by giving the project team improved methods to analyze the benefits and barriers of their traditional workflows. A natural benefit of the technology was the project's use of integrated project delivery (IPD) principles such as co-location, which took the form of weekly coordination meetings that included all parties, if not in person, then via the Web. This

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helped the team uncover and resolve issues before finding them in the field – avoiding potential cost and delay. In addition to accurately modeling the building systems to avoid clashes in the field during construction, data elements like equipment model, manufacturer, and other attributes were entered into the BIM models to eliminate the manual entry of operations and maintenance data after building handover. This allowed the project team to place complete and accurate FM information into the hands of the owner before occupancy.

The project faced two barriers to fully integrating BIM and FM during the construction process. The first was the learning curve involved in the transition from traditional two-dimensional construction documentation to the newer three-dimensional, data-centric process. While many architecture, engineering, and construction firms have adopted BIM, many subcontractors still work in CAD-based products, which cause problems when integrating their data. The second issue that was addressed on this project was the determination of data detail for the FM model. Because FM integration with BIM technology is still evolving, there is a need to outline the steps or guidelines required to implement these processes. Despite these barriers, the MathWorks Campus Expansion project is a well-planned attempt toward a milestone for BIM\FM technology integration (Bernardi and Donahue 2012).

APPENDIX B

Case Study 2: Texas A&M Health Science Center

A Case Study of BIM and COBie for Facilities Management

Georgia Institute of Technology:

Rebecca Beatty, Charles Eastman, Kyungki Kim, and Yihai Fang

Management Summary

The enriched data captured in building information modeling during design and construction has important uses during the full operating lifetime of a facility. The identification, capture, and processing of data useful for this lifetime has just begun. The Texas A&M Health Science Center's (TAM HSC) most recent completed project, Phase 1 in Bryan, Texas, has taken multiple steps to integrate BIM into their facilities management program. This case study reviews efforts made to capture digital information about the spaces, systems, and equipment used for facility management on HSC facilities across nine campuses. The primary focus of the case study is on the implementation of COBie on the Bryan campus location, the first campus to implement COBie. The second campus to implement COBie was in Round Rock, Texas, for a facility that was a few years old, but the FM data was intact enough to apply the process to an existing building. The long-term intent is to evaluate the benefits for new and existing facilities and to validate the predicted benefits and return on investment. Once

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validated, the process will be applied to other campuses and existing facilities to re-baseline and normalize their facilities management data across the enterprise.

TAM HSC is the owner\client for this project and defined the initial target requirements for the use of BIM on the project in coordination with recommendations and proposed approaches from Broaddus & Associates. The owner team (TAM HSC and Broaddus) identified the use of COBie to generate the base data for supporting preventive maintenance and facility condition analysis. The computerized maintenance management system (CMMS) selected to carry out the maintenance activities was AiM (developed and sold by AssetWorks). AiM is web based and was used to import all the existing datasets for the Bryan campus and also from the other campuses to unite them into a single integrated CMMS system. Broaddus & Associates of Austin, Texas, was the program manager for the Phase 1 project for Texas A&M University. They oversaw the design, construction, and commissioning process for the $130 million dollar Phase 1 project. Early in the project, the subject of BIM was introduced to the project team. Broaddus worked with key TAM HSC leadership to implement the COBie process for TAM HSC. The project's three main BIM objectives were (1) to deliver as-built 3D models from the construction process, (2) to deliver facilities management data in the COBie format, and (3) to facilitate the import (upload) process of the data and documents into the CMMS. TAM HSC staff also conducted a requirements analysis for an enterprise asset management system, competitively procured it, and administered the deployment and configuration of the CMMS. AiM by AssetWorks was the system

selected and installed. Broaddus assisted the TAM HSC in formatting specific BIM and COBie requirements and test scenarios used in the procurement process.

This study reports on the new precedent that the project has set for the Texas A&M University System and reviews the lessons learned for future projects and how to realize the targeted integration between BIM and their CMMS system. TAM HSC was one of the first large-scale educational institutions to implement COBie in their building program all the way into their facility management application. Bryan Campus Phase 1 also serves as an example for improvement and gives a glimpse into the future for the facility management industry. Future improvements being addressed include, but are not limited to, the development of a BIM POR (program of requirements) that is specific to TAM HSC and will allow them to further pursue BIM with consistency in the areas of campus strategy, 3D modeling criteria, FM data criteria (COBie), and utilization in AiM.

APPENDIX C

Case Study 3: USC School of Cinematic Arts

Victor Aspurez

PE Assistant Director – Engineering Services, Facilities Management Services,

University of Southern California; PhD student in the Sonny Astani Department of

Civil and Environmental Engineering, University of Southern California

Angela Lewis, PE, PhD, LEED AP

Project Manager with Facility Engineering Associates

Management Summary

The University of Southern California (USC) School of Cinematic Arts is an example of a successful BIM FM project that challenged current industry practice. The complex of six buildings was constructed in three separate phases, starting in 2007 to the present day. The first phase of the project used BIM in a construction centric manner. During Phase 1, the University Capital Construction Division (CCD) and Facility Management Service (FMS) really started to understand the potential value of BIM FM. Phase 2 was design BIM centric. During this phase, designers were required to leverage BIM. Phase 3 is considered facility management-centric. This phase is ongoing as this case study is written in 2012. During this phase, FM-related information from BIM is

being collected from the design and construction process, as a result of following BIM Guidelines established by the university.

The major advances from the three-phase project include:

- The development of a BIM Guideline that includes a document approach of how to use multiple common industry standards, including OmniClass, the National CAD Standard and COBie. These guidelines provide a framework for project stakeholders in the execution of their services and the completion of deliverables required to meet FM goals.

- The realization that the most significant information for FM is the data from the BIM models. The 3D graphic model is of secondary importance.

- The development of a facility management portal, created with the needs of FM personnel in mind, made it easier to find information.

The major stakeholders that largely influenced the outcome of BIM FM over the 3 phases include the primary donor; the USC Facility Management Services (FMS) team; the BIM integrator, View By View; the Architect, Urban Design Group; and a middleware software provider, EcoDomus. Additionally, university and consultant project principals played a significant role in influencing the vision and project requirements.

One of the biggest challenges during the project was finding the resources to update as-built building models after completion of construction, as required for FM purposes. These models were needed for facility management decision making and building operations troubleshooting. These FM systems (such as the building automation

system [BAS]) require access to accurate real-time data. These goals cannot be satisfied by referencing 2D static as-built drawings and closeout documentation. Additional technology and human resources are needed to support the management of models and their related information. In addition new FM processes are required to support the integration of BIM with FM.

Key technologies on this project included BIM authoring software (Revit Architecture, Revit MEP, and Tekla Structures), middleware (NavisWorks Manage and EcoDomus) and FM systems (facilities asset management information system [FAMIS], Enterprise Building Integrator, and Meridian Enterprise).

The most important lessons learned include:

- New processes do not necessarily require that new types of software to be developed to replace traditional FM information systems. In some cases, it is a matter of using BIM FM more effectively along with existing FM software (CMMS, CAFM, BAS, and DMS).

- Recommendations about what practices or standards to use are often role based, e.g. a designer will favor standards that are traditionally used for design. Thus, the team determining what practices and standards to use should be representative of all key stakeholders, including those from FM.

- BIM FM is not an "out-of-the-box" product. It requires new processes, new technologies, and new lines of communication.

APPENDIX D

Case Study 4: Implementation of BIM and FM at Xavier University

Elijah Afedizie, Rebecca Beatty, Erica Hanselman, Eric Heyward, Aisha Lawal, Eric Nimer, Laura Rosenthal, and Daryl Siman

Management Summary

This case study describes the use, integration, and delivery of BIM through all stages of construction in Xavier University's latest construction projects. The major players in delivering the completed project were Messer Construction Co., Shepley, Bulfinch, Richardson & Abbott, Michael Schuster Associates, and the Xavier Facilities Maintenance department. This project was the largest and most costly expansion in the school's history – adding 25 percent to the total portfolio (from approximately 2 million GSF to 2.5 million GSF) and four new campus buildings: Smith Hall (housing the Williams College of Business), Conaton Learning Commons, Central Utility Plant, and Bishop Fenwick Place.

The chosen BIM program, Autodesk Revit, was utilized to facilitate design and construction. However, the subcontractors modeled the mechanical, electrical, plumbing, and fire protection systems in various CAD-based software products. The CAFM system, FM:Interact by FM:Systems, is used to manage space and occupancy and track architectural finishes. The CMMS system, WebTMA by TMA Systems, is used to

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manage maintenance and track building system assets. While a thoroughly vetted cost\benefit life-cycle analysis is not yet available, Xavier estimates that over a person-year of data entry was avoided by leveraging data in the BIM. Also, initial estimates reveal that the use of BIM on these projects will generate significant cost savings for facility management over the life cycle of the buildings. Additionally, data from the models assisted Xavier in forecasting life-cycle facilities costs – helping the facilities department increase their renewal and replacement budget from $750,000 per year to $12 million per year, which represents 2.3 percent of the total replacement value of the campus facilities. The additional budget will fund projects that allow the facilities department to reduce deferred maintenance and support a vibrant campus environment.

As Xavier's first attempt at using BIM on a large-scale project, it was not completed without challenges. Most important, the FM department was not involved in the early phases of the project. This led to additional costs to revise the models to support FM integration. In addition to these added modeling costs, the CMMS used for these buildings (WebTMA) is not currently easily linked to the BIM software. As a result, Xavier had to work with traditional methods to populate their CMMS asset inventory. Even with these added costs, Messer's use of BIM on the project led to construction being completed under budget and ahead of schedule – more than compensating for the BIM-FM integration efforts.

Furthermore, Xavier's FM department feels confident that the benefits of BIM use on future projects will continue to grow as university personnel become more comfortable working with these software applications and their processes evolve. In

addition to the learning curve benefits of completing their first BIM project, Xavier also learned that it is important for the owner to specify the BIM data requirements as early as possible in the process to ensure the appropriate stakeholders are entering the required information in the proper way.

After full immersion in the life cycle with the use of BIM for FM, the Xavier staff is convinced of the added value, ease of use, and life-cycle cost savings associated with the tool. They intend to implement its use in future projects as well as for existing facilities on campus.

Case Study 5: State of Wisconsin Bureau of Facilities Management,

Division of State Facilities, Department of Administration

Angela Lewis, PE, PhD, LEED AP

Project Professional with Facility Engineering Associates

Management Summary

The State of Wisconsin Bureau of Facilities Management, Division of State Facilities, Department of Administration, started implementing a BIM FM pilot program in 2011. This case study captures the processes and lessons learned of two of the four BIM FM pilot projects completed between 2011 and 2012. The first project is a residential hall on the University of Wisconsin River Falls (UWRF) campus. The primary phases of the life cycle captured were design and facility management. Thus, the main contributors to the BIM FM efforts were the Wisconsin Division of State Facilities, the UWRF facilities team, and SDS Architects. The second project is the Wisconsin Energy Institute, located on the University of Wisconsin Madison campus. The primary phases captured were construction and facility management. Thus, the main contributors to the BIM FM efforts were the Wisconsin Division of State Facilities and M.A. Mortenson Company.

The use of technology was important to both projects. Both projects used both 2D and 3D object-based parametric modeling software, as well as collaboration software and a computerized maintenance management system (CMMS). Autodesk Revit was the most commonly used 3D modeling software. Collaboration software used by the UWRF project included Submittal Exchange, Logmeln, and an FTP site. The main collaboration software used by the Wisconsin Energy Institute project was Skier Unifier. Several processes to support collaboration on the Wisconsin Energy Institute were also performed, including the plan of the day, having a computer with a large monitor on the job site, and the use of a BIM protocol manual. A TMA Systems CMMS was used at UWRF, while AssetWorks was used on the University of Wisconsin Madison campus.

Comparing the two projects, it is clear that the members of the project team have a large impact on the information flows, availability of information for facilities management from design through construction, and the format in which the information is handed over to the facility management team. Although many of the details between the two projects are different, the major challenges and most important lessons learned were similar. Major challenges for both projects included:

- The architecture and the engineering design communities across the state of Wisconsin are still transitioning from 2D to 3D object-based parametric modeling software. Thus, the learning curve for how to use 3D object-based BIM parametric modeling software, as well as for understanding the value of linking information to object-based parametric models, is very steep.

- Communication across the different phases of the project life cycle is uncommon. Thus, many project team members were unfamiliar with the processes and vocabulary of other disciplines. In order for BIM FM to be implemented more effectively, it will be necessary to increase communication and understanding of the different phases of the project life cycle by designers, constructors, and facility managers.

Considering both projects, the most important lessons learned were:

- Well-written BIM FM specifications and guidelines are necessary for the facility management team to receive the information in a format that is most useful for FM. However, the development of such requirements is difficult when it is necessary to keep the requirements general enough that they can be applied across the entire state, while also being sufficiently specific to ensure that the information provided is of value.

- Each BIM FM project needs to have at least two champions, one who is either a member of the design or construction team and one who is a member of the facility management team. In the case of the residential hall, the architect served as one of the BIM champions, while the general contractor served as one of the BIM champions for the Wisconsin Energy Institute.

Case Study 6: University of Chicago Administration Building Renovation

Angela Lewis, PE, PhD, LEED AP

Project Professional with Facility Engineering Associates

Management Summary

The University of Chicago Administration Building renovation case study focuses on the information handover between construction and facility management (FM). Thus, the major players were the construction manager (CM), M.A. Mortenson Company, and the University of Chicago. A large portion of the case study discusses the transition from construction to facility management, including determining the level of detail with which data should be collected; discussions with decision makers about how they would use the data; and collecting, organizing, and structuring data.

The most important insight from this case study was that the processes to support the use of technology within BIM FM are in their infancy. Skills that are needed to advance process development within the industry include the ability of more professionals to communicate across industry specialties and more knowledge among professionals about computerized maintenance management system (CMMS) databases. Thus, leadership from owners, designers, builders, software companies, and FM consultants is necessary to help advance the industry's vision for BIM FM.

The primary challenges addressed by the case study include:

- Determining to what level of detail information should be collected to support facility management processes and decision making.

- Understanding how the 3D BIM could be used for facility management and how to determine what software, if any, should be procured to support the use of 3D models by the University of Chicago.

- Aligning and leveraging the varying team members' skill sets to deliver a valuable FM tool for the university.

The construction and FM teams both used a variety of different technologies. Software used by the design and construction team included Autodesk Revit, Autodesk NavisWorks, and 3D MEP fabrication software. Additionally, the use of laser scanning was very important to help verify the existing as-built drawings because of the limited space available to run ductwork, piping, and electrical systems. Maximo is the primary facility management software discussed within this case study. The use of Archibus for space management and eBuilder for project management and procurement is briefly discussed.

The largest benefit resulting from the project was the creation of a process that will be of benefit to future renovation and new construction projects: a process to capture data during construction so that it can be used for operations and maintenance over the life of the building.

APPENDIX G

Institutional Review Board (IRB) Approval

ĀĪM | TEXAS A&M
U N I V E R S I T Y

DATE: April 16, 2014

MEMORANDUM

TO: Edelmiro F Escamilla, PhD
TAMU - College Of Architecture - Architecture

FROM: Human Subjects Protection Program
Institutional Review Board

SUBJECT: Expedited Approval – Initial Review

Study Number:	IRB2014-0175
Title:	Implementation of Building Information Modeling in Facilities Management i Higher Education Institutions in Texas
Approval Date:	04/16/2014
Continuing Review Due:	05/15/2015
Expiration Date:	04/15/2015

Documents Reviewed and Approved:

Title	Version Number	Version Date	Outcome
Online Survey	Version 2.0	03/31/2014	Approved
Sample Email to Director	Version 1.0	03/31/2014	Approved
Phone Script	Version 2.0	03/31/2014	Approved
Phone Interview - Directors	Version 2.0	03/31/2014	Approved
PhD Proposal	Version 1.0	03/31/2014	Approved
Assent Letter Form	Version 2.0	03/31/2014	Approved
interview - (see phone script)	Version 1.0	03/04/2014	Approved
Interview - (See Phone Script)	Version 1.0	03/04/2014	Approved
Consent Form - Darrell Thompson	Version 1.0	03/04/2014	Approved

Document of Consent: Waiver approved under 45 CFR 46.117 (c) 1 or 2/ 21 CFR 56.109 (c)1

This research project has been approved. As principal investigator, you assume the following responsibilities:
1. **Continuing Review:** The protocol must be renewed by the expiration date in order to continue with the research project. A Continuing Review application along with required documents must be submitted by the continuing review deadline. Failure to do so may result in processing delays, study termination, and/or loss of funding.
2. **Completion Report:** Upon completion of the research project (including data analysis and final written papers), a Completion Report must be submitted to the IRB.
3. **Unanticipated Problems and Adverse Events:** Unanticipated problems and adverse events must be reported to the IRB immediately.
4. **Reports of Potential Non-compliance:** Potential non-compliance, including deviations from protocol and violations, must be reported to the IRB office immediately.

APPENDIX H

Assent Letter Form

Building Information Modeling in Facilities Management Survey

[Click to select the date]

Texas A&M University
Division of Research
Research Compliance
750 Agronomy Road, Suite 2701
TAMU 1186
College Station, Texas 77843-1186

Attention: Aline Lovings

RE: Letter of Support for Research at Texas A&M University

Dear Ms. Lovings:

We acknowledge the research study and survey being conducted at Texas A&M University in the College of Architecture, Department of Construction Science, by Darrell Thompson (co-investigator) and Dr. Edelmiro Escamilla (primary-investigator) associated with the topic; Building Information Modeling in Facilities Management. In the effort to protect participants in this on-line study, the survey shall be administered by the director of facilities management at [School Name].

The research team (Escamilla-Thompson) agrees to provide a copy of the approved TAMU IRB prior to commencement of any data collection.

Sincerely,

[Your Name]
[School Name]
[School Address]
[City, State ZIP]
[Your Phone]

APPENDIX I

Interview Consent Form

Interview Consent

We, at the Department of Construction Science in Texas A&M University, are conducting a study titled Building Information Modeling (BIM) in Facilities Management (FM). The purpose of this study is to investigate avenues toward increasing the use of BIM in FM.

If you agree to participate in this study, you will be asked to answer questions associated with Building Information Modeling and questions associated with Facilities Management. The interview should not take longer than 15 minutes to complete. The risks associated in this study are minimal, and are not greater than risks ordinarily encountered in daily life. There is no compensation for your participation on this survey. However, you will make a contribution to the improvement of how to better use BIM in FM and potentially increase its use.

Your participation is VOLUNTARY. Information about you will be kept confidential to the extent permitted or required by law. People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly. Research records will be stored securely and only Edelmiro F. Escamilla (primary-investigator) and Darrell Thompson (co-investigator) will have access to the records. Completion and return of the survey/questionnaire indicates permission to use the data in the study.

If you have questions regarding this study, you may contact Darrell Thompson at (303) 744-2244, or email dthompson@arch.tamu.edu. This research study has been reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For research related issues or questions regarding your rights as a research participant, please contact IRB at (979) 458-4067 or irb@tamu.edu.

If you are in agreement with the aforementioned conditions of the interview consent, please, continue with the interview.

APPENDIX J

Survey Consent Form

Survey Consent

We, at the Department of Construction Science in Texas A&M University, are conducting a study titled Building Information Modeling (BIM) in Facilities Management (FM). The purpose of this study is to investigate avenues toward increasing the use of BIM in FM.

If you agree to participate in this study, you will be asked to answer questions associated with Building Information Modeling and questions associated with Facilities Management. The survey should not take longer than 10 minutes to complete. The risks associated in this study are minimal, and are not greater than risks ordinarily encountered in daily life. There is no compensation for your participation on this survey. However, you will make a contribution to the improvement of how to better use BIM in FM and potentially increase its use.

Your participation is VOLUNTARY. Please do NOT enter your name or contact details on the questionnaire, so information provided by you remains confidential and no identifiers linking you to this study will be included in any sort of report that might be published. Information about you will be kept confidential to the extent permitted or required by law. People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly. Research records will be stored securely and only Edelmiro F. Escamilla (primary-investigator) and Darrell Thompson (co-investigator) will have access to the records. Completion and return of the survey/questionnaire indicates permission to use the data in the study.

If you have questions regarding this study, you may contact Darrell Thompson at (303) 744-2244, or email dthompson@arch.tamu.edu. This research study has been reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For research related issues or questions regarding your rights as a research participant, please contact IRB at (979) 458-4067 or irb@tamu.edu.

If you are in agreement with the aforementioned conditions of the survey consent, please, continue with the survey.

APPENDIX K

Phone Script

Phone Script

Hello, this is {Darrell Thompson} a PhD candidate calling from {Texas A&M University, College Station}. May I please speak to {DIRECTOR OF FACILITIES MANAGEMENT}?

[IF SPEAKING WITH SAMPLE MEMBER, GO TO INTRODUCTION-1.]
[IF SAMPLE MEMBER IS NOT AVAILABLE, GO TO INTRODUCTION-2.]

INTRODUCTION-1. {TEXAS A&M UNIVERISTY - CONSTRUCTION SCIENCE DEPARTMENT} is conducting a study to learn about your experiences with {Building Information Modeling (BIM) in Facilities Management (FM)}. The study, in part, is an on-line study that is anonymous and voluntary, coupled with an interview of the FM Director.

The process begins with a phone interview (myself and you, the Director) that takes about 15 minutes. Like the survey, the phone interview is voluntary and has a consent form prior. I will ask questions specific to how you and your team currently operate for the interview portion of the study.

Following the interview is an on-line survey for your FM team. I will send you an email with the embedded consent form. You can then distribute the survey to your team. Directors of Facilities Management of other universities \ institutions will be asked the same questions. In this way, we are able to determine current practices among higher education institutions in Texas, as related to BIM and Facilities Management. This study encompasses both private and public institutions in Texas.

This survey takes approximately 5-10 minutes to complete. The result of this study is to identify the current practices in facilities management and how, if at all, you are using BIM. Please note that this study is specific to higher education institutions in Texas. A consent form applies prior to the survey.

As the Director of your Facilities Management team, the survey will be distributed to willing, VOLUNTARY participants on your team. With the distribution of the survey is the attached consent form allowing each participant the opportunity to evaluate their option to participate. Additionally, an Assent Form will be provided in a forthcoming email that needs to be signed and forward to the Institutional Review Board (IRB). The address and recipient of the Assent Letter is provided.
[GO TO CONSENT STATEMENTS BELOW.]

INTRODUCTION-2. [SCHEDULE TIME TO CALL BACK:]

Can you tell me a convenient time to call back to speak with (him/her)? Thank you and have a good day.

[RECORD CALLBACK TIME ON CALL RECORD]

[CONSENT STATEMENTS:]

If you agree to conduct the interview and complete the questionnaire, we will then send you an email with an embedded website address to the survey; and consent forms for both. The survey is done through SURVEY MONKEY, a common surveying tool.

APPENDIX K

Phone Script (Continued)

Phone Script

At this time I would like to verify your current contact information. I have initially taken the contact information from the current website for your respective university \ institution.

[NAME OF DIRECTOR OF FACILITIES MANAGEMENT]

[EMAIL ADDRESS]

Let me take this opportunity to tell you a little about the study before we continue. We have selected you and other directors from other universities \ institutions to represent current practices in facilities management and the usage of BIM. First, an interview (with you, the Director) will take place via phone (about 10-15 minutes). Then, a voluntary on-line survey is is conducted. It is focused on how your team is integrating (or not integrating) BIM in Facilities Management. Your answers are very important to our study.

Would you and your team be willing to participate? Great.

Your participation is VOLUNTARY. A consent form precedes the survey, and ALL participants have the option to take, or NOT take the survey. The questions should take about {5 – 10 minutes} to answer, pending your respective response, however, there is no set time limit if you want to elaborate.

Those are all the instructions\questions that I have. Do you have any questions for me? I will be sending you an email with the embedded survey link shortly.

Thank you very much for your help with this study. Have a nice (day). Goodbye.

APPENDIX L

Sample Email to Director for Survey

Ladies and Gentlemen:

I am working on my PhD at Texas A&M and my topic is focused on implementing Building Information Modeling tools for an improved efficiency for Facilities Management for higher education institutions in Texas. Attached\embedded is the consent form and the on-line survey for my study.

Consent Form@example.com (also, attached as PDF)

BIM & FM Survey@surveymonkey.com (also, attached as PDF)

For convenience the surveys will be conducted on-line) via SURVEY MONKEY (5-10 minutes); and the interviews (10-15 minutes) shall be via telephone.

I recognize that your time is valuable and most likely limited, however, your participation would be most appreciated and beneficial.

Please feel free to contact should you have any questions or comments. I hope that you have a pleasant day and I look forward to hearing from you.

Thank you,

Darrell Thompson
PhD Candidate and Instructor
Texas A&M University
College Station, Texas
Construction Science Department
dthompson@arch.tamu.edu
303-744-2244

Survey

Building Information Modeling in Facilities Management - Survey

Welcome to the Building Information Modeling in Facilities Management Survey

As a facilities management professional your point of view is wanted to benefit a research study focused on perceptions of usage of Building Information Modeling in Facilities Management. The survey duration will be conducted as part of a 1 year study beginning Summer 2014. The survey should not take you longer than 5-10 minutes to complete.

Please read the following information concerning this survey. The purpose is to provide you
information that may affect your decision as to whether or not to participate in this research study. If
you decide to participate in this study, this agreement will also be used to record your consent.
You have been asked to participate in a research project studying the perceived usage of Building Information Modeling in Facilities Management for Higher Education Facilities in the state of Texas. You were selected to be a possible participant because you are currently a Facilities Management Professional working in a Higher Education Institution in the state of Texas.
If you agree to participate in this study, you will be asked to answer questions concerning your
perceptions toward usage of Building Information Modeling in Facilities Management. The risks associated in this study are minimal, and are not greater than risks ordinarily encountered in daily life. There is no compensation for your participation on this survey. However, your will make a contribution to the improvement of understanding the perceptions towards Building Information Modeling usage in Higher Education Facilities. Your participation is voluntary. You may decide not to answer partially any of the survey without your current or future relations with Texas A&M University being affected.
This study is confidential. The records of this study will be kept private. No identifiers linking you to this
study will be included in any sort of report that might be published. Research records will be stored
securely and only Dr. Edelmiro F. Escamilla will have access to the records. If you have questions
regarding this study, you may contact Dr. Edelmiro F. Escamilla at (979) 845-4226, eescamilla@arch.tamu.edu. This research study has been reviewed by the Human Subjects'
Protection Program and/or the Institutional Review Board at Texas A&M University. For research related problems or questions regarding your rights as a research participant, you can contact these
offices at (979) 458-4067 or irb@tamu.edu.

If you agree please, continue with the survey.

Demographics

1. What is your gender?

○ Female

○ Male

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Survey (Continued)

Building Information Modeling in Facilities Management - Survey

2. What best describes your role in Facilities Management?

○ Executive

○ Facilities Manager

○ Facilities Technician

○ Facilities Staff

Other (please specify)

_____

3. What is your Facilities Management Experience Level?

○ 1 to 5 years

○ 6 to 10 years

○ 11 to 15 years

○ 16 to 20 years

○ 20 plus years

4. What is the name of your Institution?

_____

5. Your institution is classified as the following.

○ Public

○ Private

6. What best describes your employment status.

○ Directly Employed by the University

○ Separately Outsourced

7. How many Square Feet of Facility are managed by your team?

○ 0 to 1,000,000 Square Feet

○ 1,000,000 to 5,000,000 Square Feet

○ 5,000,000 to 10,000,000 Square Feet

○ 10,000,000 to 20,000,000 Square Feet

○ 20,000,000 Plus Square Feet

○ I Do Not Know

Technology Usage

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Survey (Continued)

Building Information Modeling in Facilities Management - Survey

8. Rate your usage of BIM in your Facilities Management process.

No Use at All	Some Use	Moderate Use	Extreme Use
○	○	○	○

9. What is your perceived awareness of the following:

	Not at All Aware	Slightly Aware	Somewhat Aware	Moderately Aware	Extremely Aware
Building Information Modeling (BIM)	○	○	○	○	○
BIM Technical Specifications	○	○	○	○	○
BIM As-Built-Models	○	○	○	○	○
Available BIM Training and Certifications	○	○	○	○	○

10. Describe your ability to manipulate a Building Information Model using the following BIM Software.

	Not at all able to Manipulate	Somewhat able to Manipulate	Moderately able to Manipulate	Extremely able to Manipulate
Autodesk Revit	○	○	○	○
Bentley Architecture	○	○	○	○
FM:Systems FM:Interact	○	○	○	○
Graphisoft ArchiCAD	○	○	○	○
RhinoBIM	○	○	○	○

11. Is any BIM software training available at your Institution?

○ Not at all Available

○ Somewhat Available

○ Readily Available

12. Describe your participation in the following:

	Never	Sometimes	Almost Every Time	Every Time
I actively participate in writing BIM Technical Specification for FM	○	○	○	○
Given the chance would you give input for BIM Technical Specification writing	○	○	○	○
I use written BIM Technical Specification to perform my FM tasks	○	○	○	○

13. What would be your willingness to lead the implementation of a better BIM Technical Specification for Facilities Management.

Not Willing at All	Somewhat Willing	Mostley Willing	Completely Willing
○	○	○	○

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Survey (Continued)

Building Information Modeling in Facilities Management - Survey

14. Does your BIM Technical Specification provide detailed information about items you manage?

Not at All	Somewhat	Most of the Time	Always	N/A
○	○	○	○	○

15. Are you familiar with Construction Operations Building Information Exchange (COBie)?

○ Yes

○ No

16. Does your facilities software use COBie data?

Not at All	Somewhat	Most of the Time	Always	N/A
○	○	○	○	○

17. If you use COBie, is the data easily accessible for FM tasks?

Not Accessible at All	Somewhat Accessible	Mostley Accessible	Extremely Accessible	N/A
○	○	○	○	○

18. If you use COBie, is the accessible data accurate?

Not Accurate at All	Somewhat Accurate	Mostley Accurate	Extremely Accurate	N/A
○	○	○	○	○

19. What kind of documents do you utilize for Facilities Management (answer all that apply)?

☐ Photographic Images

☐ 2D Paper Blueprints

☐ 2D Electronic Blueprint Files

☐ 3D Electronic Building Models

☐ 3D Electronic Building Information Models

Other (please specify)

20. Based on the documents you currently use, describe the level of difficulty to extract information for Facility Management?

Extremely Difficult	Very Difficult	Somewhat Difficult	Not Difficult At All
○	○	○	○

Learning Styles

21. When I operate new equipment I generally:

○ Read the instructions first

○ Listen to an explanation from someone who has used it before

○ Go ahead and have a go, I can figure it out as I use it

Building Information Modeling in Facilities Management - Survey

22. When I need directions for travelling I usually:

- Look at a map
- Ask for spoken directions
- Follow my nose and maybe use a compass

23. If I am teaching someone something new, I tend to:

- Write instructions down for them
- Give them a verbal explanation
- Demonstrate first and then let them have a go

24. When I am learning a new skill, I am most comfortable:

- Watching what the teacher is doing
- Talking through with the teacher exactly what I am supposed to do
- Giving it a try myself and work it out as I go

25. If I am choosing food off a menu, I tend to:

- Imagine what the food will look like
- Talk through the options in my head or with my partner
- Imagine what the food will taste like

26. When I have to revise for an exam, I generally:

- Write lots of revision notes and diagrams
- Talk over my notes, alone or with other people
- Imagine making the movement or creating the formula

27. If I am explaining to someone I tend to:

- Show them what I mean
- Explain to them in different ways until they understand
- Encourage them to try and talk them through my idea as they do it

28. I find it easiest to remember:

- Faces
- Names
- Things I have done

Survey (Continued)

Building Information Modeling in Facilities Management - Survey

29. Most of my free time is spent:

- ○ Watching television or reading a book
- ○ Talking to friends or listening to music
- ○ Doing physical activity or making things

30. I remember things best by:

- ○ Writing notes or keeping printed details
- ○ Saying them aloud or repeating words and key points in my head
- ○ Doing and practicing the activity or imagining it being done

Implementation

31. Whether you are doing so now, or possibly in the future, rate the importance of the following:

	Not at All Important	Somewhat Important	Moderately Important	Extremely Important
BIM Training	○	○	○	○
Influenced BIM Technical Specification	○	○	○	○
Quality BIM Model	○	○	○	○

32. Do you perceive that FM Managers \ FM Technicians in your company are successfully using BIM for Facilities Management?

Not at All Successful	Somewhat Successful	Moderately Successful	Extremely Successful
○	○	○	○

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APPENDIX N

Institutional Review Board Training Status Report

APPENDIX O

Institutional Review Board Training Completion Report Number

APPENDIX P

Institutional Review Board Training Completion Report

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI)
HUMAN RESEARCH CURRICULUM COMPLETION REPORT
Printed on 04/01/2014

LEARNER   Darrell Thompson (ID: 4099272)
PHONE   303-744-2244
EMAIL   dthompson@arch.tamu.edu
INSTITUTION   Texas A&M University
EXPIRATION DATE   03/31/2017

IRB REFERENCE RESOURCE : All CITI modules are available for ongoing use and reference when you join this Learner Group. If you are required to complete the CITI modules as a prerequisite for conducting human subjects research, you should enroll in a Learner Group listed above and complete all requirements. If you enroll in this group you will be required to complete ALL CITI modules. You may change your Learner Group status to "IRB Reference Resource" later to access review any of the CITI modules.

COURSE/STAGE: IRB Reference Basic/1
PASSED ON: 04/01/2014
REFERENCE ID: 12711679

REQUIRED MODULES	DATE COMPLETED	SCORE
Introduction	04/01/14	No Quiz
Research and HIPAA Privacy Protections	04/01/14	5/5 (100%)
Students in Research	04/01/14	10/10 (100%)
ELECTIVE MODULES	**DATE COMPLETED**	**SCORE**
History and Ethical Principles - SBE	04/01/14	5/5 (100%)
History and Ethics of Human Subjects Research	04/01/14	7/7 (100%)
Defining Research with Human Subjects - SBE	04/01/14	5/5 (100%)
The Regulations - SBE	04/01/14	5/5 (100%)
Basic Institutional Review Board (IRB) Regulations and Review Process	04/01/14	5/5 (100%)
Assessing Risk - SBE	04/01/14	5/5 (100%)
Informed Consent - SBE	04/01/14	5/5 (100%)
Informed Consent	04/01/14	4/4 (100%)
Privacy and Confidentiality - SBE	04/01/14	5/5 (100%)
Social and Behavioral Research (SBR) for Biomedical Researchers	04/01/14	4/4 (100%)
Records-Based Research	04/01/14	2/2 (100%)
Genetic Research in Human Populations	04/01/14	2/2 (100%)
Research With Protected Populations - Vulnerable Subjects: An Overview	04/01/14	4/4 (100%)
Research with Prisoners - SBE	04/01/14	4/4 (100%)
Vulnerable Subjects - Research Involving Prisoners	04/01/14	4/4 (100%)
Research with Children - SBE	04/01/14	4/4 (100%)
Vulnerable Subjects - Research Involving Children	04/01/14	3/3 (100%)
Research in Public Elementary and Secondary Schools - SBE	04/01/14	4/4 (100%)
Vulnerable Subjects - Research Involving Pregnant Women, Human Fetuses, and Neonates	04/01/14	3/3 (100%)
International Research - SBE	04/01/14	3/3 (100%)
International Studies	04/01/14	3/3 (100%)
Internet Research - SBE	04/01/14	5/5 (100%)
Avoiding Group Harms - U.S. Research Perspectives	04/01/14	3/3 (100%)
FDA-Regulated Research	04/01/14	5/5 (100%)
Vulnerable Subjects - Research Involving Workers/Employees	04/01/14	4/4 (100%)
Hot Topics	04/01/14	No Quiz
Conflicts of Interest in Research Involving Human Subjects	04/01/14	5/5 (100%)
The IRB Member Module - 'What Every New IRB Member Needs to Know'	04/01/14	1/7 (14%)

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI Program participating institution or be a paid independent learner. Falsified information and unauthorized use of the CITI Progam course site is unethical, and may be considered research misconduct by your institution.

Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Program Course Coordinator

APPENDIX Q

Pilot Study Interview

Pilot Study Interview

1. Building Information Modeling – Quality BIM

    a. Does any of your team use BIM?
    b. Does any of your team create BIM models?
    c. The way you currently manage facilities, is a quality BIM model necessary?
    d. The way you currently manage facilities, would a quality BIM model make a difference?
    e. Do you process any work orders with a quality BIM model?
    f. Would a quality BIM model make work order processing more efficient?
    g. Does a poorly created BIM make facilities management more difficult?
    h. If a quality BIM model was provided to your team would you use it?

2. Influenced Specifications for Building Information Modeling – BIM Technical Specifications

    a. Does your institution use specifications for BIM models?
    b. Do the current specifications generate a quality BIM model?
    c. Do the specifications for BIM models actually impact the quality of a BIM model?
    d. Does your team influence the specifications for BIM models?
    e. Would a specification influenced by a facilities management team \ team member generate a more quality and usable BIM model?
    f. Do facilities management team members know specifically what is needed from a BIM model to manage a facility?
    g. Do you use Construction Operations Building Information Exchange (COBie)?

3. FM Training for BIM

    a. Does your institution provide BIM training for your FM team?
    b. Would an FM team \ team member with BIM training encourage the use of BIM?
    c. Do you have the financial resource to train your FM team for BIM?
    d. Do you have the time resource to train your FM team for BIM?
    e. Do you have the need to train your FM team for BIM?
    f. Is BIM too difficult to learn or use for your FM team?
    g. If your FM team \ team member were trained, would they be better suited to influence a BIM specification?