A STUDY OF TECHNOLOGY INNOVATIONS AND APPLICATIONS IN TRANSFORMING SAFETY AND SECURITY IN HEALTHCARE FACILITY MANAGEMENT

A Thesis

by

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ABSTRACT

The increasing complexity of construction projects has transformed the Architecture, Engineering, and Construction (AEC) industry through technology adoption over the last decade. But, Facility Management (FM) as an industry has been slow in technology adoption. Growing market competition, corporate demands and new ways of attracting clients for owners are compelling FM professionals to be more efficient. This requirement is driving technology adoption by FM professionals. This study identifies technologies adopted by Healthcare Facility Management (HFM) professionals for improving safety and security of users that have capabilities and conceived and/or developed applications that can or in some cases are at present used in HFM. Simultaneously, it also looks into potentials and capabilities of a handful of other technologies in further improving safety and security.

Using Literature-Based Discovery (LBD), the technology applications and innovations aimed towards safety and security are discovered from the literature that falls within the purview of HFM to form a picture of how these technologies enhance the practice of FM. The study aims at detecting how technologies have contributed towards transforming user experience. Also, this study identifies existing technologies and innovation demands (knowledge and gaps in knowledge), a general understanding of technology, its use and capabilities, and its recognition by users and industry professionals (adoption/rejection). They serve to illustrate how and to what degree the technologies will come to be used in facility management.

Technologies, as they mature, will come to be used by facility managers in similar functions and hypothetically, entirely new ones. One should create a better user experience tailored to the functionality demanded. It is important for facility managers to partner with technology companies presenting innovative solutions to create a platform that is tailored to user-specific needs. Acceptance of a unified process, together with input from users, facility managers, and an assessment of current technologies and new advances in practice are productive ways to develop technologies that drive user satisfaction. This paper works to illustrate a future vision of HFM based on these technologies. Healthcare facility managers will have a reference that assembles multiple technological proficiencies that can function in their practice going forward.

DEDICATION

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NOMENCLATURE

AEC	Architecture, Engineering and Construction
FM	Facility Management
HFM	Healthcare Facility Management
LBD	Literature Based Discovery
RFID	Radio Frequency Identification
IT	Information Technology
HIT	Health Information Technology
WSN	Wireless Sensor Network
CMMS	Computerized Maintenance Management System
TAM	Technology Acceptance Model
CCTV	Closed-Circuit Television
PZT	Pan Zoom Tilt

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CHAPTER I

INTRODUCTION AND BACKGROUND

1.1 Facility Management

The early definition of facility managers scope of work only embraced with the "hardware functions" such as furniture, buildings, and equipment's (Becker, 1990). In later years, "software functions" such as people, process, health, environment, and safety were added to facility managers scope of work (Tay & Ooi, 2001).

In modern times FM has emerged as broad remit providing a comprehensive cradle to grave approach (Payne, 2000). At present, FM has developed into a complex industry that takes care of the operation and management aspects of a facility.

1.2 Introduction

Innovations in technology, technology acceptance, adoption and application in real world scenarios are transform existing industries and businesses precipitously; outlined by their uniqueness, applications, impact and scope. Similar patterns resulting in progressive impact can be observed across architecture, engineering and construction businesses where technology have exponentially transformed the industry.

The purpose of FM is to contribute towards organizational success. Another important objective of FM is to realize owners interest, staying ahead of competitors, attract new users while retaining existing; achieved through providing quality services for the users. Facility management as an industry is considered a dawdler in the technology

adoption curve (Thomson, 1990). Economic and business pressure has pushed FM towards technology acceptance and adoption (Nazali Mohd Noor & Pitt, 2009).

The present-day market is highly competitive, and the competition is bound to grow. Hence, owners and facility managers must align and be current with technology development in order to remain competitive and relevant today's world.

1.3 Background

Facility management tasks vary as per the functions of the facility, and every facility has multiple functions. Healthcare facilities are one of the most complex facilities to manage, comprising of multiple management tasks aimed towards organizational effectiveness and enhancing user experience; safety and security being one of them. Innovations in technology have led to improved user experience in healthcare. Facilities like the healthcare industry whose primary focus is proliferation of innovations aimed at enhancing quality of life, longevity, diagnostic and treatment options, as well as efficiency and cost-effectiveness of the healthcare system have stepped into technology adoption for improving comfort, safety and security of the patients/users, resulting in enriched user experience (Omachonu & Einspruch, 2010). Factors that have led to this perception are circulation of innovations, technology acceptance, participative decision making, and organizational change. Nowadays, safety culture assessment tools for improving patient safety in healthcare organizations are being established; dedicated towards cultural aspects of patient safety, improvement efforts showing an increased focus towards safety and security can be realized (Patterson, Cook, & Render, 2002).

One can argue, for healthcare facility managers, the most important duty of all pertains to maintaining facility security. Having knowledge of who is entering or leaving the building, who is permitted or restricted (in a dedicated functional space), is of utmost importance; safety of both the facility and its occupants, is vital for desired level of facility operation. This literature review discovers technologies that have shown affirmative impact in enhancing safety and security duties in healthcare facilities that fall under the preview of healthcare facility management. The technology adoption behavior curve is studied to understand the hierarchy involved in technology acceptance. In addition, technologies that might in future develop safety and security enhancement applications in healthcare facility management are reviewed.

1.4 Current knowledge

Monitoring a facility manually is challenging and one cannot overlook the possibility of human error; technology applications can assist, eliminate, or to a certain level minimize unwanted irregularities in facility operations. One such technology is Radio Frequency Identification (RFID); RFID offers tracking capability to detect supplies, equipment, and people in real time. Its adoption in healthcare found RFID to be practical and efficient in areas such as asset tracking, patient identification and security (Yao, Chu, & Li, 2012). Individuals visiting a healthcare facility are limited from invasion of restricted spaces; enhancing safety of patients/users and avoiding unwanted security concerns. RFID technology offers healthcare facility mangers advantages in improve patient safety (Yao, Chu, & Li, 2010).

Also, the study explores the various other safety and security technologies; namely, Healthcare Information technology (HIT), Computerized Maintenance Management Systems (CMMS), and, Close- Circuit Cameras (CCTV)/TV Surveillance. The user experience with technology is also explored. What should be considered during technology development process and the role of users and facility managers in technology development?

1.5 Problem Statement

The present-day market is highly competitive, and the competition is bound to grow. Hence, the owners and facility managers must align with technology development and adoption to remain competitive and relevant in present scenarios: attracting new users while retaining existing.

1.6 Research Question

What are the technologies accepted and adopted by Healthcare Facility Managers as a tool for enhancing safety and security of users?

What is the progress of utilizing potential technologies as a tool for healthcare facility managers in transforming user experience (safety and security): concerning technology capabilities, widespread adoption, and challenges?

Which innovations and new technologies have the potential to impact safety and security in healthcare facility management? What stage of development or adoption are these technologies at present?

1.7 Research Goal and Objectives

The overall goal of this study is to provide a visual of how technological abilities are being applied to safety and security in facilities which falls within the purview of FM. Providing healthcare facility managers, a reference of how the technologies are being developed and applied today have the potential to change their industry of the future. The study does this by first collecting a list of organizational functions that an HFM usually carry out for providing safety and security in a healthcare facility.

Secondly, the technologies that have developed applications for improving safety and security are assessed from literature. At the same time, any technology that has capability or applications that could be or are being applied towards safety and security enrichments of a facility are analyzed for their potential in healthcare facility management.

Finally, these technology capabilities and applications are connected to the safety and security functions of FM they serve to illustrate how and to what degree the technologies are being used to transform safety and security of users.

CHAPTER II

LITERATURE REVIEW

2.1 Healthcare Facility Management (HFM): Safety & Security Functions

Healthcare is one of the most complex and multi-functional facility. A facility managers organizational functions comprises of; management, operation, and maintenance functions (Colling & York, 2009). For a healthcare facility manager, there is no shortage of work; task varies from performing daily operation and maintenance to figure out how to make their facilities more sustainable and energy oriented. The most important duty of all pertains is to maintaining facility safety and security; facility managers need to make sure that patient, user, visitor or any person entering or leaving a facility secure and safe. Safety and security function of an HFM include fire safety and overall security of the facility (Table 1). This includes safety and security policies, installation of hardware, implementation of technologies and innovative decision-making systems; securing and monitoring individuals entering or exiting the facility, both interior and exterior perimeters of the facility.

Table 1: Facility managers safety & security organizational function.

Safety & Security functions of Facility Manager (Colling & York, 2009)	**Scope of work (Colling & York, 2009)**
Overalls security of the facility	Maintenance of security hardware as well as regular inspection and testing. Installation of new equipment or technology.
Fire Safety and security	Maintenance, inspection and testing of all fire safety systems and equipment. Installation of new equipment or technology.

2.2 Brief history of Safety and Security Operations in Healthcare Facilities

The security personals should have a clear understand and knowledge of who is entering or exiting a facility; it is of paramount importance for safety and security of both the occupants and facility, which is fundamental to facilities smooth operation (Rusbult, Martz, & Agnew, 1998). Log-books and sign-in sheets have dominated front desks for decades; monitoring time spent by patient, visitor, employee or doctor. The amount of power they hold often goes overlooked, as the real problem, unfortunately, does not become fully evident until disastrous incursions.

Problems and difficulties such as visitors shun sign-in sheets, illegibility of credentials, fake names and in some cases receptionist missing in action has paved the way for adoption of technology in monitoring safety and security in healthcare facilities (Carpman & Grant, 2016). Technology-driven solutions are revolutionizing safety and security. Facility managers are challenged with never-ending duties on a daily basis. Fortuitously, recent technological advances, some of these can be better managed and efficiently streamlined. With technology inputs visitor registration and management; guest's whereabouts, maintain building security and effectively managing visitor/host interactions can now be monitored efficiently. The greatest challenge for a facility manager is to find a single technology solution that tackles all safety and security functions.

2.2.1 Next generation sign in sheets

These days the process of signing-in is as simple as the visitor clicking the correct name displayed, which then alerts the patient to the guest's arrival. Registration apps with

the ability to print out personalized visitor badges are being developed; this process of visitor monitoring begins with visitor preregistering before they even arrive (Lai, Huang, & Yang, 2016).

2.2.2 Monitoring

Biometric and facial recognition software systems for visually tracking patients, visitors, employees and support staff provide significant security benefits (Jain, Ross, & Prabhakar, 2004).

2.3 Technologies: Safety and Security applications in Healthcare Facilities

2.3.1 Radio Frequency Identification (RFID)

The adoption of Radio Frequency Identification (RFID) in healthcare facilities is far behind earlier expectation. RFID is a hybrid system of barcodes that is improving the accuracy of security in healthcare facilities. This technology is low cost and convenience of identifying an object without physical contact. RFID systems provide innovative, promising and efficient applications in many domains (Chien, Yang, Wu, & Lee, 2011). RFID based technology can uniquely identify objects and personals; ensuring security and can limit unauthorized individuals from being able to access restricted areas within a facility (Welbourne et al., 2009). RFID technology based employee and patient tags indicate when a restricted area is entered; alarm would be triggered to alert security personnel in case of unauthorized entry (Wicks, Visich, & Li, 2006).

RFID technology is also being used for identifying, tracking, and locating patients, clinicians, equipment, supplies, and controlled drugs in hospital facilities (Miller, 1999). Tags are being used to determine whether supplies and instruments had been sterilized.

RFID tags track residents in long-term care facilities, monitor access to restricted areas, identify implantable medical devices, and scan information from implanted equipment (Wicks et al., 2006). Providing tracking capability to locate people in real time, RFID also provides efficient and accurate access to locate equipment; eliminating theft and securing inventory (Yao et al., 2010). RFID have demonstrated implementations of automated equipment tracking technology (Costin, Pradhananga, & Teizer, 2012).

Although this technology is very useful for security services, it invades the privacy of an individual. This elaborates the developments made through technology to ensure security within a facility. Given the increasing pace of technology implication in health care and the high cost of patient safety technologies, healthcare organizations cannot afford to make mistakes that lead to failures (Karsh, 2004); it is important to proceed with caution. Also, it is important to understand that technology can only be successful if applied in synchronization with human behavior (Luo, Li, Zhang, & Shim, 2010).

2.3.2 Health Information Technology (HIT)

The face of healthcare is changing as new technologies are being incorporated. Information Technology (IT) has revolutionized businesses; Health Information Technology (HIT) is leading the way in security and safety operation enhancements for a healthcare facility. Practical application of IT in healthcare and hospital management is increasingly improving safety and security. HIT uses diverse means of security interface for tracking, such as; sensor mechanism, a password, PIN, or piece of personal information, a card key, smart card or token, and a biometric (Liu & Silverman, 2001).

The Wireless Sensor Networks (WSN) is one of the main building blocks in ambient intelligence (Kaseva, Hämäläinen, & Hännikäinen, 2011). WSN consist of densely arrayed, independent, and collaborating micro-sensors which are highly resource-constrained concerning energy, processing, and data storage capacity (Mekhjian et al., 2002). With the hospital security WSN, personnel can send wireless alarms in threatening situations (e.g., to police), receive acknowledgments notifying that assistance is on its way, create numerous kind of measurements, and use actuators (a type of motor that is responsible for moving or controlling a mechanism or system).

Password authentication has been adopted by multiple businesses as one of the most commonly used solutions in complex settings to protect resources from unauthorized access. Improvement of remote user authentication scheme using smart cards, computer standards & interfaces and improved remote authentication scheme with a smart card, respectively has made possible the use and adoption of a smart card based password authentication system for security monitoring in healthcare facilities (Xu, Zhu, & Feng, 2009).

Biometrics measure a person's distinctive physical characteristics to recognize or validate their identity; conventional physical biometrics include retina, iris, or facial features, and fingerprint (hand or palm geometry). Biometrics offer superior security and accessibility than traditional methods for people identification. The most efficient property of biometric security systems is that level of safety is approximately counterpart for all users in a system; which is not true for other security technologies (Faundez-Zanuy, 2006). Biometric security systems are computerized methods of validating or identifying the

identity of a living person; based on physiological features such as fingerprints, hand geometry, and retina patterns, and known as behavioral biometric methods such as signature, voice, keystroke and pointing patterns (Deane, Barrelle, Henderson, & Mahar, 1995). Biometrics has advanced security procedures and elevated user confidence in HFM (Anderson, 2010).

2.3.3 Computerized Maintenance Management System (CMMS)

The Computerized Maintenance Management System (CMMS) is a cohesive system that maintains a computer database of information about an organization's operation and maintenance operations including safety and security database.

Security operation and management records relating to the hospital facility are as important as medical device or patient record. CMMS are progressively being used to manage multifaceted operation and maintenance activities. CMMS systems can store data accurately and has an optimal level of security capabilities that prevent tampering with records and unauthorized changes; in case, should an individual be injured or killed on hospital grounds, and a lawsuit follow, the estates team can be confident that it has accurate data to prove it has fulfilled its duty of care (Easton, 2013). CMMS has practical applications to serve as database for security and safety in and around hospital facility. CMMS offers room for enhancement with the analytical abilities its database system offers (Korka, Oloufa, & Thomas, 1997). This allows for data collection and storage of information of facilities operations and history; studying the historical data, nature of operations (safety and security) can serve as base for development of new technologies to counter safety and security threats.

Although, the benefits of CMMS application are noteworthy and practical, the adoption of CMMS is not widespread. Organizations resistance to change, the need to hire personnel, and high cost of maintenance has refrained its adoption by facility managers (Smailer, 1983).

2.3.4 Closed-Circuit Television (CCTV) & TV Surveillance

The history of the association concerning the photographic image and crime control can be traced back almost to the birth of photography itself. Photographing of personals to prevent escapes and to a manuscript, a tendency is being officially encouraged by crime control institutions globally (Lemagny & Rouille, 1987). Computer-based Closed-Circuit Television (CCTV) surveillance system is being used for detecting potential criminal activity in public areas. This system monitors all activity in the surveillance area, the vast majority of which is people innocently going about their regular business. It will alarm when the observed activities of the particular individual match any of the pre-defined "suspicious behavior criteria" programmed into the system. At the same time as analyzing movement behavior, the system uses computer-controlled Pan Tilt Zoom (PTZ) cameras to obtain close-up video recordings individuals present in a facility. In a healthcare facility, CCTV surveillance system provides automatic surveillance in many different situations, from parking areas and lobby areas to equipment storage, visitor seating and patient monitoring. It is particularly suited to monitor safety and security challenges in hospitals areas where it is not possible to install perimeter fences (Thiel, 2000).

Overall, the available evidence advocates that CCTV has become a global tool for surveillance; although there will be different rates of growth in the use of CCTV in healthcare settings, gradually it will become omnipresent. Misfortunate events triggered by particular events such as a child-kidnapping, patient security, a terrorist outrage or rising safety and security concerns, has led to acceptance and real-world applications of video surveillance in healthcare facilities (Norris, McCahill, & Wood, 2002).

2.3.5 Fire Safety and Security Systems

The designers and architects often view fire safety as delivering a series of construction and hardware solutions; fire resistance ratings, egress plans, fire escape stairs, automatic sprinklers, and smoke control. Over the past few decades, it has been found that these built-in features do not necessarily establish occupant safety at the desired level (Proulx & Richardson, 2002). Technology solutions have shown to have a significant impact on improving fire safety; improved fire-detection capabilities/technologies, such as fire alarm systems, smoke detectors have shown tremendous potential in safety (Gottuk, Peatross, Roby, & Beyler, 2002). Combining planning with technology inputs.

In reality, it is impossible to conduct rescue tests in burning buildings to study the human behavior. Building Information Modeling (BIM) approach for the exploration of the effect of building condition on human behavior during the evacuation process can help improve fire safety and rescue operations (Rüppel & Schatz, 2011). BIM models can be simulated for egress planning to generate data for human behavior in emergency situations; knowledge of which can help in efficient planning and placement fire safety equipment.

2.4 Future Perspective for Technology and Innovation

The modern day world is open to endless possibilities, with technology shaping the future of user experience (Usoro, Schick, & Negahdaripour, 1985). However, it is critical not to ignore previous and existing trends (in retrospect, it should be used as a benchmark for future possibilities). Creating a comprehensive census of studies investigating the acceptance of and detachment from innovations in various organizations and systematizing these studies into an inductively derived categorization scheme to evaluate strengths and weaknesses (reflect on the implications for future research) is the foundation for future innovations (Rye & Kimberly, 2007). Deciding what innovations to adopt and which not to adopt, and identifying the strengths and weaknesses of each provide a vision into future possibilities. Also, conducting interviews with innovators and users involved in existing use of technology can provide further scope for research, which in turn, can provide a vision for developers and user possibilities (Davies & Harty, 2011). Focus on core concepts, real-world applications, and benefits for users are required, and in addition, it can provide a list of risks and barriers for implementation and future trends (Azhar, Khalfan, & Maqsood, 2015).

2.4.1 User Experience; Human-Technology Relationship (Acceptance/Rejection Dynamic)

Understanding experience is an important subject for a variety of professions, particularly design; experience helps in interpreting social interaction perspective to develop experiential applications through technology (Forlizzi & Battarbee, 2004). The relationship between information design and interaction design, both being new concepts,

is imperative to understand the communication factor and to develop appropriate types of interactivity. Hence, the idea is to bridge the gap between innovators and users; users providing input on what they demand, and innovators producing technologies as per user suggestions and needs.

An understanding of the experiences of the individual and co-experience (gaining insight into user experience) as a sensitizing concept to help interpret meaning from a social interaction perspective is required (Forlizzi & Battarbee, 2004). Collaborating product and social interaction use influence for individual's product experiences. Primarily, a common way to talk about experience, understanding what affects experience and what qualities of experience are, and an initial framework for understanding what kinds of experiences can be created, and how experiences shift over time (Forlizzi & Ford, 2000). Furthermore, it is important to realize that almost all interactions whether part of a book, a directory, a catalog, a newspaper, or a television program can be created or addressed by one process: user experience (Shedroff, 1999). Exchange of disembodied information between the user and product via information channels is an important aspect of an innovation process (Lundvall, 1985). Innovations in technology have led to improved user experience across facilities. Facilities like the healthcare industries whose primary focus is proliferation of innovations aimed at enhancing quality of life, longevity, diagnostic and treatment options, as well as efficiency and cost-effectiveness of the healthcare system have stepped into technology adoption for improving comfort, safety and security of the patients (users), resulting in enriched user experience (Omachonu & Einspruch, 2010). Various technologies have been installed in healthcare facilities helping

in curtailing security and safety threats; instilling confidence in patients and patient care, thus improving user (patient) experience and attracting more visitors in need of medical services (Boyce, 2011).

Although there are substantial innovations in technology (healthcare industry), they are not sufficient either in foci or methodologies; a need for generating new technology innovations through the process of understanding its users (Länsisalmi, Kivimäki, Aalto, & Ruoranen, 2006). Technology developers should gain a first-hand experience in understanding the need/demand; one way to achieve this is involving users in technology development process (bridging the knowledge gap). A structured process resulting in user involvement in technology development (as per their needs) can help establish a positive correlation between technology innovation and user experience. A structured process is crucial in investigating the involvement of users in the development/assessment of technology (Ghulam Sarwar Shah & Robinson, 2006). Also, higher education facilities can help in innovations through conducting research for technology developers (King et al., 1994). Besides, thorough research that applies an array of methods and multi-level analysis in the field would offer a sound scientific knowledge base for technology success (acceptance) and failure (rejection).

Understanding technology adoption behavior can help eliminate failures in technology acceptance. A research was carried out which proposed a Technology Acceptance Model (TAM) to capture the adoption behavior at the organizational level analyzing internal factors, business model and user expectations (Wang & Qualls, 2007); this research is an example of how critical thinking and analysis adds to innovation.

Although innovation requires creative thinking, coming up with a new idea is only the first step in ensuring successful service innovations (Verma et al., 2008); it attracts new customers, as well as encourages repeat customers; customer focus, innovation process, and continuous improvement. Also, there are various other factors to be considered that contribute towards acceptance of information technology in a workplace; taking an integrative approach, to develop a rich understanding of the mechanisms is essential for technology acceptance (Jackson, Mun, & Park, 2013).

Thus, through this study, an overall understanding of user experience can be established: a schematic pattern that leads to the development of user (satisfaction) driven technology. Integrating users and facility managers in phases of technology development (idea, purpose, and ease of use), analysis, implementation and trends for future growth are studied. There is a need to implement such decision-making process in order to enrich the productivity. The literature presented above shows lead developments in these key areas. An accumulative assessment of the impact of an integrated process can be done. This assessment can help to determine the far-reaching effects of an integrated process in technology development for improving transforming safety and security in healthcare facilities.

2.4.2 Virtual Reality and Augmented Reality

Technologies like augmented reality have a huge scope in improving the user experience. The computer revolution has changed the way we think about computers: augmented reality is a technology that lets people use familiar, everyday objects in ordinary ways (Mackay, 1998). Exploring the world of augmented reality, rather than

immersing people in an artificially created virtual world, augment objects in the physical world (developing real life scenarios for an experiment can help identify and eliminate errors conflicting with desired user experience) (Mathieson & Keil, 1998). Also, it is important to explore augmented reality in terms of its present applications and limitations of existing technologies and the technological glitches that designers need to overcome (Van Krevelen & Poelman, 2007). Establishing an articulate approach towards designing education software on emerging technology platforms (for both educational purpose and mobile computing) is imperative for the success of this future technology in real-world scenarios (Guttentag, 2010). The rationale and main benefits of using virtual reality in healthcare education and training require a substantial research exploring limitations, future development, and scope. Virtual Reality Training can provide a rich, interactive, engaging educational context, thus supporting experiential learning-by-doing (Klopfer & Squire, 2008); it can, in fact, contribute to raise interest and motivation in trainees and to effectively support skills acquisition and transfer, since the learning process can be settled within an experiential framework (Mantovani, Castelnuovo, Gaggioli, & Riva, 2003). Human-computer interaction is the key within this integrated framework – laying down ambitious visions for innovation, such as augmenting human intelligence (Shneiderman, 2000). Area of focus for human-computer interaction research is to develop an information technology framework that supports an integrated process; achieving results through creativity, exploring and evaluation of possibilities by building upon collection of knowledge (information) from previous work and study (Shneiderman, 2000). Human-computer interaction is the key within this integrated framework. This interaction can help

develop new technology that enhances user experience. First and foremost, user interface tools from the past with both cases of success and failure (as themes) should be considered to extract success as a path to improve upon, and failures or mistakes as lessons for future. This basic concept can be elaborated through learning from mistakes and building on successes (Myers, Hudson, & Pausch, 2000). Second, experimental designs to test the effectiveness of physiological measures as evaluators of user experience with entertainment technologies are vital; providing an initial step towards measuring user experience with entertainment technologies (Myers et al., 2000). The perceived ease of use (EOU) is also a function of task/technology fit; EOU is the key factor that determines whether an individual will voluntarily use an information system. A good interface alone does not make an information system easy to use (Myers et al., 2000). EOU is a major contributing factor, and as a matter of fact, it can be the biggest contributing factor related to technology fit.

Virtual Reality and augmented reality are the frameworks that support creativity; creating a real-life scenario for future innovation adoption can help eliminate errors (extracting failures and mistakes) way before the technology is ready to be implemented in real-world setups. The application of virtual reality and augmented reality need to be further investigated, in detail, in varied facility settings to realize its true capabilities.

CHAPTER III

RESEARCH METHODS

3.1 Data Collection

3.1.1 Research Strategy and Selection Criteria

Relevant literature associating user safety and security through technology input is identified by searching the database (see Table 2) for primary research material. A total of ninety research papers published between 2000 through 2016 are considered for the study. In order to ensure that relevant studies were not missed, the search terms remained extensive within the decisive criteria formulated; as explained below.

Table 2: List of database, keywords searched, and criteria of inclusion in the study

Database searched	Keywords used for search	Literature inclusion criteria
1. Google Search 2. Engineering village: Compendex 3. ASCE Library 4. IEEE Xplore 5. Medline ProQuest 6. ACM Digital Libraray 7. Knovel 8. ResearchGate 9. MEDLINE	1. Healthcare Facility Management. 2. Healthcare facility managers organizational functions. 3. Healthcare facility managers safety and security functions. 4. Technology applications for improving safety and security. 5. Safety and security issue in healthcare facility. 6. Safety enhancing technologies. 7. Security enhancing technologies. 8. Literature Based Discovery (LBD) methodology.	1. Published between 2000-2016. 2. Studies are carried out in English. 3. Qualitative or quantitative research. 4. Present or future technologies and its scope in safety and security enhancement (should fall in facility managers organizational function). 5. Technology advancements and acceptance in facility management.

Studies are eligible for consideration in this review if: (a) the focus of the study is user/patient safety and security in healthcare industry, (b) technology advancements and acceptance in healthcare facility management related field (Roper & Payant, 2014) are presented; (c) future technologies and its scope in healthcare facility management are discussed, and (d) there are at least one parenting variable measured. Also, the technologies considered in the study have a prevailing literature published between 2000 through 2015.

3.1.2 Study Description

A detailed examination of selected literature is carried out. The paper is retained if it employed direct association between the user, safety and security, advancements in technology, technology acceptance behavior in healthcare facility management; and the studies that include future innovations that hold scope for improving safety and security across healthcare facilities. In addition, all the studies have direct correlation to healthcare facility managers safety and security functions. Overall, approximately seventy-five papers were included in the literature review; include both, qualitative and quantitative studies. The majority of studies correlate – that is they investigated user experience with technology, technologies adopted in enhancing safety and security, and its acceptance or rejection by the user and decision makers (healthcare facility managers). Conclusively, the papers included for literature review have in their titles or abstracts a clear mention of the keyword combinations used in the respective searches and showed applicability to the safety and security in healthcare facilities. This study used only peer reviewed and published sources.

Database (Table 2) searches produced multiple pages of results for each search. The papers included in the literature review were first narrowed down by eliminating any work published before the year 2000. This filtration was carried out to establish and determined a reasonable threshold to stay current on each technology's capabilities while maintaining uniformity since safety and security technologies, for example, has been around for decades. Finally, the papers that made it to the literature review have in their titles or abstracts explicit mentions of the keyword combinations used in the respective searches and showed applications in the healthcare facility management practice.

3.2 Data Analysis and Methodology

3.2.1 Literature Based Discovery

The study is carried out exercising literature review and Literature-Based Discovery (LBD) method. LBD is a process that explores for concealed and significant connections between data embedded in published literature; engaging ways from Information Retrieval and Natural Language Processing (Ganiz, Pottenger, & Janneck, 2005). LBD operates on automatically generating hypothesis for research by finding overlooked implicit connections in the research literature (Hristovski, Friedman, Rindflesch, & Peterlin, 2006); using published, scientific literature as a source of discovery or finding (Gordon & Dumais, 1998). The extent of investigational data and published scientific information is overpowering and ever growing; it requires an additional set of technical approaches that are expressed here as literature-based discovery (Weeber, Kors, & Mons, 2005). As researchers formulate new hypotheses to test, they have to identify connections to their work from other parts of the literature. However, the

current plethora of information has developed as a massive barrier for this task. Literature-Based Discovery (LBD) systems have evolved to help researchers identify new knowledge that bridges gaps across distinct sections of the literature (Yetisgen-Yildiz & Pratt, 2009). LBD method is being used progressively by reserchers to identify the missing link or pattern; few examples of research carried out though LBD are listed in below (Table 3).

Table 3: LBD based research examples

S.No.	Area of Research (Topic)	Author
1	Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching	(Kirschner, Sweller, & Clark, 2006)
2	Wall Finish Selection in Hospital Design: A Survey of Facility Managers	(Lavy & Dixit, 2012)
3	In silico pharmacology for drug discovery: methods for virtual ligand screening and profiling	(Ekins, Mestres, & Testa, 2007)
4	Method Meets Art, Second Edition: Arts-Based Research Practice	(Leavy, 2015)
5	Using Literature-based Discovery to Identify Novel Therapeutic Approaches	(Hristovski, Rindflesch, & Peterlin, 2013)

3.2.2 Methodology

In this study, LBD is aimed towards identifying capabilities and applications of technology presenting the impact of technology in transforming safety and security in healthcare facilities. Technologies such as Radio Frequency Identification (RFID), Healthcare Information technology (HIT), Computerized Maintenance Management Systems (CMMS), Close- Circuit Cameras (CCTV)/TV Surveillance, Fire safety equipment and technology and are explored. Also, the human behavior is studied to get a better understanding of technology acceptance/rejection by users.

The literature review considers overall features of different technologies (Table 4) used for enhancing safety and security in the healthcare industry; selection criteria (acceptance/rejection), their applications, and impacts on user. This is done to demonstrate the range of applications and capabilities of the technologies that are directly applicable to safety and security in healthcare facility management: illustrating how facility management's safety and security competencies can be aided and transformed by new technology applications.

Table 4: Technologies aiding HFM in Safety and Security.

Safety and Security	
Role (Colling & York, 2009)	**Technologies**
Overall Security of Facility	Radio Frequency Identification (RFID)
Overall Security of Facility	Computerized Maintenance Management System (CMMS)
Overall Security of Facility	Healthcare Information Technology (HIT)
Overall Security of Facility	Wireless Sensor Networks (WSN)
Overall Security of Facility	Closed-Circuit Cameras (CCTV)/TV Surveillance
Overall Security of Facility	Biometric (fingerprint, iris and facial recognition)
Fire Safety	Wireless Sensor Networks (WSN)
Fire Safety	Closed-Circuit Cameras (CCTV)/TV Surveillance
Fire Safety	Smoke Detectors and Sensors
Fire Safety	BIM Simulation for Egress planning

3.3 Summary

This study was conducted to find out the practical applications of technology and innovation in healthcare industry transforming safety and security of the facility. Present

day technology applications were explored to determine their impact on facilities safety and security organizational functions. Using literature-based discovery method prevailing literature on technology applications were examined; industrywide impact, acceptance/rejection dynamics were also studies to observe a better understanding of human-technology dynamics.

CHAPTER IV

FINDINGS

4.1 Initial Findings

4.1.1 Technologies

An assessment of tools for improvement of safety and security is carried out. In the past, the healthcare industry was primarily focused on new approaches to diagnosis, while little attention was given to safety and security concerns, but nowadays, healthcare organizations are becoming aware of the importance of transforming organizational culture and adoption of innovative technology solutions to improve patient safety. Using Literature-Based Discovery, capabilities and application areas for RFID, CMMS, HIT, CCTV/TV Surveillance, Fire Safety based technologies were identified and connected to safety and security organizational function areas healthcare facility manager to illustrate just how and to what degree these technologies impact the facility management industry (Table 5 through Table 9). Also, user behavior technology and technology acceptance/rejection dynamics are studied along with the application of future technologies to understand human behavior and experiment technology capabilities for safety and security application in healthcare facilities (Tables 10 and 11).

The study found that RFID shows significant prospective and has already been used in FM with variable gradations of success. Through the LBD, applications of RFID include tasks in safety and security operations. It has already been successfully used in various facilities for security, safety, equipment monitoring, fire safety and overall facility

management. RFID has a wide variety of applications for security and safety operations. It's a low-cost technology for identifying location and monitoring movement of individuals within or around a facility.

CMMS sees all manner of applications in Facility Management. It enhances the process of maintains of medical records; the true potential of CMMS is yet to be explored. CMMS true value comes with being able to overlay facility data; capable of managing and storing security and safety data for analysis, monitoring and future use. CMMS application will enable Facility managers to pull up data on safety and security of a Facility and its sections as and when they need it based upon the area (localization) of the facility.

Information technology has taken over every aspect of human life in modern times. Healthcare Information Technology is working dynamically to develop approaches to smart buildings; safety and security functions have been vastly improved. Biometric technology applications have systemized facility managers tasks, and its applications are now being explored in various functions of safety and security. Facial recognition, iris, fingerprints are unique to every individual; security technologies based on these functions eliminate unwanted interference by individuals.

CCTV/TV Surveillance; once, a tool for safety in public areas only has come a long way and now has applications in private and domestic sector. Healthcare facilities are being monitored 24x7 through strategically places cameras for security; be it human factor that causes it or a system malfunctioning.

Artificial Intelligence (Virtual Reality & Augmented Reality) sees potential applications in safety and security analysis and research. Experimenting technology

applications in virtual setting can help recognize errors in technology, and it further sees possibilities in the automation of historical data for analysis.

4.1.2 User Experience

Understanding experience is an important subject for a variety of professions, particularly design; experience helps in interpreting social interaction perspective to develop experiential applications through technology. The relationship between information design and interaction design, both being new concepts, is imperative to understand the communication factor and to develop appropriate types of interactivity. Hence, the idea is to bridge the gap between innovators and users; users are providing input on what they demand, and innovators producing technologies as per user suggestions and needs. This understanding can help minimize technology rejection in real-world scenarios.

Table 5: Applications for RFID in Safety and Security in HFM

RFID Applications		
1	RFID offers tracking capability to detect supplies, equipment, and people in real time. Its adoption in healthcare found RFID to be practical and efficient in areas such as asset tracking, user/patient identification and security.	(Yao et al., 2012)
2	RFID technology is low cost and convenience of identifying an object without physical contact. Radio Frequency Identification (RFID) systems provide innovative, promising and efficient applications in many domains.	(Chien et al., 2011)
3	Providing tracking capability to people in real time RFID also provides efficient and accurate access to locate equipment; eliminating theft and securing inventory.	(Yao et al., 2010)
4	RFID tags track residents in long-term care facilities, monitor access to restricted areas, identify implantable medical devices, and scan information from implanted equipment.	(Wicks et al., 2006)

Table 6: Applications for CMMS in Safety and Security in HFM

CMMS Applications		
1	CMMS systems can store data accurately and has an optimal level of security capabilities that prevent tampering with records and unauthorized changes; in case, should an individual be injured or killed on hospital grounds, and a lawsuit follow, the estates team can be confident that it has accurate data to prove it has fulfilled its duty of care.	(Easton, 2013)
2	CMMS has practical applications to serve as database for security and safety in and around hospital facility. CMMS offers room for enhancement with the analytical abilities its database system offers.	(Korka et al., 1997)
3	Although, the benefits of CMMS application are noteworthy and practical, the adoption of CMMS is not widespread. Organizational resistance to change, the need to hire personnel, and high cost of maintenance has refrained its adoption by facility managers.	(Smailer, 1983)
4	CMMS allowed for data collection and storage of information of facilities operations and history; studying the historical data, nature of operations (safety and security) can serve as base for development of new technologies to counter safety and security threats.	(Korka et al., 1997)

Table 7: Applications for HIT in Safety and Security in HFM

HIT Applications		
1	HIT uses diverse means of security interface for tracking, such as; sensor mechanism, a password, PIN, or piece of personal information, a card key, smart card or token, and a biometric.	(Liu & Silverman, 2001)
2	With the hospital security WSN, personnel can send wireless alarms in threatening situations (e.g., to police), receive acknowledgments notifying that assistance is on its way, create numerous kind of measurements, and use actuators (a type of motor that is responsible for moving or controlling a mechanism or system).	(Mekhjian et al., 2002)
3	Improvement of remote user authentication scheme using smart cards, computer standards & interfaces and improved remote authentication scheme with a smart card, respectively has made possible the use and adoption of a smart card based password authentication system for security monitoring in healthcare facilities.	(Xu et al., 2009)

Table 7: Applications for HIT in Safety and Security in HFM.....(continued)

4	Most efficient property of biometric security systems is that level of safety is approximately counterpart for all users in a system; which is not true for other security technologies.	(Faundez-Zanuy, 2006)

Table 8: Applications for CCTV/TV Surveillance in Safety and Security in HFM

CCTV/TV Surveillance Applications		
1	In a healthcare facility, CCTV surveillance system provides automatic surveillance in many different situations, from parking areas and lobby areas to equipment storage, visitor seating and patient monitoring. It is particularly suited to monitor safety and security challenges in hospitals areas where it is not possible to install perimeter fences.	(Thiel, 2000)
2	Misfortunate events triggered by particular events such as a child-kidnapping, patient security, a terrorist outrage or rising safety and security concerns, has led to acceptance and real-world applications of video surveillance in healthcare facilities.	(Norris et al., 2002)
3	Computer-based Closed-Circuit Television (CCTV) surveillance system is being used for detecting potential criminal activity in public areas. The system monitors all activity in the surveillance area, the vast majority of which is people innocently going about their regular business.	(Lemagny & Rouille, 1987)

Table 9: Fire safety applications in HFM

Fire Safety Applications		
1	Improved fire-detection capabilities/technologies, such as fire alarm systems, smoke detectors have shown tremendous potential in safety. Combining planning with technology inputs.	(Gottuk et al., 2002)
2	Building Information Modeling (BIM) approach for the exploration of the effect of building condition on human behavior during the evacuation process can help improve fire safety and rescue operations.	(Rüppel & Schatz, 2011)
3	Designers/Architects often view fire safety as delivering a series of construction and hardware solutions; fire resistance ratings, egress plans, fire escape stairs, automatic sprinklers, and smoke control.	(Proulx & Richardson, 2002)

Table 10: User Experience: Human-Technology Dynamics

User Experience		
1	Creating a comprehensive census of studies investigating the acceptance of and detachment from innovations in various organizations and systematizing these studies into an inductively derived categorization scheme to evaluate strengths and weaknesses (reflect on the implications for future research) is the foundation for future innovations.	(Rye & Kimberly, 2007)
2	Conducting interviews with innovators and users involved in existing use of technology can provide further scope for research, which in turn, can provide a vision for developers and user possibilities	(Davies & Harty, 2011)
3	An understanding of the experiences of the individual and co-experience (gaining insight into user experience) as a sensitizing concept to help interpret meaning from a social interaction perspective is required.	(Forlizzi & Battarbee, 2004)
4	A common way to talk about experience, understanding what affects experience and what qualities of experience are, and an initial framework for understanding what kinds of experiences can be created, and how experiences shift over time.	(Forlizzi & Ford, 2000)
5	Exchange of disembodied information between the user and product via information channels is an important aspect of an innovation process.	(Lundvall, 1985)
6	A structured process is crucial in investigating the involvement of users in the development/assessment of technology.	(Ghulam Sarwar Shah & Robinson, 2006)
7	Higher education facilities can help in innovations through conducting research for technology developers.	(King et al., 1994)
8	Focus on core concepts, real-world applications, and benefits for users are required, and in addition, it can provide a list of risks and barriers for implementation and future trends.	(Azhar et al., 2015)

Table 11: Future Technologies: Virtual reality and Augmented Reality

Virtual reality and Augmented Reality Applications		
1	Technologies like augmented reality have a huge scope in improving the user experience. The computer revolution has changed the way we think about computers: augmented reality is a technology that lets people use familiar, everyday objects in ordinary ways.	(Mackay, 1998)
2	Exploring the world of augmented reality, rather than immersing people in an artificially created virtual world, augment objects in the physical world (developing real life	(Mathieson & Keil, 1998)

Table 11: Future Technologies: Virtual reality and Augmented Reality.....(continued)

	scenarios for an experiment can help identify and eliminate errors conflicting with desired user experience).	
3	Virtual Reality Training can provide a rich, interactive, engaging educational context, thus supporting experiential learning-by-doing; it can, in fact, contribute to raise interest and motivation in trainees and to effectively support skills acquisition and transfer, since the learning process can be settled within an experiential framework.	(Klopfer & Squire, 2008) (Mantovani et al., 2003)
4	Area of focus for human-computer interaction research is to develop an information technology framework that supports an integrated process; achieving results through creativity, exploring and evaluation of possibilities by building upon collection of knowledge (information) from previous work and study.	(Shneiderman, 2000)

4.2 Conclusion on basis of Initial Findings

From the LBD, we learned that these technologies and their capabilities and applications show a lot of potential for safety and security in healthcare facility management. Implementation of hardware technology and information technology has revolutionized safety and security functions of healthcare facility management. Also, new experimental technologies show potential for studying human behavior and test applications in virtual settings. As all the technologies continue to mature and more and more capabilities and applications are developed, the security and safety functions will enrich. This is an illustration of how technology has transformed healthcare facility managements safety and security functions over the years.

4.3 Analysis of Findings

On the basis of analysis, there is one important pattern that can be found in the literature based discovery. In the description of papers, repetitive use of user comfort and

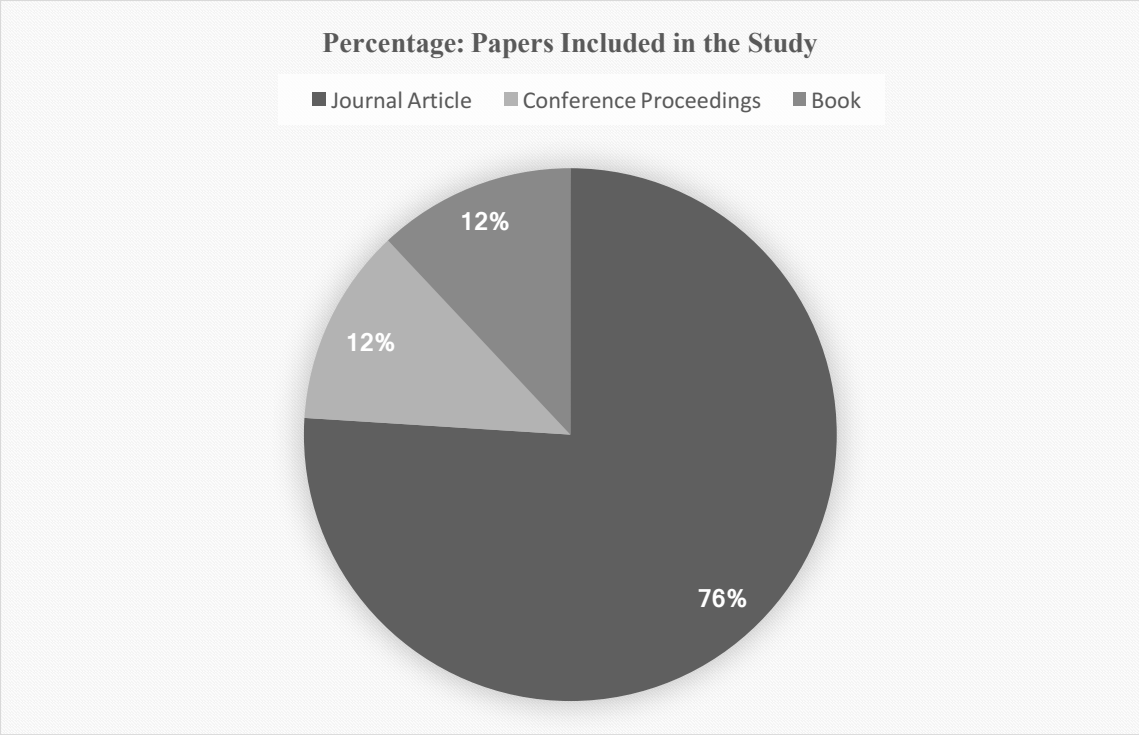
acceptance of technology was found. This pattern of LBD motivated to discuss the importance of user experience in technology acceptance or rejection. It is of importance that we further investigate deeper to find a solution to the concerns. In the second level of LBD we will analyze the user perspective; understanding user technology dynamics, role of facility manager and technology developer to work efficiently towards technology development.

Technology is growing at a rapid pace with advancements taking place exponentially. Thus, it is of importance for facility managers to identify relevant technologies in facility management. The future of facility management is bound to grow into a more challenging sector (Vanier, 2001). With ever increasing number of new construction, renovation, and alterations projects (Henderson, 2012); it is of utmost importance for facility managers to keep up with the recent developments and ensure to acquire the required technologies that improve the user experience. In this study, the focus was to understand the user experience and to identify recent lead developments in technology transforming user experience. Facility managers are expected to provide a great user experience, coupled with feature-filled innovations, to promote user adoption. A clear understanding of user (type), user requirements and demands (depending upon propose of a facility) help technology developers to work towards the development of user-focused innovative technology, which can eliminate technology failures. To improve customer satisfaction, one should create a better user experience tailored to the functionality demanded. Facility managers are seen more and more partnering with

technology companies to present innovative solutions and to create platforms that are tailored to user specific needs.

4.3.1 Source of Literature

Figure 1: Publication Platforms



Literature review material (papers) for the study were selected from three publication platforms (Figure 1). This percentage gives indicates that the majority (76%) of papers were available in form journal articles published by researchers. There is a low percentage (12%) of material available (regarding safety and security technology application) in the form of books and conference proceedings.

An elaborated context (books) on safety and security technology and application can help FM industry professionals and FM aspirants to better understand the technology-

driven user environment. Need to generate new context (books) on technology (for safety and security application) can be realized.

Figure 2: Publication Platform & Area of Research

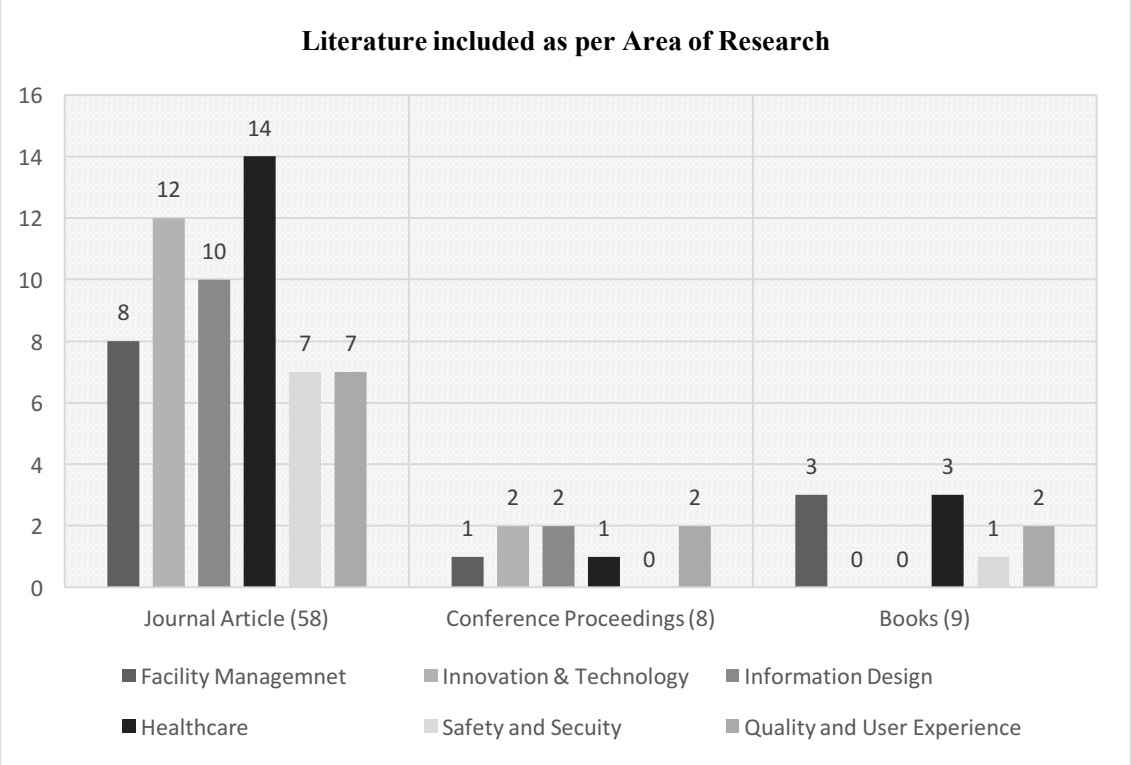


Figure 2 gives us an idea of the amount of research work that is being directed towards FM safety and security functions (concerning technology and innovation) over the year. FM researchers are dedicated to improving user safety, a substantial number of researches have been carried out to propose new solutions and theories.

The given data (Figure 2) also suggest that an integrated effort by FM, IT, Healthcare, innovation and Technology professionals is required to work towards enhancing safety and security: improving quality of user experience.

CHAPTER V

CONCLUSIONS

5.1 Technologies in use

The security of hospital can be severely compromised without the implementation of proper channels of technology and software. Healthcare facilities are implementing innovative technology as a haven against such breaches of security. Technology helps to make sure that information and access are available only to the right people, and makes it nearly impossible for pertinent information to be leaked. Remote monitoring is an efficient way to keep an eye on facilities operations; censoring systems now provide the ability to arm or disarm security systems, send fire or intrusion alerts, and stream surveillance camera feeds. Security kits can sense an individual's presence and open or close the door automatically; sensors detect movement in hallways and rooms. Images have become less grainy and cameras have become more adaptable. CCTV technological advances have allowed for cameras to be smaller; perfect to avoid detection by infiltrators. Once a futuristic fantasy, fingerprint scanning is now a reality; fingerprint scanning devices are quickly gaining popularity. Fingerprint door locks are also being widely used for security. Security cameras are cheaper, easier to install, and smarter than ever. The modern smart cameras come with Wi-Fi connectivity, one can easily stream live feeds of what is going on inside or outside a facility; HIT capability these live feeds to be stored in the cloud; which can be reviewed, later on, should there be a need.

Through this study one can realize the positive influence on technology and innovation in transforming safety and security operations in healthcare facility. Given that,

there are various concerns associated with technology adoption. Significant barriers to technology adoption include prohibitive costs, technological limitations, and privacy concerns; study corroborates that the general population is acutely alarmed about privacy and individual rights protection. These factors, coupled with the looming threats such as terrorism and identity theft may create the "perfect storm" in which consumers forgo the battle to ensure control over when and by whom they can be perceived by others (Perakslis & Wolk, 2005).

5.2 Technology Development: Facility Manager, User and Technology Developers

In the previous sections, application of various technologies (transforming user experience) is discussed. Progressive adoption of innovative technology by hospitality, healthcare and educational institutes aimed towards transforming the user experience while enhancing safety and security. The aspect of the utility of virtual reality, augmented reality, and machine learning is also discussed. Since these technologies are new for other advanced fields too, it is of importance up to what extent, where and how technology developers can use such advancements to improve the user experience. At present virtual reality and augmented reality can help develop virtual setting to test various functions of a facility such as, safety and security; helping in assessment of the compatibilities of present procedures with upcoming potential technologies. The impact of implementation of such advanced technologies in facility management also needs detailed assessment. Such technological advancements present the potential to bring relevant changes in transforming the user experience.

Understanding user perspective; his/her expectations form a facility (be it safety, security, and operations etc.) is of highest importance. This understanding/knowledge can be combined with facility managers experience and technology developer's skills to foster new technology. This interaction will help user, facility manager and technology developer understand each other's perspective while sharing issues/concerns and working towards innovation. One productive way to develop future technologies is through the adoption of an integrated process, involving input from users and facility managers, and an assessment of present technology and new developments in practice. The study reveals that development of a successful technology widely adopted for facility management operations, aimed at improving user experience require inputs form users and facility managers during its development process. Also, for owners and facility managers to remain competitive, the basic process is to acclimatize to the recent technology developments. As facility managers, the focus of all the developments will cater the users in the best possible manner.

5.3 Limitations of the Study

This research attempts to make a reasonable projection of the technology capability that has or may have the potential to transform safety and security in the healthcare facility. As such, it is based on an exploration of prevailing literature on these technologies and their potential applications.

A limited number of technology advancements are selected and studied. It is beyond the scope of this work to accumulate an exhaustive list of technologies that have or might impact safety and security of users/patients in healthcare facilities.

5.4 Significance of Study

This research studies the capabilities of technology, innovation and its applications in transforming safety and security in healthcare facility management. It investigates how they are being used today and how the future technologies may be applicable to the practice of healthcare facility management; subsequently one might come to be adopted industry wide for a variety of safety and security functions.

Also, the paper discusses the factors essential for developing new technologies; what role users and facility mangers can play in technology development process. Understanding user-technology dynamics; acceptance/rejection behaviors.

5.5 Future Research

This work studied the capabilities of RFID, HIT, CMMS, CCTV/TV Surveillance, WSN, smoke detectors and sensors, and BIM in transforming safety and security in healthcare facilities management. It does not attempt to perform an exhaustive study of all the technologies that may come to impact the practice of healthcare facility management (enhancing safety and security).

In this study, only a few areas of development in technology are discussed. There is a scope for an in-depth study on the role of the user and facility manager in the development of technologies aimed to cater the user. Also, future research could be aimed at identifying the current drawbacks with these technologies and study how and what strides could be taken to resolve them.

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