FLOOR FINISH SELECTION IN HOSPITAL DESIGN:

A SURVEY OF FACILITY MANAGERS

A Thesis

by

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ABSTRACT

Flooring materials have a considerable impact on the indoor environment of healthcare facilities. In recent years, flooring options such as vinyl flooring and vinyl composite tiles have emerged as a popular choice in such facilities. They have been preferred extensively because of properties that make them durable, resistant to infections, and easy to maintain with minimum expenditure. However, there is limited literature and research which comprehensively evaluates floor finishes and their selection criteria in healthcare environments and the opinion of facility managers regarding the same.

This study analyzed, identified and systematized literature on selection criteria for flooring in healthcare facilities. It found out the preferences of healthcare facility managers regarding floor finishes and their selection criteria and assigned empirical values to their opinions and carried out further analysis.

This research investigated literature on different types of floor finishes currently used in healthcare facilities and the criteria applied for their selection. The literature review for this study was conducted through search engines using relevant keywords. Peer-reviewed studies and articles published between 2000 and 2016 and consistent with the research design were included. A questionnaire survey was conducted among healthcare facility managers in the state of Texas. Hence, Wilcoxon Rank Sum Test was used for data analysis.

The top five floor finishes used in the healthcare sector were identified: vinyl flooring, vinyl composite tile (VCT), rubber, linoleum, and ceramic flooring. Top five selection criteria that were identified: durability, infection control, ease of maintenance, maintenance cost, and user safety.

Based on specific selection criteria the choice of floor finish may differ because each material exhibits its own properties which are different from other materials. For e.g. vinyl flooring could be preferred due to durability, infection control and low initial and maintenance cost. However, if selection criteria such as the effect on healing and aesthetics are preferred, then carpet flooring could be a better choice. The scope of future research has been provided.

DEDICATION

Dedicated to

Tulika

who inspired me to pursue Master's at Texas A&M

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CHAPTER I

INTRODUCTION AND BACKGROUND

Facility design and maintenance are the two phases of a building's lifecycle that have a huge impact on the performance of an organization. However, during decision making in terms of facility design, the topic of facility maintenance of rarely addressed which affects the performance of the organization (Pati et al., 2009). The subsequent sections have analyzed the preferences of healthcare facility managers regarding interior floor finish materials and the criteria applied to select them.

Healing of a patient in a hospital is dependent on its environment. An evidence-base has emerged that supports the designing of healthcare buildings for quality, safety and providing a favorable environment could significantly improve patient outcomes, satisfaction and healing process. It would reduce expenditures and render benefits to healthcare organizations, workers, and patients (Harris & Detke, 2013). Onaran, (2009b) stated that floor finish materials, along with other interior surfaces like the ceiling and wall finishes influence the indoor air quality. Previous studies such as Onaran, (2009a) suggested that the internal environment is most impacted by floor coverings. Color and pattern on the finish materials of a hospital affect the behavior of its users, such as the patients and the hospital staff. The finishes should not be reflective as it might cause disturbance to the users. It might as well disorient patients. The quality of indoor atmosphere depends upon the character of the finishes (Onaran, 2009b). The life cycle of a healthcare facility is significantly impacted the flooring choices made during its design

phase. Floor coverings generate continued expenditure during their operations and maintenance phase because of frequent cleanings lined out as per regulations and periodic fixing and replacement (Harris & Fitzgerald, 2015).

Harris & Detke, (2013) found that a multitude of factors impact indoor environment quality in healthcare facilities. Acoustics was identified as one of the crucial ones (Harris, 2015). Studies like Okcu et al., (2011) found that noise cancellation due to better acoustical design in healthcare facilitated patient recovery. In addition, Harris & Delke, (2013) stated that patient experience in a hospital has a potential of generating reimbursable rates. Patients were willing to pay more for an improved experience. Therefore, to establish conducive patient outcome, it was important to design a space which was comfortable and quiet (Onaran, 2009a). Choice of a floor covering influenced sound levels in the indoor spaces and enhance the satisfaction of users (Harris, 2015). However, traditionally the surfaces used in a healthcare building do not cancel out noise and cause increased levels of sound which is distressing to patients (Ulrich et al., 2008).

Along with noise cancellation, other significant properties to be considered for the selection of interior materials for a healthcare facility are non-toxicity, low-Volatile Organic Compound (VOC) emission and chemical inertness (Borrelli, 2007). Furthermore, designers of healthcare institutions preferred the following factors for material selection, in the increasing order of importance: life-cycle cost, ease of installation, infection control, maintenance cost, initial cost, client preference, ease of maintenance, durability, and aesthetics (Blakey & Rohde, 2002). The flooring materials

in a hospital should be solid, robust and durable because their repair and maintenance are likely to cause disruption in patient services and affect the activities being carried out in it (White, 2007). Another study by Onaran, (2009b) found that functionality of a space was one of the other significant determining factors which is important in choosing an appropriate flooring material. For example, in the dining space PVC tiles were preferred; whereas, in an area accessible to the outside, terrazzo or ceramic tiles could be used. In spaces, such as a visitor or a quiet area, use of flooring options such as carpets could be viable (Onaran, 2009a).

While selecting floor finishes for a hospital, infection control issues should be given maximum preference. The design principles implemented to accommodate infection control practices would render long-lasting benefits spanning up to 30 years (Wilson & Ridgway, 2006). More than 120 studies have linked infection to the physical environment of a healthcare facility (Boyce, 2007). Floor finishes like sheet vinyl and vinyl composite tile bear sterile properties which are essential for infection control and is a superior choice among other options in the USA (Sherif, 2013). Some indoor building materials released different gasses into the indoor air due to their chemical composition, such as VOCs. These materials are being used extensively in the interiors of a healthcare facility (Rossi & Lent, 2006).

Among flooring materials, sheet vinyl and plywood flooring were identified as the two major sources of VOCs, which significantly affected the indoor air quality of a space (Hodgson, 2000). Even though the use of vinyl products resulted in the emission of harmful substances into the indoor air; they were still preferred over other alternatives

because of their durability and infection control properties (Sherif, 2013). Vinyl flooring has no bio-based product as its constituent and currently, there is no potential for any such product being added to its chemistry as a replacement of any of its significant part. Therefore, it is not possible for the manufacturers of flooring materials to eliminate the harmful PBTs from the composition of a vinyl floor type (Lent et al., 2009).

CHAPTER II

LITERATURE REVIEW

2.1 FLOOR FINISHES AND THEIR SIGNIFICANCE IN HEALTHCARE FACILITY MANAGEMENT

In a hospital, efficient operations and management procedures are dependent upon the type of interior finish materials put into use (Wilson & Ridgway, 2006). In due consideration with floor finish selection, the decisions made during the architectural design phase of a healthcare building should complement and support its operations and management phase while the facility is occupied. In the healthcare industry, floor coverings with chemically or heat welded seams have a preferred use because they render infection control properties in the interior environment (Bower, 2006). For spaces, such as operation theaters where hygiene is of paramount importance; flooring types should be seamless, hard and easy to clean. It should withstand strong germicidal and cleaning agents as the floor of likewise areas undergo daily washing with such solutions (Abreu & Potter, 2001). In the past, research has been conducted examining the application of floors finish materials with intrinsic antibacterial activity, to help control the contamination in clinical areas such as ICUs that accommodate high-risk patients (O'Connell & Humphreys, 2000). Although, flooring types could harbor bacterial growth and act as their reservoir; there is no historical data supporting the transmission of infections via floor surface in a healthcare facility. Without the presence of stickiness or residual moisture, the risk of transmission was minimal (Lankford et al.,

2006). In addition to this, ICUs undergo rough usage due to the continuous movement of equipment, heavy footfall and accidental spillages of corrosive fluids. Therefore, to address safety issues and fall prevention; the floor finishes of similar critical areas should be slip resistant under damp conditions (O'Connell & Humphreys, 2000).

The cost of maintenance associated with flooring in a healthcare facility is substantial when compared with its initial cost (Harris & Fitzgerald, 2015). Furthermore, two studies found that the initial cost associated with most flooring systems was incongruous to their life cycle costs. For example, the most economical cost of installation did not assure a low life cycle cost (Lozada, 2004). It is important to note that publications analyzing the life cycle cost of flooring types are limited. Emphasis should be laid on factors other than the installation cost of flooring. Apart from cost related issues, there are multiple non-financial aspects that play a significant role in the selection of floor finishes (Bogenstätter, 2000); such as ease of maintenance, durability, the safety of users, sound isolation and aesthetics. However, it was observed that budget constraints often restricted the choices available (Harris & Fitzgerald, 2015). Additionally, the decision-making process is influenced by regulations and acts set forth in hospitals. All healthcare facilities funded federally must have a compliance with the Hill-Burton Act, as delineated by the *Minimum Requirements of Construction and Equipment for Hospital and Medical Facilities* (Schultz & Committee, 1979). There are different types of floor finishes available and the selection of most appropriate materials among them becomes a difficult task and demands thorough study. Moreover, the staff members and employees from different departments of a hospital are involved in the

determination of finish materials for different spaces. They represent varied opinions. Hence, a survey among healthcare facility managers considering their preferred choices would be beneficial (Lavy & Dixit, 2012).

2.2 FLOOR FINISH MATERIALS

The flooring types could be divided broadly into three categories: (1) hard flooring systems; (2) resilient flooring systems; and (3) soft flooring systems (Moussatche & Languell, 2001). Hard flooring systems are defined as those flooring materials that bear rigid and non-scrapeable properties and are integral with the building (Robinson, 1996). This classification includes ceramic tiles, quarry tiles, exposed concrete flooring, terrazzo flooring, epoxy flooring, laminated wood flooring, wood plank flooring and others (Moussatche & Languell, 2001). Resilient flooring systems are defined as those which have a fair amount of durability and are resistant to water and stains (Bower, 2006; Tuladhar et al., 2015). Linoleum flooring, vinyl composition tiles, vinyl sheets, rubber flooring, etc. are some examples of resilient flooring systems (Moussatche & Languell, 2001). Some of the currently used resilient flooring types in the healthcare marketplace are vinyl flooring, synthetic rubber, polyolefin, and linoleum (Lent et al., 2010). Soft flooring systems primarily refer to carpets and rugs which could be woven, cut pile or tufted in looped (Robinson, 1996). However, material selection for a healthcare facility is a tedious task (Lavy & Dixit, 2012). Potential health and environmental impacts associated with a flooring type must be assessed before its installation. Characteristics associated with the material should be identified and explored such as its durability; safety – traction and effect on falls, slips and trips; glare;

comfort, strain and fatigue; acoustics; installation, including evaluation of installation processes and toxicity of sealants and adhesives advised for use with the floor materials; time constraints; and cleaning, operation and maintenance (Lent et al., 2009).

2.3 CHARACTERISTICS OF FAVORABLE FLOOR FINISH FOR HEALTHCARE

Floor finish ideal for application in a healthcare facility should exhibit a wide range of properties (Harris & Fitzgerald, 2015). Its maintenance cost should be low and the service life should be long (Federal Facilities Council, 2001). Criteria for selection of flooring materials also depends upon easy installation and maintenance procedures (Kishk et al., 2007). Studies have suggested that hospital flooring systems should be durable (Noskin & Peterson, 2001) and have good visual characteristics especially in rest areas of the hospital staff (Sadatsafavi et al., 2015). Pattern on the floor is important because it affects absorption and reflection of light and sound through them. Highly polished flooring surfaces are inappropriate for use in healthcare sector as they reflect light and produce additional glare. Strong contrast between the flooring materials should be avoided because it could cause confusion, disorientation or could be interpreted as change in level. (Onaran, 2009). It should be able to provide underfoot comfort to the users, minimize fatigue (Reiling et al., 2008) and reduce impact due to fall incidents (Drahota et al., 2007). Movement of equipment and walking on the floor should be easy (Harris & Detke, 2013). It should have flame resistance (Onaran, 2009) and noise cancellation properties (Okcu et al., 2011). Nonetheless, the characteristics of the

flooring types should help create a space that enhances the satisfaction level of patients; contributing towards their health and healing (Schweitzer et al., 2004).

2.3.1 Durability and Resilience

Floor coverings which are resilient have broad applications in the healthcare industry. They are popular due to durability, comfort, ease of cleaning and routine maintenance, low cost and an availability of broad range designs (Lent et al., 2009). Resilience and durability renders water resistant properties to floor finishes (Noskin & Peterson, 2001). It is important for finishes used in a hospital to be smooth and resist water, especially around plumbing fixtures because dampness might support microbial growth (Ninomura et al., 2006). Rubber flooring was found to be one of the superior resilient varieties (Hallas, 2011); which could be manufactured using natural rubber (Tom Lent et al., 2010). Being a superior choice, rubber flooring did not find likewise widespread application in spaces such as operating rooms, where vinyl flooring was a preference. As per a previous research, 84.7% of the surveyed operating rooms in hospitals used sheet vinyl as a floor finish material (Sherif, 2013).

2.3.2 Underfoot Comfort and Fatigue Reduction

Environmental stressors like fatigue, stress and physical injury walk a fine line between the efficiency of an organization and facility design that bolsters the processes of a health care institution (Harris, 2015). They negatively impact mood, alertness and cognitive performance of healthcare employees (Hales & Pronovost, 2006; Reason, 2000; Shojania et al., 2001). In comparison to hard floors; soft and resilient flooring systems such as carpets and rubber floor coverings provided lower impact force

underfoot (Redfern & Cham, 2000; Reiling et al., 2008). These systems neutralized fatigue-causing effects of long work hours and workload (Harris, 2015; Sadatsafavi et al., 2015). In a healthcare facility where workers preferred comfort in their rest areas (Lent et al., 2009); selection of flooring types which have comfort factor associated with them becomes important (Kaplan et al., 2009). The properties of flooring types, e.g. elasticity, thickness and stiffness played an important role in causing discomfort in the lower extremities and the lower back of an individual's body (Cham & Redfern, 2001; Redfern & Cham, 2000).

2.3.3 Safety, Impact and Slip Resistance and Prevention of Fall and Injury

National Council on Aging states that 30% of fall incidents in a hospital or acute healthcare facility results in a serious injury (Harris & Detke, 2013). Also, falls occur frequently in hospitals and cost about $3.6 billion annually (Gulwadi & Calkins, 2008). They are epidemic and account for the highest number of nonfatal injuries occurring during hospitalization of patients (Agency for Healthcare Research and Quality, 2008b). Flooring material types and shock absorbing floor tiles could prove to be important for injury prevention in hospitals (Drahota et al., 2007). Vinyl flooring could be used for prevention of falls (Donald et al., 2000; Tse, 2005); whereas, adoption of absorbent varieties such as linoleum sheets and carpet flooring could prevent sustenance of injury or other physical consequences due to falls (Lange, 2012; Tse, 2005). Only 15% of the patients who fell on carpets sustained injuries; while, 91% got injured in case of vinyl flooring (Donald et al., 2000). Therefore, an element of safety should be associated with the preferred choices of floor finishes for healthcare facilities (Kaplan et al., 2009).

2.3.4 Favorable Acoustical Properties and Noise Cancellation

Excessive noise and poor acoustics in healthcare facilities can obstruct the healing process of patients (Hagerman et al., 2008; Parthasarathy & Tobin, 2004), cause tension (Morrison et al., 2003), contribute to poor communication levels (Blomkvist et al., 2005), which could result in errors. Nurses have reported fatigue, headaches and irritation due to noise at workplace. Moreover, hearing loss due to noise has been a cause of concern for orthopedic surgeons (Kracht et al., 2007; Love, 2003). It is evident from renovation projects carried out in the past, such as The Barbara Ann Karmanos Cancer Institute; which emphasized on acoustics and lighting, observed a considerable reduction in errors among hospital staff and the usage of pain medication among patients (Bilchik, 2002). Hence, it is important to consider the way these aspects are affected by the flooring choices. Although, noise cancellation is minimal with all commonly used floor finishes, the noise generated can be reduced by the use of resilient flooring (White, 2007). For that reason, rubber flooring systems are preferred in hospitals (Harris & Detke, 2013). Better acoustics makes them popular among the nursing staff (Rossi & Lent, 2006). In addition to this, acoustic rubber flooring efficiently suppresses noise which escalates the healing process of patients (Okcu et al., 2011).

2.3.5 Ease of Maintenance

While facility design is playing a defining role in strategizing organizational objectives, concerns related to maintenance of a facility have typically been overlooked during the process of design related decision-making. It has mainly originated from the inadequacy of a defined approach to consciously represent information regarding facility

maintenance during the building design phase (Pati et al., 2009). One of the important factors for floor finish selection is its ease of cleaning (Warren & Hanger, 2012). In a previously conducted research it was found that all case studies done by it on healthcare facilities, made efforts to choose floor finishes that were easily maintained; however, the knowledge required to make an informed decision on this issue is limited (Quan et al., 2011). Vinyl, being one of the most versatile plastics in modern society; has been used extensively as a resilient flooring material in the healthcare sector (Borrelli, 2007). Majority of the hospital staff preferred vinyl composition floor surfaces over others because of greater ease in cleaning up spills (Harris, 2000).

2.3.6 Emission of Volatile Organic Compounds into The Indoor Air

Flooring materials were found to be responsible for the release of emissions, such as VOCs into the indoor air of a building (Rossi & Lent, 2006). Upon the measurement of secondary degradation emission rate of flooring products; it was concluded that adhesives used in a flooring system decomposed in an alkaline environment and hence, gave rise to alarming rates of secondary emission (Sjöberg & Ramnäs, 2007). In the year 2010, in Sweden, through a statistical analysis, the assessment of the relationship between the PVC-flooring in bedrooms and the incidence of certain lung related inflammatory diseases like asthma and eczema, in its occupants was carried out. It was found that a strong co-relationship existed between the two (Larsson et al., 2010). Volatile organic compounds released into the indoor environment due to off-gassing of the floor finish material, degrade the quality of air (Baker, 2006).

2.3.7 Infection Control and Resistance to Bacterial and Mold Growth

Bacteria found on environmental surfaces in a hospital was found to be associated with infections acquired in such facilities. Especially, in in-patient environments, those surfaces have the potential to host pathogens ranging from a few hours to months (Harris et al., 2009). Diseases were caused due to bacterial or mold build up when the floor remained moist or dirty (Berry et al., 2002). However, there is no concrete evidence which associates floor finish materials with the transmission of infections to patients and staff (Foarde & Berry, 2004; Foarde, 2001). If all the user guidelines suggested by the manufacturer were followed sincerely, mold growth in the floor was checked effectively (Harris, 2009). A research study conducted in a school environment revealed that the carpeted area showed 25 times more contamination with bio-contaminants than tiled flooring (Foarde, 2001). However, clean carpet did not support mold growth even at prolonged and elevated temperatures and humidity levels (Berry et al., 2002). In another study, vinyl floor samples exhibited a lower number of genera than observed in carpet samples; although, in comparison to the carpet, higher numbers of species associated with the genera of pathogenic bacteria were observed in vinyl floors (Harris et al., 2009).

2.3.8 Sustainability

Sustainability was found to be one of the most important considerations in the building industry in the present-day scenario (Onaran, 2009). To close the loop, a product must be designed in such a way that after its usable life it is recycled back into such materials which can be used to manufacture items of similar grade. However, most

vinyl flooring systems used in hospitals constitute of less than 5% of recycled content which is used as a filler, rather than as a replacement for the PVC (Lent et al., 2009; Lent et al., 2010). Other studies have shown that the use of floor finish made of recycled rubber may raise concern because its constituents are highly toxic (Lent et al., 2009; Lent et al., 2010). Products manufactured using recycled tires contain high levels of VOCs, such as naphthalene, aniline, and toluene. They are reproductive toxicants or carcinogens (Denly et al., 2008). Using recycled and sustainable floor finishes can be advantageous as it would reduce the consumption of minerals and fossil fuels and would avoid the use of toxic chemicals involved in the manufacture of products from virgin raw materials (Lent et al., 2009; Lent et al., 2010).

2.3.9 Life Cycle Cost

Finish materials play a significant role in the determination of construction costs whether in initial or operation and maintenance costs. However, the selection decisions should always evaluate and compare the cost of the finish material with its efficiency, durability and required cleaning methods (Shafie & Sherif, 2010). Moreover, the cost of maintenance should not be considered as a final decisive tool for the selection of floor finishes (Lozada, 2004; Moussatche & Languell, 2001). In the case of an institutional building; it was found that rubber; as a flooring material contributed to one of the higher values of such costs. It also accounted for higher operational and maintenance costs (Lozada, 2004). Rubber floor type accounted for higher maintenance costs; since it had a shorter service life. The initial cost of installation of a rubber type floor incurred higher costs when compared with certain other flooring types (Harris & Fitzgerald, 2015).

2.4 STUDIES INVESTIGATING FLOOR FINISHES AND THEIR SELECTION CRITERIA

In Table 1. findings of selected studies have been enlisted which is relevant for the current study. Table 1 also provides a list of methodologies adopted by these studies to investigate their objectives.

Table 1. Relevant findings from previous studies that used different methodologies

S. No.	Research Study	Methodology	Findings
1.	Sherif, 2013	Questionnaire Survey Study	• According to this research study which was conducted in relation to Operation Theatres (OTs) in the hospitals of USA, 84.7% of total participant hospitals used sheet vinyl flooring, while 8.6% used epoxy flooring, 6.2% used ceramic tiles and 06% used linoleum flooring. • Vinyl floor covering on a hard concrete base, with its seams heat-sealed and adhered to the base via non-water-soluble material was acceptable for installation in OTs. • Sheet vinyl flooring is advantageous over all the other flooring types studied with an exception of its durability. Its sterile properties are highly valued.
2.	Harris, 2015	Longitudinal Comparative Cohort Study	• This study showed that the healthcare workers reported about healthier indoor air, lower reflected glare, underfoot comfort and visual appeal in the case of carpet flooring. • When corridor had carpet flooring, patients agreed that the area in the vicinity of their room was quieter. • Vinyl flooring has sterile properties.
3.	Kaplan et al., 2009	Literature Review and Cochrane Systematic Review	• An example of Brigham and Women's Hospital, Boston was discussed where the previously used chlorinated vinyl tile flooring was replaced by rubber flooring for the reduction of their toxic environmental impact. • Rubber flooring is ecologically friendly. • A range of flooring types composed of PVC was suggested which have lesser chemical hazards and have a great potential for further improvement.
4.	Sadatsafavi et al., 2015	Cross-sectional Study	• This paper evaluated the characteristics of rubber flooring that could neutralize the fatigue-causing effects of long work hours and workload in a healthcare setting. It was established that the workers preferred comfort and good visual characteristics of flooring materials especially in non-clinical areas such as rest spaces. • Among all the workers, the younger staff gave more preference to the improvement of aesthetical features related to floor finish selection in all spaces. • Finishing materials and indoor air quality have the highest level of impact on the overall satisfaction of the employees.

Table 1. Continued

S. No.	Research Study	Methodology	Findings
5.	Pati et al., 2009	Secondary Data Analysis	• Facility maintenance performance of floor finish materials should be considered as a significant criterion during the different phases of the procurement cycle. • Strategies for facility maintenance have an impact on the organizational objectives at all levels. • Considerations for facility maintenance strategies during the design decision-making process is crucial.
Note. The table identifies studies which derive conclusions that are significant for this literature review			

In Table 1, the methodology adopted and findings of key floor finish studies have been enlisted. These key floor finish studies are some of the most comprehensively conducted studies for choices of appropriate finish materials in the field of healthcare facility management. The conclusions derived from these studies have enlisted some of the existing gaps in the literature and have suggested the future scope of research. The enlisted studies were referenced for the methodology adopted, conclusions derived and future scope of study delineated.

2.5 SUMMARY

Based on this literature study, it was found that mostly 10 different types of floor finishes are used in the healthcare facilities. Namely, rubber flooring, carpet flooring, sheet vinyl flooring, vinyl composition tiles (VCT), linoleum flooring, ceramic tiles, concrete flooring, hardwood flooring, laminated hardwood flooring, and mosaic flooring. Along with the flooring types, 16 different selection criteria were identified. They are initial cost, ease of installation, maintenance cost, ease of maintenance, durability, noise cancellation, ease of movement, underfoot comfort, impact resistance, flame resistance, indoor air quality, infection control, sustainability, aesthetics, glare, and effect on healing. In addition to this, the literature study evaluates the impact of floor

finish choices on higher-level organizational objectives and vice versa. It investigates the significance of making facility management decisions with respect to a health care institution, while it is still in its design phase. When the construction of such a facility is complete; it is handed over to a different group of people who make decisions for its operation and maintenance stage. The decisions that are made with respect to the facility management of a building are the ones that are responsible for keeping the facility fit for its intended use. Therefore, adoption of dissimilar strategies would have a different impact on the processes carried out in it. In the case of a healthcare facility, it might cause injuries and hospital acquired nosocomial infections to patients. The unpredictability associated with facility management procedures has led to its exclusion from the design decision-making process. Decisions regarding the flooring systems to be installed in the case of hospitals have typically been neglected from such crucial stages. It is evident from this study that the views of facility managers regarding the floor finish selections should be included in the design decision-making process.

2.5.1 Key Findings of the Literature Review

Table 2 presents the list of selection criteria analyzed or suggested by the referred studies using different methodologies. The literature study revealed 11 different types of floor finishes used in the healthcare facilities investigated in the referred studies. These finishes included rubber flooring (Harris & Detke, 2013), carpet flooring (Harris, 2009), vinyl flooring (Sherif, 2013), vinyl composition tiles-VCT (Blakey and Rohde, 2002), linoleum flooring (Lent et al., 2010), ceramic tiles (Harris & Fitzgerald, 2015), concrete flooring (Gulwadi & Calkins, 2008), hardwood flooring (Tuladhar et al., 2015), laminated

hardwood flooring (Bower, 2006), mosaic flooring (Ulrich et al., 2008), polyolefin flooring (Lent et al., 2009).

Table 2. Research studies vs selection criteria for floor finishes

S. No.	Research Study	Methodology	Aesthetics	Durability	Ease of installation	Ease of maintenance	Ease of movement	Effect on healing	Flame resistance	Glare	User safety	Indoor air quality	Infection control	Initial cost	Maintenance cost	Noise cancellation	Recyclability	Underfoot comfort
1	Tse, 2005	Literature Review									*							
2	Drahota et al., 2007	Cochrane Review											*					
3	Harris et al., 2009	Experimental Analysis														*		*
4	Harris, 2015	Cohort Study					*	*			*		*			*		*
5	Harris & Detke, 2013	Literature Review				*								*	*			
6	Harris & Fitzgerald, 2015	LCC Assessment										*	*					
7	Hutter et al., 2006	Questionnaire Survey									*						*	*
8	Kaplan et al., 2009	Personal Interviews											*					
9	Lankford et al., 2006	Experimental Analysis										*						
10	Larsson et al., 2010	Cohort Study				*			*			*					*	
11	Lent et al., 2009	Comparative Analysis										*					*	
12	Lent et al., 2010	Literature Review				*						*		*	*		*	
13	Figueroa, 2004	LCC Assessment														*		
14	Okcu et al., 2011	Observational Study									*							
15	Oliver et al., 2007	Meta-analysis/regression		*		*	*			*	*	*				*	*	
16	Onaran, 2009a	Field Study	*	*		*	*	*	*	*	*	*			*	*	*	
17	Onaran, 2009b	Literature Review										*					*	
18	Petersen & Solberg, 2004	Life Cycle Assessment				*						*	*		*		*	
19	Quan et al., 2011	Questionnaire Survey									*		*			*		*
20	Reiling et al., 2008	Cross-Sectional Study		*		*		*				*				*	*	*
21	Rossi & Lent, 2006	Case Study	*								*	*	*					*
22	Sadatsafavi et al., 2015	Cross-Sectional Study										*	*					
23	Sauerhoff, 2008	Literature Review										*						
24	Sjöberg & Ramnäs, 2007	Experimental Analysis		*								*		*	*		*	
25	Tuladhar et al., 2015	Triple Bottom Line Study	*	*		*	*			*	*	*		*	*	*	*	*
26	Ulrich et al., 2008	Literature Review		*			*				*		*					
27	Wilson & Ridgway, 2006	Observational Study				*						*			*		*	
28	Noskin & Peterson, 2001	Literature Review										*					*	
29	Baker, 2006	Meta-Analysis	*					*										
30	Schweitzer et al., 2004	Literature Review		*		*						*	*				*	
31	Borrelli, 2007	Headspace Analysis	*	*							*		*	*				*
32	Bower, 2006	Case Study		*		*									*			
33	Pati et al., 2009	Existing Data Analysis										*	*					
34	Shafie & Sherif, 2010	Case Study	*	*					*		*		*		*			*
35	Sherif, 2013	Questionnaire Survey		*	*	*					*				*	*		
36	Lavy and Dixit, 2012	Questionnaire Survey									*				*			
37	Warren & Hanger, 2012	Observational Study									*							

Table 2. Continued

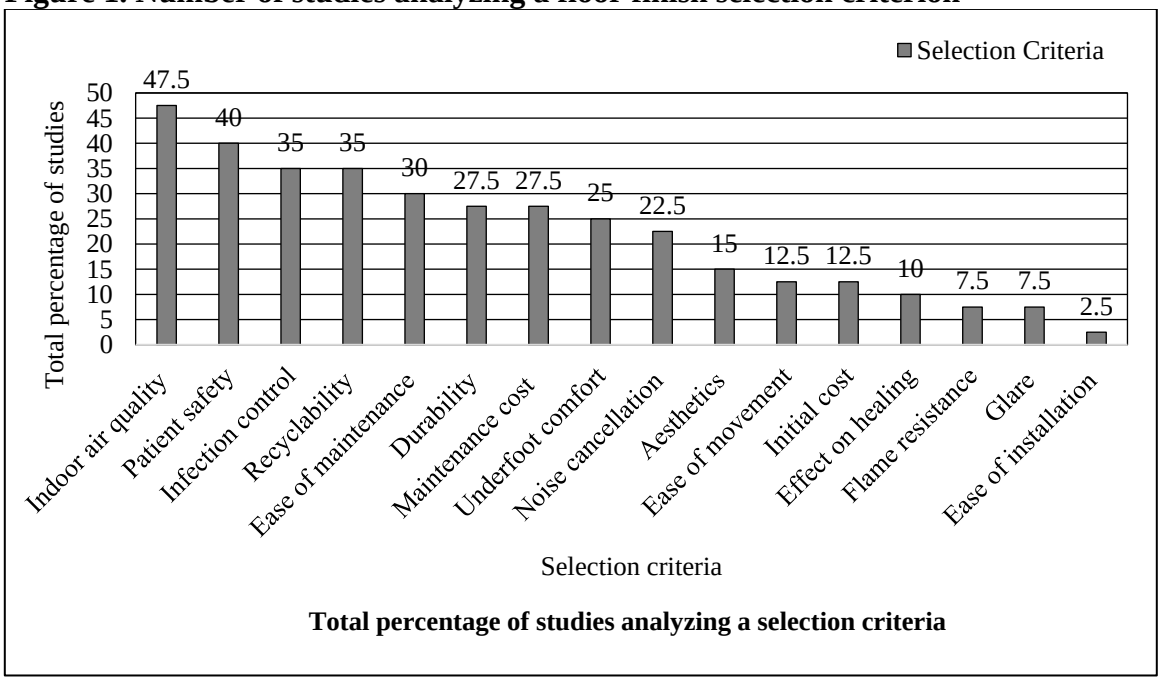
S. No.	Research Study	Methodology	Aesthetics	Durability	Ease of installation	Ease of maintenance	Ease of movement	Effect on healing	Flame resistance	Glare	User safety	Indoor air quality	Infection control	Initial cost	Maintenance cost	Noise cancellation	Recyclability	Underfoot comfort
38	Lange, 2012	Experimental Analysis											*					
39	Wahlström et al., 2012	Observational Study																*
40	Casey, 2006	Case Study									*							
41	Makhmalbaf et al., 2011	Case Study		*					*				*					
42	Abreu & Potter, 2001	Literature Review		*		*							*					
43	Berry et al., 2002	Literature Review											*					
44	Bilchik, 2002	Literature Review						*			*		*			*		*
45	Blakey & Rohde, 2002	LCC Assessment														*		
46	Blomkvist et al., 2005	Literature Review									*							
47	Boyce, 2007	Comparative Analysis															*	
48	Cham & Redfern, 2001	Meta-analysis/regression																*
49	Denly et al., 2008	Experimental Analysis		*								*		*	*		*	
50	Donald et al., 2000	Meta-analysis/regression									*							
51	Foarde & Berry, 2004	Life Cycle Assessment											*					
52	Gulwadi & Calkins, 2008	Personal Interviews											*					
53	Hagerman et al., 2008	Field Study	*	*		*	*		*		*				*		*	
54	Hales & Pronovost, 2006	Triple Bottom Line Study	*	*		*	*			*		*		*		*	*	*
55	Hallas et al., 2011	Observational Study									*							
56	Harris, 2009	Existing Data Analysis											*					
57	Harris, 2000	Literature Review																
58	Hodgson et al., 2000	Personal Interviews										*						
59	Kishk et al., 2007	Headspace Analysis		*	*	*									*	*		
60	Kracht et al., 2007	Field Study	*	*			*		*	*	*	*			*	*	*	
61	Love, 2003	LCC Assessment														*		
62	Morrison et al., 2003	Literature Review																
63	Parasarthy & Tobin, 2004	Experimental Analysis		*								*		*			*	
64	Petersen & Solberg, 2003	Literature Review										*		*	*		*	
65	Reason, 2000	Personal Interviews											*					
66	Redfern & Cham, 2000	Case Study																*
67	Shojania et al., 2001	Cross-Sectional Study										*	*					
68	Ulrich, 2000	Life Cycle Assessment				*						*	*		*		*	
69	Weinstein & Hota, 2004	Meta-Analysis	*					*										
70	White, 2007	Comparative Analysis		*		*	*			*	*			*	*	*	*	*
71	Ninomura et al., 2006	Case Study				*												

Note. This table identifies the selection criteria considered critical by the corresponding research studies

With the help of the reviewed literature, it was found that the most commonly used floor finishes in healthcare facilities are sheet vinyl, rubber, and carpet flooring. Along with the flooring types, 16 different selection criteria were also identified (Refer

Figure 1). These are initial cost, ease of installation, maintenance cost, ease of maintenance, durability, noise cancellation, ease of movement, underfoot comfort, user safety, flame resistance, indoor air quality, infection control, recyclability, aesthetics, glare, and effect on healing. Results revealed that indoor air quality, infection control, and impact resistance are the most critical selection criteria for floor finishes in a healthcare facility. Other criteria, such as glare, flame resistance and ease of installation were rendered as least important.

Figure 1. Number of studies analyzing a floor finish selection criterion



Based on **Figure 1**; it was found that indoor air quality, infection control, and impact resistance are the most critical selection criteria for floor finishes in a healthcare facility. Other criteria, such as glare, flame resistance and ease of installation were rendered as least important.

CHAPTER III

RESEARCH DESIGN AND METHODOLOGY

3.1 RESEARCH METHODOLOGY

3.1.1 Problem Statement

In the healthcare construction industry, preferences of facility managers for floor finish choices and their selection criteria have not been well understood. Hence, an investigation of opinions of such professionals, who play a significant role during the life cycle of a facility; is important.

3.1.2 Research Objectives

The objective of this study was: (1) to review the existing literature and developing a preferred list of floor finishes and their selection criteria in healthcare, (2) to conduct a survey of healthcare facility managers for identifying the most preferred floor finish and selection criteria, and (3) to investigate the similarity in ranking of floor finishes and their selection criteria across different healthcare units using non-parametric statistical methods. The similarity in ranking for floor finishes and selection criteria was investigated by using Wilcoxon Rank Sum Test. The *p*-values were tested for 4 different null hypotheses: (1) the ranking of each floor finish material is similar in the two paired healthcare units, (2) the ranking of each floor finish material is similar across the three healthcare units, (3) the ranking of each selection criteria is similar in the two paired healthcare units, and (4) the ranking of each pair of selection criteria for floor finishes is similar across the three healthcare units. For the above-mentioned null hypothesis (1)

and (3), three pairs of healthcare units were formed for hypothesis testing. They were: (a) emergency and surgery units, (b) surgery and in-patient units, and (c) emergency and in-patient units.

3.1.3 Limitation and Delimitation

The questionnaire survey for this study was limited to not-for-profit hospitals located in metropolitan regions (Wang et al., 2001). This study is delimited to the healthcare facility managers working in the state of Texas, USA.

3.1.4 Assumptions

It was assumed that the respondents of the questionnaire survey would answer the questions without any bias and that they had sufficient knowledge and expertise to participate. It was also assumed that for a healthcare facility, the material selection depended on the design type, availability of the material locally and traditional selection procedures. For the state of Texas, it was assumed that similar floor finish materials were available for installation in healthcare.

3.1.5 Research Methods

This study was conducted in four step method to investigate the preferences of healthcare facility managers regarding floor finish choices and their selection criteria. The steps were: (1) reviewing related literature, (2) developing questionnaire survey, (3) conducting a pilot study, administering questionnaire survey and collecting data, (4) analyzing and interpreting collected data. The following sub-sections describe these steps.

3.1.5.1 Reviewing related Literature

The literature review for this study was conducted in three steps. First, the selected keywords were used to identify relevant research published in English between the year 2000 and 2015. Lavy & Dixit, 2012 conducted a similar study, which thoroughly reviewed the related literature to identify wall finishes and their selection criteria in healthcare facilities. Therefore, we focused on the last 15 years' published studies to investigate floor finishes and their criteria of selection. In addition, due to technological and socio-economic changes, new materials are emerging and design trends are changing (Bower, 2006). In such situations, keeping the review current may be more insightful for the research goal.

Altogether, six databases were investigated comprehensively using 25 keywords (Refer Table 3). In addition, a combination of keywords was also used and reference lists of selected studies were explored to identify other relevant literature. Initial search using a broad inclusion criterion in the six enlisted databases found 17,251 published studies. They included published journal papers, conference proceedings, industry research reports, government documents, published and unpublished theses, white papers, etc. However, in the second step, the search was narrowed down by applying nine criteria of inclusion (Refer Table 1). 71 studies were adjudged as meeting the desired criteria of inclusion. Of those 34% articles focused on health environment, 18% on architecture, 15% on health science, 13% of public health, 10% on facility management, 7% in construction, and 3% on hospital management (Refer Figure 2). The identified studies investigated the general characteristics of different flooring types used

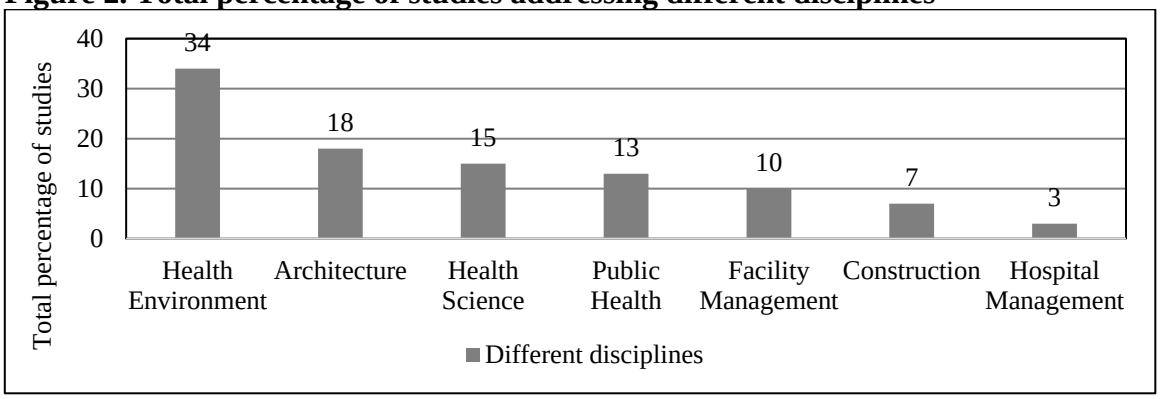
in the healthcare facilities, their applications, and impacts on hygiene and indoor air quality and sustainability. They also analyzed the different criteria associated with floor finish selection in healthcare facilities.

During the process of floor finish selection for a healthcare facility, it is important for decision makers to understand the criticality of certain selection criteria. Hence, in the final step, a matrix was created which listed the identified research studies and their research methods along the Y-axis and their corresponding selection criteria along the X-axis. It was observed that two of the selected studies investigated the preferred finishes and their selection criteria by healthcare facility managers. Lavy & Dixit, 2012 investigated and ranked wall finishes; while, Sherif, 2013 analyzed the performance of finish materials used in healthcare by deriving mean scores with respect to seven selection criteria. However, the scope of these two studies was limited and neither of them specifically ranked floor finishes nor did they comprehensively investigate floor finish selection criteria.

Table 3. List of databases, keywords, and criteria of inclusion for literature review

Databases	Keywords	Criteria for Inclusion
Google Scholar, Google search engine ResearchGate EBSCO PubMed MEDLINE	Healthcare facility management Healthcare floor finish Floor finish selection criteria Rubber floor finish Carpet floor finish Vinyl floor finish Linoleum floor finish Wood floor finish Mosaic floor finish Concrete floor finish Cost Installation Maintenance Durability Noise Movement Comfort Impact Flame Indoor air Infection Sustainability Aesthetics Glare Healing	Studies published in English Published between 2000 and 2015 Peer reviewed research papers Conference proceedings Government reports Industry reports Theoretical and empirical studies Addressed indoor healthcare environments Addressed healthcare floor finishes
Note. This table enlists the databases, relevant keywords and inclusion criteria used for literature review		

Figure 2. Total percentage of studies addressing different disciplines



3.1.5.2 Developing Questionnaire Survey

A questionnaire survey was formulated to gather data and investigate the preferences of facility managers for floor finish choices in the clinical spaces or units of a health care facility as categorized by Lavy & Dixit, 2012. The identified healthcare units were: (1) emergency unit, (2) surgery unit, and (3) inpatient unit. Altogether, the questionnaire survey consisted of 4 questions. The current study aimed at developing a concise questionnaire survey.

The literature review conducted for this study had identified 11-floor finishes used in the hospitals and 16 criteria for their selection in healthcare environments. The enlisted items were then used to draft questions of the survey. In addition to this, each of the four questions was designed to collect responses simultaneously for all identified healthcare units. Please refer to APPENDIX A which enlists the questions asked in the conducted survey. The objective of the first question was to find data regarding the floor finishes currently installed in different units of the healthcare facility, with which the respondents are currently associated. It also asked them to rate the performance of floor finishes based on their level of satisfaction. The second question aimed at formulating a preference list of facility managers for floor finishes in different units of the healthcare facility they are associated with. It also asked them to rank their preferences for floor finishes. The third question found out about the preference of facility managers for different selection criteria adopted to choose floor finishes in different healthcare units. It also asked them to rank their preferences of selection criteria. The fourth question aimed at identifying the selection criteria that facility managers specified for the

selection of floor finishes in the different healthcare units. It also asked them to rate the significance of the selection criteria based on their experience.

3.1.5.3 Conducting Pilot Study, Administering Questionnaire Survey and Collecting Data

The questionnaire survey was sent to the Institutional Review Board (IRB) at the Texas A&M University, College Station for its approval because the involvement of human subjects was required for collecting data. The Hospital Survey Unit, Center for Health Statistics of the Texas Department of State Health Services, and the American Hospital Directory stated that as of 2013, there were 225 for-profit, short-term acute care hospitals in the metropolitan regions of the state of Texas. Since the study was delimited to the state of Texas, the survey was conducted only among the healthcare facility managers working in this state. A pilot study was conducted with 4 of the 225 identified healthcare facilities. Complete responses were received from all respondents. After administering the pilot study and inculcating the suggested revisions, no further modifications were made to the questionnaire.

The data collection was conducted in a two-step process. In the first step, a web-based survey was conducted and the questionnaire was emailed to the facility managers of the 225 identified hospitals. Their email addresses were retrieved from two sources: (1) official website of the hospital, and (2) membership directory and resource guide of the Texas Association of Healthcare Facilities Management (TAHFM). Follow-up emails requesting the participation of the respondents were sent on a weekly basis over a period of 2 months. Twenty-seven complete responses were received during the entire process. In the second step, a presentation was organized in relation to this study at the

TAHFM Interlink, Houston, TX on March 27th, 2017. This conference was attended by the healthcare facility managers working in the state of Texas. The presentation was aimed at encouraging the facility managers to participate in the questionnaire survey. During the two-day conference, personal communication was established with 33 facility managers regarding their participation. Twenty-two complete responses were received within a week from the start date of the event. The attendee list was retrieved and follow-up emails were sent on a weekly basis over a period of 1 month. Nineteen complete responses were received. Altogether, the data collection process received 68 complete responses from the total population of 221 healthcare facility managers. Incomplete responses were excluded from this study. Although, the questionnaire survey did not ask the respondents about their experience in this sector.

3.1.5.4 Analyzing and Interpreting Collected Data

To collect the data from the respondents, an ordinal scale was used. Descriptive statistical methods, tabular descriptions, and graphical displays were used for data analysis and interpretation.

For the analysis on the ranking preferences of the healthcare facility managers for floor finishes and their selection criteria, Wilcoxon Rank Sum Test was used. Hayter, (2007) said that the Wilcoxon rank sum test could be applied for analyzing any given data which has an unspecified or unknown data because it was a non-parametric statistical analysis method which took no assumption for the data distribution. Hence, it could be used for the analysis of data which does not follow a normal distribution. However, regardless of the population distribution model, the central limit theorem

(CLT) states that the sample mean tends to be normally distributed around the population mean as the sample size increases. Although, certain conditions should be met before the CLT could be applied: (1) the samples used for analysis must be independent of each other, and (2) the sample size should be large enough (Gupta & Kapoor, 2000).

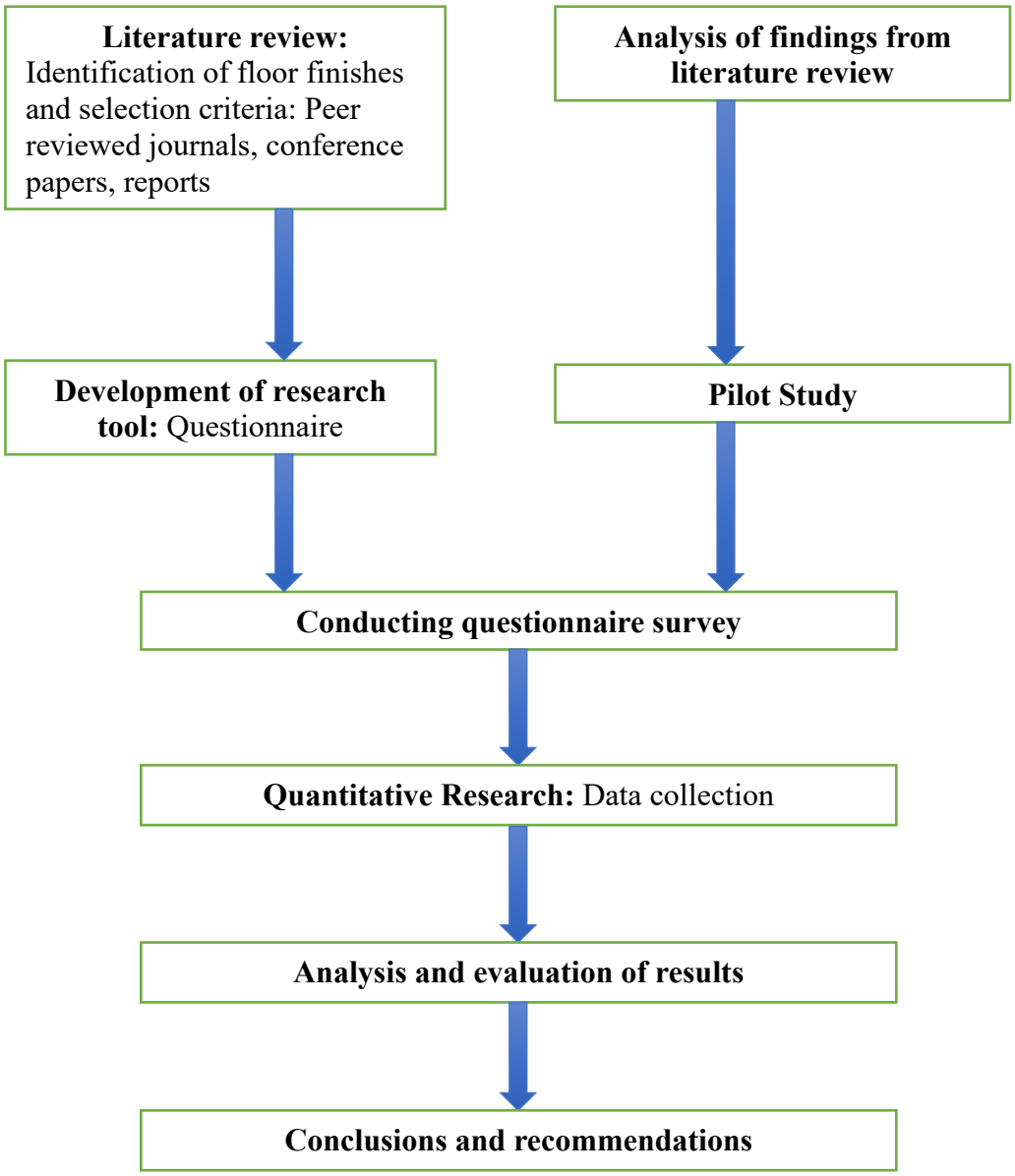
For the analysis of the rating of performance and rating of selection criteria for floor finishes, mean values were used to determine the central tendency of the collected data. Gupta & Kapoor, 2000 suggest that if a Likert scale is defensibly approximated to an interval scale, then for data analytics, the central limit theorem allows the data collected from Likert scale to be treated as an interval data measuring a latent variable. Norman, 2010 said that the Likert scale data could be analyzed using parametric statistical methods. There were enough empirical evidence and literature supporting this claim. Although, it was acknowledged that the debate regarding the parametric analysis of Likert scale data would prevail. Boone & Boone, 2012 suggested that the mean values of the Likert scale data could be used to determine the central tendency. In addition to this, open source platform of the data analytics tool “r” and SPSS was explored and it was found that they analyzed Likert scale data using mean values and determined central tendency. Therefore, for data analytics in this research and with the support of sufficient literature, it was decided to analyze the Likert scale data by calculating mean values to analyze the central tendency of the opinion of facility managers regarding floor finishes and their selection criteria.

3.2 SUMMARY

This study was conducted to find out the opinion of healthcare facility managers regarding floor finish choices and their selection criteria. Using statistical methods empirical values were assigned to their preferences. The Wilcoxon Rank Sum Test which was used to analyze the collected data was an appropriate non-parametric statistical method to study a data set which does not follow a normal distribution. However, when the responses across all three healthcare units were combined for a cumulative analysis, the central limit theorem allowed the calculation of mean values after a defensive approximation of the Likert scale as an interval scale (Gupta & Kapoor, 2000).

Figure 3. Diagrammatic representation of research method

Figure 3 is a diagrammatic representation of the research method adopted to conduct this study. It also highlights an interconnection between the different steps involved in the process.



CHAPTER IV

RESULTS

In the questionnaire survey, all questions were designed using multiple matrices to collect different data sets in relation to the identified healthcare units: (1) emergency units, (2) surgery units, and (3) inpatient units. Questions 1 and 2 aimed at collecting data regarding floor finish choices of healthcare facility managers, while, questions 3 and 4 aimed at exploring their preferences for floor finish selection criteria (Refer APPENDIX A).

4.1 FLOOR FINISH MATERIALS

Data specific to floor finish materials such as: (1) information on types of floor finishes currently installed in the healthcare facility that the respondents were working with at the time of participation in the questionnaire survey, and (2) the ranking of identified floor finish choices based on their experience in the field of healthcare facility management, were collected via questions 1 and 2.

4.1.1 Interpretation of Data Collected via the First Question

The objective of the first question was to collect data regarding the floor finishes currently installed in different units of the healthcare facility the respondents were associated with. It also asked them to rate the performance of floor finishes based on their level of satisfaction. Their satisfaction level on the performance of the floor finishes currently installed in the different health care units was rated on a Likert Scale ranging from 1 through 5, where: (1) choice 1 signified that they were completely

dissatisfied, (2) choice 2 signified that they were dissatisfied, (3) choice 3 signified that their opinion was neutral, (4) choice 4 signified that they were satisfied, and (5) choice 5 signified that they were completely satisfied. The data collected with respect to (1) emergency units is summarized in Table 4, (2) surgery units is summarized in Table 5, and (3) inpatient units are summarized in Table 6. Tables 4, 5, and 6 also list the total number of respondents who stated that their facility had a respective floor finish installed in different healthcare units along with their satisfaction level on the Likert Scale. In Tables 4, 5, and 6, the values of the: (1) total number of respondents who stated that their health care facilities had a specific type of floor finish installed have been listed under – Total Response, and (2) satisfaction level of the respondents with the corresponding floor finish have been listed under – Rating of Performance.

This study received complete responses from 68 respondents. However, in the Tables 4, 5, and 6 the values of the total number of respondents stating that their facility had the corresponding type of floor finish installed are less than 68. As low as 7 respondents stated that in the surgery unit of their healthcare facility, mosaic flooring was currently installed. Whereas, as high as 49 respondents said that vinyl composition tile was installed currently in the in-patient units of their healthcare facility. It was evident due to the fact the healthcare facilities across a given geographic region use different types of floor finishes based on their preference of selection criteria (Sherif, 2013).

Table 4 shows that vinyl composition tile was used in most emergency units of healthcare facilities across the state of Texas, whereas, concrete and carpet flooring were

the least used floor finishes. Based on the total response received with respect to each floor finish, the highest percentage for completely satisfied (5) was received by laminated hardwood flooring (40.00%), whereas, carpet flooring received the highest percentage (71.43%) for completely dissatisfied (1).

Table 4. Type of floor finish in emergency unit vs total number of healthcare facilities where they are installed vs response rate for satisfaction level of facility managers

##	**Emergency Units.** Note: (5) – Completely satisfied, (4) – Satisfied, (3) – Neutral, (2) – Dissatisfied, (1) – Completely dissatisfied.						
	Type of Floor Finish	**Total Response**	**Rating of Performance (%)**				
			(5)	(4)	(3)	(2)	(1)
1.	Rubber Flooring	25	16.00	40.00	4.00	24.00	16.00
2.	Carpet Flooring	7	0.00	0.00	28.57	0.00	71.43
3.	Vinyl Flooring	30	36.67	43.33	6.67	0.00	13.33
4.	Vinyl Composite Tile (VCT)	46	15.22	34.78	26.09	13.04	10.87
5.	Linoleum Flooring	13	15.38	30.77	23.08	15.38	15.38
6.	Ceramic Flooring	25	32.00	20.00	0.00	24.00	24.00
7.	Concrete Flooring	7	0.00	0.00	42.86	0.00	57.14
8.	Hardwood Flooring	9	0.00	0.00	44.44	33.33	22.22
9.	Laminated Hardwood Flooring	15	40.00	0.00	26.67	13.33	20.00
10.	Mosaic Flooring	11	36.36	0.00	45.45	0.00	18.18
11.	Polyolefin Flooring	9	0.00	22.22	55.56	0.00	22.22

Table 5 shows that vinyl flooring is used in most surgery units of healthcare facilities across the state of Texas, whereas, hardwood, mosaic, and polyolefin flooring are the least used floor finishes. Based on the total response received with respect to each floor finish, the highest percentage for completely satisfied (5) was received by rubber flooring (48.48%), whereas, carpet flooring received the highest percentage (55.56%) for completely dissatisfied (1).

Table 5. Type of floor finish in surgery unit vs total number of healthcare facilities where they are installed vs response rate for satisfaction level of facility managers

##	**Surgery Units.** Note: (5) – Completely satisfied, (4) – Satisfied, (3) – Neutral, (2) – Dissatisfied, (1) – Completely dissatisfied.						
	Type of Floor Finish	**Total Response**	**Rating of Performance (%)**				
			(5)	(4)	(3)	(2)	(1)
1.	Rubber Flooring	33	48.48	30.30	3.03	0.00	18.18
2.	Carpet Flooring	9	0.00	0.00	22.22	22.22	55.56
3.	Vinyl Flooring	40	25.00	52.50	10.00	0.00	12.50
4.	Vinyl Composite Tile (VCT)	31	9.68	58.06	12.90	12.90	6.45
5.	Linoleum Flooring	13	15.38	46.15	7.69	15.38	15.38
6.	Ceramic Flooring	17	23.53	29.41	0.00	11.76	35.29
7.	Concrete Flooring	9	0.00	22.22	33.33	0.00	44.44
8.	Hardwood Flooring	7	0.00	0.00	28.57	42.86	28.57
9.	Laminated Hardwood Flooring	9	22.22	0.00	44.44	0.00	33.33
10.	Mosaic Flooring	7	28.57	0.00	42.86	0.00	28.57
11.	Polyolefin Flooring	7	0.00	28.57	42.86	0.00	28.57

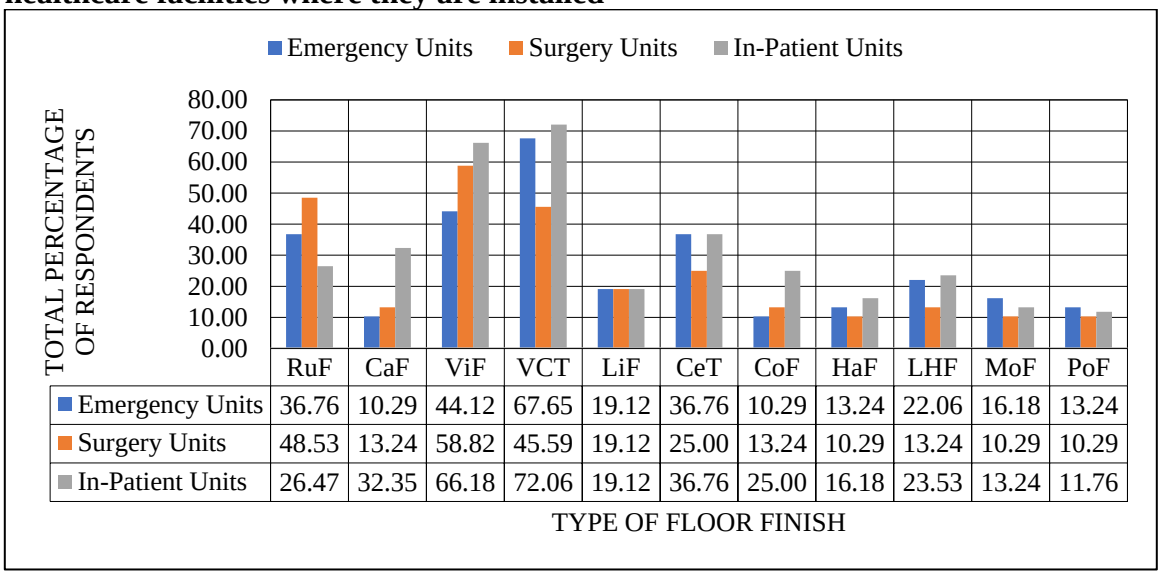
Table 6 shows that vinyl composition tile is used in most inpatient units of healthcare facilities across the state of Texas, whereas, polyolefin flooring is the least used floor finish. Based on the total response received with respect to each floor finish, the highest percentage for completely satisfied (5) was received by vinyl flooring (48.89%), whereas, carpet flooring received the highest percentage (40.91%) for completely dissatisfied (1).

Table 6. Type of floor finish in in-patient unit vs total number of healthcare facilities where they are installed vs response rate for satisfaction level of facility managers

##	**In-Patient Units.** Note: (5) – Completely satisfied, (4) – Satisfied, (3) – Neutral, (2) – Dissatisfied, (1) – Completely dissatisfied.						
	Type of Floor Finish	**Total Response**	**Rating of Performance (%)**				
			(5)	(4)	(3)	(2)	(1)
1.	Rubber Flooring	18	11.11	22.22	5.56	38.89	22.22
2.	Carpet Flooring	22	36.36	13.64	9.09	0.00	40.91
3.	Vinyl Flooring	45	48.89	24.44	22.22	0.00	4.44
4.	Vinyl Composite Tile (VCT)	49	24.49	32.65	20.41	12.24	10.20
5.	Linoleum Flooring	13	0.00	30.77	38.46	15.38	15.38
6.	Ceramic Flooring	25	28.00	28.00	8.00	8.00	28.00
7.	Concrete Flooring	17	11.76	47.06	17.65	0.00	23.53
8.	Hardwood Flooring	11	18.18	0.00	36.36	27.27	18.18
9.	Laminated Hardwood Flooring	16	31.25	0.00	25.00	12.50	31.25
10.	Mosaic Flooring	9	22.22	0.00	55.56	0.00	22.22
11.	Polyolefin Flooring	8	0.00	12.50	62.50	0.00	25.00

The data from Table 4, 5, and 6 was not analyzed statistically because the total number of responses received for each type of floor finish was insufficient. However, the values of the total number of respondents stating that the corresponding floor finish was installed in their facility were used for comparison across all healthcare units in Figure 3. For comparison, the number values associated with a floor finish were converted into percentage values with respect to the total responses received against them in different healthcare units. Figure 3 shows that the top three floor finishes mostly used in different health care units were vinyl composition tile, vinyl flooring, and rubber flooring.

Figure 4. Type of floor finish in different healthcare unit vs total number of healthcare facilities where they are installed



	RuF	CaF	ViF	VCT	LiF	CeT	CoF	HaF	LHF	MoF	PoF
Emergency Units	36.76	10.29	44.12	67.65	19.12	36.76	10.29	13.24	22.06	16.18	13.24
Surgery Units	48.53	13.24	58.82	45.59	19.12	25.00	13.24	10.29	13.24	10.29	10.29
In-Patient Units	26.47	32.35	66.18	72.06	19.12	36.76	25.00	16.18	23.53	13.24	11.76

In **Figure 3.** the floor finishes have been coded as (1) RuF – Rubber Flooring, (2) CaF – Carpet Flooring, (3) ViF – Vinyl Flooring, (4) VCT – Vinyl Composite Tile, (5) LiF – Linoleum Flooring, (6) CeT – Ceramic Tile, (7) CoF – Concrete Flooring, (8) HaF – Hardwood Flooring, (9) LHF – Laminated Hardwood Flooring, (10) MoF – Mosaic Flooring, (11) PoF – Polyolefin Flooring

4.1.2 Interpretation of Data Collected via Second Question

The objective of the second question was to collect data regarding the preferences of facility managers for floor finishes in different units of healthcare facilities. The respondents were asked to mutually rank their preferences for floor finish choices from an identified list in different healthcare units. Ranking of choices was given from rank 1 through rank 11, where rank 1 was the highest preference and rank 11 was of least preference. The floor finishes were ranked was from 1 through 11 because the literature review identified a list of 11-floor finish choices for healthcare. The data collected with respect to (1) emergency units is summarized in Table 7, (2) surgery units is summarized in Table 8, and (3) inpatient units are summarized in Table 9. Tables 7, 8, and 9, list out the total number of responses received for each type of floor finish under the given ranks. For each type of floor finish, the total number of responses received under all ranks summed up to 68.

Table 7 shows that vinyl flooring received most responses (33) under rank 1, whereas, carpet flooring received most responses (58) under rank 11 for emergency units. In addition to this, under rank 1, vinyl composition tile received the second highest (14) responses.

Table 7. Occurrences of each type of floor finish in all ranks for emergency units

##	Emergency Units.											
	Type of Floor Finish	Rank										
		1	2	3	4	5	6	7	8	9	10	11
1.	Rubber Flooring	7	4	37	10	2	0	2	4	0	2	0
2.	Carpet Flooring	0	0	0	0	4	0	2	0	2	2	58
3.	Vinyl Flooring	33	18	9	0	0	6	0	2	0	0	0
4.	Vinyl Composite Tile (VCT)	14	28	4	18	1	1	0	0	2	0	0
5.	Linoleum Flooring	2	14	8	13	21	0	0	2	4	0	4
6.	Ceramic Flooring	0	0	4	23	15	4	6	4	8	4	0
7.	Concrete Flooring	0	0	0	1	4	45	0	1	5	10	2
8.	Hardwood Flooring	2	0	6	0	0	4	6	41	3	4	2
9.	Laminated Hardwood Flooring	4	0	0	2	9	2	5	6	4	34	2
10.	Mosaic Flooring	6	0	0	0	0	6	44	6	0	6	0
11.	Polyolefin Flooring	0	4	0	1	12	0	3	2	40	6	0

Table 8 shows that vinyl flooring received most responses (28) under rank 1, whereas, carpet flooring (60) received most responses under rank 11 for surgery units. In this regard, the results shown in Table 7 and 8 were similar. However, a difference was observed when the second highest responses were compared to rank 1. Unlike, Table 7, Table 8 shows that rubber flooring received second highest responses (20) under rank 1. In addition to this, vinyl composition tile received one of the least responses (2) under rank 1 for surgery units.

Table 8. Occurrences of each type of floor finish in all ranks for surgery units

##	Surgery Units.											
	Type of Floor Finish	Rank										
		1	2	3	4	5	6	7	8	9	10	11
1.	Rubber Flooring	20	5	31	4	4	0	2	0	0	2	0
2.	Carpet Flooring	0	0	0	0	0	0	2	0	4	2	60
3.	Vinyl Flooring	28	24	4	10	0	0	0	2	0	0	0
4.	Vinyl Composite Tile (VCT)	2	13	12	23	13	1	2	0	2	0	0
5.	Linoleum Flooring	8	18	9	20	3	2	0	4	0	4	0
6.	Ceramic Flooring	0	0	2	3	12	6	6	6	33	0	0
7.	Concrete Flooring	2	0	8	3	2	25	4	1	3	20	0
8.	Hardwood Flooring	0	0	0	0	4	8	21	24	3	2	6
9.	Laminated Hardwood Flooring	4	0	2	2	3	2	19	21	4	9	2
10.	Mosaic Flooring	4	2	0	0	0	26	5	4	6	21	0
11.	Polyolefin Flooring	0	6	0	3	27	0	7	4	13	8	0

Table 9 shows that vinyl flooring received most responses (29) under rank 1, whereas, carpet flooring (37) received most responses under rank 11 for in-patient units. Considering, responses under rank 1, Table 9 and Table 7 showed similar results. In both cases, vinyl flooring and vinyl composite tile received the highest and the second highest responses, respectively. However, under rank 11, carpet flooring observed a huge difference in the number of responses. From 58 and 60 in emergency and surgery units, respectively, it reduced considerably and came down to 37 for in-patients.

Table 9. Occurrences of each type of floor finish in all ranks for in-patient units

##	In-Patient Units.											
	Type of Floor Finish	Rank										
		1	2	3	4	5	6	7	8	9	10	11
1.	Rubber Flooring	3	4	23	8	4	2	2	0	14	8	0
2.	Carpet Flooring	0	1	6	2	0	0	4	0	6	12	37
3.	Vinyl Flooring	29	24	11	0	2	0	0	2	0	0	0
4.	Vinyl Composite Tile (VCT)	24	23	8	10	0	1	0	0	2	0	0
5.	Linoleum Flooring	0	12	12	20	8	0	2	8	0	6	0
6.	Ceramic Flooring	0	2	4	13	21	14	4	3	7	0	0
7.	Concrete Flooring	2	0	2	4	4	12	3	2	16	9	14
8.	Hardwood Flooring	0	0	2	6	2	8	14	13	13	8	2
9.	Laminated Hardwood Flooring	4	0	0	4	3	10	12	21	6	6	2
10.	Mosaic Flooring	6	0	0	0	2	15	14	13	0	13	5
11.	Polyolefin Flooring	0	2	0	1	22	6	13	6	4	6	8

The questionnaire survey of this study collected data using two types of ordinal scales: (1) a Likert scale ranging from values 1 through 5, to understand the satisfaction and significance level of healthcare facility managers regarding performance of floor finishes and the relevance of their preferred selection criteria, respectively, and (2) a ranking of floor finishes and selection criteria on an ordinal scale ranging from 1 through 11 and 1 through 16, respectively. The data was collected for different healthcare units identified in this study and the Wilcoxon Rank Sum Text was used for data analysis.

The first null hypothesis was established. The *p*-values were calculated using the selected non-parametric statistical analysis method. It was assumed that the opinion of healthcare facility managers regarding their preference for floor finishes was mutually independent. The three healthcare units: (1) emergency, (2) surgery, and (3) inpatient units were simultaneously paired with each other and each type of floor finish was tested using Wilcoxon Rank Sum Test. The *p*-values for each type of floor finish with respect to the corresponding pair of health care units was listed out in Table 10.

Table 10 shows that none of the calculated *p*-values were below 0.05 (95% confidence interval). Hence, it meant that in none of the cases null hypothesis was rejected with 95% confidence interval. Moreover, most of the values were significantly higher than 0.05. Therefore, the null hypothesis was not rejected and the ranking of different types of floor finishes was accepted as similar in the three healthcare units.

Table 10. Testing p-values for null hypothesis: the ranking of each floor finish material is similar in the two health care units as paired below

##	Type of Floor Finish	P-value		
		Emergency & Surgery	Surgery & In-Patient	Emergency & In-Patient
1.	Rubber Flooring	0.8137	0.4835	0.5267
2.	Carpet Flooring	0.7665	0.2057	0.3156
3.	Vinyl Flooring	0.9761	0.9760	0.9714
4.	Vinyl Composite Tile (VCT)	0.7886	0.5659	0.8381
5.	Linoleum Flooring	0.9734	0.9733	0.8671
6.	Ceramic Flooring	0.6871	0.6638	0.7887
7.	Concrete Flooring	0.4248	0.5290	0.1445
8.	Hardwood Flooring	0.9466	0.5711	0.3689
9.	Laminated Hardwood Flooring	0.9466	0.6187	0.5507
10.	Mosaic Flooring	0.8081	0.7875	0.4247
11.	Polyolefin Flooring	0.5901	0.7645	0.3021

After the Wilcoxon Rank Sum Test, it was found that the floor finishes were similarly ranked in the three healthcare units. Hence, another analysis was carried out

which combined the 68 responses for each type of floor finish across the three healthcare units. By combining 68 responses for each healthcare unit, the final sample space increased to 68 x 3 = 204, responses. Scores were assigned to each rank which was equal to the mathematical face value of the ranks. This implies that rank 1 was assigned score 1, rank 2 was assigned score 2, and so on for all 11 ranks. Sum of all the ranks was calculated for each type of floor finish and was averaged by dividing it with the total sample size (204 responses). The averaged values were called the arithmetic mean ranks of floor finishes and were enlisted in Table 11.

Alternatively, the standard deviation of the arithmetic mean ranks for the combined sample was calculated and enlisted alongside the values of the arithmetic mean ranks in Table 11. The method followed in this case was similar to the one adopted by Lavy & Dixit, 2012 to analyze the opinion of facility managers for wall finish choices in healthcare facilities. Simultaneously, the floor finishes were rearranged and were placed in ascending order of their arithmetic mean rank. The lowest arithmetic mean rank of vinyl flooring (2.0980) signified that it was the most preferred floor finish, whereas, its highest value in the case of carpet flooring suggested that it was least preferred floor finish for a combination of all healthcare units. It was interesting to find out that the vinyl products were the most preferred floor finish materials which had the least values for standard deviations of their arithmetic mean ranks. The arithmetic mean rank of vinyl flooring and vinyl composition tile had a standard deviation of 1.5410 and 1.7268, respectively. The standard deviation was highest in the case of rubber flooring (2.5592).

The different floor finishes were then compared with each other and tested using the similar Wilcoxon Rank Sum Test. The null hypothesis was that the ranking of each pair of floor finish was similar across the three healthcare units. Table 11 shows that none of the calculated *p*-values were below 0.05. Most of the *p*-values were significantly higher values. Hence, the null hypothesis was not rejected and the ranking of different types of floor finishes was accepted as similar in the three healthcare units. Wherever, the *p*-values were not rejected with 95% confidence interval, it meant that for those comparisons the ranking done for floor finish choices across all the health care units was similar. There was no other way to analyze the pairs which generated *p*-values more than 0.05, other than comparing their arithmetic mean ranks.

With the highest arithmetic mean rank value, it was found that carpet flooring was the least preferred floor finish material across all the health care units. However, studies like Harris & Detke, 2013 conducted a research which revealed installation of floor finishes like carpet in in-patient units could have an impact on the rate of healing of the patients. Use of carpets and other home-like features in such spaces helped the patients heal at a faster rate than in comparison to other similar spaces which had a different floor finish installed.

Table 11. Testing p-values for null hypothesis: the ranking of each pair of floor finish material is similar across the three healthcare units

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.		
	Type of Floor Finish	**Vinyl Flooring**	**Vinyl Composition Tile (VCT)**	**Rubber Flooring**	**Linoleum Flooring**	**Ceramic Tile**	**Polyolefin Flooring**	**Mosaic Flooring**	**Concrete Flooring**	**Laminated Hardwood Flooring**	**Hardwood Flooring**	**Carpet Flooring**	**Arithmetic Mean Rank**	**Standard Deviation**
1.	Vinyl Flooring		0.7636	0.2750	0.2478	0.4254	0.4450	0.6657	0.2897	0.2338	0.3044	0.9467	2.0980	1.5410
2.	Vinyl Composite Tile (VCT)			0.7170	0.5101	0.8171	0.7411	0.9210	0.5753	0.5977	0.5977	0.5503	2.9412	1.7268
3.	Rubber Flooring				0.8433	0.8693	0.9475	0.8434	0.9475	0.6216	0.9737	0.1470	3.9167	2.5592
4.	Linoleum Flooring					0.8691	0.9738	0.6684	0.8688	0.8177	0.8952	0.1064	4.2892	2.4474
5.	Ceramic Tiles						0.9737	0.8431	0.8950	0.8434	0.9737	0.2091	6.1863	2.0855
6.	Polyolefin Flooring							0.7919	0.9475	0.6888	0.9737	0.1971	7.0735	2.3717
7.	Mosaic Flooring								0.6929	0.6448	0.6685	0.3718	7.0882	2.3971
8.	Concrete Flooring									0.7176	0.9737	0.1466	7.2108	2.4272
9.	Laminated Hardwood Flooring										0.7922	0.0992	7.4853	2.4343
10.	Hardwood Flooring											0.1292	7.5098	1.8369
11.	Carpet Flooring												10.1814	1.9378

In Table 11. for the calculation of arithmetic mean rank for each type of floor finish, at first, an average of the cumulative responses across the three health care units was calculated. Secondly, the standard deviations of their means were calculated. Finally, the floor finishes were rearranged in the ascending order of their arithmetic mean.

4.2 SELECTION CRITERIA FOR FLOOR FINISH MATERIALS

Data specific to the selection criteria of floor finish materials were collected via questions 3 and 4, for e.g.: (1) information on the preferred ranking of identified criteria for selection of floor finishes based on the experience of facility managers in healthcare and (2) opinion of the respondents on significance of each selection criteria for floor finishes in different healthcare units.

4.2.1 Interpretation of Data Collected via the Third Question

The objective of the third question was to collect data regarding the preferences of facility managers for floor finish selection criteria in different units of healthcare facilities. The respondents were asked to mutually rank their preferences for the identified choices of selection criteria for floor finish list in different healthcare units. Ranking of choices followed a similar method as in the question 2. However, in this case, the respondents had 16 options and hence, the choices were ranked from 1 through 16, where rank 1 was the highest preference and rank 16 was of least preference. The data collected with respect to (1) emergency units is summarized in Table 12, (2) surgery units is summarized in Table 13, and (3) inpatient units are summarized in Table 14. Tables 12, 13, and 14, list out the total number of responses received for each choice of selection criteria for floor finishes under the given ranks. For each choice of selection criteria, the total number of responses received under all ranks summed up to 68.

Table 12 shows that durability received most responses (20) under rank 1, whereas, recyclability received most responses (43) under rank 16 for emergency units.

In addition to this, under rank 1, infection control received the second highest (17) responses.

Table 12. Occurrences of each selection criteria in all ranks for emergency units

##	Emergency Units.																
	Selection Criteria	Rank															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Initial cost	12	4	7	4	12	4	2	2	0	4	0	4	2	5	6	0
2.	Ease of installation	0	6	0	6	7	0	8	2	8	4	4	5	4	7	7	0
3.	Maintenance cost	1	8	12	22	0	6	3	5	2	2	2	5	0	0	0	0
4.	Ease of maintenance	8	9	13	12	9	4	0	2	7	2	0	0	0	2	0	0
5.	Durability	20	5	9	5	10	8	3	2	0	0	0	6	0	0	0	0
6.	Noise cancellation	0	0	6	0	2	2	2	6	13	6	9	2	10	8	0	2
7.	Ease of movement	0	10	0	3	1	4	11	8	4	13	8	0	2	4	0	0
8.	Underfoot comfort	0	0	0	2	4	11	6	4	9	7	4	8	7	4	2	0
9.	User Safety	2	11	3	9	2	11	10	8	4	0	2	0	6	0	0	0
10.	Flame resistance	6	2	0	2	6	1	4	6	6	7	5	11	6	2	4	0
11.	Indoor air quality	0	1	2	2	4	7	1	8	4	8	10	11	4	4	0	2
12.	Infection control	17	10	10	1	4	4	4	2	4	6	0	4	0	0	0	2
13.	Recyclability	0	0	0	0	0	0	0	0	0	0	0	2	8	0	15	43
14.	Aesthetics	0	2	2	0	2	2	10	4	2	7	16	2	2	17	0	0
15.	Glare	0	0	4	0	0	0	2	0	1	2	0	6	5	14	20	14
16.	Effect on healing	2	0	0	0	5	4	2	9	4	0	8	2	12	1	14	5

Table 13 shows that infection control received most responses (29) under rank 1, whereas, recyclability (28) received most responses under rank 11 for surgery units. For surgery units, it was observed that infection control became the most crucial selection criteria unlike in the case of emergency units where durability received the maximum responses under rank 1. Under rank 1 the second highest responses were received by initial cost and durability.

Table 13. Occurrences of each selection criteria in all ranks for surgery units

##	Surgery Units.																
	Selection Criteria	Rank															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Initial cost	8	4	7	5	14	2	4	2	0	2	4	2	3	9	2	0
2.	Ease of installation	0	6	0	2	2	2	14	4	6	1	0	15	7	7	2	0
3.	Maintenance cost	1	10	12	10	2	6	1	14	1	0	5	4	0	2	0	0
4.	Ease of maintenance	4	7	14	14	7	2	8	1	9	2	0	0	0	0	0	0
5.	Durability	8	7	17	9	8	10	3	4	0	0	2	0	0	0	0	0
6.	Noise cancellation	6	0	0	2	4	4	2	6	7	8	7	6	10	4	0	2
7.	Ease of movement	2	2	0	8	4	4	7	8	8	9	10	0	0	4	2	0
8.	Underfoot comfort	2	10	3	2	7	5	2	6	10	2	6	4	3	4	2	0
9.	User Safety	2	9	5	9	2	13	2	4	6	8	2	0	6	0	0	0
10.	Flame resistance	6	2	0	0	10	0	6	2	7	10	11	6	4	0	4	0
11.	Indoor air quality	0	1	4	0	2	9	3	4	10	12	2	10	5	6	0	0
12.	Infection control	29	10	4	3	4	6	0	2	0	2	6	2	0	0	0	0
13.	Recyclability	0	0	0	0	0	0	0	0	0	0	0	0	10	2	28	28
14.	Aesthetics	0	0	0	2	0	4	12	4	2	7	3	6	0	11	0	17
15.	Glare	0	0	0	0	0	1	2	0	0	0	0	9	8	18	20	10
16.	Effect on healing	0	0	2	2	2	0	2	7	2	5	10	4	12	1	8	11

Table 14 shows that infection control received most responses (21) under rank 1, whereas, recyclability (48) received most responses under rank 11 for in-patient units. Considering, responses under rank 1, Table 14 and Table 12 showed dissimilar results. In Table 14, under rank 1, infection control, initial cost and durability were ranked in the decreasing order of priority, whereas, in Table 12, durability was given more preference than infection control. In addition to this, recyclability was given least priority in all healthcare units.

Table 14. Occurrences of each selection criteria in all ranks for in-patient units

##	In-Patient Units.																
	Selection Criteria	Rank															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Initial cost	14	4	6	4	6	4	4	0	2	4	4	4	1	9	2	0
2.	Ease of installation	2	6	0	5	0	0	8	2	10	0	2	7	6	7	11	2
3.	Maintenance cost	1	12	14	6	0	7	3	10	6	7	0	0	2	0	0	0
4.	Ease of maintenance	6	7	16	10	12	0	0	2	3	0	0	8	2	2	0	0
5.	Durability	12	7	15	7	6	16	3	2	0	0	0	0	0	0	0	0
6.	Noise cancellation	4	0	0	0	9	4	0	12	13	4	0	0	10	8	2	2
7.	Ease of movement	0	0	2	2	5	12	13	2	2	18	6	2	0	4	0	0
8.	Underfoot comfort	0	0	0	4	4	1	6	6	6	6	6	15	6	6	2	0
9.	User Safety	2	7	1	11	6	7	4	4	4	8	10	0	4	0	0	0
10.	Flame resistance	4	2	0	2	6	0	2	2	5	6	11	12	0	10	6	0
11.	Indoor air quality	0	1	4	0	2	4	5	7	8	6	4	6	4	10	7	0
12.	Infection control	21	10	4	5	2	6	4	4	0	0	2	2	0	0	2	6
13.	Recyclability	0	0	0	6	0	0	0	0	0	0	0	2	4	0	8	48
14.	Aesthetics	2	10	4	4	4	2	12	6	6	7	7	0	0	2	2	0
15.	Glare	0	0	0	0	2	0	0	0	0	2	8	6	11	9	22	8
16.	Effect on healing	0	2	2	2	4	5	4	9	3	0	8	4	18	1	4	2

For the analysis of the data collected in this section, the second null hypothesis was formulated and the *p*-values using a similar methodology as in the section 4.1.2. It was assumed that the opinion of healthcare facility managers regarding selection criteria for floor finishes was mutually independent. A similar Wilcoxon Rank Sum Test was used, healthcare units were paired with each other, corresponding *p*-values for each selection criteria were calculated and listed out in Table 15.

Table 15 shows all the *p*-values calculated were significantly more than 0.05 (95% confidence interval). Hence, the null hypothesis was not rejected and the ranking of selection criteria for floor finishes was accepted as similar in all healthcare units.

Table 15. Testing p-values for null hypothesis: the ranking of each selection criteria is similar in the two health care units as paired below

##	Selection Criteria	P-value		
		Emergency & Surgery	Surgery & In-Patient	Emergency & In-Patient
1.	Initial cost	0.9388	0.8322	0.9535
2.	Ease of installation	0.5796	0.7590	0.9543
3.	Maintenance cost	0.8634	0.8932	0.8775
4.	Ease of maintenance	0.9381	0.9845	0.9380
5.	Durability	0.9529	0.7501	0.8892
6.	Noise cancellation	0.7884	0.6873	0.8473
7.	Ease of movement	0.8932	0.5902	0.8476
8.	Underfoot comfort	0.9840	0.8932	0.8326
9.	User Safety	0.9694	0.9544	0.8784
10.	Flame resistance	0.8332	0.9840	0.7158
11.	Indoor air quality	0.8791	0.7608	0.9089
12.	Infection control	0.5119	0.5758	0.9847
13.	Recyclability	0.9802	0.7938	0.7755
14.	Aesthetics	0.9691	0.5782	0.4617
15.	Glare	0.6721	0.8220	0.9523
16.	Effect on healing	0.9391	0.8935	0.8938

Wilcoxon Rank Sum Test was run to mutually compare the selection criteria for floor finishes in all healthcare units. Identical steps were followed as in section 4.1.2 and corresponding *p*-values were generated for each selection criteria (Table 16). Some of the *p*-values in this table were observed to be below 0.05 (95% confidence interval). This signified that the null hypothesis for only those comparisons was rejected with a 95% confidence interval. The null hypothesis was rejected when the comparison was done between all choices, ranked from 2 (infection control) through 14 (effect on healing) based on ascending order of their arithmetic mean ranks, and recyclability. In addition to this, the steps followed in section 4.1.2 for calculating the arithmetic mean ranks and standard deviations of the calculated arithmetic mean ranks for each floor finish choice was adopted in this section. Hence, arithmetic mean ranks for each selection criteria and their standard deviations was calculated and listed out in Table 16.

The selection criteria with the highest preference was durability because it had the lowest value of arithmetic mean rank (4.0686). The highest value of arithmetic mean rank was calculated for recyclability. Hence, it was found that recyclability was the least preferred among all the available choices. The least value of standard deviation of the arithmetic mean ranks was observed for recyclability (2.1869), whereas, its highest value was for the initial cost (4.7314). Observing the lowest value of the standard deviation, it was inferred that most of the respondents chose recyclability as the least preferred floor finish choice. For the initial cost, the value of its arithmetic mean ranked as the 6^{th} preferred choice. However, it had the highest value for its standard deviation of arithmetic mean rank. This signified that the respondents were inconsistent in ranking it as the 6^{th} preferred selection criteria out of all the available choices. As the value of the standard deviation of the arithmetic mean ranks for each selection criteria increased from 2.1869 to 4.7314, inconsistency in the response of the participants increased.

Table 16. Testing p-values for null hypothesis: the ranking of each pair of selection criteria for floor finish material is similar across the three healthcare units

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.		
	Selection Criteria	**Durability**	**Infection control**	**Ease of maintenance**	**Maintenance cost**	**User Safety**	**Initial cost**	**Ease of movement**	**Underfoot comfort**	**Flame resistance**	**Ease of installation**	**Aesthetics**	**Noise cancellation**	**Indoor air quality**	**Effect on healing**	**Glare**	**Recyclability**	**Arithmetic Mean Rank**	**Standard Deviation**
1.	Durability		0.6744	0.7458	0.6073	0.7016	0.3622	0.4819	0.4370	0.4821	0.4947	0.4044	0.4949	0.4150	0.3345	0.9847	0.1836	4.0686	2.5568
2.	Infection control			0.7607	0.8944	0.4701	0.2619	0.5311	0.2967	0.3535	0.5693	0.6618	0.5693	0.3935	0.6219	0.3043	0.0144	4.6127	4.2254
3.	Ease of maintenance				0.8500	0.8052	0.4269	0.8351	0.6101	0.6366	0.6639	0.5452	0.6233	0.5711	0.6233	0.4823	0.0385	4.8922	3.1635
4.	Maintenance cost					0.7907	0.3347	0.6897	0.4728	0.6101	0.7764	0.6496	0.6365	0.5833	0.5831	0.4374	0.0233	5.6078	3.2107
5.	User Safety						0.8794	0.9840	0.8642	0.9546	0.8352	0.9698	0.9096	0.8648	0.8060	0.5178	0.0465	6.5049	3.3901
6.	Initial cost							0.9849	0.5575	0.8053	0.8798	0.8349	0.8794	0.9840	0.6227	0.1611	0.0066	6.7059	4.7314
7.	Ease of movement								0.5574	0.9397	0.8196	0.8641	0.8496	0.7473	0.8795	0.3833	0.0158	8.1029	3.1301
8.	Underfoot comfort									0.8650	0.9840	0.6775	0.8650	0.9699	0.6236	0.2122	0.0079	8.9951	3.5338
9.	Flame resistance										0.9849	0.9098	0.9548	0.9849	0.6919	0.3156	0.0155	9.1618	3.9627
10.	Ease of installation											0.9547	0.9840	0.9247	0.9849	0.2727	0.0110	9.4314	4.1368
11.	Aesthetics												0.9849	0.8501	0.8649	0.1508	0.0045	9.4412	3.9977
12.	Noise cancellation													0.8651	0.9098	0.2335	0.0093	9.4902	3.6652
13.	Indoor air quality														0.8354	0.2649	0.0094	9.6225	3.3158
14.	Effect on healing															0.1454	0.0052	10.7941	3.7740
15.	Glare																0.1149	13.5931	2.5608
16.	Recyclability																	14.9755	2.1869

In Table 16. for the calculation of arithmetic mean rank for each type of floor finish, at first, an average of the cumulative responses across the three health care units was calculated. Secondly, the standard deviations of their means were calculated. Finally, all choices of selection criteria for floor finishes were rearranged in the ascending order of their arithmetic mean. Wherever, the *p*-values were not rejected with 95% confidence interval, it meant that for those comparisons the ranking done for selection criteria across all the health care units was similar. There was no other way to analyze the pairs which generated *p*-values more than 0.05, other than comparing their arithmetic mean ranks.

4.2.2 Interpretation of Data Collected via Fourth Question

The objective of the fourth question was to collect data regarding the significance level of the selection criteria for floor finishes in different healthcare units. the respondents were asked to rate each selection criteria which they thought was significant for floor finish selection in healthcare. The level of significance was measured with the help of a Likert Scale. The range of the Likert Scale was from 1 through 5, where: (1) choice 1 meant that the choice was not significant at all, (2) choice 2 meant that the choice was least significant, (3) choice 3 meant that their opinion was neutral about the choice, (4) choice 4 meant that the choice was significant, and (5) choice 5 meant that they considered the choice as most significant. The data collected with respect to (1) emergency units is summarized in Table 17, (2) surgery units is summarized in Table 18, and (3) inpatient units are summarized in Table 19. In Tables 17, 18, and 19 the corresponding percentage values of the responses collected in relation to the significance

level of selection criteria have been listed under the heading - Rating of Selection Criteria. This study received complete responses from 68 respondents.

Table 17 shows that infection control received the highest percentage (65.63%) of responses under most significant (5), whereas, recyclability received the highest number of responses (37.50%) under not significant (1). In addition to this, the second and third highest responses under most significant (5) were received by durability (48.48%) and flame resistance (40.63%), respectively. Flame resistance is one of the important criteria which has been addressed previously by healthcare organizations and government sanctioning bodies. Most healthcare organizations have mandatory guidelines which enforce strategies related to flame resistance during the design and approval stage (Federal Facilities Council, 2001).

Table 17. Choice of selection criteria in emergency unit vs response rate for significance level of facility managers

##	**Emergency Units.** Note: (5) – Most Significant, (4) – Significant, (3) – Neutral, (2) – Least Significant, (1) – Not Significant.					
	Selection Criteria	**Rating of Selection Criteria (%)**				
		(5)	(4)	(3)	(2)	(1)
1.	Initial cost	3.33	43.33	21.67	21.67	10.00
2.	Ease of installation	0.00	17.24	41.38	27.59	13.79
3.	Maintenance cost	28.33	56.67	11.67	3.33	0.00
4.	Ease of maintenance	30.88	60.29	5.88	2.94	0.00
5.	Durability	48.48	48.48	0.00	3.03	0.00
6.	Noise cancellation	7.02	22.81	42.11	14.04	14.04
7.	Ease of movement	0.00	45.45	45.45	9.09	0.00
8.	Underfoot comfort	20.37	25.93	29.63	20.37	3.70
9.	User Safety	28.33	51.67	20.00	0.00	0.00
10.	Flame resistance	40.63	25.00	28.13	3.13	3.13
11.	Indoor air quality	13.79	58.62	18.97	8.62	0.00
12.	Infection control	65.63	34.38	0.00	0.00	0.00
13.	Recyclability	0.00	3.57	23.21	35.71	37.50
14.	Aesthetics	6.67	55.00	20.00	18.33	0.00
15.	Glare	0.00	25.86	39.66	17.24	17.24
16.	Effect on healing	8.93	50.00	30.36	10.71	0.00

Table 18 shows that infection control received the highest percentage (75.00%) of responses under most significant (5), whereas, recyclability received the highest number of responses (37.50%) under not significant (1), which was identical to the percentage of responses received by it in the case of emergency units. In addition to this, the second and third highest responses under most significant (5) were received by durability (54.84%) and flame resistance (43.75%), respectively.

Table 18. Choice of selection criteria in surgery unit vs response rate for significance level of facility managers

##	**Surgery Units.** Note: (5) – Most Significant, (4) – Significant, (3) – Neutral, (2) – Least Significant, (1) – Not Significant.					
	Selection Criteria	**Rating of Selection Criteria (%)**				
		(5)	(4)	(3)	(2)	(1)
1.	Initial cost	3.45	41.38	25.86	18.97	10.34
2.	Ease of installation	0.00	17.24	37.93	31.03	13.79
3.	Maintenance cost	28.33	60.00	8.33	3.33	0.00
4.	Ease of maintenance	37.10	53.23	6.45	3.23	0.00
5.	Durability	54.84	41.94	0.00	3.23	0.00
6.	Noise cancellation	10.53	22.81	45.61	10.53	10.53
7.	Ease of movement	7.27	41.82	41.82	9.09	0.00
8.	Underfoot comfort	24.07	29.63	25.93	16.67	3.70
9.	User Safety	28.33	58.33	13.33	0.00	0.00
10.	Flame resistance	43.75	28.13	25.00	0.00	3.13
11.	Indoor air quality	26.67	50.00	15.00	8.33	0.00
12.	Infection control	75.00	25.00	0.00	0.00	0.00
13.	Recyclability	0.00	12.50	30.36	19.64	37.50
14.	Aesthetics	9.68	43.55	25.81	17.74	3.23
15.	Glare	10.34	25.86	32.76	17.24	13.79
16.	Effect on healing	12.07	51.72	25.86	10.34	0.00

Table 19 shows that infection control for the third time, received the highest percentage (56.25%) of responses under most significant (5), whereas, recyclability remained the least significant. In addition to this, the second and third highest responses under most significant (5) were received by durability (48.48%) and flame resistance (43.75%), respectively.

Table 19. Choice of selection criteria in in-patient unit vs response rate for significance level of facility managers

##	**In-Patient Units.** Note: (5) – Most Significant, (4) – Significant, (3) – Neutral, (2) – Least Significant, (1) – Not Significant.					
	Selection Criteria	**Rating of Selection Criteria (%)**				
		(5)	(4)	(3)	(2)	(1)
1.	Initial cost	9.38	43.75	34.38	9.38	3.13
2.	Ease of installation	0.00	31.67	35.00	26.67	6.67
3.	Maintenance cost	26.56	59.38	10.94	3.13	0.00
4.	Ease of maintenance	26.56	57.81	12.50	3.13	0.00
5.	Durability	48.48	45.45	3.03	3.03	0.00
6.	Noise cancellation	29.82	22.81	35.09	8.77	3.51
7.	Ease of movement	3.64	38.18	45.45	12.73	0.00
8.	Underfoot comfort	13.46	30.77	30.77	21.15	3.85
9.	User Safety	35.00	51.67	13.33	0.00	0.00
10.	Flame resistance	43.75	28.13	25.00	0.00	3.13
11.	Indoor air quality	23.33	53.33	15.00	8.33	0.00
12.	Infection control	56.25	43.75	0.00	0.00	0.00
13.	Recyclability	0.00	3.57	23.21	35.71	37.50
14.	Aesthetics	17.24	68.97	13.79	0.00	0.00
15.	Glare	6.90	24.14	37.93	17.24	13.79
16.	Effect on healing	31.03	58.62	10.34	0.00	0.00

CHAPTER V

DISCUSSION

According to the literature review it was found that the top five floor finish materials preferable for use in healthcare facilities are vinyl composition tile, vinyl, rubber, carpet, and linoleum flooring, and the top five selection criteria for floor finishes are indoor air quality, patient safety, infection control, recyclability and ease of maintenance. However, with respect to the questionnaire survey conducted among the healthcare facility managers, it was found that the results were not entirely identical to the findings of the literature review. According to the questionnaire survey, the top five preferences for floor finishes of healthcare facility managers were vinyl, vinyl composition tile, rubber, linoleum and ceramic flooring, and the top five selection criteria for floor finishes were durability, infection control, ease of maintenance, maintenance cost, and user safety. These results are based on observation of Tables 11 and 16 which present a cumulative data for all healthcare units. A difference was observed when individual units were investigated.

However, from the literature review, as well as the questionnaire survey, it was evident that the vinyl products: (1) vinyl flooring, and (2) vinyl composition tile remained a popular choice based on different selection criteria. In a survey of healthcare interior designers, Wilson & Ridgway (2006) found the vinyl and sheet vinyl were the most preferred wall finish materials in public/community healthcare spaces and patient rooms, respectively. In a survey of healthcare facility managers by Lavy and Dixit

(2012) revealed that vinyl was the most preferred choice of wall finish material in healthcare facilities. It was the most preferred material in all three surveyed spaces: surgery, emergency, and inpatient units. Later, Sherif, (2013) conducted another questionnaire survey of finishes in operating rooms in the United States and Egypt and found that sheet vinyl was the most preferred finish material. Although, vinyl is found to be the material of choice for interior finishes; studies such as Tuladhar et al., (2015) warned that vinyl products may have a greater environmental impact than other interior finishes. When the floor finish selection criteria were compared, some differences surfaced. The results revealed that indoor air quality was the most significant criteria for floor finish selection. When compared with literature, Sadatsafavi, (2015) found that user safety was the prime criteria for floor finish selection in healthcare facilities. Another study by Harris & Detke, (2013) identified infection control as the most important selection criteria for floor finishes followed by ease of movement, user safety, and noise cancellation.

This study is relevant for three different groups of professionals. They are (1) design decision makers such as architects, interior designers, and owners, (2) facility managers, and (3) floor finish manufacturers. Pati et al. (2009) said that the first group of professionals, the design decision makers are closely associated with the higher-level organizational objectives. Making facility management decisions, specifically in relation to healthcare institutions, during the design phase is not one of their priorities (Bower, 2006). When construction of such a facility is complete; it is handed over to facility managers, a different group of professionals who make decisions for its operation and

maintenance (Lavy and Dixit, 2012). They are responsible for keeping the facility fit for its intended use. However, it was observed that they adopted strategies that did not align with the design decisions. As a result, the processes carried out in the building were negatively affected. In the case of a healthcare facility, patients got injured due to slip and fall events (Sadatsafavi, 2015) and acquired nosocomial infections (Weinstein, 2004). Bower, (2006) said that typically, decisions regarding the choice of floor finishes being installed in such facilities have been neglected at design stages. Although, this study has found that the views of facility managers regarding the floor finish selections should be included in the design decision-making process. To predict the facility management procedures at the design decision-making phase remains a challenge (Harris, 2015). However, it should be encouraged to reduce the negative impacts on the patients and subsequent financial lawsuits against hospitals (Gulwadi & Calkins, 2008).

For the second group, the facility managers, this study provides a comprehensive list of preferred floor finish choices and their selection criteria in healthcare facilities as supported by existing literature. In addition to this, Ulrich et al. (2008) said that the future scope of research outlined by this study would make the comparison and selection of floor finishes a straightforward process for them. The third group of manufacturers gain knowledge of the preferred selection criteria for floor finishes in healthcare facilities. For example, vinyl products for floor finishes contain at most 5% of recycled content. Rest 95% of their composition is virgin material. However, there were studies such as Tuladhar et al. (2015) that advocated for the increase of recycled content

percentage in them. They could strive towards the production of improved material choices conducive for the healthcare sector.

The trade-off from this study is the scope of development for an application which will enable its users to make accurate decisions regarding floor finish choices based on different selection criteria. The end-users of this product will be design decision makers such as architects, interior designers and owners, facility managers, and manufacturers. The tool is being developed using a genetic algorithm and is a part of an ongoing research in this series of publications. Different floor finish choices will be awarded points on a scale of 10 with respect to each selection criteria. A minimum points requirement will be set for each of them. This requirement will be determined after an extensive multi-center study which will examine the performance of existing floor finishes and the satisfaction of its end-users, designers and facility managers. Currently, there is no tool available in the healthcare sector which considers all selection criteria for floor finish choices. Hence, there is a strong possibility that those selections are being made in negligence of certain criteria. Choosing an appropriate floor finish for a healthcare facility is a difficult task. It involves consideration of different selection criteria. For e.g. if a selection is made considering less initial cost, it does not ensure less maintenance cost. Or, if a selection is made considering less initial and maintenance cost, it is not ensured that the chosen floor finish would perform better in terms of infection control and noise cancellation. Acknowledging these issues, the development of this application becomes significant as the final selection of floor finishes will then be made considering the minimum points scored under each selection criteria.

CHAPTER VI

CONCLUSIONS

Floor finishes in healthcare played a significant role in maintaining an environment free of infection, along with accelerating the rate of healing of patients. It provided comfort to it users, especially the hospital staff who worked for longer hours. The literature review established that there was a difference in the opinion of the design decision makers and facility managers. The designer's point of view was driven majorly by high-level project perspectives such as design concepts and budget. However, the opinion of the healthcare facility managers was driven primarily by the building functionality related aspects which played a significant role in the operations and maintenance stage of a facility. After extensively analyzing related literature, this study focused on conducting a questionnaire survey among the healthcare facility managers in the state of Texas to collect data regarding their preferences for floor finish choices and selection criteria. Their responses were statistically analyzed and empirical values were assigned to their preferred choices. The intention was not to undermine the ideas or viewpoints of the designers. The main objective of this research was to make the design team aware of the choices of the respondents based on their experience in the field of facility management.

It is important to note that this study was conducted under various limitations and delimitations. This study makes its conclusions based on the limited number of responses it received. Moreover, it was delimited in the state of Texas. The

recommendations made would have been more conclusive if the healthcare facility managers of different states were included in the survey. A larger sample space and a study with a broader scope would have generated a more accurate result.

Integration of facility management aspects during the design phase of a building would facilitate an informed design process which would help the cause of facility managers who have a better understanding of building operations, maintenance and management. This study will provide empirical evidence for floor finish choices preferred for installation by healthcare facility managers. The results of this study will assist the decision makers such as owners, architects, and interior designers to make an informed decision regarding the selection of floor finishes in healthcare facilities. Analysis of the results of this study will assist the floor finish manufacturers to better understand the perspective of facility managers regarding the characteristics of most preferred floor finishes.

Future studies are encouraged to conduct similar studies for other healthcare facilities as well such as mental health care, super-specialty, nursing homes, etc. In addition to this, future research should also explore the floor finish choices and their selection criteria for the different types of clinical spaces within the identified healthcare units: emergency, surgery, and inpatient units. Apart from the scope of survey studies, there are opportunities for conducting future studies which would be required to fill the gaps in the existing literature. Research work studying the impact of some newly introduced floor finish choices in the healthcare industry such as luxury vinyl tile (LVT) has not been conducted yet. It is interesting to note that in the recent years, floor finish

manufacturers have started advocating the use of LVT, however, its performance in healthcare facilities in consideration with selection criteria such as durability, user safety, initial cost, ease of movement, underfoot comfort and noise cancellation have not been studied yet. Future studies should also aim at including the opinion of the end users such as hospitals staff, patients, and visitors. It would be interesting to find out their preferences and compare it with the opinion of designers and facility managers to derive conclusions satisfying the requirements of all because ultimately it is the end user satisfaction that would generate reimbursable rates for the healthcare institutions.

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APPENDIX A QUESTIONNAIRE

QUESTION 1

1	Please check the type of floor finish currently installed in the Emergency Unit / Surgery Unit / In-Patient Unit; and rate their performance based on your satisfaction level. Note: (1) – Completely dissatisfied, (2) – Dissatisfied, (3) – Neutral, (4) – Satisfied, (5) – Completely satisfied.								
	Type of Floor Finish	**Healthcare Units**			**Rating of Performance**				
		Emergency Units	Surgery Units	In-Patient Units	(1)	(2)	(3)	(4)	(5)
	Rubber Flooring								
	Carpet Flooring								
	Vinyl Flooring								
	Vinyl Composite Tile								
	Linoleum Flooring								
	Ceramic Flooring								
	Concrete Flooring								
	Hardwood Flooring								
	Laminated Hardwood Flooring								
	Mosaic Flooring								
	Polyolefin Flooring								
	Other Flooring (please specify)								

QUESTION 2

2	Please rank your preference for type of floor finish in the Emergency Unit / Surgery Unit / In-Patient Unit, from "1" to "11"; where "1" represents most preferred and "11" represents least preferred choice.				
	List of types of floor finish	**Rank**	**Your preferences for types of floor finishes in different healthcare units**		
			Emergency Unit	Surgery Unit	In-Patient Unit
	Rubber flooring	1			
	Carpet flooring	2			
	Vinyl flooring	3			
	Vinyl composition tile (VCT)	4			
	Linoleum flooring	5			
	Ceramic tile	6			
	Concrete flooring	7			
	Hardwood flooring	8			
	Laminated hardwood flooring	9			
	Mosaic flooring	10			
	Polyolefin flooring	11			
	Other Flooring (please specify)				

QUESTION 3

3	Please rank your preference of selection criteria for the type of floor finish in the Emergency Unit / Surgery Unit / In-Patient Unit, from "1" to "16"; where "1" represents most preferred and "16" represents least preferred selection criteria.				
	List of selection criteria	**Rank**	**Your preferences for selection criteria in different healthcare units**		
			Emergency Unit	Surgery Unit	In-Patient Unit
	Initial cost	1			
	Ease of installation	2			
	Maintenance cost	3			
	Ease of maintenance	4			
	Durability	5			
	Noise cancellation	6			
	Ease of movement	7			
	Underfoot comfort	8			
	User Safety	9			
	Flame resistance	10			
	Indoor air quality	11			
	Infection control	12			
	Recyclability	13			
	Aesthetics	14			
	Glare	15			
	Effect on healing	16			
	Other Flooring (please specify)				

QUESTION 4

4	Please check the selection criteria for the type of floor finish that you would specify for Emergency Unit / Surgery Unit / In-Patient Unit; and rate their significance based on your experience. Note: (1) – Not significant, (2) – Least significant, (3) – Neutral, (4) – Significant, (5) – Most significant.								
	Selection Criteria	**Healthcare Units**			**Rating of Selection Criteria**				
		Emergency Units	Surgery Units	In-Patient Units	(1)	(2)	(3)	(4)	(5)
	Initial cost								
	Ease of installation								
	Maintenance cost								
	Ease of maintenance								
	Durability								
	Noise cancellation								
	Ease of movement								
	Underfoot comfort								
	User safety								
	Flame resistance								
	Indoor air quality								
	Infection control								
	Recyclability								
	Aesthetics								
	Glare								
	Effect on healing								
	Other Flooring (please specify)								

APPENDIX B IRB EXEMPTION CERTIFICATE

DIVISION OF RESEARCH

TEXAS A&M UNIVERSITY

January 23, 2017

MEMORANDUM

TO: Manish Dixit

FROM: Graeme Wright
Human Subjects Protection Program

SUBJECT: FLOOR FINISH SELECTION IN HOSPITAL DESIGN: A SURVEY OF FACILITY MANAGERS

The information you have provided has been reviewed and does not require IRB review or approval because the study does not qualify as human subjects research. Federal Regulations define both terms research and human subjects (45CFR46.102). Research is ''a systematic investigation, including research development, testing, and evaluation, designed to develop or contribute to generalizable knowledge." Further, human subject means "a living individual about whom an investigator conducting research obtains: data through (1) intervention or interaction with the individual, or (2) identifiable private information". Given that this study is not human subjects research, the IRB application has been withdrawn.

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