A KNOWLEDGE REPRESENTATION TOOL FOR ARCHITECTURAL SPACES: A STUDY ON SURGERY UNITS

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ABSTRACT

A KNOWLEDGE REPRESENTATION TOOL FOR ARCHITECTURAL SPACES: A STUDY ON SURGERY UNITS

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The nature of construction projects is very iterative and there are various people involved from different disciplines and organizations in the process. Design stage is unique, complex and require combination and expertise of different people. The capture and reuse of design experience is considered as an efficient way to promote a better design process and efficient building solutions. The smallest part in a building is the space. It is a long-term asset of a building; therefore, a space knowledge management method is studied in this research. The innovative progression of technology, growth in population, changing models of medical care and changes in policies, services increase the necessity for changes in healthcare facilities. To cope with this, the study on standardized knowledge acquisition and knowledge re-use process for healthcare facilities is made. Surgery units have been chosen for this research since they are the most risk intensive spaces in healthcare facilities. The research on spaces in surgery units of hospitals is made first through literature than among participants in architectural design process of healthcare facilities. The knowledge and space classification are made to be able to use in knowledge management processes. The representation of the classification is made with UML class diagram and visualization is made with a BIM-based data management tool, called dRofus. With standardization of space data, a new approach to tacit knowledge

visualization is achieved, design knowledge visualization is made for knowledge management in healthcare facilities.

Keywords: Knowledge Management, Space Design, UML, Data Management, Data Visualization

ÖZ

MİMARİ MEKANLAR İÇİN BİR BİLGİ GÖRSELLEŞTİRME ARACI: CERRAHİ BİRİMLER ÜZERİNE BİR ÇALIŞMA

Us, Mehtap
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İnşaat projelerinin niteliği çok çeşitlidir, bu süreçte farklı disiplinlerden ve organizasyonlardan çeşitli insanlar yer almaktadır. Bir tasarım aşaması benzersiz, karmaşıktır ve farklı kişilerin birleşimi ile uzmanlığını gerektirir. Tasarım deneyimini yakalamak ve yeniden kullanmak, daha iyi bir tasarım süreci ve verimli bina çözümleri geliştirmek için etkili bir yol olarak kabul edilir. Mekân bir binanın uzun vadeli bir parçasıdır; bu nedenle bu araştırmada bir mekân bilgisi yönetim yöntemi incelenmiştir. Teknolojinin yenilikçi gelişimi, nüfus artışı, değişen tıbbi bakım modelleri, hizmetler ve politikalardaki değişiklikler, sağlık tesislerindeki değişikliklere olan ihtiyacı artırmaktadır. Bununla başa çıkabilmek için sağlık tesisleri için standartlaştırılmış bilgi edinimi ve bilginin yeniden kullanımı süreci üzerine çalışma yapılmıştır. Bu araştırma için cerrahi üniteler sağlık tesislerinde en fazla risk yoğunluğuna sahip alanlar oldukları için seçilmiştir. Hastanelerin cerrahi birimlerindeki mekanlarla ilgili araştırmalar, önce literatür araştırmalarıyla sonra ise sağlık tesislerinin mimari tasarım sürecine katılanlar yoluyla yapılmıştır. Bilgi ve mekân sınıflandırması, bilgi yönetimi süreçlerinde kullanılabilmek için yapılmıştır. Sınıflandırmanın gösterimi UML sınıf diyagramı ile, görselleştirmesi ise dRofus adı verilen BIM tabanlı bir veri yönetim aracı ile yapılmıştır. Mekân verilerinin standartlaştırılmasıyla, sağlık hizmetlerinde bilgi yönetimi için tasarım bilgisinin görselleştirildiği yeni bir bilgi yaklaşımı elde edilmiştir.

Anahtar Kelimeler: Bilgi Yönetimi, Mekan Tasarımı, UML, Veri Yönetimi, Veri Görselleştirme

To my mother

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I have dedicated this thesis to my mother Emel Arısoy, who showed me how to be powerful under any circumstances. Her endless support and unconditional love have helped me to do the best through my life. I would like to thank her for the patience and support she has given me through this thesis study. I also would like to thank the lovely Us family; Murat, Özlem, Zehra Neva and Zeynep Ela. With the perspective and guidance my brother Murat had given me, I found the strength to be ambitious and to do more. Without my family I wouldn't accomplish so far.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

IT	: Information Technology
KM	: Knowledge Management
IFC	: Industry Foundation Class
BIM	: Building Information Modelling
OR	: Operation Room
OT	: Operation Theatre
PRE-OP	: Pre-Operational
POST-OP	: Post Operational
ICU	: Intensive Care Unit
SM	: Space Management
UML	: Unified Modelling Language
OO	: Object Oriented
AUSHFG	: Australian Health Facility Guideline
HBN	: Health Building Note (UK)

CHAPTER 1

INTRODUCTION

In this chapter, background information, aim and objectives, and contribution of the thesis will be explained. The disposition of the thesis will be described in the final part of this chapter.

1.1. Background Information

PMBOK defines project as a temporary endeavor undertaken to create a unique product. Construction industry is a project-based industry. In a typical construction project, there are many people with different disciplines and organizations involved in the process, and the projects are generally unique, complex and require the knowledge combination and expertise of these different people (Tan et.al. 2010). Therefore, it can be inferred that construction companies define themselves in the industry with the knowledge and expertise they gained through the projects they accomplished.

The inefficient results in construction industry usually comes from lack of appropriate knowledge. Therefore, knowledge management which is achieved by sharing best practices and learning from past projects is very effective on creating and efficient results in construction. Ineffective acquire and transfer mechanisms have failed knowledge management initiatives (Ahn et.al., 2007).

Knowledge management have become more important in design and construction industry since it is directly related with the competitiveness of the firms involved and effectiveness of the designs. The projects in the industry is composed of multidisciplinary teams and temporary team members, heavy reliance on experience, projects' one- off nature, tight schedule, limited budget, etc. These all can be indorsed by managing the knowledge. In the industry the creation of knowledge is fostered however, the capture of knowledge and transfer of knowledge have been neglected for a long time. Therefore, it can be said that the industry is not working properly when it comes to making gained knowledge available to other individuals, teams or companies (Khalfan et.al., 2003).

Knowledge is a company's most valuable asset especially in projects-based environments like construction industry. In construction industry, companies can enhance their project quality and competition skills via better knowledge management strategies.

Among construction projects stages architectural design stage is very important. With strong design stage, the quality of the end product and the quality of the construction process increases. Every participant of a projects creates a unique experience and knowledge network. The necessity of gathering and sharing this knowledge arises. The sharing of knowledge represents a basis for improving the quality of healthcare. Knowledge sharing promotes a better decision-making process and organizational development (Corrao et.al., 2008). In order not to lose this knowledge during project stages, a knowledge gathering and knowledge sharing method is necessary. The level of uncertainty is highest, hence risk of failing to achieve the objectives is greatest at the start of the project (PMBOK, 2004). With a knowledge management methodology; the risks encountered before, knowledge facilitated for previous projects and the experience gained through the process would not be lost and used effectively.

Hospital design is based on practice and standards implemented by designers, governments, experts etc. The main reason behind hospital design should be to promote modernization, efficiency, functionality and flexibility. With good design comes better building outcomes. The functionality of the hospital increases when the design of the hospital improves (Holst, 2015).

A good design in healthcare facilities have proven to increase care providers' productivity, to reduce medical errors and to decrease injury and stress and this kind of a powerful effect has been determined in the early stages of building life cycle

(Zhang, 2012). Therefore, taking the early design stage seriously and providing the best practice during the design stage have direct impact on the operation stage of healthcare facilities. Making enhancements in the design stage results in an efficient process of hospital management which effects user safety and wellbeing directly. As being the initial phase of the construction process, architectural design requires solutions according to the needs of specific building types.

Diaz et.al. (2016) define building design as a complex and creative process which includes many conflicting criteria. The iterative process of design sometimes takes a lot of time to generate therefore design optimization term arises. In order not to waste time and resources during design stage, some optimization methods through academic studies have emerged one of which is computational design methods.

Architecture has developed by the help of materials and technology. Therefore, today what shapes architecture is the computational potential. Referring to computational potential that the industry provides, unveils the design enhancement of the building types with high complexity (Holst, 2015).

One of the characteristics of healthcare facilities is permanent high occupancy and the need for uninterrupted operation. These characteristics define most of the design requirements and reveals a design challenge (FEMA, 2013) Besides the specifications from government guidelines or international design guidelines, hospital design is developed by every single project. Hospital designers are now expected to use the evidence-based design approach to develop the design quality of hospitals in every project. Evidence based design approach is supported by guidelines, international research and built environment evaluation. While starting a new project, a hospital design team is required to develop a design process with this information. While creating new healthcare facility models, guidelines and hospital schemes from Australia, United Kingdom and Canada are most important examples. However, the use of these examples is very rare. The willingness to access these documents and process the information is very low.

Space is one of the important elements in healthcare facility design (Zhang, 2013). The reason behind it is to find the optimum solution to meet users' requirements and functions of the building because, any activity in any building must be executed in a space and building. This shapes the spatial requirements of a healthcare facility.

One of the smallest elements in architectural design is the space and there are numerous studies on space use. An architect must create a space which not only forms a volume but also serves best to its function. The case of space in hospitals is more complicated than most of other building types. The space knowledge in hospitals carries not only standardized information but also designer, constructer and user experience. The achievement of effectiveness and efficiency in a hospital space comes with not only with function but also coping with global changes, current resources, public expectations and demands.

A taxonomical knowledge share strategy decreases knowledge loss which will affect the quality of succeeding projects. Carrying knowledge share stage into the design stage itself will reduce risks of failing design quality in a hospital space. A computerized space planning process provides an easy way of gathering and sharing knowledge and can develop a foundation of a database that can help practitioners of construction industry to share knowledge in an easier and productive way.

1.2. Aim and Objectives

The aim of this study is to create a standardized knowledge acquisition and knowledge re-use process for healthcare facilities. The case for this study is the operation theatre unit since it is the most risk intensive spaces among hospital units. The objectives for this aim are;

- To create a standardized knowledge taxonomy that will be used to gather and share knowledge
- To standardize tacit knowledge in a format that can be transferred to explicit knowledge and shared amongst professionals,

- To review the regulations, expert opinion and the standards for hospital operation unit spaces and create an effective classification for knowledge share system
- To visualize the space knowledge in a space planning tool that works with BIM modelling programs starting from the early design stages.
- To enhance information flow quality in space design and ease the participation of architectural designers in knowledge management process.

1.3. Contribution

There are various studies about knowledge management in construction projects in literature. Space is a long-term asset of the building. The changing situation in economy, technology, politics have created the need for changes in space planning and management. Space planning in general is made to meet an organizations' objectives in terms of the physical environment that these objectives are achieved.

The search for optimum design solutions has been continuing for decades. The iterative nature of the design activity which is called space layout planning, determines the performance and characteristics of a building through its life cycle. Therefore, the growing interest in space layout planning have been showing that it has the opportunity to enhance design quality and have the possibility to find proper solutions to design problems.

Therefore, this study will put forward a complex project framework for knowledge management strategy. Turkey has changed its healthcare building understanding and to better cope with this change the information gathered through this changing stage is very important. In order not to lose this gained knowledge, first a standardization strategy is needed. This information flow will allow recurrent projects to have knowledge in very early stages and the opportunity to find information quickly. The importance of "live" knowledge transfer in certain projects will be put forward since the literature covers the drawbacks of the opposite. With main objective being increase in project efficiency; it is intended to create a knowledge transfer strategy for participants of the projects, the transmitter and recipient of the tacit knowledge.

1.4. Disposition

This thesis includes five chapters. The first chapter covers background information, aim and objectives, contribution and disposition parts.

The second chapter is the literature review part in which knowledge management, space design and space layout design, space management and healthcare space design concepts are explained. A critical review of the literature will briefly be explained at the end of this chapter.

The third chapter is material and methods chapter. In this chapter first the classification of spaces that is made for this study will be explained. Then the validation method and the strategy will be mentioned for this classification. The study will continue on the taxonomical framework for gathering space knowledge and its validation. Then the methodology to represent the space knowledge classification will be explained and put forward.

The fourth chapter is results and discussion part. The methodology efficiency will be discussed with architects. Subjects mentioned in the previous chapter will be used to visualize the knowledge in a design support tool named d-Rofus. BIM integration of this tool will be explained. And the visualization of space knowledge examples will be shown.

The final chapter is the conclusion part in which the methodologies for this thesis will be summarized with the results. Finally, the limitations and the recommendations for future studies will be explained.

CHAPTER 2

LITERATURE REVIEW

In this chapter, literature associated with thesis topic is analyzed in four sections. First, knowledge management is described. Knowledge management in architectural design, knowledge transfer methods and definition of knowledge management related terms are presented. The second section is about space design and space layout design terms. The definition and methodology of space design is explained. The third section is on healthcare space design and space regulations. In the last part evaluation on literature review is delivered.

2.1. Knowledge Management

There are numerous definitions on the term knowledge. The most precise definition would be made by Brooking (1999) quoted in Williams (2007) as; “knowledge can be defined as information in context with an understanding of how to use it.” Tan et.al. (2010) define knowledge in two categories: by comparing it to data and information or by relating it to data and information. In the first perspective knowledge is perceived as an entity which is in higher level than data and information. This point of view gives the practitioners the power to make decisions to produce. In the second perspective, knowledge is defined by its characteristics, not by comparing it to data and information. This perspective supports Davenport and Pursuak’s (2000) definition; is it a mix of experiences, expert insight, contextual information and values. From the project management point of view, data is produced in every process group and when come together form information (Negri & Dülgerler, 2016).

After being observed by a group of professionals, information becomes knowledge. Knowledge can be transferred in different forms like reports, guidelines etc. However, knowledge is always improving, and this makes managing knowledge a continuous activity (Negri & Dülgerler, 2016).

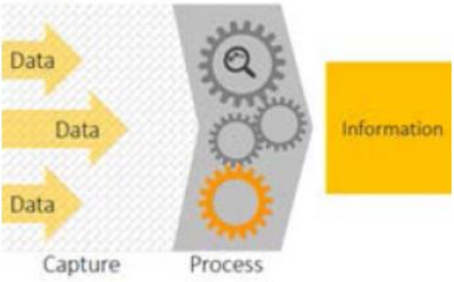

Figure 2.1. Transforming data into information (Negri & Dülgerler, 2016)

Khanlfan (2003) makes a great explanation on knowledge by defining the society' s basic economic resource as knowledge and entitles the society as "knowledge workers" This explains the need to enhancements in knowledge management in all sectors including construction. Therefore, making knowledge management available to everyone participating in the production process of a project improves the efficiency in managing knowledge since participants will understand the aim and the convenience that KM provides.

Knowledge management is an endeavor to use knowledge in an organization with a systematic and organized approach in order to transform its ability of storing and using knowledge to improve performance (KPMG, 1998) The term is also defined as the process by which knowledge is first created, then acquired, communicated, applied and finally effectively used and shared. This process has a goal to meet both existing and emerging needs to obtain and identify knowledge assets (Egbu & Boterill, 2002). Knowledge management has two main goals; first it unifies organizational processes of data combinations and information processing, second it captures the creative and innovative accumulation of practitioners of related occupation (Venkateswaran & Aundhe, 2013).

Knowledge management impact on variety of disciplines is perceived as a way to increase the intellectual property and improve organizational performance. Hence, it is necessary to emphasize that interdisciplinary and integrated approach is necessary for knowledge management to succeed (Jashapara, 2004). The dimensions of knowledge management are grouped in Figure 2.2:

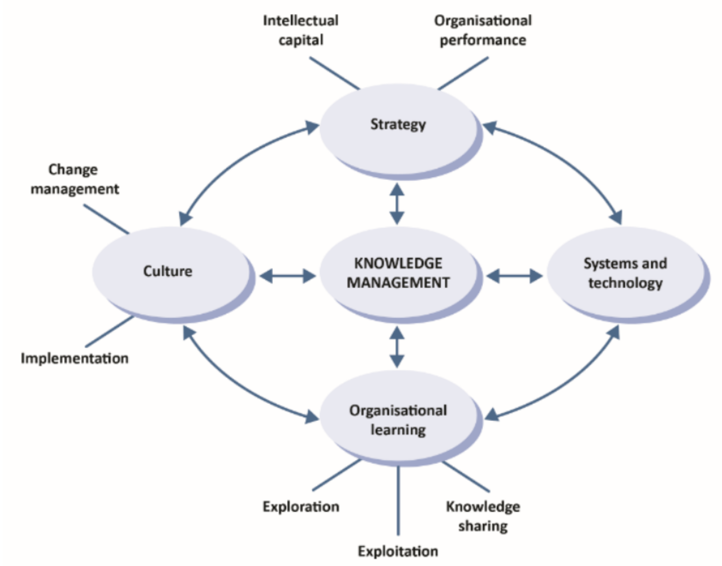

Figure 2.2. Dimensions of Knowledge Management (Jashapara, 2004)

Some of the advantages of KM to organizations are listed by Negri & Dülgerler (2016) as follows;

- Reducing risk and uncertainty,
- Enhancing decision-making capabilities to make better and faster decisions
- Creates learning organizations by developing a learning routine
- Avoiding unnecessary effort
- Using advantage of existing expertise and experience

The requirements of a company can be listed as quality, service, value, innovation and business success. All of these create a competitive environment and to cope with this environment using the most important asset, the knowledge, is very crucial. (Williams, 2007). Moreover, knowledge can be described with terms called “know-what, know-how, know-who” (Tan et.al.,2010).

Types of knowledge

There are different types of knowledge. The most common classification of knowledge in construction industry is tacit and explicit knowledge. Anumba, Egbu and Carillo (2005) define tacit knowledge as a type of knowledge that is stored in individuals' minds. Tacit knowledge includes technical experiences, insights and intuition. On the other hand, explicit knowledge is defined as written documents or procedures (Anumba, Egbu and Carillo, 2005). This type of knowledge can be codified and reusable which is an easier manner to share. To improve knowledge management, both tacit knowledge and explicit knowledge should be related.

Williams (2007) defined tacit and explicit knowledge in the table below:

Table 2.1. *Tacit and Explicit Knowledge (Williams, 2007)*

Explicit Knowledge	**Tacit Knowledge**
Relatively easy to capture and store in documents.	Knowledge that people have in their minds, more difficult to access.
Can be either structured or unstructured.	Transfer of tacit knowledge involves personal contact and trust.
Structured explicit knowledge is organized in a particular way for future retrieval.	Highly valuable, provides a context for ideas and experiences.
Examples would be documents and spreadsheets	Considerable amounts of tacit knowledge exist within construction companies.
Unstructured explicit knowledge includes e-mails and images that contain knowledge but are more difficult to retrieve.	The tacit knowledge of experts is the most valuable asset of a construction company.

The knowledge is classified in two main groups; explicit and tacit. Explicit knowledge is the type that can be codified and put into words in a formal way and can be represented and shared. On the other hand, tacit knowledge is the type that is difficult to codify, cannot put into words easily. The difference between these types is important because to gather and share different types of knowledge need to be managed differently. From the construction project life cycle view, tacit and explicit knowledge is created from the knowledge and experience that comes from the projects (Lin and Tserng, 2003). Valuable knowledge in construction sector exists in different forms, knowledge management aims to collect this knowledge effectively and systematically using knowledge management systems. Lin and Tserng (2003) describe that knowledge reuse minimizes the learning from past projects by reducing time spent on them and cost of the projects by improving design and solution to the design process of the construction projects. With the help of this sharing process, the problems encountered during design stage does not need to be solved repeatedly. This reduction has two main benefits; reduction in cost and the probability of design defects during construction stage (Lin and Tserng, 2003). Information and knowledge from a project can be identified as project components, as well as the documents used during project and design life cycle. These components need to be collected and given a form that can be transferred and reused.

Figure 2.3: Construction project life cycle. (Lin and Tserng, 2003)

2.1.1. Knowledge Management in Construction Industry

Construction industry is a project based and knowledge-oriented industry. Some characteristics are being multi-disciplinary, being unstable, budget limitations etc. (Eken et.al.,2015). These all make the knowledge in construction industry difficult to handle. Construction projects involve variety of disciplines, people and organizations with expertise through a duration of a project. The projects are usually perceived to be unique and very complex and to deliver projects expertise and combined knowledge of all the project team members are necessary. Therefore, this shows that most of the knowledge in construction projects is formed during project delivery process by practitioners belonging different disciplines (Tan et.al., 2010).

Knowledge management in construction projects has two levels of occurrence; project level and firm level. Standards, guidelines, codes are used in firm level; however, this project-based industry needs more knowledge from projects that have been projected or ongoing. The knowledge capture methods in the industry are not very effective due to personnel negligence, insufficient time, etc. (Eken, et.al.,2015).

An architectural design stage is a part of construction process and it also involves different disciplines. The architectural design is a complex and iterative process. Design stage has number of parameters and these parameters are evaluating through feedback. Therefore, each design process has special features that are nor easily standardized (Harputgil et.al.2014). Architectural design in general have both objective and subjective elements; however current studies show that as design information evolves through experiences, the necessity to record these evolving ideas is increasing.

Both construction and architectural design is performed on project basis, therefore it is very possible to lose knowledge if not carefully gathered. However, to collect knowledge that can be employed in another project develops the design and construction quality (Williams, 2007).

2.1.2. Lessons Learned and Know-How

The knowledge gathered from a project needs to be managed efficiently not only to prevent reiteration in projects but also to avoid making same mistakes in different projects. Therefore, an ability to manage lessons learned creates a basis for overall improvement and innovation. This shows that, knowledge, especially lessons learned, can be acquired both from positive cases and mistakes. It is very important to learn within and across projects but quite difficult to accomplish (Tan et.al.,2010).

Lessons learned is defined by The Construction Industry Institute as knowledge gained from experiences either successful or unsuccessful. Another definition of lessons learned can be saving of experimental or tacit knowledge to promote good practice and repetition of mistakes (Ferrada et.al.2014). According to Kartam (1996) there are three components of lessons learned;

- Attribute sets to define and explain the lesson,

- Information about the source and the context where the lesson is collected,
- The intention to classify the lesson in a fast and clear manner.

Negri & Dülgerler (2016) state five steps of a process-based use of project experience; collection, prioritization, documentation, communication, assimilation.

The reduction of rework and continuous improvement and better sharing of tacit knowledge are other benefits defined by Carillo et. al. (2004) At the end of a project knowledge can be lost and this increases the risk of encountering same problems or to develop best practice in the recurrent projects. The competitive environment forces construction companies to use their resources effectively. Every project requires different expertise, however with an organizational learning and transfer strategy every single form of expertise gained through projects can be used as a company asset.

In terms of knowledge management, the know-how and experiences of practitioners do not only require manpower; it also requires a great cost and time to accumulate. In construction industry knowledge management is the process that promotes an integrated approach to creation, capture, access and use of a domain knowledge on products, services and processes (Lin and Tserng, 2003). During the project phase, the problems, solutions and briefly the know-how are in individuals' minds; therefore, this knowledge is usually not documented or stored and needs to be in order to reuse of that knowledge for the improvements in the project quality and speed.

2.1.3. Limitations of Knowledge Management

In construction industry, the nature of project basis knowledge management is not working effectively due to not being able to collect knowledge during the correct phase of the project. In other words, recording knowledge about good or bad practices in different stages would be common so that the lessons learned in one project will not be lost in other phases of another project (Ferrada et.al., 2014).

Sometimes even in same company the communication between professionals might be slow due to the complexity and immense number of projects. According to the knowledge management recognition study Ferrada et.al. (2014) made, the time limitation during project execution is one of the major constraints. Another one is the lack of defining what knowledge to store clearly and where to store knowledge.

Knowledge transfer tools have been tried to be implemented in the construction industry; however, there are barriers to this implementation. First, with many workload construction managers see documenting lessons learned process as an extra work. It can be said that there is no proper motivation for knowledge management systems. This shows that a knowledge management system should be easy to use and have a simple and clear user interface. To encourage participation in knowledge management not only expert knowledge should be promoted but also knowledge from every practitioner should be gathered (Williams, 2007).

Some barriers to knowledge management are; time, lack of standard workflow, organizational culture, financial issues, employee unwillingness, lack of IT infrastructure. Most of the literature focus on the lack of motivation from experts to put knowledge for lessons learned database system. However, the solution to this would to encourage the total of employees working in the process to knowledge management implementation (Tan et.al., 2010).

2.1.4. Knowledge Transfer Process

Developing KM techniques in construction area is an ever-evolving process. Providing a company's knowledge base first is a start to knowledge management process through the sector. Many types of knowledge are valuable and requires sharing to enhance the project quality (Williams, 2007).

There are different studies in the literature for defining the process of knowledge management. However, within the construction sector, the sequence of knowledge management is as follows; knowledge capture, knowledge sharing, knowledge reuse and knowledge maintenance (Tan et.al., 2010). Before these definitions, Bhatt (2001) first implemented these processes; knowledge creation, knowledge validation, knowledge presentation, knowledge distribution and knowledge application.

Knowledge capture is composed of three stages; identifying and locating knowledge, representing and storing knowledge, validating knowledge. The categories and types of knowledge must be identified for an easy share process, either capturing internally or externally. The knowledge representations provide a general understanding on where the knowledge is generated or where the knowledge will be used. Validation of knowledge increases the credibility of knowledge (Tan et.al., 2010).

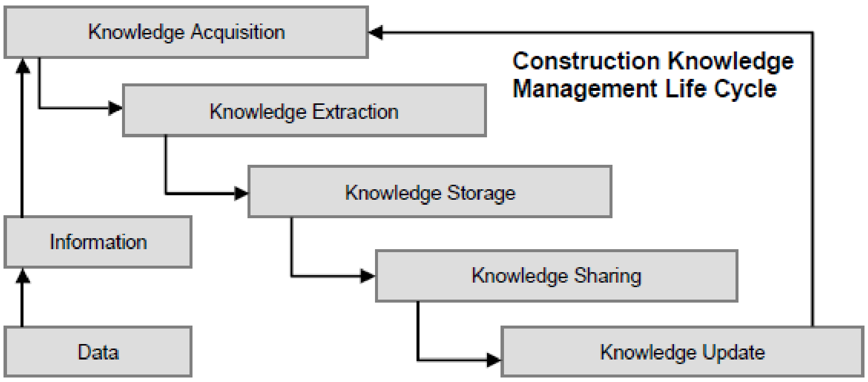

Figure 2.4: Knowledge management life cycle stages. (Lin and Tserng, 2003)

The best practice in knowledge transfer is to understand the knowledge management life cycle. The literature summarizes knowledge management life cycle in five stages; knowledge acquisition, knowledge extraction, knowledge storage, knowledge sharing and knowledge update (Lin and Tserng, 2003).

Table 2.2: *The descriptions of knowledge management life cycle. (Lin and Tserng, 2003)*

KM Phase	Key Activites
KM Acquisition	The knowledge to be shared must be acquired. In view of the construction phase, most information and knowledge mainly come from the job site. Therefore, knowledge collection on a job site plays an important role in the first phase. In the main office, the content of knowledge collection is the same as those in the other industries. During knowledge acquisition, most work is done in the main office because all the information or tacit knowledge sent back from the job site can be transferred to explicit knowledge.
KM Extraction	Some knowledge that must be extracted for reuse and storage may be only in the heads of experts and engineers. It typically arises in the context of certain problem-solving situations. Mechanisms are required to collect such new experiences when they become available.
KM Storage	The collected knowledge could be stored for future reuse. During knowledge storage, all information and knowledge are centralized and stored in the knowledge bank (central database) to avoid redundant knowledge. In order to store all information and knowledge in the system, the data must be electronic and be in a standard format for each type of file such as a specific document format or vector drawing format.
KM Sharing	Knowledge sharing is the ultimate goal of knowledge management. After the development of knowledge management, only people who need related-knowledge concerning of the select projects can access and select appropriate knowledge for reuse. If necessary, they can adapt knowledge to a new project and solve the new problem by reusing the knowledge.
KM Update	Available knowledge and experience should be updated continuously. During problem solving, reused experience can be evaluated in the context of the new problem to be solved. The evaluation can be in terms of the appropriateness of the selected experience, or in terms of the accuracy and actuality of the retrieved experience. Such evaluation is important to continuously improve the process of experience reuse. Invalid knowledge must be identified and be removed or updated. Knowledge update can be triggered by a negative experience evaluation or can be performed precautionary.

Knowledge sharing is about supplying correct people with correct knowledge at the correct time. This process can be passive such as putting knowledge in a place and waiting for people to gather it or active such as alerting people with the existing of knowledge and motivating them to use at the right time (Tan et.al., 2010). There are five type of knowledge transfer stated by Dixon (2000): serial, near, far, strategic, expert transfer. It is interpreted that knowledge can be transferred from people to people, from people to computer or from computer to computer (Tan et.al., 2010).

The knowledge which is captured and/or shared needs to be reused. The reuse of knowledge process includes the integration and adaptation of knowledge into the project process. This process consists of searching for the problem are to use the knowledge and adapting knowledge for re-using to solve the problems (Tan et.al., 2010).

2.2. Space Design and Space Management

‘A ‘space’ becomes a ‘place’ when people make use of it by carrying out activities and providing it with its own character (Lawson, 2001). Spaces need to increase instructional effectiveness, improve the efficiency of the facility and extend the life of a building.

Ekholm and Fridqvist (2000) define space as a basic concept that links us to the material world, an empty volume that is closed materially or experientially. In building context this empty volume becomes a space when things are embedded in. Space is important both for construction process of the buildings and the facilities management of the buildings. Spatial properties of a building are identified in the early stages of the design process before most of the structural and systematic requirements are identified. Therefore, introducing computer aided design in early stages of this process, the constraints of a spatial representation of a building can be identified earlier. The spatial features of a building are identified according to the organization and the built environment both.

The conceptual definition of “space” has been made for the buildings, however in information systems for building classification it is unclear (Ekholm and Fridqvist, 2000). The most appropriate way of classifying building space should be to do it according to their function, but most buildings lack a detailed description of its spaces and this results in less detailed production and design process. The study conducted by Ekholm and Fridqvist (2000) have identified the importance of spatial classification and representation in built environment as it proposes solutions to space design problems in building design processes.

According to Ekholm and Fridqvist (2000) in construction context space is “an aggregate of things, including construction entities or their parts, with a materially or experientially enclosed void that may accommodate users or equipment.”

User activity space is directly related with the space term in buildings. The user activity space defines spaces according to the activities, shapes and use of spaces in a building. Activity spaces are a valuable step to classify building spaces accordingly. There are several approaches undertaken to classify the building spaces, but functional classification is the most appropriate one to direct early design process (Ekholm and Fridqvist, 2000). However, a functional state of classification doesn't describe the compositional view of the spatial features. Ekholm and Fridqvist (2000) suggested that both compositional and functional point of view is useful during design stages.

2.2.1. Space Efficiency and Effectiveness

The term efficiency is generally described as how well an activity or operation is performed. In other words, as Kenny stated (2008), efficiency evaluates how well an organization does what it does. Space Management Group (2006) describes the space effective facility concepts as; providing the minimum necessary space for the desired functions to be properly accommodated, with minimum 'waste' between net internal area and gross internal area or between net usable area and net internal area. Moreover, a high level of space utilization needs to be provided for space efficiency because the space is used for the maximum possible amount of time. To have spatial efficiency in facilities, according to facilities' most common features space standards are implemented.

The space efficiency of buildings relates to the quantity of space, the number of users, and the amount of time the space is used. Also as stated by New Castle University Space Management Guideline (2008), space efficiency not only provides a healthier environment for users but also promotes a more cost-effective understanding for facilities.

Efficient space indicates a space that has the ability to be modified cost effectively when functional requirements change, this emphasizes the long-term use potential of a space. Other than long term use potential, a space is efficient when not only changing but also maintaining it is cost effective (SMG, 2006). Efficient spaces are built to last.

2.2.2. Space Design

In the architectural design process, architects/ designers are obliged to organize and design spaces effectively and creatively for the purpose of the building, space planning is one of the essential tasks in building design (Yin and Yin, 2014). With buildings loaded with design information, space design has not only effects on design quality but also on internal operation of the building.

Shikder et.al. (2010) argue that when designer is involved in the problem solving and methodology design process, more rational solutions and active design processes have been achieved. Architects and designers usually work the best when the design issues, development of the data is visualized. That has been the subject of several space layout design studies.

Liggett (2000) have identified the representation of space in three steps;

- Space as discrete objects,
- Space as area,
- Space as are and shape.

Both the problem solutions and problems formulations in space layout design literature have shaped among these representations.

Information and knowledge on spaces in a building is always useful, but the most valuable course is to use them during design stage. This will have direct effect on activity efficiency and maintenance of the buildings (Ekholm and Fridqvist, 2000). A space in a building have several properties like material, shape, temperature etc. These all define a characterization stage for building spaces and in building process the designer must accomplish first the characterization of the spaces then the other properties.

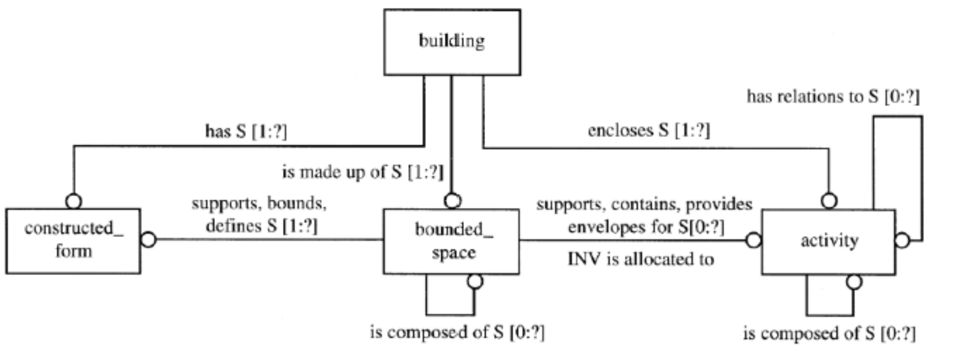

Figure 2.5: An analysis of basic concepts in space design (Eastman and Siabiris,1995 in Ekholm and Fridqvist, 2000)

A definite outcome is quite unlikely in design since it's a creative and unconstrained activity in which objective evaluation criteria is absent. Therefore, minimum criteria are satisfied by designers since the best outcome would be too costly to come up with (Dino, 2016). The design process is developed via the continuous cycle of broadening and narrowing the design space. Dino (2016) argues that one of the features of architectural design is “architectural form making” Architectural form have been cared much since it defines the identity and impact of the building. However not only the architectural form but also the space design is important in determining the quality of the building.

Medjdoub and Yannou (2001) grouped the architectural elements and defined them via attributes to create a better knowledge flow. The structural elements are not included, and the main class is named as space class. Space class have three sub-classes; room, circulation and floor. This knowledge model has provided a clean and systematic methodology for space layout planning. This have proven that with a proper classification and attribute definition, space design could evolve and become more practical for the designer.

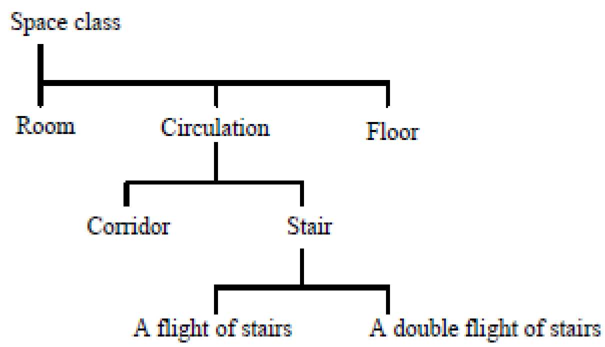

Figure 2.6: Hierarchy class in ArchiPlan (Medjdoub and Yannou, 2001)

Arvin and House (2015) mention the responsive design concept and its relation to automated design processes. Automated space design has given the designer the opportunity to test the design decisions and alter the solutions prior to the design implementation. This process has given the opportunity to flexible design and an interactive solution process to design problems. The effects of automated design process increase the design quality and supports the iterative process of building design in a multi-participant way. This creates an easy modifiable design process with the "best" achievement of design product. The architectural space layout problems have always been seen ill-defined and solving process of ill-defined problems have lots of constraints to be identified (Arvin and House, 2015). On the other hand, problems with several constraints have several solutions and it is difficult to identify the best one. The approaches in space layout design have been considering the settlement of constraints and the search for the best solution. Some of the constraints that have been subjected to space layout design are dimension, ratio, adjacency, orientation and shape etc.

2.2.3. Space Layout Design and Space Layout Problems

As being the initial phase of the construction process, architectural design requires solutions according to the needs of specific building types. Zhang (2013) quotes this process as an "optimization activity" since satisfying design requirements and the attempt to find the optimum solution is the aim of the process.

Eastman (1970) have put forward the term space planning and explained that, many problems within design consist of location problems which is the effects of functions or distance between the elements and their arrangement. This aspect is named as “space planning” aspect. Automation of space planning have been identified by him as representing this location and arrangement problem in a computer. Before identifying the space planning problems, Eastman (1970) has identified how drawings have been interpreted. He defines lines on paper as spatial domains with two-dimensional space, each point within a building is a representation of real physical space. For each domain, attributes are described, all points that are closed by a line are assumed to have similar attributes and by this the domain will have a homogeneous representation. Spatial information in each domain which are dimension, shape, attribute etc. should be available to process or easy to obtain. This situation is for all domain either empty or full with materials.

Zhao et. al. (2009) define space layout design as a primordial activity in architectural design for new construction and sometimes in building adaptation. A building is a component and the initial process of layout design is to satisfy the spatial relationships within this component. Maximizing design goals is the primary aim in layout design which is locating spaces in a container space.

Many attempts have been undertaken for space layout design and automated space layout planning since the 1960s. There have been several methodologies attempts however, no attempt has been fully comprehensible and successful to solve the design problems wholly (Schneider et.al., 2011). Layout design task in architecture defined as arrangement of spaces or areas, however, mostly attempts to refer architectural space as optimized empty spaces have failed since the design process needs more informative, rational and efficient processes. Schneider et.al. (2011) quote Polanyi (1966) and explains why the distinguish between tacit and explicit knowledge is vital for this problem. Tacit knowledge is defined as non-verbalized and non-formalized type of knowledge which is an essential point for heuristic procedures. The complex nature of design process requires a simultaneous effort of both designing and problem solving. Tacit knowledge is a component of problem-solving procedure. Moreover, if a digital tool is supposed to help the complexity of the design stage, that tool must become a part of the design stage itself. The tool must be open to be explored and developed by the designers and shouldn't block the flow of the design process. Schneider et.al. (2011) describe a design support tool as creating a flexible working environment to allow one to explore and develop the problems as efficient as possible.

Michalek et.al. (2002) also identified space layout design as space configuration and explain as finding feasible locations and dimensions to meet design requirements and maximize design quality according to design preferences. Architectural design is concerned with not only aesthetic of the layout but also the usability and efficiency quality of the layout.

In space layout design, there is one basic spatial unit and it is represented with nodes, polylines etc. The dynamic system of space representation uses only the volumes and the relationship between the volumes. The objectives to define the data of a space are topological and geometrical. Topological objectives include; adjacency, separation, orientation, location and geometrical objectives include; alignment, offset, area, proportion (Arvin and House, 2015). The space layout design that has been covered through the literature study have been testing the relationships that effects the spaces, physical dimensions determination and lacks the representation of data that defines the interior and exterior physical components of the spaces. Therefore, it is inevitable to suggest that to solve space planning problems one of the main steps is to consider not only the space layout issues but also the space planning components.

Ligget (2000) defined the three main methods of space planning problem solution. First one is the organization of functions in order to minimize the material flow between the spaces. Second one is to define the space layout with a graph in which the nodes represent the activity and the lines represent the adjacency. The last method is to optimize the measure or variable to satisfy constraint relations. All these methods have been defined via two subgroups, topological constraints and geometrical constraints.

The generation of layout is composed of functional requirements and relationships between spaces (Shikder et.al., 2010). Eastman (1973) explains that in layout problems, topological relationships and other functional properties are primary concern. By topological relationship, adjacency, alignment, grouping is meant and by functional properties, shape, dimension, distance is meant. There are different types of layout problems such as floor plan layout, equipment arrangement in a room, site planning, in other words two-dimensional planning problems. Several approaches have been tried in automated space layout design as well as space layout problems. The most useful approach to solve space problem is to integrate design knowledge and experience in the design process, this also collaborates well with the iterative environment of the construction projects (Shikder et.al., 2010).

Space layout design has been studied for a long time, from management system to product design; it has a variety of applications. As stated by Yin and Yin (2014) the space layout design has two subsets; topology and geometry. They both serve for different purposes and features in finding a solution to space design problem. The methodology in space layout optimization have been identifying the hierarchical relationship of the components in terms of the defined attributes like adjacency, dimensions etc.

Medjdoub and Yannou (2001) have identified space layout planning as an architectural design problem which deals with finding an efficient and satisficing space arrangement with respect to requirements. Requirement have been divided in two constraints in the literature; dimension and topological constraints. In the past, there are several attempts to use computational decision-making methods or expert systems to solve this problem and the studies continues today.

2.2.4. Automation in Space Layout Design and Computer Aided Space Design

Through literature reviews that have been made, since 1960s space layout problems have been tried to be automated and computationally solved. The objectives of these studies are quite wide, and the interest mostly came from architects, designers, researchers who are into designing large facilities such as hospitals, office buildings, department stores.

The growing demand in computational design tools, space layout design has been considered as an automated design activity for a long time. Facility layout simply deals with settling activities to spaces in a way that design requirements are met and optimized (Liggett, 2000). Facility layout problems vary in scale; either about a space design in a new building or allocation of a space in an existing building. Space allocation in a new building can be used to test different building configuration in the early design stage. Liggett (2000) argues that space design in the early design process can be used to optimize building layout, evaluate the best use, optimization of plans and foresee the possible space management problems.

Dino (2016) describes space layout design (SLD) as a complex problem but an essential aspect of architectural design which is the work to achieve an optimal spatial configuration to satisfy particular objectives. SLD can be supported by computational design by generating and developing design alternatives. By this SLD tries to obtain well working design solutions to space configuration problems. The nature of architectural design creates an environment for designer to create number of alternatives until one is completely fulfills the design objectives.

In architecture, construction and engineering industries, visualization via computer can help to define whole life cycle of a building starting from initial design stages to operation and maintenance issues (Bouchlaghem et.al., 2004). Visualization of a product is not the final stage in architecture. Design and visualization processes need to be recurring, because in every decision or change, visualization and the design changes foster each other. However, this process brings about the need for a proper software help. The design process involves many participants and design of a building needs to share an understanding between all participants for quality in the end product (Bouchlaghem et.al., 2004).

Space planning is a process of problem solving and search. Baykan and Fox (1991), have defined that this methodology can solve these issues;

- Knowledge representation
- Acquisition and maintenance of design expertise
- User interface for graphical specification of constraints
- User interface for interactive design.

The methodology put forward a space planning system working with CAD system. However, nowadays the industry is showing that BIM has more power in problem solving as it takes a process in different dimensions. Space planning as explained by Baykan and Fox (1991) works with two dimensional layouts, such as floor plans, equipment, site plans etc. What has been concerned is the spatial arrangement and spatial features such as shape, dimensions, distance etc. With the changing understanding of building design, a designer must care for not only the design process but also to the occupancy process. Therefore, what space planning used to be doesn't comply with the current advances in architectural design and construction.

In space planning, constraints have an importance on minimizing the search complexity via enabling to choose best decision according to certain constraints (Baykan and Fox, 1991).

Baykan (2001) defines space planning as a configuration design and an arrangement of solids or spaces in 2D spaces. It is a design problem and search for effective solutions to compare alternatives is very important.

Cavaliere et.al. (2019) describe BIM both as a tool and a methodology which is able to manage building's data through its life cycle. The development use and transfer of knowledge is what BIM focuses on with the aim of improving design, construction and operation quality of the buildings. BIM has the opportunity to pre-make design decisions through early design analysis and managing design alternatives to see better results. BIM enhances the collaboration therefore; it is easier to manage different design decisions in BIM. It has the potential to deal with more complex buildings and design alterations. BIM expands the design process in not only building modeling or drawing but also to design, planning, construction and operation of a facility.

Kusy (2013) made a list of values that BIM integrated design stage of the buildings;

- BIM provides an interoperability among computer aided design (CAD) software, facility management and analysis software by using industry foundation class (IFC) format.
- It provides a better cooperation by providing an accessible remote cooperation through the process.
- It has a canonical knowledge resource on the whole life cycle of the building.
- It provides faster and more transparent procedures from design to operation stage.

2.3. Healthcare Facility Design

Health is defined as "a state of physical, mental and social well-being and not merely the absence of disease or infirmity" by The World Health Organization (1946). Healthcare environment is not only a place where treatment is given but also a place to avoid risk of healthcare-associated infections and should provide spaces contributing to the process of healing. The main purpose while designing a hospital should be the function and type of services that will be provided to the community. These services are evolving according to developments in healthcare industry and the needs of users. It is an ethical issue that one of the governments' major priorities are providing better healthcare facilities for people. However, the creation of a healthcare environment is not enough. Design quality is as important as responding the need for an efficient healthcare which effects directly the design principles (HBN, 2014).

Main reasons behind the changes in the healthcare industry can be named as technological improvement, changing medical methods or approaches, political changes, human needs etc. (Heng et.al.2005). The innovative progression of technology, growth in population, changing models of medical care and changes in policies and services increase the necessity for changes in facilities, in other words increase the necessity for design innovation of public facilities. This is an ordinary process for other type of buildings, however for hospitals it is a complex and challenging task. Medical service is a basic human right and need. For this reason, the need for more space and equipment in hospitals is increasing, especially in government hospitals.

McKee and Healy (2007) state the argument about creating larger hospitals by explaining the positive features of complex units. Interrelating set of functions and gathering different specialties under the same roof increases optimal use of spaces such as scanners or operating theatres.

2.3.1. Healthcare Space Design

While designing a hospital, the shape and size is shaped according to the services to be delivered in that facility. This is defined by the needs of the community and the government base studies. Before stating to a design process, a model of care is presented as a part of design brief. This model of reflects both national and local priorities as well as service models accepted by healthcare practitioners. Arrangement of the services should be determined in the context of this model and the creation of this model also needs to cover the workflow relations.

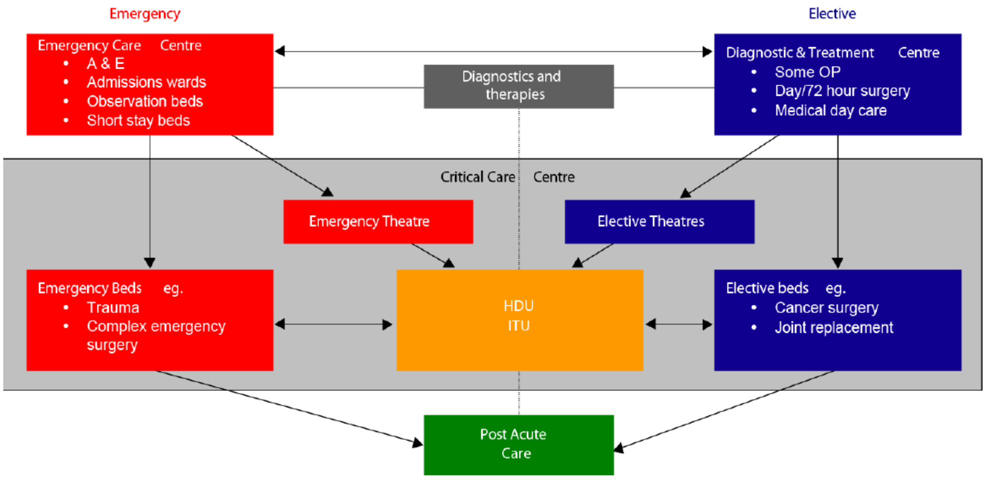

Figure 2.7. Example model of care (HBN, 2014)

After "model of care" framework is decided, next stage should be assessing operational principles and policies. Operational principle explains how each service will function. Policies describes how spaces relate to each other in order that a department can be planned in an efficient and functional way (HBN, 2014). These staged are all steps to define a working design brief.

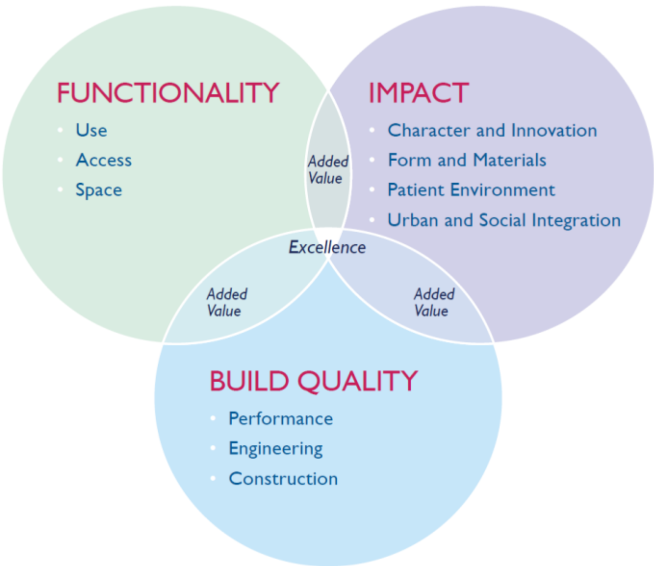

Figure 2.8. Example of the main components of design brief for healthcare buildings (HBN,2014)

The categorization of spaces according to their functions is a useful way to describe and characterize a construction project. A hospital is a good example to a complex facility because, no department is similar to another in terms of activities, people and objects. The variety of professionals that involve in a complex project like this can use a categorization to determine the scope precisely. The categorization not only direct people to relevant information but also can be used as an indicator while transferring requirements during project stages (Rashid, 2014). Categorization of spaces can also overcome the uncertainties during the design stage, that is a categorization of space can work as a checklist for space design.

2.3.2. Healthcare Space Layout Design

Healthcare facilities are the most complex building types. There are several services and functional units in a hospital; diagnostic and treatment functions, clinical laboratories, imaging, emergency rooms and surgery. Therefore, before designing a hospital the architect must formulate a detailed "functional & space programs".

Healthcare facility is defined by Holst (2015) as a multi-product facility. The building framework must evolve constantly according to technology, demography and diseases. On the other hand, construction materials, construction technologies and advancements in design technologies also has direct impact on the development of healthcare buildings. Above all, the Functional planning that the healthcare buildings necessarily need is the primary driver in the design practice in healthcare design (Holst, 2015). There should be two focus in healthcare design; evidence-based and patient-centered.

Working on typologies and space layout on hospital design is one approach in explaining a framework for the built environments, another one is to work according to a standardized framework where simplified and generalized principles valid the design (Holst, 2015). In the last decade the industry has been using an automated space layout design process. This have important results on more efficient and care-focused hospitals since it promotes an efficient space configuration and a planning path for the design process (Holst, 2015).

Space layout design in healthcare facilities is challenging, because there are several complicated relationships among spaces which in hospitals called functional units. The relationships in healthcare facilities cannot be minimized to adjacencies but also attributes that define the space features like accessibility, level of sterility etc. need to be handled (Zhao et.al., 2009).

The spatial organization and space design in hospitals have direct effect on the quality and the efficiency of healthcare services as well as patient satisfaction, therefore, layout is considered to be a long-term decision (Arnolds and Nickel, 2014). architectural planning of a hospital is usually based on experiences and benchmark. Clinical process, medical resources, facility requirements, legal regulations and the data available according to experiences shape the data to be used in optimizing a layout design.

Zhao et.al. (2009) describe that because of the complex relationship of spaces in healthcare facilities, it is essential to consider the factors effecting the design and outcome of space layouts. Every single development and change in healthcare facilities have direct effect on design of the spaces which results in direct effect on efficiency and productivity.

The space design in healthcare facilities used to be on physical requirements of space and service delivery. The benefits of the spaces to users have been neglected and the understanding of “healing environments” have been developing recently. As the focus in healthcare design changes, the process of healthcare design is altering accordingly. With changing understanding of patient centered and evidence-based design, the factors influencing space layout design in healthcare facilities have been identified by Zhao et.al. (2009).

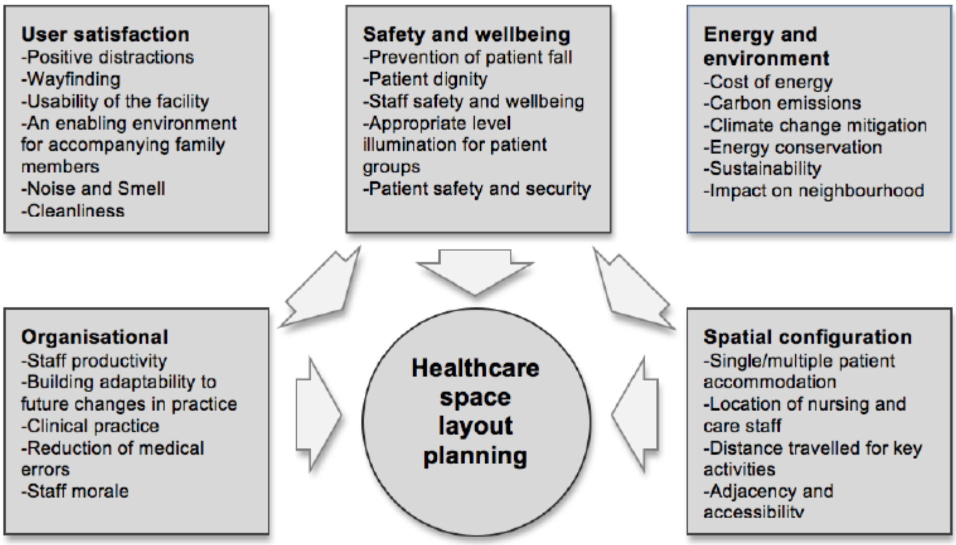

Figure 2.9: Factors that influence space layout design in healthcare facilities. (Zhao, et.al., 2009)

The findings in the research conducted by Zhao et.al. (2009) have suggested that, the developments and health and care delivery understanding have direct effects on the design of space and space layout in facilities and the design process needs to be altered according to the intentioned outcomes such as efficient and productive environments. A well designed and functioning hospital is what governments are aiming to achieve, therefore the necessary standards for effective healthcare facilities should be implemented in the design process.

Lin et.al. (2015) have made a comprehensive research on hospital projects and what is argued in this research is that; hospitals are changing according to economic, political, technological advancements. Healthcare facilities are complex building systems that need to be handled carefully. Operating rooms are one of the most critical spaces in healthcare facilities not only because of the expenses but also the effects on human life. Quality of an OR effects the whole process of hospital operation; therefore, in hospital design ORs are bottleneck for the efficiency of the hospitals. In the previous studies, facility layout optimization of existing ORs have been researched, however what needs to be cared most is the early design stage of the ORs. Due to their fragile and delicate nature of the ORs and their being one of the critical services of the hospitals, before making an optimization on existing OR units early design of ORs need to be planned carefully and systematically. Another reason behind the difficulties of facility layout planning in hospitals is the connection between diverse functions in hospitals and links between different departments. Implementation of an efficient facility layout design becomes extremely difficult (Lin et.al., 2015).

2.3.3. Operation Unit Design in Healthcare Facilities

In a hospital, operating room is a high-risk environment with more problematic features within patient care environments (Joseph et.al., 2018). Operating theatres even built 30 years ago, can operate today, but not adequately designed to respond to technology, equipment, processes and professional users of ORs (Wahr et.al., 2013).

Off all the departments in a hospital, the surgery unit is known to be studied the most. The primary design criteria in a surgery unit design is the separation between soiled and the sterile. Therefore, while working on space layout design in hospitals, the most important feature is sterile classification. On the other hand, while the layout design takes the sterility levels into consideration, the functional classification needs to be studied for the identification of the spaces.

The functional requirements of an OR are defined by functional zones of OR. Three zones have been identified in the OR planning and literature; sterile zone, circulating zone and anesthesia zone (Joseph et.al., 2018).

Some of the requirements stated by governments’ s hospital design guidelines are as follows:

- A surgery area should be short-way and sheltered access from/to surgery suite to/from ICU and trauma wards and emergency service.
- Acute wards shall have a direct vertical connection to surgery suite
- Functional adjacency (e.g. direct vertical connection via clean and unclean elevators) to sterile processing department is required.

- Logistic supply for OT shall be operated directly via vertical cores from logistic level without any horizontal transport through other patient areas.
- Surgery suite caters for inpatient surgical procedures, angiography/cardiac catheterization caters for in and outpatient interventions.
- All patients for surgical procedures are transferred via inpatient holding and transition locks into the green zone) before entering the central pre-OP-areas for preparation; after transfer into the assigned OR, anesthesia is done; recovery takes place in post-OR-area which is located outside the green zone and thus reached by passing the transition lock; patients for angiography/cardiac catheterization have separated transition and pre-/post-facilities.
- Staff for OR's green zone enters the unit via a 3-chamber staff lock system, whereas all staff for OR's white zones have separated staff changing facilities.
- Sterile goods supply is operated via sterile supply system, whereas medical goods supply and disposal is operated via the internal OR corridor.

2.4. Critical Review of the Literature

In this chapter, the fields of knowledge management, space design, space layout design and hospital space design topics are explained. The capture and reuse of project knowledge is applicable with knowledge management. Knowledge management is an endeavor to use knowledge in an organization with a systematic and organized approach in order to transform its ability of storing and using knowledge to improve performance (KPMG, 1998). Knowledge gains more value when transferred from expert to practitioners. With a proper knowledge management strategy, the design quality can enhance in a project. Architectural design is an iterative part of construction projects. Gaining knowledge in one field can be used in repetitive projects. However, to motivate the transfer and use of knowledge a clear methodology is crucial. In construction industry, the practitioners usually see documenting the tacit knowledge as an extra work. With clearly defined knowledge transfer paths, not only experts but also others can benefit from this process. With complex projects come the complexity in design process and in this complexity, one would lose valuable information easily. In order to put forward a methodology in this field a knowledge management literature review is made.

Space in architectural design is the most informative item. Spaces carry the information that is beneficial not only for construction but also for operation process. Therefore, creating an effective space has direct effect on building life cycle. With buildings loaded with design information, space design has not only effects on design quality but also on operation and maintenance of the building. Space design have been studied in the literature and the result is with a proper classification and attribute definition, space design could evolve and become more practical for the designer. The studies in field have suggested that automated space design gives the designer an extended overview of the decisions they are making.

Space layout design have also been defined in this chapter. It is a space configuration method and aims to find feasible locations and dimensions to accomplish design requirements and maximize the design quality. The integration of design knowledge and experience in design process have also affected space layout design positively since construction projects have an iterative environment. The space layout design has been defined to have two subsets, topology and geometry. It is observed that the information embedded in the space have also direct effect on design quality, therefore the knowledge of the space needs to be managed as well as the topology and geometry of the space.

The visualization of the space has been the topic of many research. The visualization via computer have proven to define whole life cycle of the building. Space layout have been defined by computer aided design and direct link between computer aided design and knowledge representation also have the potential to increase design efficiency.

It has been discussed that healthcare facilities are complex project types. To understand this complexity healthcare facilities are researched in terms of design regulations. There are standards to be followed but following the standards must not mean reducing or not caring about design quality. Therefore, healthcare environment is not only a place where treatment is given but also a place to avoid risk of healthcare-associated infections and should provide spaces contributing to the process of healing. The main purpose while designing a hospital should be the function and type of services that will be provided to the community. The space is the smallest part of a hospital complex. The quality of whole design is affected by space directly. For this reason, the study continued by understanding the space efficiency and effectiveness concept in hospitals. Therefore, the research continues with space knowledge representation for knowledge share in hospitals. Surgery unit in hospitals is the most risk intensive space. Thus, the study is made on surgery unit spaces.

CHAPTER 3

MATERIAL AND METHOD

The necessity for knowledge share in complex construction projects like healthcare facilities has been covered in the previous chapter. Successful attempts have been made to generate the architectural design process computationally to manage knowledge. However, there is still need for a strategy to handle large scale buildings with continuous variables computationally (Michalek et.al., 2002). The architect of a hospital building uses the expertise s/he gained, relevant legal regulations of healthcare facilities, the opinions of the practitioners. Every knowledge in healthcare design values and lack of knowledge fails to create an efficient healthcare facility design end product and process. Therefore, as Arnolds and Nickel (2014) argue, methodologies for knowledge support and decision-making process is very important for healthcare facility designers. Healthcare facility architects are becoming more concerned and open minded with the supporting tools and options for the design stage. However, it has been covered that design support tools require a more standardized working environment. To have the adequacy to arrange design process and design tools, first a simple but comprehensible methodology is needed. The methodology of this thesis aims to put forward a knowledge share support for healthcare building design. The process of knowledge gathering, and knowledge sharing is supported by design stage itself, therefore this knowledge needs to be open for update and re-processing. The flow of the process is tried to be explained by Figure 3.1. In order not to lose knowledge and to gather information, a classification of knowledge is proposed. The classification has been made both in space types and in space knowledge.

Operating theatres are the most delicate services in a hospital, because they are multifunctional treatment rooms. Their being prone to problems and direct relation with variety of concepts like anesthesia, sterile-nonsterile areas, delicate equipment etc. The taxonomy is created according to the standards derived from guidelines from Australia and United Kingdom. After creating space taxonomy, the attributes are created to define a space. Attributes are also used to classify space information in different categories. The created system is validated to healthcare architects and consultants since they are the ones to use the knowledge share strategy. The validation process has been made with a three stepped Delphi method. The results have been described.

After making a comprehensive classification study, the results have been formatted into UML diagram. This is chosen because in order not to lose data and to represent it in a more universal way is decided to be more appropriate. UML also provides easy and simple way of flow and update of information. After these studies, a design support tool has been chosen and the data is visualized in this system, dRofus. This system will provide a visualization from experience to knowledge. The study in this chapter will form the relationship between spaces and the definition of spaces in architectural terms.

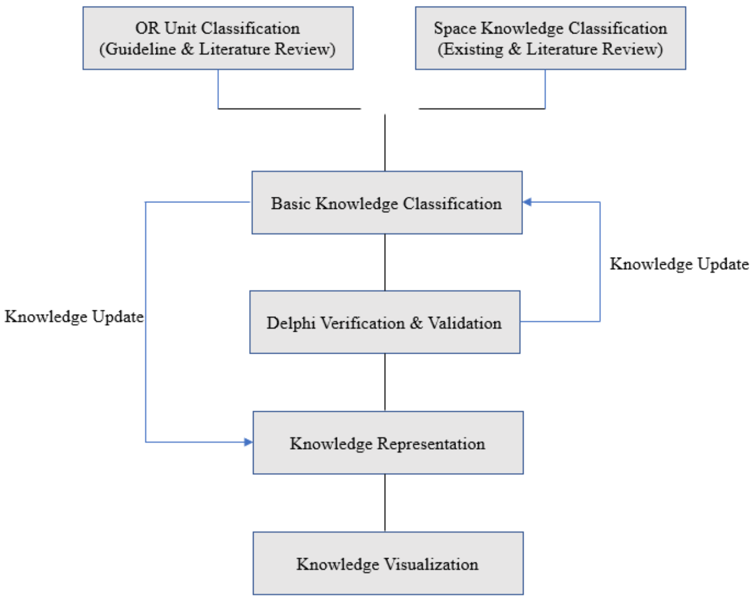

Figure 3.1: Methodology flow diagram

3.1. Operation Unit Space Classification

Hospitals are complex building types and design of a hospital is focused on its complex functional requirements. The functionality of a hospital has several criteria to follow, such as; sterility, safety, workflow, user differentiation etc. Besides these, hospitals also need to have design quality. The important thing while designing a hospital is to follow the requirements by not reducing design quality.

The basic principle in a hospital is to control user movement. There are different types of users in a hospital; visitor, patient, medical personal, facility management personal. The movement of these users need to follow a certain workflow in order to control infection which is one of the important features that a hospital contains. This creates different zones in the hospital; restricted zones, semi-restricted zones, free zones. The creation of zones is the foundation of the design activity. There are major and minor design zones in a hospital. Taxonomies in building design works as an overview of the design and gives a clear understanding on creating something new. By classification, making selections from presented alternatives works better (Jørgensen, 2009).

The surgery area is physically a distinct and controlled area. The unit itself accommodates perioperative care that consists of; pre-op phase including patient management and patient transfer to OR, intraoperative phase including surgery and procedures, post-op phase considered to be first recovery stage until the transfer to inpatients units. The activity in the operating room is surgery. The size of these rooms depends on the type of surgery and the equipment that will be used during the surgery. The size of the service depends on the operating room numbers, this will affect the design and operational solution. The environment should be designed to eliminate the risk of infection with considerations like materials, equipment, air handling systems, flow of the people etc.

In the UK guideline, the surgery unit is defined in two main categories; operational facilities and support facilities. In this structure, from main entrance to post-op all the zones are named as operational facilities. In support facilities, rooms for staff, offices, educational rooms are named. The relationship with other services is described in Figure 3.2;

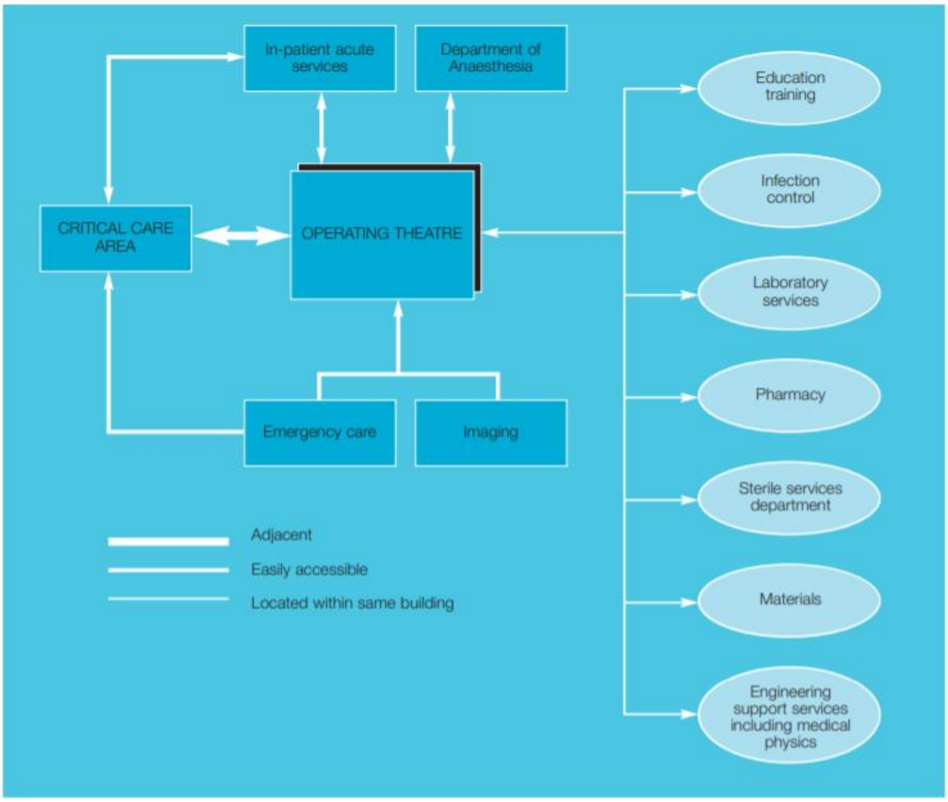

Figure 3.2: OR relation with on-site services (HBN, 2004)

While explaining the functional relationships of the surgery unit, the inpatient flow was the base for designing a surgery unit. The zones are defined one by one and the relation between them are named in Figure 3.3.

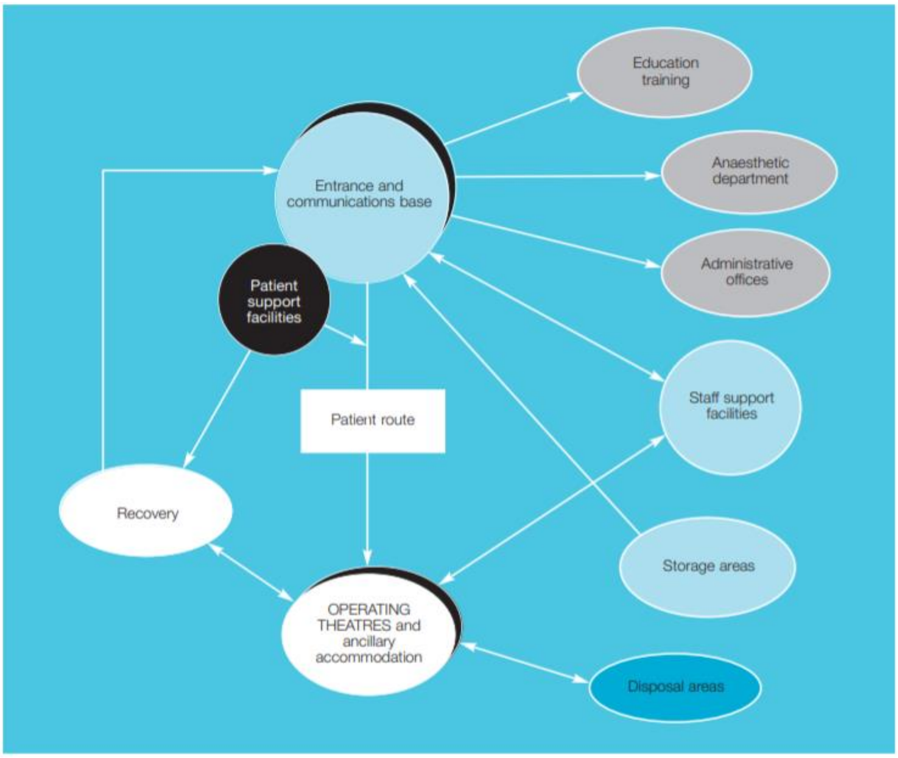

Figure 3.3: Functional Relationship (HBN, 2004)

Operating rooms need to enable easy maintenance, effective utilization and sterility. The main objectives of planning are defined by Gupta et.al. as follows; (2005)

- Promote high standard of asepsis.
- Ensure maximum standard of safety.
- Optimize utilization of OT and staff time.
- Optimize working conditions.
- Patient & staff comfort in terms of thermal, acoustic and lighting requirements.
- Allow flexibility.
- Facilitate coordinated services.
- Minimizes maintenance.
- Ensure functional separation of spaces
- Provide soothing environment.
- Regulates flow of traffic.

These objectives are emphasizing the importance of OR planning which needs to be a detailed planned and scientific process to ensure its functioning, efficiency and effective utilization.

It is also inevitable to add that; all of the functional zones are described in accordance to degree of cleanliness. That is, for operating room units there are four main zones with different risk factors of infection. These are; protective, clean, sterile and disposal zones (Wheeler, 1964) Another design concept is the “three-zone concept” which consists of unrestricted, semi-restricted and restricted zones (Miller and Swensson, 2012) The restricted area being operating rooms, semi restricted and unrestricted areas are defined by users and cleanliness factor.

The Australian guideline divides surgery unit into 6 different functional zones. These are; entry & reception and waiting, preparation and holding, operating room module, clinical support, recovery and staff areas. The design principles are divided in categories like environmental considerations, space standards and components, safety and security, finishes, fixtures-fittings and equipment, building service requirements. The functional relationship defined by Australian guideline is described in Figure 3.4.

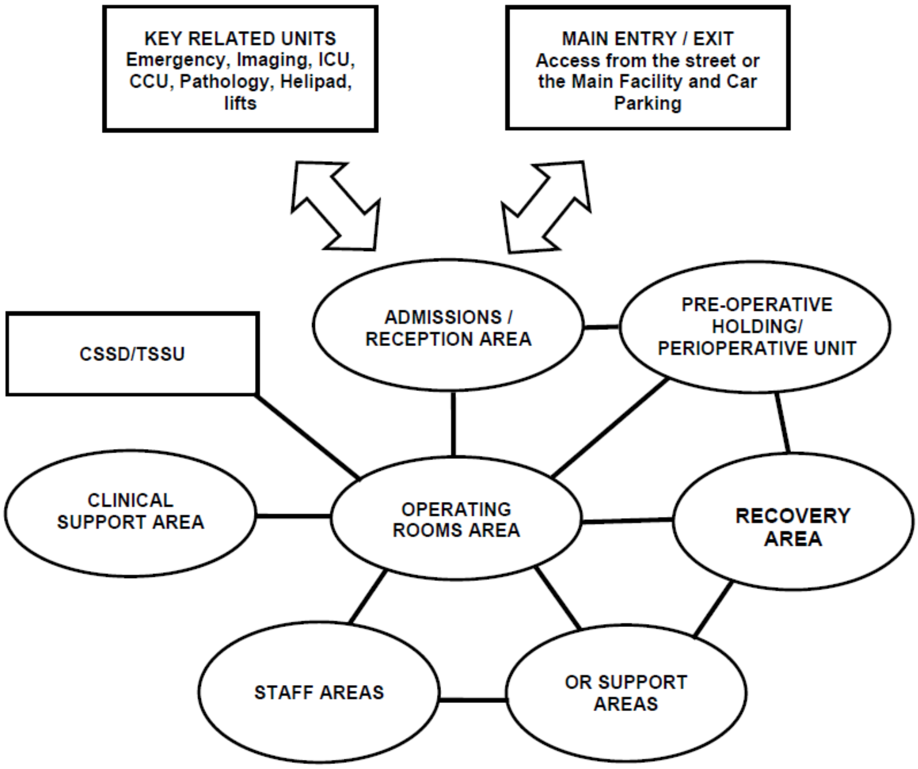

Figure 3.4: Functional Relationship (AusHFG, 2018)

These two guidelines are the most comprehensive and popular ones in healthcare facility design; however, a guideline has also been implemented by the Turkish government. This guideline mentions the importance of sterile classification of spaces; however, makes a classification of spaces according to functions. The functional units in Turkish guideline are; surgical rooms, surgery support areas (pre-op, post-op), surgery service areas (sterilization, medical gas and storage, laboratory, pathology, clean work rooms), personnel areas (resting, changing, working).

After the research process on spaces and space knowledge is made, the validation process becomes necessary. The nature of hospital as discussed before is very complex and without a proper classification within the departments, architects could fail to form an efficient hospital workflow. There are various spaces in hospital operating units, for this reason it is better to decide zones and sub-zones to create and validate an effective space taxonomy. Before deciding on a proper classification of OR zones in healthcare facilities, a Delphi study have been conducted with group of people. Research will be defined in the next chapters.

The workflow in OR unit have been covered in the literature review. Since the workflow in healthcare facilities play an important role on the design process, the first classification is made accordingly. However, for this space classification to be used as a knowledge acquisition method, the knowledge that will be acquired from the spaces should be classified too.

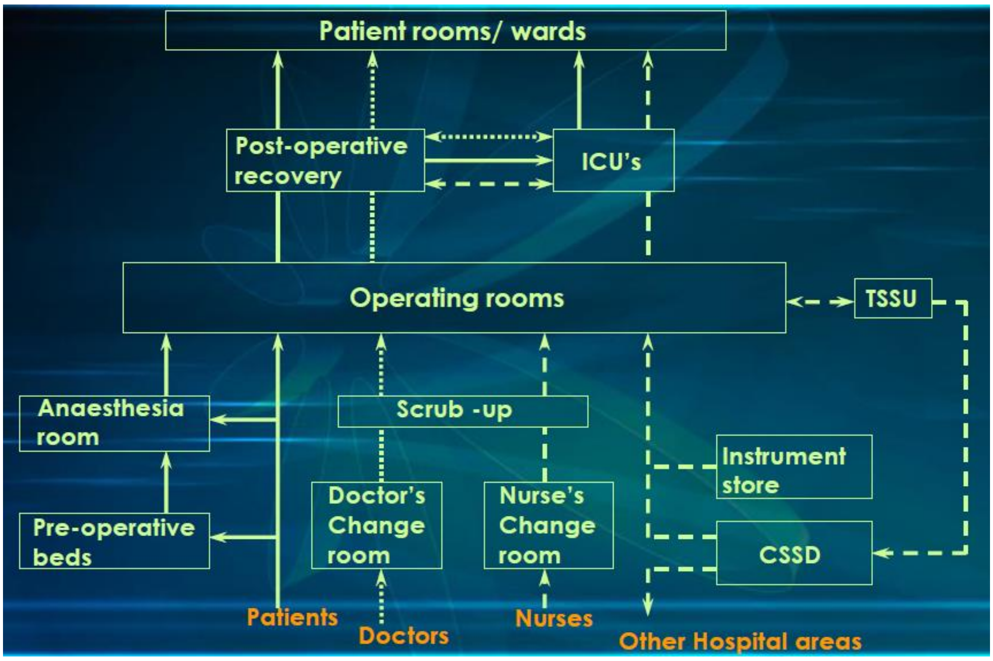

Figure 3.5: Workflow of surgery unit (Hebbar, 2011)

3.2. Space Knowledge Classification

Architectural design is a long and complex process and includes many data from many disciplines. Spatial properties of a building are identified in the early stages of the design process before most of the structural and systematic requirements are identified. The space carries the knowledge of not only topological constraints but also the functional constraints. Space layout studies have shown that they gather the knowledge of topological and geometrical objectives. However, layout design task in architecture defined as arrangement of spaces or areas, however, mostly attempts to refer architectural space as optimized empty spaces have failed since the design process needs more informative, rational and efficient processes. Therefore, classification of knowledge is important in architectural projects since classification is the first step of knowledge representation.

Delany (2017) has explained that with a proper classification system information can be found and retrieved very easily. A dictionary is the simplest form of a classification, and in dictionaries the rules are easy to understand and applying information to a dictionary is very easy. The methodology works well; thus, a classification system should carry features familiar to a dictionary. The limit to information is a controversial issue. Relevant and irrelevant information should be differentiated in order to ease the information pull and push process. Organizing the content of information is one of the solutions of differentiating relevant and irrelevant information.

Many classification systems have been developed in the built environment with the purpose of data exchange among different parties in building construction (Jørgensen, 2009) The last years, the collaboration process in construction industry have been made traditionally on the document base; however, the approaches have changed and ne support tools for architectural design have been developed. The building design have come long way into computer-based design process.

The new needs in classification systems include the relationship, that is existing classification of building data is oriented on physical components. Jørgensen (2009) argues that instead of classifying building elements according to functions, it is better to classify functions and attach building components to these functions.

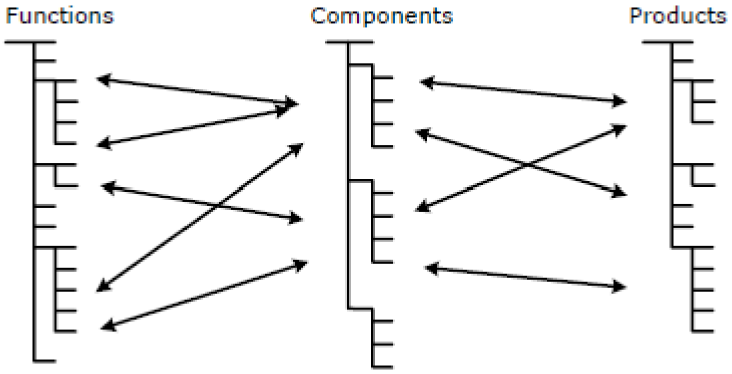

Figure 3.6: Relationship between taxonomies support efficient specification and detailing process (Jørgensen, 2009)

Classifying enables construction information to be organized, easily accessed, improved and shared, Chapman (2013) also argues that Building Information Modelling needs structured information and a good classification. The study is to create a database for supporting the design process, BIM tools would be the most up to date solution among design tools. Therefore, the above-mentioned information about classifying the knowledge takes more importance.

To better understand how to classify space knowledge, an existing building information classification tool Uniclass is studied. Chapman (2013) describes Uniclass as a structured approach for building information classification via information organization according to specific characteristics. However, Uniclass works with all the components of the built environment and this study is tried to be conducted for the specific part of a building. There is also Omniclass which is organized by building elements as Uniclass covers elements of the buildings (Jørgensen, 2009)

The methodology of Uniclass is simple, basic but easy to comprehend. Uniclass groups information in tables and these tables are placed in a hierarchy. Figure 3.7. shows the relationship and the classification of the information tables.

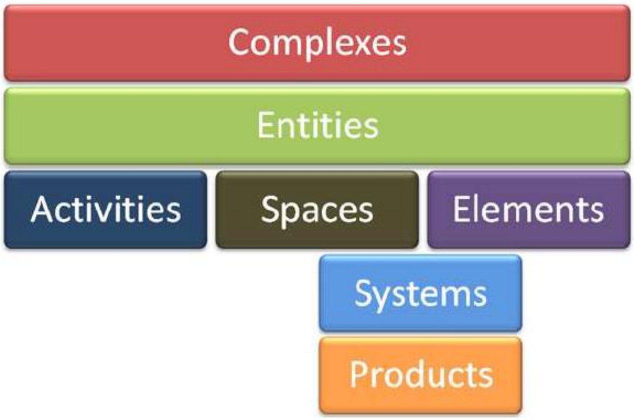

Figure 3.7: Uniclass viewed as a hierarchical classification for built asset information (Chapman, 2013)

For making a similar comprehensible and effective classification, Uniclass tables, literature on OR design and again guidelines for hospital space design have been studied. As mentioned in the literature review, for hospital spaces two main classification is very important: sterility level and user.

In this study the taxonomy of space knowledge acquisition methodology is defined with the help of guidelines and expert opinion. To illustrate, guideline define design objectives of hospitals. The UK guideline shapes design considerations with titles such as; drugs cupboards, noise and sound attenuation, finishes, doors, windows, clinical hand-wash, shelving and storage, work surfaces and bins, maintenance and cleaning. The Australasian Health Facility Guideline on the other hand grouped these titles into categories like; environmental considerations, space standards and components, safety and security, finishes, fixtures-fittings-equipment, building service requirements.

After the research process on knowledge classification is made, the validation process becomes necessary. To achieve a database for all users, literature and guidelines have been studied. Before deciding on a proper classification of space knowledge in healthcare facilities, a Delphi study have been conducted with group of people. Research will be defined in the next chapter.

3.3. Identification of Space and Space Knowledge Classification Using Delphi Technique

Delphi technique is chosen for this research, because it is expressed as a means of reconciliation and is a technique that systematically obtains expert opinions on a problem situation (Şahin, 2001) Delphi technique is used as a consensus tool in situations where there are differences of opinion on similar situations. It is a method of combining knowledge and expertise of different people, with two or more rounds this study aims to create a common view among the participants on the subject (Okoli and Pawlowski, 2004) In a typical Delphi study, two or more rounds are necessary and at least 7 participants are acceptable (Şahin, 2001)

Researchers are often confronted with situations in which a person who is considered to be an expert approaches the problem from different perspectives and these different views may sometimes conflict. These differences between opinions could form what will be the appropriate objectives, what qualifications the product should have, whether an activity that is thought to be realized is worth to be done, what priorities can be, what qualifications a person has to carry out a certain task and so on. A Delphi study doesn't work with statistical data, the importance here is on the group critics and group decision (Şahin, 2001)

The literature review has covered the importance of expert opinion and know how, therefore, in this research continuing with a process that works well with participant ideas who are considered to be expert is applicable. The participants of the Delphi study are 15 people, 11 healthcare architects, 2 doctors working as medical consultants, 1 biomedical engineer working as a medical consultant and 1 facility manager working as a medical consultant.

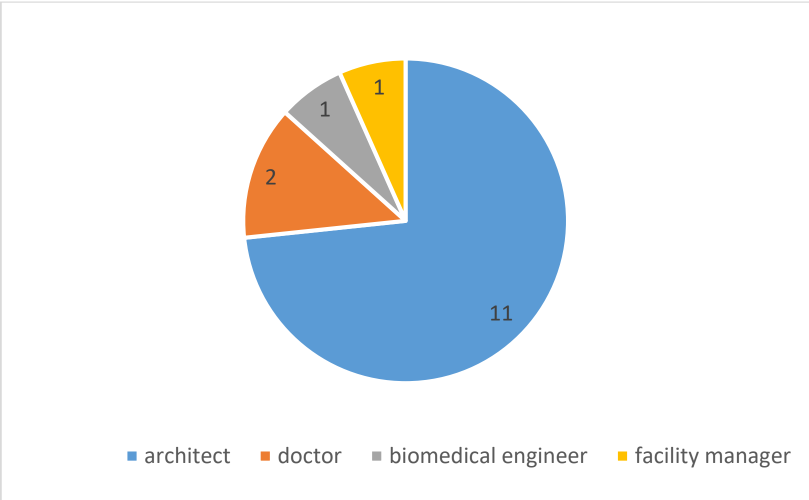

Figure 3.8: Occupation of the participants

The total expertise of participants and the expertise of healthcare facilities have been asked to participants but other than that anonymity was the prevailing feature of the research. Participants have been tried to be chosen among professionals working more than 5 years on healthcare facility design process.

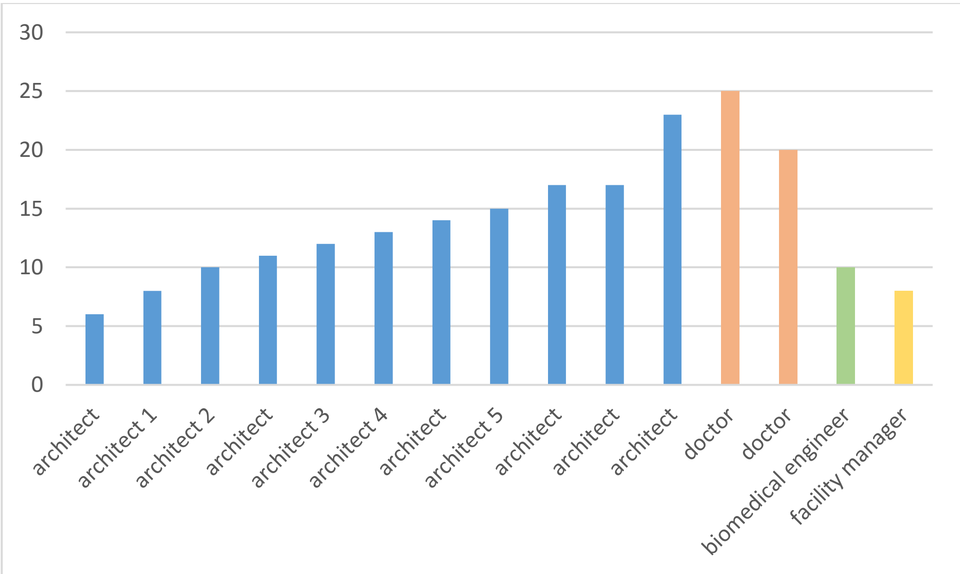

Figure 3.9: Total expertise of the participants

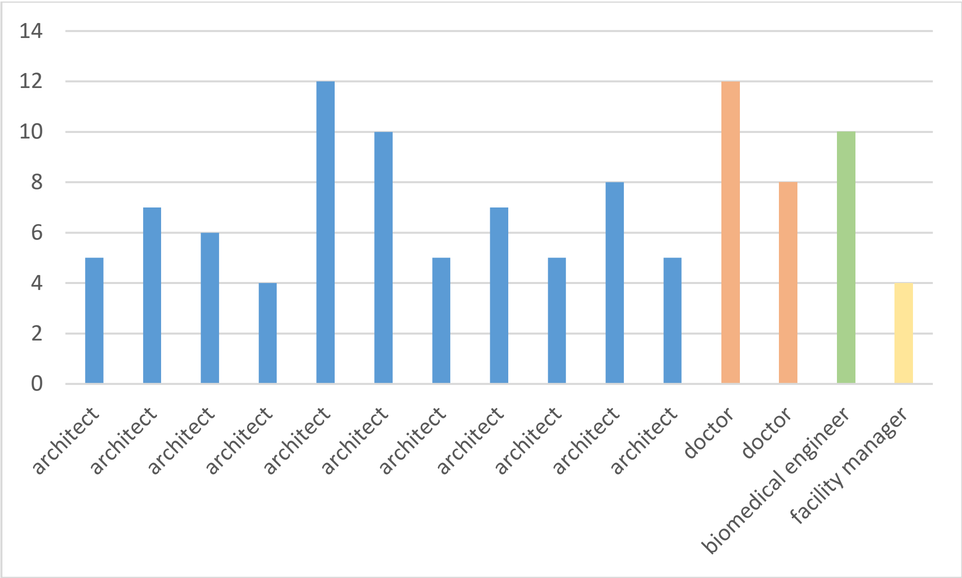

Figure 3.10: Expertise of the participants on healthcare facility design process

Every step of the research is prepared as an online form and distributed either via e-mail or mobile messaging application. These all are made to increase participation and willingness to the research. Before the Delphi process, small interviews have been made with the participants in order to explain research aim and objectives and get the primary and general information on hospital design.

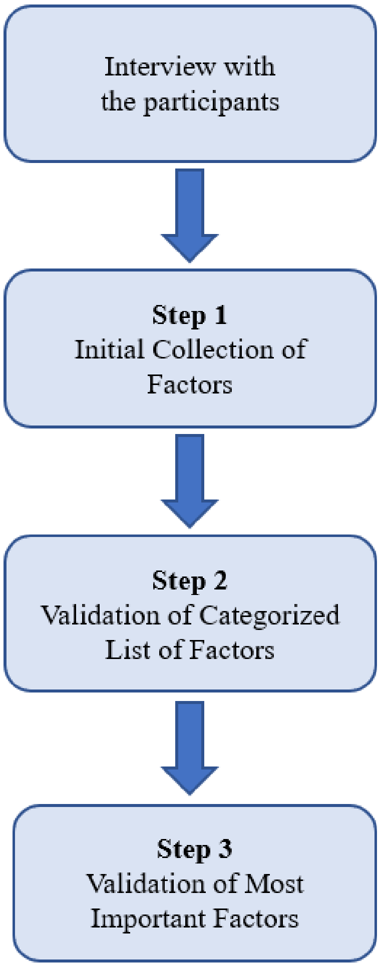

Figure 3.11: Delphi Research Process

3.3.1. Step One- Initial Collection of Factors

The initial step was a small interview for explaining research aim and objectives and also shaping research steps. In the first Delphi survey, there were questions to determine their occupation, total experience and experience on healthcare facilities.

The fourth question was asked in order to understand where the knowledge is coming in current hospital designs. The question was asking resources participants use in the design and implementation of surgery units. It was a multiple answer question in order to direct the practitioners into the knowledge resources that can be researched and analyzed.

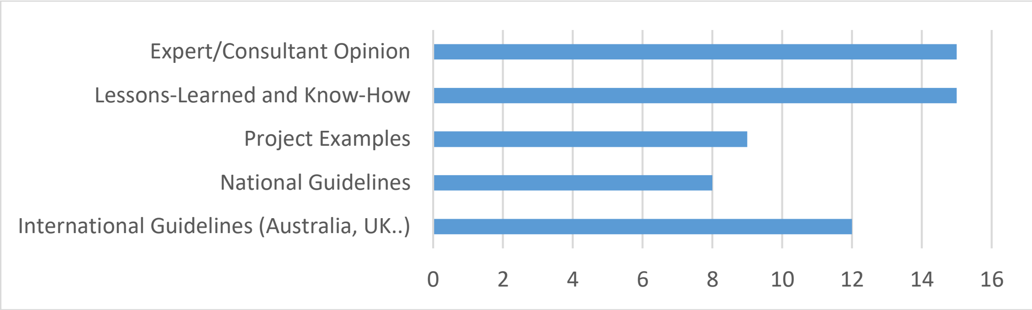

Figure 3.12: Answers to question 4

All of the participants have agreed that expert opinion and know-how is very important in the design process of the hospitals. However, the minimum importance was given to project examples and national guidelines. International guidelines are more reliable than these according to the results.

Question five was about understanding the differences that hospital design requires. The aim of the question is to understand which parts of knowledge is differentiated from other building types. There were several answers to this question, and they are represented in the graph below.

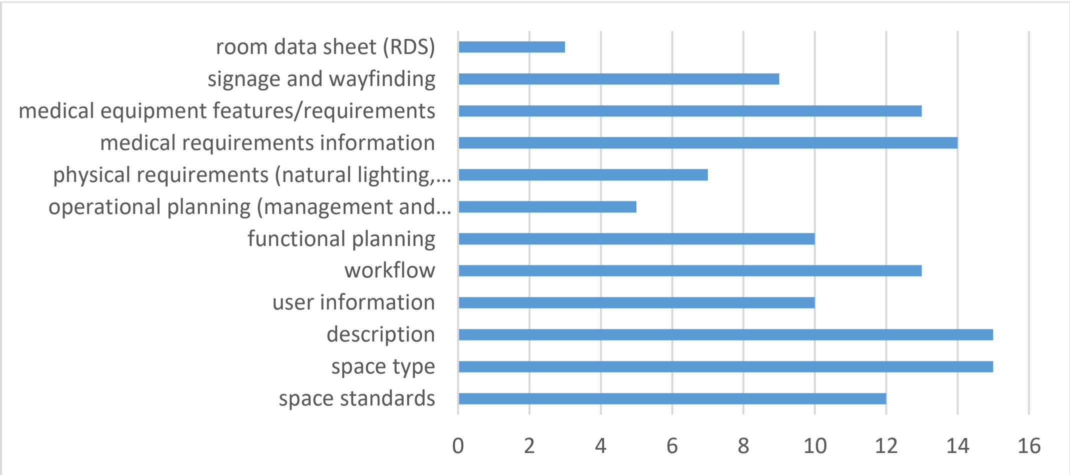

Figure 3.13: Answers to question 5

There were variety of answers since everybody used different words to identify the information they needed. However, with the information from guidelines and literature answers were compiled into general phrases and represented as above. Space type information, description of the space, workflow and all information available for the medical features of the spaces were repeatedly noted. Room data sheet (RDS) on the other hand have been noted by only three people. RDS is a type of space description sheet that gives all the information from finishes to fixtures, from mechanical to electrical requirements of a room or a space in a specific project. Therefore, for the next step of Delphi these will be added to the evaluation.

Next question was to identify whether the practitioners take a different point of view when it comes to surgery unit of hospitals. Therefore, the question was asked to identify the information needed specifically for surgery unit.

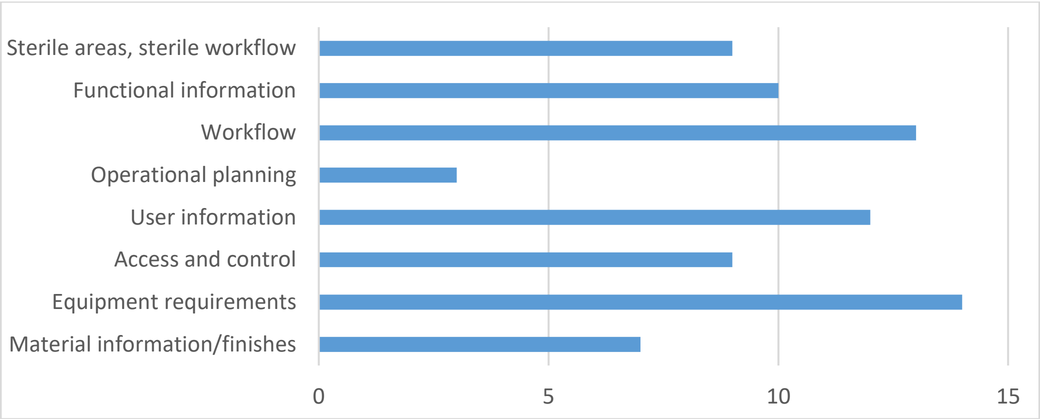

Figure 3.14: Answers to question 6

These answers show that when the issue is to gain knowledge on surgery units, the level of sterility, access information to spaces, control requirements of the spaces needed to be added.

The question seven, about space classification of OR units, was to choose a proper classification framework. The options were functional classification, operational classification, level of sterility classification and user classification.

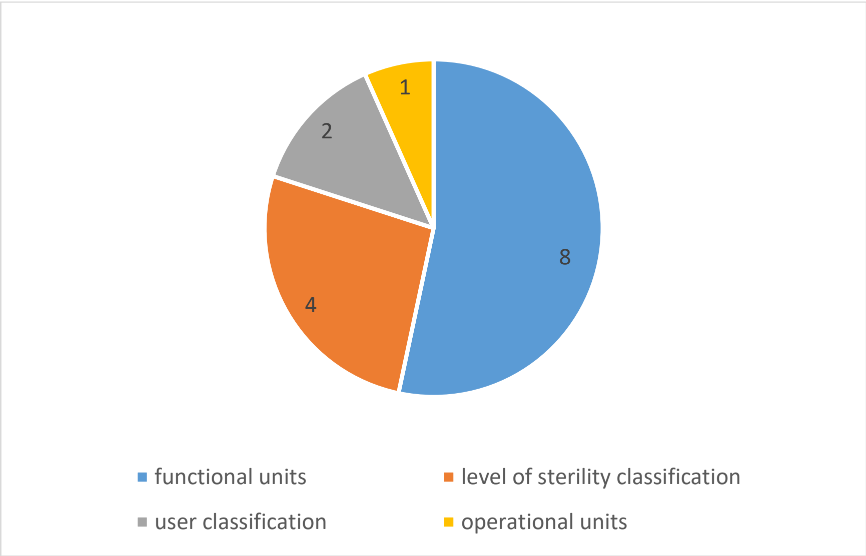

Figure 3.15: Answers to question 7

8 out of 15 participants have answered that functional classification will be more comprehensive. 1 person have answered user, 2 have answered operational and 4 have answered sterile works well in space classification. Since the majority of the answers is functional classification, space classification for the next stage will be made accordingly.

For the eight question, participants are asked to identify their own space classes while working on a surgery unit design process. This question was aimed for architects, but other participants have answered too.

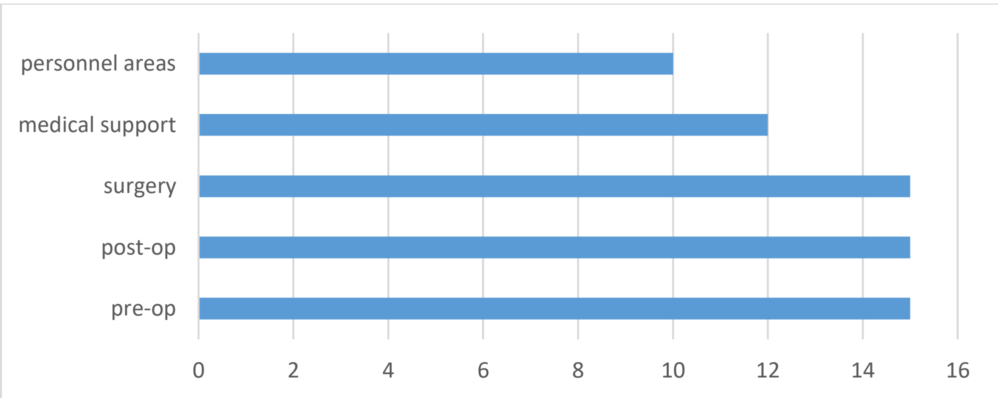

Figure 3.16: Answers to question 8

The answers comply with the studies from literature and participants' decision about functional classification. The zones have been decided accordingly. That is the functional flow is already defined in a surgery unit, this definition is used to describe the general zones. This creates the initial space classes which are;

- Entry/waiting
- Patient holding/pre-op
- Operating theatre
- Recovery/post-op
- Clinical support
- Staff area

The last question of the first step was a general question that frees the participants to write down the spaces they think necessary for the identification of surgery unit knowledge. The answers are collected without any counts since they will be used directly in the second step of the research. The spaces have been identified and grouped in functional units that decided after question eight. However, before that classification the answers are as follows;

Table 3.1: *Answers to question 9*

information desk for arrivals	sterile storage
patient/visitor waiting	medical storage
patient changing rooms	post-op bed bay
medical personnel changing rooms	equipment storage
administrative/personnel offices	utility rooms (clean, dirty)
interview room	medical equipment room
pre-op bed bay	pharmacy
anesthesia room	laboratory
medical personnel work desks	sterilization
consultation room	personnel work area
service rooms (cleaning, storage)	personnel changing
surgery room	personnel resting
scrub	office and meeting rooms

3.3.2. Step Two- Validation of Categorized List of Factors

After the completion of first stage of the Delphi research, second stage have been prepared. The purpose of this second survey is to provide participants with all the qualification items communicated through the first questionnaire and to determine the level at which they agree. Participants were asked to indicate opinion on each qualification item by writing any number from 1 to 7 on the scale in the parentheses at the beginning of the qualification item, 1 being “I certainly don’ t agree”, 7 being “I certainly agree” The answers from the first questionnaire was grouped according to literature review to better define the boundary of the research.

The first part in this stage is to identify the participant opinion on space classification. The classification mentioned above have been explained to users and their opinion on every group is asked. The majority of the participants agreed on the classification system.

Table 3.2: *Second Delphi Stage-question analysis part 1*

no	questions	Q1	MD	Q3	R
1	Entry/waiting	6	7	7	1
	Patient holding/pre-op	7	7	7	0
	Operating theatre	7	7	7	0
	Recovery/post-op	7	7	7	0
	Clinical support	6	7	7	1
	Staff area	5	6	7	1
2	Information desk/ reception	5	6	6	1
	Patient/visitor waiting	7	7	7	0
	Patient changing room	7	7	7	0
	Medical personnel changing room	7	7	7	0
	Administrative/personnel offices	6	7	7	1
	Interview room	5	5	7	2
3	Pre-op bed bay/patient room	7	7	7	0
	Anesthesia room	7	7	7	0
	Medical personnel workstation	7	7	7	0
	Consultation room	7	7	7	0
	Service rooms (cleaning, storage)	6	7	7	1
4	Operating room	7	7	7	0
	Scrub	7	7	7	0
	Sterile storage/sterilization	7	7	7	0
	Medical storage	7	7	7	0
5	Post-op bed bay/ patient room	7	7	7	0
	Equipment storage	5	6	6	1
	Utility rooms (clean, dirty)	5	5	6	1
	Medical equipment room	7	7	7	0
	Medical personnel workstation	7	7	7	0
6	Pharmacy	5	6	6	1
	Laboratory	5	6	6	1
	Sterilization	6	7	7	1
	Personnel work area	4	4	5	1
	Equipment room	5	6	6	1
	Storage	5	6	7	2
7	Personnel changing	5	5	5	0
	Personnel resting	6	6	6	0
	Office	6	6	6	0
	Meeting room	5	6	7	2

The analysis of the answers to the second Delphi questionnaire was carried out and the first quarter, median, third quarter and width values of each main cause item were determined. As Şahin points out, the low width value suggests that there is a consensus among the participants. On the comments sections, there have been some comments made about the classification. These comments are added to the third questionnaire.

The second part of the questionnaire is to identify space knowledge.

Table 3.3: *Second Delphi Stage-question analysis part 2*

no	questions	Q1	MD	Q3	R
8	Space name	7	7	7	7
	Space description (brief explanation of the space)	7	7	7	7
	Space type (medical, administrative, public etc.)	7	7	7	7
	Space user (patient, visitor, medical personnel etc.)	7	7	7	7
9	Space standards	7	7	7	0
	Finishes	4	5	5	1
	Fixtures and equipment	6	6	7	1
	Service requirements	6	7	7	1
	Access and control	7	7	7	0
10	Dimensions	4	4	7	3
	Medical requirements	7	7	7	0
	Workflow information	7	7	7	0
11	Wall	7	7	7	7
	Floor	7	7	7	7
	Ceiling	7	7	7	7
12	Storage	4	6	6	2
	Medical equipment	7	7	7	0
	Mechanical fixtures	5	6	6	1
13	Mechanical requirements	5	7	7	2
	Electrical requirements	5	7	7	2
	Medical Gas	5	5	6	1
	Wayfinding & Signage	1	2	2	1
	Acoustics	2	3	3	1
14	Infection control (sterile (+), sterile (-), non-sterile etc.)	7	7	7	0
	User access (restricted, semi-restricted, non-restricted etc.)	7	7	7	0
	Adjacency & relationships	6	6	7	1

On the comments sections, there have been some comments made about the classification. These comments are added to the third questionnaire. On the other hand, two of the items in the study have come up with very low median points. Therefore, wayfinding& signage and acoustics have been removed from question 13.

3.3.3. Step Three- Validation of Most Important Factors

When an analysis is made according to the median values obtained as a result of the third Delphi survey and the items with a median value of six or more are examined, it is clear that there is a consensus among all these classification items. Because the width value of all the items with a median value of 6 and above was realized as a value below 1 and 1.

The fact that all of these reasons are similar to those identified in the literature confirms the accuracy of the results obtained in this study.

The finalized classification table is as follows,

Table 3.4: *Delphi Results*

1	Entry/waiting
	Patient holding/pre-op
	Operating theatre
	Recovery/post-op
	Clinical support
	Staff area
2	Information desk/ reception
	Patient/visitor waiting
	Patient changing room
	Medical personnel changing room
	Administrative/personnel offices
	Interview room
3	Pre-op bed bay/patient room
	Anesthesia room
	Medical personnel workstation
	Consultation room
	Service rooms (cleaning, storage)

4	Operating room
	Scrub
	Sterile storage/sterilization
	Medical storage
5	Post-op bed bay/ patient room
	Equipment storage
	Utility rooms (clean, dirty)
	Medical equipment room
	Medical personnel workstation
6	Pharmacy
	Laboratory
	Sterilization
	Personnel work area
	Equipment room
	Storage
7	Personnel changing
	Personnel resting
	Office
	Meeting room
8	Space name
	Space description (brief explanation of the space)
	Space type (medical, administrative, public etc.)
	Space user (patient, visitor, medical personnel etc.)
9	Space standards
	Finishes
	Fixtures and equipment
	Service requirements
	Access and control
10	Dimensions
	Medical requirements
	Workflow information
11	Wall
	Floor
	Ceiling

12	Storage
	Medical equipment
	Mechanical fixtures
13	Mechanical requirements
	Electrical requirements
	Medical Gas
	Wayfinding & Signage
	Acoustics
14	Infection control (sterile (+), sterile (-), non-sterile etc.)
	User access (restricted, semi-restricted, non-restricted etc.)
	Adjacency & relationships

3.4. UML Representation of Space Classification in OR Unit

After the Delphi study, the data for the classification of space and space knowledge is achieved. However, the need to visualize this data remains. This structure of the data is not universal and is not open for updates. Therefore, ontological representation technique is chosen to visualize space classification. Ontology is a universal concept, defining a common vocabulary for professional, researchers basically for people who need to share information or data in domain. (Noy & McGuinness, 2001)

One of the most popular definition of ontology is made by Gruber (1993), that is "an explicit specialization of a conceptualization" In this explanation conceptualization refers to a simpler view of the subject and specification indicates a more formal representation of the subject that is machine readable. (Fidan, 2008) Ontology enables a classification system in a systematic manner that analyzes existing things in a structured way. That is, ontology is a knowledge type used by knowledge-based systems. (Jain and Mishra, 2014).

UML is short for Union of all Modelling Languages. UML is a language for representing, visualizing and documenting of the specified items of an object-oriented (OO) system. (Ou, 1998) UML defines elements, relationship between elements, mechanisms that organize the elements and representation of them in diagrams. One of the mostly used diagram that is supported by UML is class diagrams. UML provides simple and clear structuring of data that can be used to model items in real world.

A class is effectively a template from which objects are created. (Agile,n.d.) There are three principal kinds of relationships which are important:

- Association - represent relationships between instances of types (a person works for a company; a company has a number of offices.
- Inheritance - the most obvious addition to ER diagrams for use in OO. It has an immediate correspondence to inheritance in OO design.
- Aggregation - Aggregation, a form of object composition in object-oriented design.

For the structure of the diagram aggregation and association relationships are used. They are represented as follows;

Figure 3.17: Notation for association (Agile, n.d.)

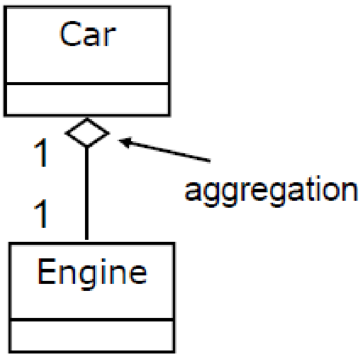

Figure 3.18: Notation for aggregation (Agile, n.d.)

Multiplicity in UML is shown in a domain model and indicated outside concept boxes, it indicates object quantity relationship to quantiles of other objects.

Table 3.5: *Multiplication indicators (Agile, n.d.)*

Indicator	**Meaning**
0..1	Zero or one
1	One only
0..*	Zero or more
1..*	One or more
n	Only *n* (where *n* > 1)
0..n	Zero to *n* (where *n* > 1)
1..n	One to *n* (where *n* > 1)

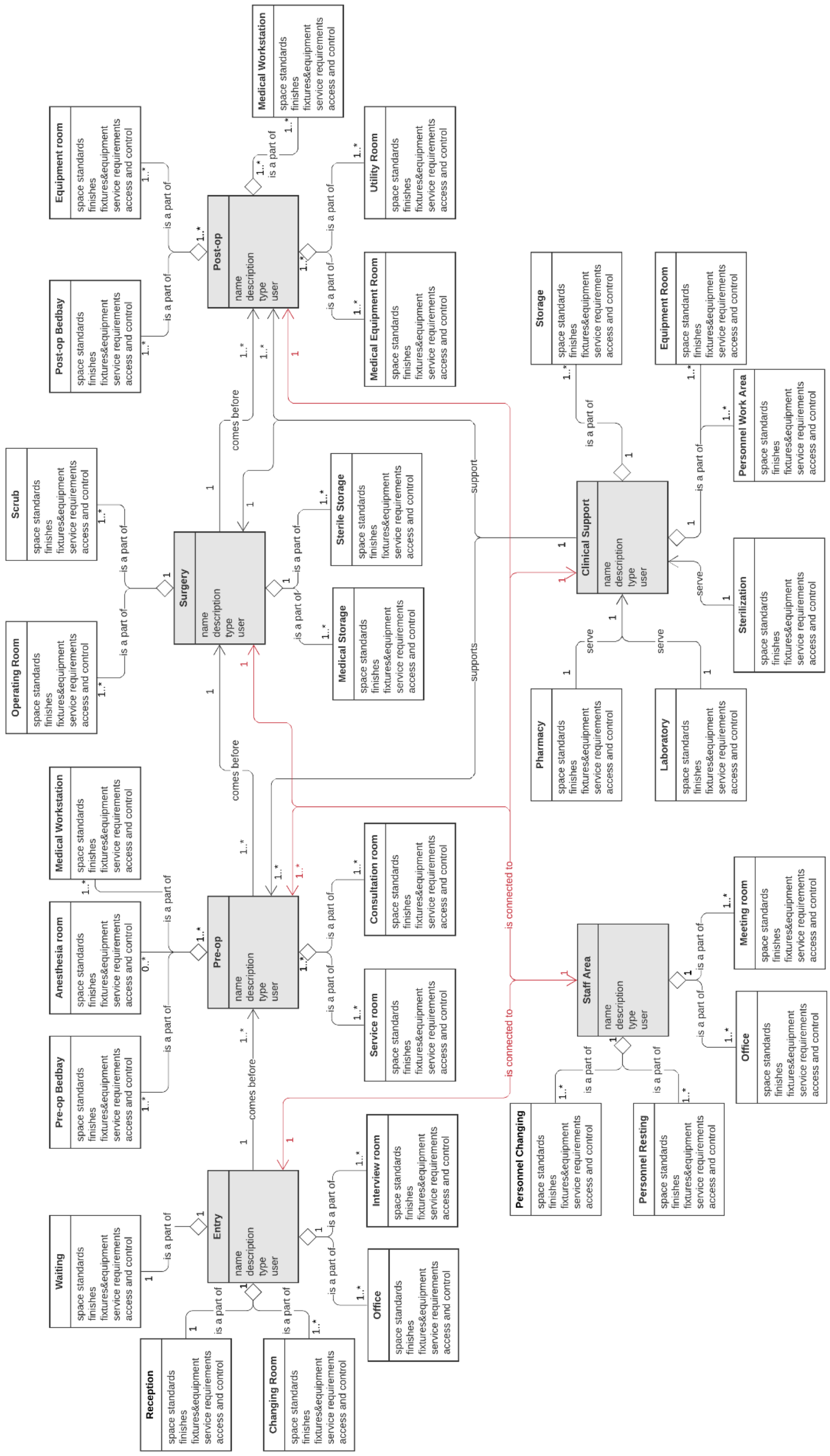

Figure 3.19: Class diagram of Space Classification in OR Unit in Hospitals

3.5. Material

The main objective of this research was to enhance information flow quality in healthcare facility design and to standardize tacit knowledge in a format that can be shared amongst professionals. For this process the smallest part of the architectural design, the space in facilities have been chosen to be studied on. The reason to work with spaces is that, architects are obliged to organize and design spaces effectively and creatively for the purpose of the building, space planning is one of the essential tasks in building design. (Yin and Yin, 2014) Methodology for this purpose is explained above. In order to achieve an efficient knowledge management technique, first the knowledge acquisition and knowledge share processes have been standardized to be managed. The research is made to create a classification system that works among practitioners to share knowledge and use developed knowledge in the early design stages. The materials for this methodology are the guidelines for healthcare design, the practitioners working in the field of healthcare facility design, a visualization tool to represent the codified knowledge and evaluation of expert opinion on the methodology.

dRofus is a planning, data management, and BIM collaboration tool. dRofus provides all stakeholders with comprehensive workflow support and access to building information throughout the building lifecycle. Therefore, since BIM is the current best way for architectural design, construction and operation process, dRofus is chosen for the visualization for the knowledge structure. dRofus logic and process have been explained to a group of architects and their perception on the benefits of the process is explained in the next chapter.

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, the objectives of the research are assessed, the visualization of knowledge transfer process and its benefits are discussed. The importance and efficiency of BIM tools have been mentioned in the previous chapters. An efficient data management methodology is achievable when all stages of a building including operation and management is considered. Therefore, 5 of the participants from Delphi research have been chosen to discuss and evaluate the methodology that has been structured. The importance of these 5 architects is that, that are familiar with the BIM concept, however, currently are working with CAD software. The study has been explained to them and first the knowledge management steps, and the necessity of KM strategy is relayed to participants. Then they are asked to compare the processes in terms of ease, time and efficiency in semi-structured interviews. After this another objective is studied with them. The knowledge gained can be transferred best when the process involves the users of the data, architects. A tool for structuring a database and transferring knowledge have been chosen and it can work with BIM software collaboratively. The data structure in this program is explained to participants in semi-structured interviews and their perception and evaluation will be shared in the next chapters.

4.1. Knowledge Management Practice Assessment

The importance of knowledge management has been studied and the stages of knowledge management is the key to a successful process. The stages of knowledge management have been explained in literature. The explanation is also made to participants and they are asked to compare the process of knowledge management with explained process and their current situation.

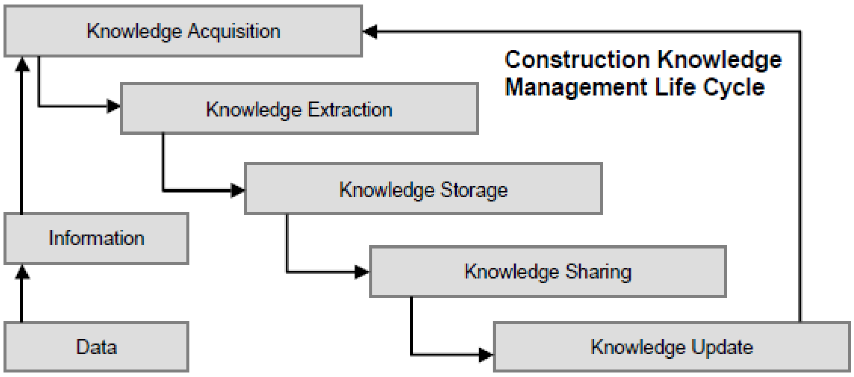

Figure 4.1: Knowledge management life cycle stages. (Lin and Tserng, 2003)

Architect 1

Architect 1 is an architect with experience total of 8 years, 7 being related with healthcare projects. She worked in a project firm and now is working in a construction company as a design office architect. When she is asked to evaluate the current situation of knowledge management processes, she mentions that the acquisition of knowledge in individuals mind is very difficult. People are unwilling to share the knowledge they gained and when there is no control mechanism over knowledge share, they simply prefer not to share. Therefore, she emphasizes that without the individual knowledge she gained through her career it will be very difficult to make decisions during design stage. On the other hand, there are several hospital projects are being designed and constructed in the firm that she works. The knowledge in each project is evolving, however, it is nearly impossible to gain that knowledge. She explains that the knowledge she already finds is not very easy to use because it is necessary to check previous projects, even as-builts of previous projects since the changes could have been made during the construction stage. Therefore, she also mentions that knowledge update process doesn’t work properly.

When the methodology that has been created for this research explained, she agreed space knowledge need to be standardized for an efficient knowledge share. Motivating people on where to put which knowledge will make a great contribution to share individual knowledge. Without a classification system she agreed that the knowledge could easily be lost, and architects might fail to follow which knowledge is valuable. She agrees that this methodology will support an efficient and less time-consuming design process of healthcare facilities.

Architect 2

Architect 2 is an architect with experience total of 10 years 6 being related with healthcare projects. He has worked in healthcare facility construction project in the field and now he is working as project architect in a construction firm. When he is asked to evaluate the current situation of knowledge management processes, he mentions that the knowledge storage phase is very problematic. He explains that they have made an excel file to store the decisions made during different projects, however the knowledge is quite tangled and the process of finding or adding knowledge is disincentive since it takes quite a lot of time and never works properly. Some likes to make a summary of the knowledge in their own way, therefore while checking for an information sometime the important parts can be missing. Therefore, he prefers to move on according to his own opinion and he also fails to share the knowledge he has. The explanation for that is, without a proper tool or a data structure it is difficult to assess which knowledge to give, thus he prefers to explain the decision he makes during design stage when asked.

When the methodology that has been created for this research explained, he agreed that two important things space knowledge and workflow need to be standardized for an efficient knowledge share. Knowledge management system fails when individuals are not aware of the acquisition, storage, share and update processes. With a proper classification of knowledge, they can easily track information and embed in their design projects. He agrees that this methodology will support an efficient and less time-consuming design process of healthcare facilities.

Architect 3

Architect 3 is an architect with experience total of 12 years, 12 being related with healthcare projects. She worked in a project firm and now owns her own project firm. When asked to evaluate the current situation of knowledge process, she explains that with her expertise she is the knowledge database in her firm. When needed she consults expert opinion but other than that she uses her own knowledge while designing a healthcare facility. However, the challenge she faces is that, work of architects working with her need to be checked. In other words, people with not much know-how on healthcare facilities more tend to make mistakes while designing. Therefore, for critical issues she checks the design later or interferes with the design process. This is considered to be useful however, time consuming and doesn't improve nor the design knowledge neither individuals' mind.

When the methodology that has been created for this research explained, she agreed that two important things space knowledge and workflow need to be standardized for an efficient knowledge share. As the scale increases in healthcare facilities, the control mechanism fails to provide an efficient work. However, with a knowledge system that can be evolved through expertise and lessons learned, individuals can easily control their own design and determine the missing parts or mistakes. She agrees that this methodology will support an efficient and less time-consuming design process of healthcare facilities.

Architect 4

Architect 4 is an architect with experience total of 13 years, 10 being related with healthcare projects. She worked in a project firm, owned her own project firm and now working as a design office chief in a healthcare construction project. When she is asked to evaluate the current situation of knowledge management processes, she mentions that control of people working with her is very difficult. She works with nearly 8 architects and several MEP designers that she needs to check and control. However, she argues that it is very difficult to circulate knowledge or decisions around them is very difficult to control. Sometime when the knowledge is not shared properly design mistakes occur with a huge impact on the constructed process. The stress and the constant need for awareness always occupies her to manage her duties as a chief which results in inefficient time management and quality of the final product.

When the methodology that has been created for this research explained, she agreed that two important things space knowledge and workflow need to be standardized for an efficient knowledge share. Knowledge management system fails when individuals are not aware of the acquisition, storage, share and update processes. With a proper classification of knowledge, they can easily track information and embed in their design projects. However, she argues that this classification should be available to all project participant and all project knowledge should be acquired through same classification system. Sometimes different disciplines want to cross-check the information embedded in the design process, thus it will be better to standardize knowledge for all disciplines. She agrees that this methodology will support an efficient and less time-consuming design process of healthcare facilities with some adding.

Architect 5

Architect 5 is an architect with experience total of 15 years, 7 being related with healthcare projects. She is working as a project manager in a construction company. When she is asked to evaluate the current situation of knowledge management processes, she mentions that the acquisition of knowledge in individuals mind is very difficult. The company have gained an individual understanding on healthcare projects and as the number of projects increased the knowledge have developed in favor of efficient design. However, it is very difficult to maintain this process with only project architects. Knowledge in building environment is from different disciplines and different stages, therefore a broader methodology is needed. In other words, to motivate participants to extract the knowledge they gained through process is necessary since in the circulating working environment in construction sector knowledge can be lost easily.

When the methodology that has been created for this research explained, she agreed that two important things space knowledge and workflow need to be standardized for an efficient knowledge share. This type of knowledge share system will create a easy environment for architects to study what is expected to be designed and what is the expected outcome in a healthcare facility. In addition, to be able to rack workflow individually is a big opportunity, since a simple design defect can cause immense impacts on hospital efficiency. She agrees that this methodology will support an efficient and less time-consuming design process of healthcare facilities.

The participant of the interview agreed that a standardization in design knowledge will increase the quality of design process and end-product. However, until now the standardization process has been only in data format. For a better understanding of the methodology a visualization of this process is necessary. BIM environment works with all aspect of the buildings, participants are aware of that. The interest in BIM software is increasing, therefore they are willing to ease the knowledge management process via BIM methodology. Most of them are working in public-private partnership city hospitals and they are aware that facility management of these hospitals play important role in the design stage. Hence what has been achieved through methodology studies is embedded to a database tool dRofus in order to evaluate architects' viewpoint on working with a knowledge management tool via BIM.

4.2. dRofus, A Tool for Space Planning and Data Management

dRofus is developed in 2011 as a hospital planning software. From then, dRofus has been developing itself as a data management program by providing a BIM collaboration. Participants of the project can access a cloud-based environment and work/manage their part of the project. dRofus provides a maintenance process of data through a building's life cycle. Planning, construction, operation and maintenance are all a part of dRofus tool. It is a data central platform with lots of different aspects.

BIM plug-ins are available with dRofus and data linkage is bidirectional and real-time. Information exchange between architectural model and dRofus database helps to fulfill design objectives without interrupting the workflow.

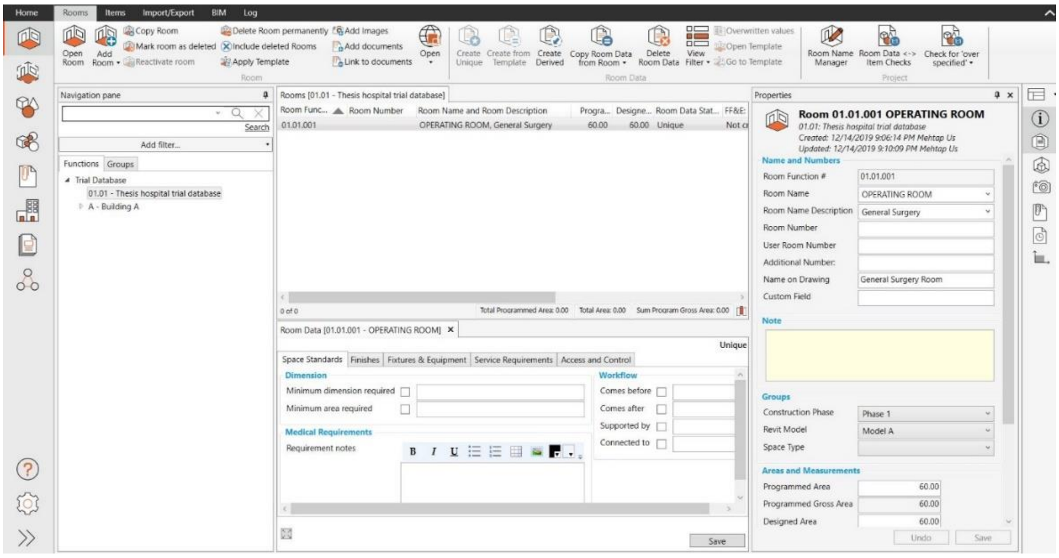

Figure 4.2: Overview of dRofus

Every type of information, from documents to knowledge, from images to guidelines can be inserted in dRofus and can be reached from anywhere. This information can be structured into templates and these templates provide standardization in spaces and changes made in the templates can be directly inserted in the architectural design process. Therefore, with dRofus, knowledge can be transferred into design process continuously which can evolve through other stages as well and transferred into iterative projects. dRofus also provides a link between IFC, Excel, Cobie, various facilities management format.

For this research, to practice knowledge management life cyle for hospital architectural design process “room data sheet” feature of dRofus is used. The knowledge management stages have been analyzed, the necessity of knowledge has been identified through research and this tool provides a visualization and easy usage of the knowledge. The room data panel in dRofus has been altered according to the classification research and the attributes created in the UML study is implemented as knowledge asset of the spaces.

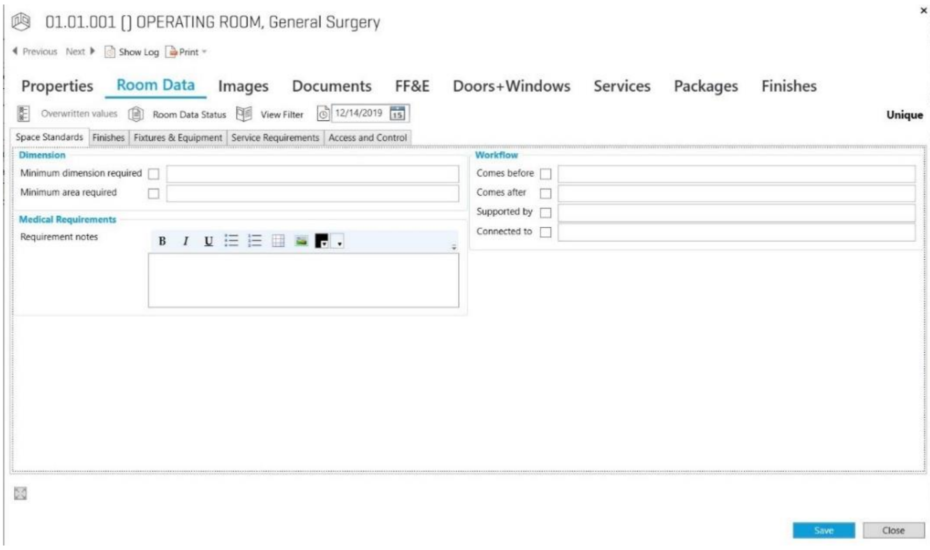

Figure 4.3: Developed Room Data Panel with altered RDS Knowledge (space standards)

The ontological study of workflow will be planned to work as a design control mechanism. That is, the relation of the spaces will be checked according to the ontological work. The structured template is identified and explained to the research group. Their evaluation on this program will be explained.

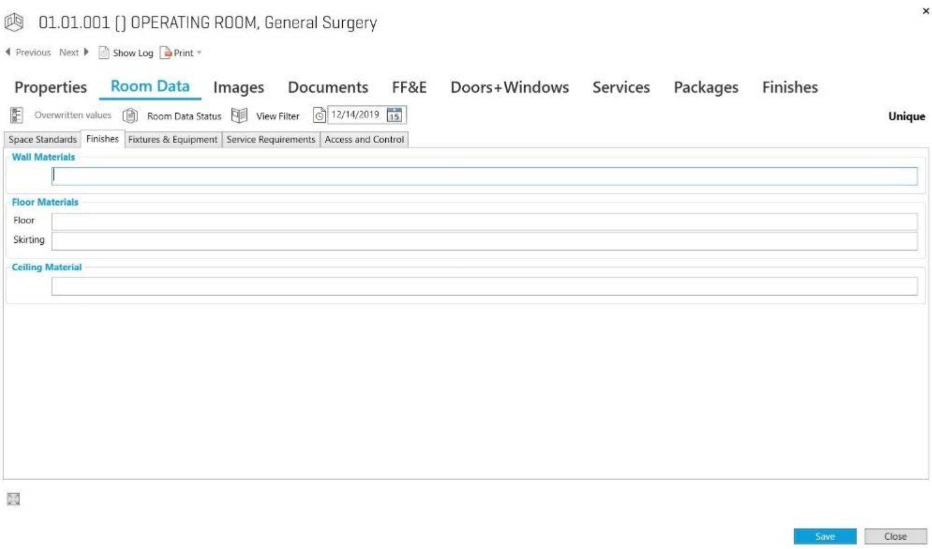

Figure 4.4: Developed Room Data Panel with altered RDS Knowledge (finishes)

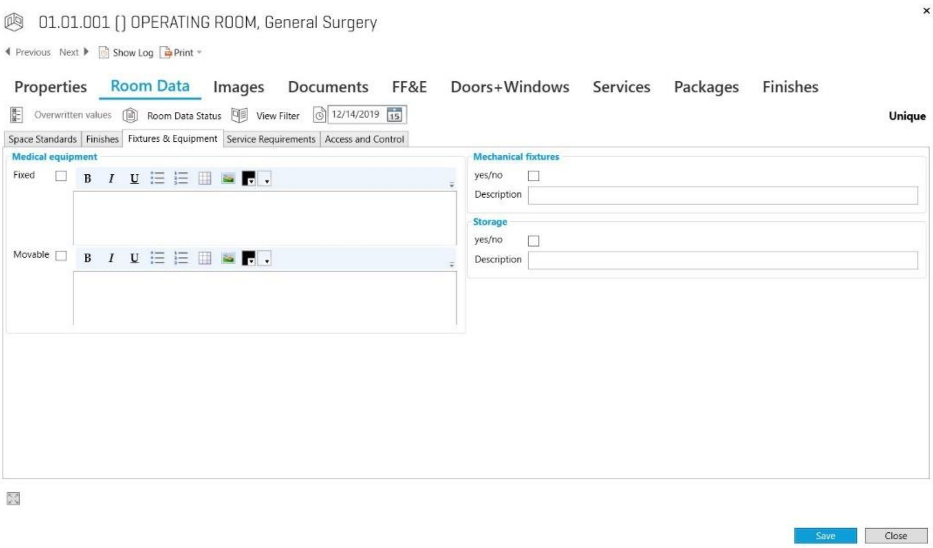

Figure 4.5: Developed Room Data Panel with altered RDS Knowledge (fixtures & equipment)

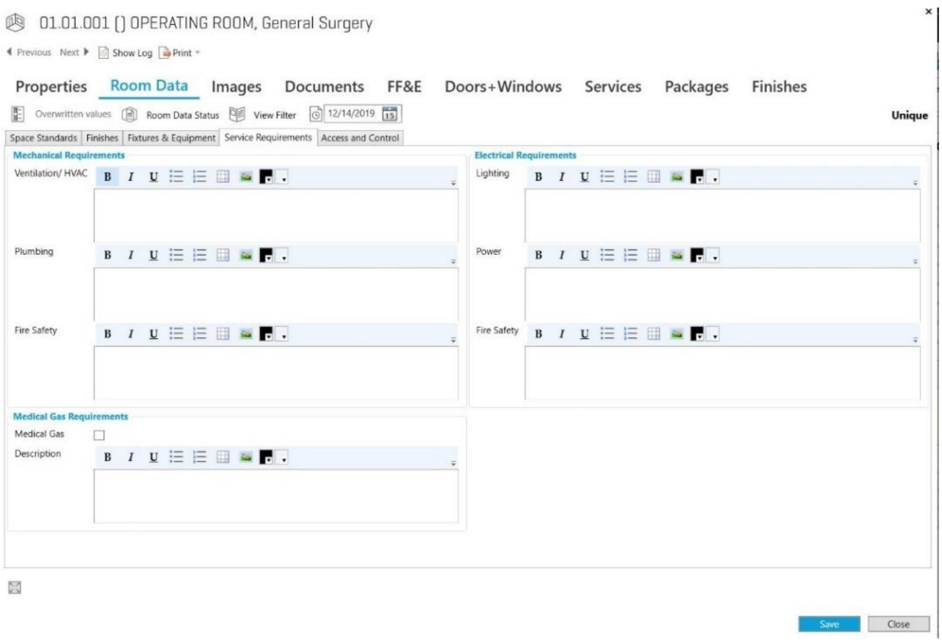

Figure 4.6: Developed Room Data Panel with altered RDS Knowledge (service requirements)

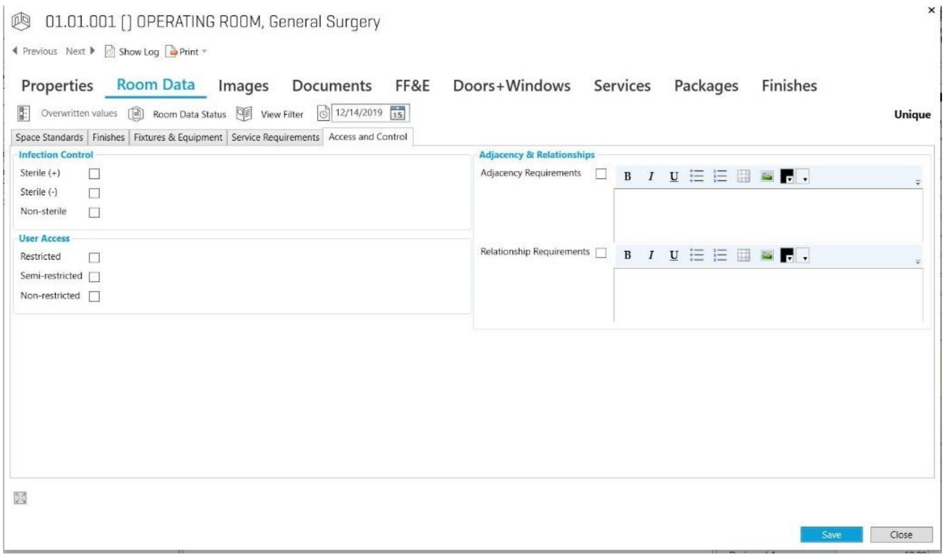

Figure 4.7: Developed Room Data Panel with altered RDS Knowledge (access and control)

The presentation of the tool is made to research group and are asked what their attitude would be when they are to use this tool for knowledge management. The general idea is that, managing knowledge in a separate tool is a promising method. The design process and data management process can be worked separately and updated virtually. The most beneficial of dRofus is that it holds the information and creates a link between architectural drawings without manual interruption.

The illustration is made according to Revit, which is the most known BIM software among researchers.

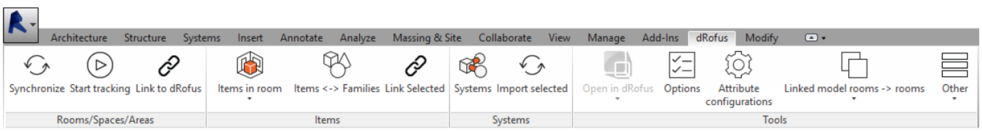

Figure 4.8: dRofus ribbon in Revit

The connection of dRofus wih Revit starts from implementing room tag to spaces. The templates created and assigned to rooms in dRofus automatically inserted into Revit model. And this process can be arranged according to the information that the user wants to transfer.

While designing spaces in Revit, when the connection with dRofus is made, the space automatically inserts the template information assigned in dRofus and this creates a control mechanism over the assigned attributes.

4.3. Discussion

The aim of this research is to create a standardized knowledge acquisition and knowledge re-use process for healthcare facilities. As explained in the first chapter, a taxonomical knowledge share strategy decreases the knowledge loss that will have a direct effect on quality of the project.

First step for achieving a result for this aim, a research for creating a proper space classification is made. The hospital is a complex building type and with classification the architects' attempt to develop an efficient design process is aimed. For this, practitioners of healthcare facility design have been included in the research since expert opinion plays an important role in hospital design. The information gathered from guidelines, design regulations and experts have been validated three times and a final classification table is achieved. This taxonomy can be used to gather and share knowledge. Not only explicit knowledge but also tacit knowledge can be transferred into this data format. However, this classification table is purely data and for this data to be transferred into knowledge, it needs to be visualized for an easy use.

The workflow in hospital design have been emphasized through the research process. For this reason, to visualize and provide a vivid control mechanism to workflow, the classification of the spaces have been visualized through an ontological representation. With UML class diagram the knowledge is tried to be standardized. This representation also aims to provide an easy way of updating design planning.

These studies than discussed with architects in order to achieve the enhancement of information flow quality in space design and ease the participation of architectural designers in knowledge management process objective. Participants are satisfied with the classified space knowledge information and workflow representation. To show a better representation of knowledge management in design process, a database tool is chosen for BIM integration since BIM is accepted as a developed design methodology for the sector. Participants agree in the methodology of dRofus, since it works as a live database tool for architectural projects. The objective of integrating knowledge management process into design and making it as easy as possible for the architects is tried to be achieved. With different positions and different ages, participants agree that dRofus has the capability of enhancing knowledge acquisition, knowledge storage and knowledge share processes in architectural design.

CHAPTER 5

CONCLUSION

In this chapter, the literature review for this study, the methodology of the thesis and results of the study will be analyzed. The study is made in five chapters. First chapter explained the background information, aim and objectives of the study and the contribution to the literature. In the second chapter, a literature study on knowledge management, space design, space layout design, healthcare space design and space regulations. These studies showed that a clearly defined methodology on knowledge management strategy in complex construction projects like healthcare facilities can enhance design quality and facilitate a time saving process of creating an end-product.

5.1. Summary of the Research

The scope of this study comprises visualization of design knowledge for knowledge management in healthcare facilities. Literature review have shown that the knowledge gained in each project have direct effect on the latter ones. With the developments and changes in design of facilities, the necessity to accomplish good design examples arises and good design is directly related with the efficiency of the building. Efficiency of the building can be achieved in the design stage. The smallest part in the facilities is space and space information give the answer to most of the design problems. Early studies in space management have been on space layout design concept. Space layout design works mainly on location and dimension of the spaces. Although these studies have been supported by various attributes, the embedded knowledge in spaces have not been studied in space design concept. Hospital is one of the most complex building types. Spaces in hospitals carry variety of knowledge from other building types. The design studies on hospitals have shown that, any error in hospital design stage could lead to building or operation defects. Therefore, studying on hospital spaces was a critical subject. For the study the most risk intensive space the surgery unit is chosen.

The main aim of this study was to create a standardized knowledge acquisition and knowledge re-use process for healthcare facilities. For this first a classification of space and space knowledge in surgery unit is made. This classification is made via expert opinion, guidelines and regulations on hospital design. Then this process also show that knowledge works better in knowledge management processes when visualized. To be able to integrate knowledge management process into design stage, the classification of spaces is represented in class diagram format. The research process has shown that workflow is one of the most important features in hospital design and this study can be seen as a subset of space layout design. After the visualization of spaces, the diagram is discussed with healthcare design architects. The contribution of this diagram and the knowledge process to healthcare design is commented on. Another visualization of data is made through a data management too that can easily collaborate with BIM software. The integration of knowledge management as a part of design stage is increasing the quality of design and decreases the limitations of knowledge management.

5.2. Main Results

The classification of knowledge in any terms is beneficial. To track down the data in an architectural design process is always beneficial. The objectives of this study were to integrate this process into architectural design. Therefore, structuring data in a format that can easily be obtained, stored, shared and updated have created a positive approach to knowledge management existence. The standardization of space data has put forward a new approach to tacit knowledge use. The guided knowledge can evolve and change via expertise, lessons learned etc. The knowledge management needs to be promoted, so that end product can gain efficiency, time can be used effectively and the unwillingness to share knowledge can be minimized.

BIM is in the ascendant in building design, construction and operation. For most of the project architects need to consider the life-cycle of the buildings. Automation design give the opportunity for design process to be used to optimize building layout, evaluate the best use, optimization of plans and foresee the possible problems in the early stage. Therefore, combining data management with a software that can transfer data from design to operation is a multi-tasking work that promotes knowledge management for all building stages.

The study has given a general understanding of knowledge management, space design and healthcare space design concepts. The knowledge representation methods have been discussed positively by healthcare architects and the visualization in a tool have proved that knowledge management in spaces can be embedded in architectural design process.

5.3. Future Work Recommendations

The limitations of the study included the variety of knowledge on healthcare design and the lack of awareness of this information in the design sector. It was difficult to find research participants with universal hospital design point of view. Another limitation is that, the hospital is a very complex building type with different space aspect. Scaling down the borders of the study required lots of literature work on hospital design.

The study is made on healthcare facilities since they are a complex building type. On the other hand, the surgery unit is chosen for the research as it is a very risk intensive space. The study for space representation and space knowledge classification is made for architectural design stage. However, hospital spaces require various knowledge types as well as architectural knowledge. The study can be expanded to comprise structural, mechanical and electrical knowledge as well. Moreover, the study can be expanded to general hospital layout for the future studies and implementation of the structured databases into an existing architectural hospital project and used for space design.

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APPENDICES

A. DELPHI RESEARCH STAGE I

1- What is your occupation?
2- What is your total expertise?
3- How many years of your expertise did you work on healthcare facilities?
4- What resources do you use in the design and implementation of operating room units? (you can mark more than one)
    - International Guidelines (Australia, UK..)
    - National Guidelines
    - Project Examples
    - Lessons-Learned and Know-How
    - Expert/Consultant Opinion
5- Unlike other building types, what information do you think is necessary to describe the spaces in a hospital?
6- What information do you think is necessary to identify spaces in an operating unit?
7- Which classification do you prefer when the rooms in the operating room need to be classified and information collected?
    - Functional Units
    - Operational Units
    - Level of Sterility
    - User Classification
8- How would you name space classes while designing or specifying the spaces in a hospital? (like bubble diagram, how will you start designing?)
9- Write down the places that you think it is crucial to collect information for the design of the surgery unit and to minimize the error in the design. (operating room, clean laundry room, patient preparation etc.)

APPENDICES

B. DELPHI RESEARCH STAGE II

The purpose of this second survey is to provide you with all the qualification items communicated through the first questionnaire and to determine the level at which you agree. You are asked to indicate opinion on each qualification item by writing any number from 1 to 7 on the scale in the parentheses at the beginning of the qualification item, 1 being “I certainly don’ t agree”, 7 being “I certainly agree”

Please write down your comments under every question if you have any.

1- Please indicate you level of agreement on the functional classification of surgery unit spaces.
   - ☐ Entry/waiting
   - ☐ Patient holding/pre-op
   - ☐ Operating theatre
   - ☐ Recovery/post-op
   - ☐ Clinical support
   - ☐ Staff area

   Comments:

2- Please evaluate the space classification made for “Entry/waiting”
   - ☐ Information desk/ reception
   - ☐ Patient/visitor waiting
   - ☐ Patient changing room
   - ☐ Medical personnel changing room
   - ☐ Administrative/personnel offices
   - ☐ Interview room

   Comments:

3- Please evaluate the space classification made for “Patient holding/pre-op”

- ☐ Pre-op bed bay/patient room
- ☐ Anesthesia room
- ☐ Medical personnel workstation
- ☐ Consultation room
- ☐ Service rooms (cleaning, storage)

Comments:

4- Please evaluate the space classification made for “Operating Theatre”

- ☐ Operating room
- ☐ Scrub
- ☐ Sterile storage
- ☐ Medical storage

Comments:

5- Please evaluate the space classification made for “Recovery/post-op”

- ☐ Post-op bed bay/ patient room
- ☐ Equipment storage
- ☐ Utility rooms (clean, dirty)
- ☐ Medical personnel workstation

Comments:

6- Please evaluate the space classification made for “Clinical support”

- ☐ Pharmacy
- ☐ Laboratory
- ☐ Sterilization
- ☐ Personnel work area
- ☐ Equipment room
- ☐ Storage

Comments:

7- Please evaluate the space classification made for “Staff area”

- ☐ Personnel changing
- ☐ Personnel resting
- ☐ Office
- ☐ Meeting room

Comments:

8- Please indicate your level of agreement on the attributes of defining basic space knowledge.

- ☐ Space name
- ☐ Space description (brief explanation of the space, relationship within hospital spaces)
- ☐ Space type (medical, administrative, public etc.)
- ☐ Space user (patient, visitor, medical personnel etc.)

Comments:

9- Please indicate your level of agreement on classification of defining detailed space knowledge.

- ☐ Space standards
- ☐ Finishes
- ☐ Fixtures and equipment
- ☐ Service requirements
- ☐ Access and control

Comments:

10- Please evaluate the classification made for defining “space standards”

- ☐ Dimensions
- ☐ Medical requirements
- ☐ Workflow information

Comments:

11- Please evaluate the classification made for defining “finishes”

- ☐ Wall
- ☐ Floor
- ☐ Ceiling

Comments:

12- Please evaluate the classification made for defining “fixtures and equipment”

- ☐ Storage
- ☐ Medical equipment

Comments:

13- Please evaluate the classification made for defining “service requirements”

- ☐ Mechanical requirements
- ☐ Electrical requirements
- ☐ Medical Gas requirements
- ☐ Wayfinding & Signage
- ☐ Acoustics

Comments:

14- Please evaluate the classification made for defining “access and control”

- ☐ Infection control (sterile (+), sterile (-), non-sterile etc.)
- ☐ User access (restricted, semi-restricted, non-restricted etc.)

Comments:

APPENDICES

C. DELPHI RESEARCH STAGE III

The purpose of this third survey is to provide you with all the evaluated items communicated through the second questionnaire and to determine if you still agree or have comments to add. The process is the same, you are asked to indicate opinion on each qualification item by writing any number from 1 to 7 on the scale in the parentheses at the beginning of the qualification item, 1 being “I certainly don’ t agree”, 7 being “I certainly agree”

Please write down your comments under every question if you have any.

1- Please indicate you level of agreement on the functional classification of surgery unit spaces.
   - □ Entry/waiting
   - □ Patient holding/pre-op
   - □ Operating theatre
   - □ Recovery/post-op
   - □ Clinical support
   - □ Staff area

   Comments:

2- Please evaluate the space classification made for “Entry/waiting”
   - □ Information desk/ reception
   - □ Patient/visitor waiting
   - □ Patient changing room
   - □ Medical personnel changing room
   - □ Administrative/personnel offices
   - □ Interview room

   Comments:

3- Please evaluate the space classification made for “Patient holding/pre-op”

- ☐ Pre-op bed bay/patient room
- ☐ Anesthesia room
- ☐ Medical personnel workstation
- ☐ Consultation room
- ☐ Service rooms (cleaning, storage)

Comments:

4- Please evaluate the space classification made for “Operating Theatre”

- ☐ Operating room
- ☐ Scrub
- ☐ Sterile storage/sterilization
- ☐ Medical storage

Comments:

5- Please evaluate the space classification made for “Recovery/post-op”

- ☐ Post-op bed bay/ patient room
- ☐ Equipment storage
- ☐ Utility rooms (clean, dirty)
- ☐ Medical personnel workstation
- ☐ Medical equipment room

Comments:

6- Please evaluate the space classification made for “Clinical support”

- ☐ Pharmacy
- ☐ Laboratory
- ☐ Sterilization
- ☐ Personnel work area
- ☐ Equipment room
- ☐ Storage

Comments:

7- Please evaluate the space classification made for “Staff area”

☐ Personnel changing

☐ Personnel resting

☐ Office

☐ Meeting room

Comments:

8- Please indicate your level of agreement on the attributes of defining basic space knowledge.

☐ Space name

☐ Space description (brief explanation of the space, relationship within hospital spaces)

☐ Space type (medical, administrative, public etc.)

☐ Space user (patient, visitor, medical personnel etc.)

Comments:

9- Please indicate your level of agreement on classification of defining detailed space knowledge.

☐ Space standards

☐ Finishes

☐ Fixtures and equipment

☐ Service requirements

☐ Access and control

Comments:

10- Please evaluate the classification made for defining “space standards”

☐ Dimensions

☐ Medical requirements

☐ Workflow information

Comments:

11- Please evaluate the classification made for defining "finishes"

- ☐ Wall
- ☐ Floor
- ☐ Ceiling

Comments:

12- Please evaluate the classification made for defining "fixtures and equipment"

- ☐ Storage
- ☐ Medical equipment
- ☐ Mechanical fixtures

Comments:

13- Please evaluate the classification made for defining "service requirements"

- ☐ Mechanical requirements
- ☐ Electrical requirements
- ☐ Medical Gas requirements

Comments:

14- Please evaluate the classification made for defining "access and control"

- ☐ Infection control (sterile (+), sterile (-), non-sterile etc.)
- ☐ User access (restricted, semi-restricted, non-restricted etc.)
- ☐ Adjacency & relationships

Comments: