Sudan University of Science and Technology

Collage of Architecture and Planning

Collage of Graduate Studies

SMART SYSTEMS IN HOSPITALS

CASE STUDY:

AL-SALAM CENTRE FOR CARDIAC SURGERY,,

الأنظمـة الذكيـة فـي المستشفيـات

دراسة حـالـــــة: مـركـز السـلام لجراحـــة القلـب،،

A Thesis Submitted for the Partial Fulfillment of Requirement of (M.Sc.) in Building Services

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الآيـــــة:

﴿ وَإِذَا مَرِضْتُ فَهُوَ يَشْفِينِ ﴾

(الشعراء : 80)

Dedication

This work is dedicated to my parents.

To my father soul, who fingerprints of grace on our life, shall not be forgotten.

To my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

Also to my brothers and sisters whom i am truly grateful for having in my life.

This thesis is dedicated to my best friends, who have always been a constant source of support and encouragement during the challenges of my whole life, those who I swear I will go anywhere with them.

To that One's, because of his continued support and love throughout writing this research and within my own life.

He has supported me in ways than anyone else.

Acknowledgment

First and foremost, i have to thank my parents for their love and support throughout my life.

I thank you both for giving me strength to reach for and chase my dreams.

I would like to sincerely thank my supervisor Dr. Saleem Elzain for his guidance and support throughout this study and to give me all kind of advices.

Most of all i must thank the managers of Al-Salam Centre for giving me an opportunity to make my case study on their hospital and spare time for answering all my questions about their Smart systems.

Last but not least, thanks will not be enough for you my soul mate. My love for you will never die.

Thank you God for always being there for me.

This research is only a beginning of my journey.

Abstract

At the present time, architecture has not been immune to the technological development that has taken place in the world. Modern technologies have begun to modernize architecture, making them think, analyze, decide and implement.

It is known that the internal environment of hospitals is considered as a catalyst for healing, which has become one of the topics that reflect the thought of the world and show the extent of intellectual development in the field of hospital design, which developed from the concept of designing an internal environment in which the principles and design criteria are considered to be more than a comprehensive and integrated concept linking architectural and interior design with Both as the most important component of the patient's healing environment.

So mankind thought that technology could serve society and future generations in energy conservation and link them with the design and implementation of public buildings and private hospitals. Smart buildings were created and intelligent control systems were installed, capable of making, deciding and controlling all the functions of the building (conditioning, lighting, firefighting, and entering patient data and many more). One of the most important of these systems is the Intelligent Building Management System, which plays the role of the thinking mind in the building, which is a central computer unit connected to the rest of the systems by wired and wireless communication. One of the most important benefits of this system is its ability to manage building energy, as well as providing convenience to users, ease of dealing with the building and increase the safety factor and comfort in it.

The use of these systems in the world has spread significantly in all hospitals of different types, but its use in Sudan is limited in a narrow framework is almost non-existent due to the lack of Sudanese companies specialized in these systems, and may be the reason for this lack of sufficient awareness of the importance of the system or fear of its costs in the belief It is expensive or not accepted by society or not yet aware of the idea of smart systems and their uses in hospital buildings.

Based on the above, some questions have been asked whether is there any possibility to introduce smart techniques within our hospitals in Sudan or why the architectural space of hospitals is not designed to meet all patients' needs and many more.

The used methodology of this research in the theoretical framework is based on the historical and descriptive approach by collecting information from sources and references in different languages related to this matter, and in the practical field, it relies on the analytical approach to the collected information on the case study after interviewing specialists concerning this matter.

However, some solutions may lie in spreading sufficient awareness of the importance of the system and the necessary facilities for investment in the system and coordination between the countries and companies wishing.

المستخلص

لم تكن العمارة في وقتنا الحالي بمنأى عن التطور التكنولوجي الذي لحق بالعالم، فبدأت التقنيات الحديثة في دورها لتحديث العمارة وصنعت منها كتلاً تفكر وتحلل وتقرر وتنفذ، كل ذلك لراحة المستخدمين وصنع بيئة مثالية.

ومن المعروف أن البيئة الداخلية للمستشفيات تعتبر كمحفز للشفاء حيث أصبحت من المواضيع التي تشغل فكر العالم وتوضح مدى التطور الفكري في مجال تصميم المستشفيات، والذي تطور من مفهموم تصميم بيئة داخلية يتم فيها مراعاة الأسس والمعايير التصميمية الى أكثر من مفهوم شامل ومتكامل يربط التصميم المعماري والداخلي مع بعضهما باعتبارهما المكون الأهم للبيئة الشفائية للمريض.

لذلك فكر الانسان في امكانية ان تخدم التكنولوجيا المجتمع والأجيال القادمة في الحفاظ على الطاقة وربطها مع تصميم وتنفيذ المباني عامة والمستشفيات خاصة. فخلقت المباني الذكية وادخلت فيها أنظمة تحكم ذكية قادرة على صنع واتخاذ القرار والتحكم في جميع وظائف المبنى (تكييف، اضاءة، مكافحة حريق، إدخال بيانات المرضى وغيرها الكثير). وأحد أهم هذه الانظمة هو نظام إدارة المبنى الذكي الذي يلعب دور العقل المفكر في المبنى، وهو عبارة عن وحدة حاسوبية مركزية مرتبطة مع باقي الأنظمة بوسائل الإتصال السلكية واللاسلكية. ومن أهم فوائد هذا النظام قدرته على إدارة طاقة المبنى وترشيدها وكذلك توفير الراحة للمستخدمين وسهولة التعامل مع المبنى وزيادة عامل الأمان والراحة فيه.

إنتشر إستخدام هذه الأنظمة عالمياً بشكل كبير في المستشفيات بأنواعها المختلفة، إلا أن إستخدامه في السودان إنحصر في إطار ضيق يكاد يكون معدوماً نظراً لعدم توفر شركات سودانية مختصة بهذه الانظمة، وقد يكون السبب وراء ذلك قلة الوعي الكافي بمدى اهمية النظام أو التخوف من تكاليفه باعتقاد أنها باهظة او لعدم تقبل المجتمع او عدم علمه بعد بفكرة الأنظمة الذكية وإستخداماتها في مباني المستشفيات.

بناءً على ماسبق ذكره، تم طرح بعض الأسئلة ومنها هل هناك أي إمكانية لإدخال تقنيات ذكية داخل مستشفياتنا في السودان أو لماذا لم يتم تصميم المساحة المعمارية للمستشفيات لتلبية جميع احتياجات المرضى وغيرها الكثير.

تعتمد المنهجية المستخدمة لهذا البحث في الإطار النظري على النهج التاريخي والوصفي من خلال جمع المعلومات من المصادر والمراجع بلغات مختلفة متعلقة بهذا الموضوع ، وفي المجال العملي ، تعتمد على المنهج التحليلي للمعلومات المجمعة حول دراسة الحالة بعد إجراء مقابلات مع المختصين في هذا الشأن.

قد تكمن بعض الحلول في نشر الوعي الكافي بمدى أهمية النظام والتسهيلات اللازمة للإستثمار في النظام والتنسيق بين الدول والشركات الراغبة.

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CHAPTER ONE

- Introduction -

1-1 Introduction:

As the quality of health care has increasingly become an issue around the world, we are focusing in this study on the hospital itself and specifically on all smart components that are offering value when built on new building or on top of already existing traditional systems.

Some newer hospitals now try to re-establish design that takes the patient's psychological needs into account, such as providing more fresh air, better views and more pleasant colour schemes.

Ever since health-care information systems have been implemented, their security is being considered an important issue, especially in the light of the fact that their data are deemed to comprise extremely sensitive information. The prospect of storing health information in electronic form raises concerns about patient privacy and data security.

Modern hospital buildings are designed to minimise the effort of medical personnel and the possibility of contamination while maximising the efficiency of the whole system. Travel time for personnel within the hospital and the transportation of patients between units is facilitated and minimised. The building also should be built to accommodate heavy departments such as radiology and operating rooms while space for special wiring, plumbing, and waste disposal must be allowed for in the design. Adding to that, all kind of smart devices that can be installed in the hospital is to facilitate the way of providing any service.

1-2 Research Importance:

Our Local Architecture needs such a Research, which teaches how to design and use intelligent systems in all health facilities. So, this will add something new, fill the essential needs, lay down the foundations for how to use the systems in hospitals in the state of Khartoum, and evaluate the existing ones.

1-3 Research Problems:

The research problem is that designers do not care about the design of smart hospitals, which is the most important element of advanced design of health buildings, in order to achieve the ideal design in terms of serving patients better.

In addition to the excessive energy consumption in hospital buildings (lighting, ventilation, air conditioning, water, security, etc.) is not needed all the time. And the consequent increase in costs to save energy, equipment and maintenance without taking into account safety factors, which poses a danger to the users of the building of patients, doctors and others.

1-4 Research Aims:

- Take advantage of the technological development and introduce it in the architecture field, especially hospitals, and collect the maximum benefit from it.
- Saving the amount of consumed energy in hospital buildings.
- Improve the internal hospital environment for patients and all hospital users.
- Provide recommendations on how to use smart systems for health buildings since the beginning of the initial design.

1-5 Research Questions:

- Why the architectural space of hospitals is not designed so that all the patients' needs are provided and easily accessible to them?
- Is there any possibility to introduce smart techniques within our hospitals in Sudan, and if there any qualified staff to deal with it?
- Is there a need to use additional smart systems in the hospital to facilitate the services provided to patients and users such as doctors and others?
- What is the mutual effect between the determinants of space (size and shape) and smart systems and how to use these determinants in providing an institution that serves the convenience of its users better?

1-6 Research Hypotheses:

The research places several assumptions, including the following:

- The possibility of applying the smart systems in health buildings in Sudan.
- The availability of sufficient capabilities to be applied efficiently and the time required to recover the cost of the system and the expected financial return after this period.
- Evaluate the current situations in hospitals, and the possibility to maintain it and improve it as well, as much as possible.

1-7 Research Plan:

We find that the strategy of this study requires knowledge of all information to achieve the objectives of the research and presenting the importance of the problems of service in health buildings in the state in general.

How to address and introduce modern ways in this area, and how was it applied in the case study (Al Salam Centre for Cardiac Surgery in Soba) and then addressing special recommendations on how to develop our health facilities.

1-8 Research Methodology:

The methodology of this research in the theoretical framework is based on the historical and descriptive approach by collecting information from sources and references in different languages related to the use of intelligent systems of all kinds through:

- General literature and personal and specialized experiences.
- Questioning the specialists in this field.
- Information from network and databases.
- General and specialist libraries.
- And in the practical field, it relies on the analytical approach to the collected information on the study after interviewing specialists concerning this matter.

1-9 Research limits:

Location limits:

Khartoum City, Soba area (Al Salam Centre).

Time Limits:

July 2018 - December 2018

1-10 Research Structure:

The first chapter presents the research basics, the introduction, the research methodology and the research problem.

The second chapter deals with the theoretical framework, which deals with historical background of health buildings and hospitals, and then presents the basics of design and how to use smart systems in each of the hospital spaces in accordance with the needs of the space itself and detail each type of smart systems for each space.

The third chapter discusses the status of the local and international study as a presentation of the current situation and its evaluation.

The third chapter will separate the case of the selected study and analyze it in order to come with a collection of abstracts in the case of the study.

The fourth chapter includes the general conclusions and recommendations for the design and use of smart systems locally, and recommendations for the case study.

CHAPTER TWO

- Literature Review –

2-1 Introduction:

2-1-1 General Introduction about Health:

The World Health Organization (**WHO**) defines health as “a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity” (WHO, 1948).

The WHO definition links health explicitly with wellbeing, and conceptualises health as a human right requiring physical and social resources to achieve and maintain. “Wellbeing” refers to a positive rather than neutral state, framing health as a positive aspiration.

Huber et al. (2011) proposed a new definition of health as “the ability to adapt and to self-manage”, which includes the ability of people to adapt to their situation as key to health. It also acknowledges the subjective element of health; what health and wellbeing mean will differ from one person to the next, depending on the context and their needs.

2-2 Defining a Hospital:

The word "hospital" comes from the Latin hospes, signifying a stranger or foreigner, hence a guest. Another noun derived from this, hospitium came to signify hospitality, which is the relation between guest and shelter, hospitality, friendliness, and hospitable reception.

A Hospital is a health care institution providing patient treatment with specialized medical and nursing staff and medical equipment.

Another definition, Hospitals are health care institutions that have an organized medical and other professional staff, and inpatient facilities, and deliver services 24 hours per day, 7 days per week.

They offer a varying range of acute, convalescent and terminal care using diagnostic and curative services.

2-2-1 Historically:

The earliest documented institutions aiming to provide cures were ancient Egyptian temples.

The Romans constructed specific buildings "valetudinarian" for the care of sick slaves, gladiators, and soldiers around 100 B.C.

During the Middle Ages, hospitals served different functions from modern institutions. Middle Ages hospitals were almshouses for the poor, hostels for pilgrims, or hospital schools.

Currently, hospitals are largely staffed by professional physicians, surgeons, nurses, and allied health practitioners.

2-2-2 Hospitals Classification:-

With the growing complexity of the healthcare system, patients now have a considerable array of choices when it comes to receiving care from providers. This often includes the option of selecting what type of healthcare facility they wish to utilize from a long list of many.

What Differentiates the Various Types of Hospitals?

In the U.S., you can differentiate hospitals based on a variety of factors that includes functionality, size, location, ownership and specialization (Gallagher Healthcare, March 2018). Here they are in more detail:

1. Functionality:

Functionality refers to whether the hospitals are general-purpose, teaching hospitals, acute care facilities, long-term hospitals, community hospitals, research hospitals or if they provide trauma care for patients.

2. Size:

There are three primary classifications when it comes to size:

1. Small hospitals: Less than 100 beds
2. Medium hospitals: 100 to 499 beds
3. Large hospitals: 500 or more beds

3. Location:

Hospitals are also classified by their locations. For example: Rural hospitals aid smaller communities and often have limited access to advanced equipment or specialized procedures and techniques.

4. Ownership:

- Private hospitals often offer access to the latest technologies and equipment, but may under-serve community members who need healthcare the most.

- Government-supported facilities operate via grants and other public funds. They have greater restrictions but also reach out to members of the community who may not otherwise receive healthcare and medical treatment.

5. Specializations:

Specialized hospitals appeal to physicians who entered the medical field with plans to treat people with a specific condition. Most physicians choose specializations due to personal reasons, an area of interest or a desire to provide a comfortable life for themselves and their families.

2-2-3 Location Considerations:

1) General Considerations:

The task of the planning team will be to choose the suitable site for the hospital as it considered as a very important factor for its suitability, which the hospital's fate and utility in future will depend on it (Rahul Choudhary).
Therefore, the following points must put to consideration:

- The site should be large enough to enable future expansion and growth.
- In dense urban areas, a large site near the periphery of the present town is suitable; due to it will become central to the major residential areas at a later date.
- Close collaboration with local town planning authorities will pay dividends in choosing the site.
- The social function of the hospital demands that a hospital should be situated in the heart of society.
- Accessibility is the most striking need of the location and must be within easy reach of the users.

2) Land Requirements:

Determining the requirement of land depends upon many factors. In rural and semi-urban areas, plentiful land may be available permitting the hospital to grow horizontally.

However, the degree of crowding on a site is considered in terms of Floor Area Ratio (FAR). It is the ratio of the total covered area on all floors of a building to the total area of the site, i.e. if a hospital building standing on a plot of land measuring 12,000 sq. metre has four floors, each floor having 1,500 sq. metre floor area (total floor area on all floors 6,000 sq. metre) the FAR at this site will be 0.5.

A floor area ratio of one represents a building whose added-up floor area of all floors equals the area of the plot of land (Rahul Choudhary).

Furthermore, it is necessary to weigh very carefully the advantages and disadvantages of concentrated versus diffused types of structure. The principal factor in the decision is the predicted amount of change.

3) Soil Structure:

In the selection of a site, two very important factors that should be looked into:

- The level of subsoil water.
- The structure of the soil.

Therefore, to determine subsoil water level and the "bearing" quality of the soil, **a preliminary soil survey** must be done, which will help to:

- Determine the type of foundation.
- Possibility of constructing a basement.
- Effectiveness of sewage plant (if it is to be built on the site).

4) Public Utilities:

Three other important considerations in site selection are (Rahul Choudhary):

- The availability of water supply.
- Sewage disposal system.
- Electric power.

- Water Supply:

Water is required for patients and patient care activities in wards and also for the supportive services. Basically, the national building code suggests 455 litres of water per consumer day (LPCD) for hospitals up to 100 beds and 340 LPCD for hospitals of 100 beds and over [(#)].

However, if staff quarters and nurses' hostel are going to form part of the hospital complex, additional availability of water for these will have to be ensured. Storage capacity for three days requirement must be built at the site.

- Sewage Disposal:

All departments and service areas in the hospital originate liquid and semisolid effluent. Solid waste from hospitals is approximately 1 kg per bed per day.

If a public sewage disposal system is in existence in the area, the hospital sewage disposal will be connected to this system. Otherwise, the hospital will have to build and operate its own sewage disposal plant.

- Electric Power:

The requirement of electric power is minimum 1 kW on a per bed per day basis. This includes the needs of all departments and services including power requirement of X-ray department, operation theatres, laboratories, central sterile supply department, laundry, and kitchen.

Keep in mind that a hospital with many life-support systems cannot afford to remain without power even for a short-time.

Also, a hospital will have its own transformer and electrical substation for distribution of power to various areas. The total substation area depending on the transformers capacity is given.

[#] These water consumption calculations do not account for us as Muslim community due to our need to wash up and ablution 5 times a day.

2-2-4 Hospitals Environment & Interior Design:

In hospitals, a properly-designed visual environment, with the appropriate use of color and lighting, will have important benefits. It can make the hospital experience more pleasant for a wide range of users from the elderly to the very young.
Hospitals are usually complex buildings, and they run more smoothly if people, both staff and visitors, can find their way about. Therefore, color design is a powerful way finding tool if it is planned with care.

Also, lighting is about more than providing a particular task luminance, although good task lighting is itself a valuable aid to productive healthcare. The appearance of spaces is also vitally important, and good lighting and color design can make spaces look lively and welcoming instead of drab and institutional. For example, windows play a key role here as they provide daylight, sunlight and contact with the outside.
However, to provide both lighting and color, a proper maintenance plan needs to be drawn up at the design stage.
Color design and lighting should be considered at a much earlier stage than currently appears to be the case. Their joint role in making environments inclusive for all users should be recognized by developers of healthcare premises.

2-3 Intelligence & Smart Building:

2-3-1 Intelligence Definition:

Generally, intelligence includes many mental abilities, which is related to the ability to analyse, plan, solve problems, find conclusions and speed the mental judgments. Also, it includes the ability of good thinking, collect and coordinate ideas, identifying languages and fast learning. According to some scientists, intelligence is also about the ability to sense and show feelings and understand the feelings of other human being.

Therefore, we find out that the common and general understanding of intelligence contains all of those previous things and may be linked to the power of memorising.

However, some psychological studies see intelligence as a behavioural characteristic independent of creativity, personality, wisdom and even the power of observation.

2-3-2 Artificial Intelligence:

Artificial intelligence is a group of specific behaviour and characteristics of some computer programs that makes it imitate the human mental abilities and how they function. The most important of these characteristics is the ability to learn and react to some new situations that have not been programmed into the machine. However, this term is controversial because there is no accurate definition of intelligence.

The artificial intelligence is considered a branch of computer science. Meanwhile, the common definition of the artificial intelligence in many references is “The study and design of smart customers”.

2-3-3 Artificial Intelligence Specialization:

It divides into two:

- Focus on the nature of human intelligence and trying to imitate it, with the intention of copying, matching it or perhaps exceed it.
- Building expert systems that shows intelligent behavior regardless of human intelligence.

Also, the last section is all about building intelligent tools to assist people in complex tasks such as medical diagnosis, security and safety, figuring faults in machines, etc.

2-3-4 Intelligence and Construction:

Nowadays, the modern architecture is beginning to expand its interests, which is influenced by the variables and special achievements in each fields of knowledge, including all the sciences and technological achievements in all form of architecture.
So, to expand this knowledge, architects have begun to talk about the need to follow the latest scientific developments in the field of computers and software and to take advantage of the latest computer simulation techniques for the physical and environmental forces that affect a building.

To begin with, mostly, the term **"Intelligent Building IB"** has been in use since the early 1980s. Thus, the first definition, coined by the Intelligent Buildings Institute "IBI", defines an intelligent building as "one which provides a productive and cost-effective environment through optimization of four basic elements: structure, systems, services and management, and the interrelationship between them". (Matias Peluffo)

According to this initial definition, an intelligent building is one that optimally matches its four elements to the users' needs with an emphasis on the technology that makes the interrelationship between the elements possible.

However, we can see that, intelligent buildings are beginning to take hold around the world in the late 1980s and 1990s. Many competing definitions were put forward.

In Europe, the European Intelligent Buildings Group "EIBG" coined a new definition stating that an intelligent building "creates an environment which maximizes the effectiveness of the building's occupants while at the same time enabling efficient management of resources with minimum life-time costs of hardware and facilities," (Matias Peluffo) which is tilting the spotlight towards the occupant's needs to be served by technology.

More recently, definitions are starting to take into account the emergence of Internet of Things technologies "IoT", applications and their impact on intelligent buildings.

Today, major shifts are occurring in the way buildings are designed, operated and used. Although there are multiple and evolving perspectives on this subject, it is becoming increasingly clear that an intelligent building is **A Connected** and **Efficient** Building (Matias Peluffo).

A Connected Building boasts an integrated communications infrastructure that supports wired and wireless networks and applications. It also facilitates three types of communications within the building and with the outside world, and they are:

- Person-to-person communications.
- Person-to-machine communications.
- Machine-to-machine communications.

The previous types of communications are using a state of the art intelligent, flexible, wired and wireless platform. The platform supports wired LAN, Wi-Fi, in-building wireless, audio/visual, sensors, lighting and building management applications.

An Efficient Building leverages:

- A state-of-the-art connectivity platform.
- Facilities and IT challenges to improve energy efficiency.
- Space utilization.
- Occupant satisfaction.

2-3-5 Intelligence in the Healthcare Facilities:

Architecture, design and operations are often largely separate from building and asset information in every process. This means that it's very difficult to get a clear picture of how any building will operate as a whole once the project is delivered. And this, in turn, makes it a challenge to make maintenance or daily operational decisions with any clarity.

Therefore, the aim is to create a building with lifecycle program that connects all the information available to them with using all types of intelligent devices. So, eventually if buildings are getting smarter, then medical facilities have to be ***Brilliant.***

2-3-6 Smart Hospital:

The future of all buildings is about creating positive experiences for the people that use them. Imagine, for example, a hospital that can adapt to each patient's differing needs by offering flexible services, such as:

- Monitor and optimize space in real time to get a clearer picture of where alterations can be made to save space.
- A large healthcare space might offer some space sensors to detect which rooms are available.
- Voice-enabled rooms could respond to voice commands and answer all patients request.
- Parking-spot sensors could help employees or visitors and patients easily locate available parking spaces as well as in emergency cases.

The overarching goal of smart hospitals is to deliver optimal patient care by making the most of advanced ICT, like:

- The availability of all relevant information when required.
- Access to internal and external expertise when needed.
- An efficient and effective surgical /diagnosis process that facilitates achieving this goal with low error rate and cost effectively.

Therefore, **a Suitable Definition** of the term **"Smart Hospitals"** should be:
"A smart hospital is a hospital that relies on optimised and automated processes built on an ICT environment of interconnected assets, particularly based on Internet of things (IoT), to improve existing patient care procedures and introduce new capabilities".

Thus, this leads us to the smart hospital objectives (EUANIS, 2016), which are (see figure 2-1):

1. **Improved diagnostics / surgical ability:**

ICT does not only enable new treatment methods but can also improve the existing methods.
Hospitals are increasingly able to mine patient data to help with diagnosis or choosing the best course of treatment, also sophisticated software solutions are allowing them to facilitate their administrative processes.

2. **Seamless patient flow:**

Caring about efficient healthcare as well as efficient patient flow can help:

- Reduce waiting times and the duration of hospital stays.
- Boost patient (and employee) satisfaction.
- Reduce errors.
- Increase profits.

In smart hospitals, efficient healthcare and efficient patient flow, for instance, could be supported by automatic updates of medical information across networked devices and information systems, which could be resulting in the availability of patient information in all stages - from entry to exit – and the optimization of admission, scheduling and other processes around it.

3. **Remote medical care:**

One of the key objectives of introducing IoT devices in the healthcare context is the ability to extend the hospital borders and provide remote medical care. Various medical devices, e.g. implantable devices, wearable devices and other mobile devices introduce the ability to patient monitoring through measurement of key vital signs and make these measurements readily available to hospital staff and systems via network connections.

4. **Enhanced patient safety:**

Enhancing healthcare delivery and patient flow also increases patient and clinical safety. It is important though that healthcare delivery and patient flow do not improve at the expense of safety. Without doubt, devices collecting data about patient vital signs and medication intake, or monitoring life support machines, can lead to increased patient safety if they are connected and able to provide timely warning.

5. **Cyber Resilience:**

Cyber Resilience refers to the ability of a hospital to ensure the availability and continuity of its services that rely on ICT assets. Higher ICT penetration inevitably leads to greater ICT dependency, which, in turn, increases the relevance of information security for smart hospitals.

In smart hospitals, achieving this is more challenging than in traditional hospitals because the number of components could be affected by service unavailability is much higher.

6. **Trustworthiness:**

Being perceived as trustworthy and having a good reputation is a competitive issue in areas when choosing between different providers is an option. Trustworthiness also affects adherence to medications and continuity of care, which has implications for the outcomes a hospital can achieve.

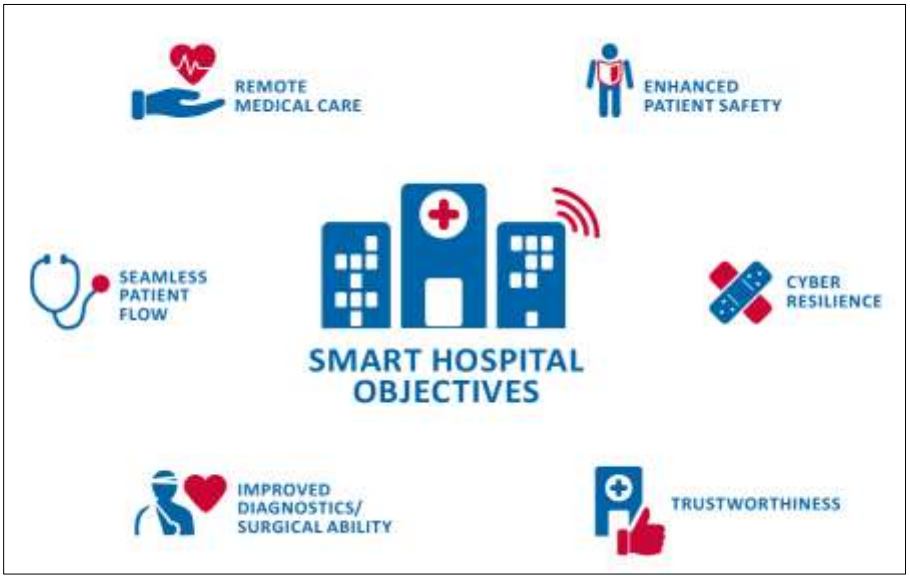


Figure 2-1 Hospital Objectives

Source: Smart Hospitals, 2016

2-3-6-1 Smart Hospitals Consideration:

Although all kind of smart technologies is going to be implemented in the hospital, that's doesn't mean it is going to be a flawless building. The hospital can still be exposed to many threats, such as: human errors and system failures. However, manufacturers of information systems and devices used in smart hospitals have to take certain measures too.

According to what have been mentioned, including all kinds of flaws that can occurred in the hospital system, here are some key recommendations) primarily for hospital executives (EUANIS, 2016. Namely hospitals should:

- Establish effective enterprise governance for cyber security.
- Implement state-of-the-art security measures.
- Provide specific IT security requirements for IOT components in the hospital.
- Establish an information security sharing mechanism.
- Conduct risk assessment and vulnerability assessment.
- Perform penetration testing and auditing.

Also, to enhance the level of information security in smart hospitals, we could put the following points in consideration:

- Incorporate security into existing quality assurance systems.
- Involve third parties (healthcare organizations) in testing activities.
- Consider applying medical device regulation to critical infrastructure components.
- Support the adaptation of information security standards to healthcare.

2-3-6-2 Smart system fields in hospitals:

- What if buildings owners could see exactly how their building is being used at any given time?
- What if they knew how many people are using each room?
- How much energy is being consumed through heating, air conditioning or lighting?
- The condition of the drainage system, electrical equipment and elevators?

All of these previous questions can be answered by using an artificial intelligence (AI), data from Internet of Things (IoT) devices, and occupant behaviour.
Digital devices, beacons and even social media statuses give insights into every aspect of a building's condition and operation. This can span from infrastructure, climate, water and energy use, to an individual occupant's experience.
Moreover, smart buildings can use this information to automate building systems, to respond to changing external and internal factors.

Mainly, the "Internet of things" is a revolution for the ICT world. For instance, connected medical devices transform the way the healthcare industry works, both within hospitals and between different actors of the healthcare industry. So:

- Could you imagine an electronic device collecting information on patients' vital signs becoming "smart"?
- Or life supporting machines monitors can be able to react on any change of status?

Connected medical devices can increased patient safety and efficiency, particularly if connected to Clinical information systems. Therefore, when this applies to the whole healthcare organization ecosystem, it becomes a **"Smart Hospital"**.

Now, because of this, intelligent buildings have the potential to:

- Increase operational efficiency.
- Improve occupant experience.
- Optimize space and asset use.

2-3-6-3 Smart System Classification:

➢ Way Finding & Directions:

Hospitals are complex structures comprising a large number of primary and secondary destinations for a range of first time, repeat and frequent users including: patients and accompanying persons, visitors permanent and visiting, clinical staff, administrators, visiting technical, maintenance and domestic support staff (IUSS Health Facility Guides, 2013).
As hospital buildings become larger and more complex it becomes more difficult for users to navigate their way through the building "to and from their intended destination".

Therefore, Way-finding is the system that assists patients to find their way from one place to another. The tools to assist people in way-finding can include:

- Printed information.
- Architectural features and design elements.
- Permanent signage.
- Digital devices (for example information screens).
- Existing landmarks (natural or man-made), like using colors to show which way leads to the wanted department (e.g. Blue for X-rays, Red for Emergency, etc.).
- Human interactions (for example, with information officers).

Way-finding maps should be located at strategic points throughout the site and allow visitors to orientate themselves. The maps should be consistent with the signage and the typology needs to be clear and concise (see Figure 2-2). Also, maps need to be located on all floors and be strategically placed at floor access nodes throughout the building. (G.Abbott, 2015)

Figure 2-2 Example of main entrance at Mitchell's plain hospital

Source: Hospital Design Principles, 2015

Figure 2-3 Examples of destination points

Source: Google Pictures, 2018

Examples of Indoor Positioning Systems:

Even though there are floor distribution maps and guide signs in department floors of most hospitals, many patients are still worried about they may spend much time finding their way (figure 2-3 shows examples of destination points).

In recent years, with the development of computer technology and short-range wireless communication technology, the concept of intelligent medicine emerges. Intelligent medicine refers to the use of the most advanced technology - Internet of things, to make possible interaction between patients, medical personnel, medical institutions, and medical equipment. We can provide, through the advanced concept and technology about intelligent medicine, indoor positioning for patients, thus improving their treatment experience (International Journal of Smart Home, 2015).

At present day, indoor positioning technology is increasingly perfect. It is commonly used in large and medium-sized commercial buildings; however it can be applied in hospitals.

Indoor positioning is realized via:

- WLAN (Wireless Local Area Network).
- Bluetooth.
- Radio frequency identification (RFID) technology.

❖ The iBeacon Technology:

The iBeacon is a piece of equipment for indoor positioning issued by Apple Corp in September 2013 (Jingjing Yang, Zhihui Wang and Xiao Zhang, 2015).

The working mechanism include a communication device equipped with low power Bluetooth sends, by using Bluetooth technology and its own ID, which a mobile Internet device will take some actions according to it (see the figures below).

The iBeacon has merits of both Internet of things and mobile internet and achieves the goal of indoor positioning within hospitals. It has the advantages of:

- Low power consumption.
- Fast response.
- Accurate positioning.
- Bringing great convenience to patients.

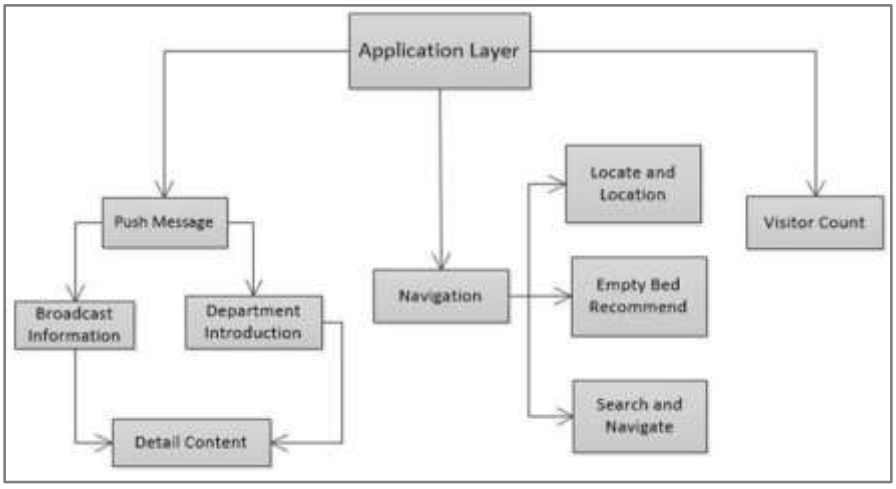


Figure 2-4 the Architecture of Application Layers

Source: International Journal of Smart Home, 2015

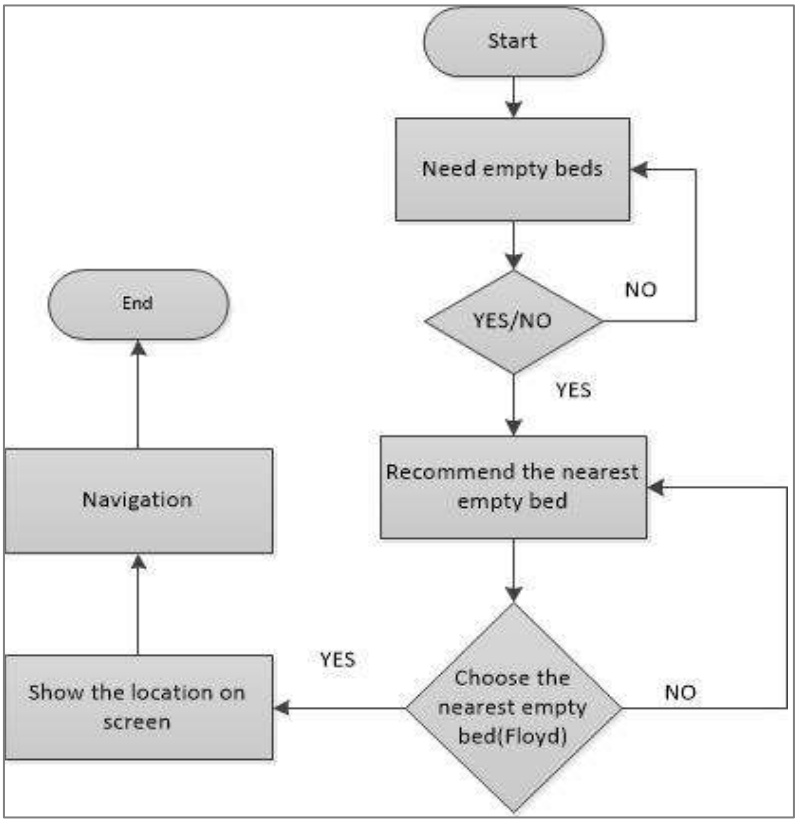
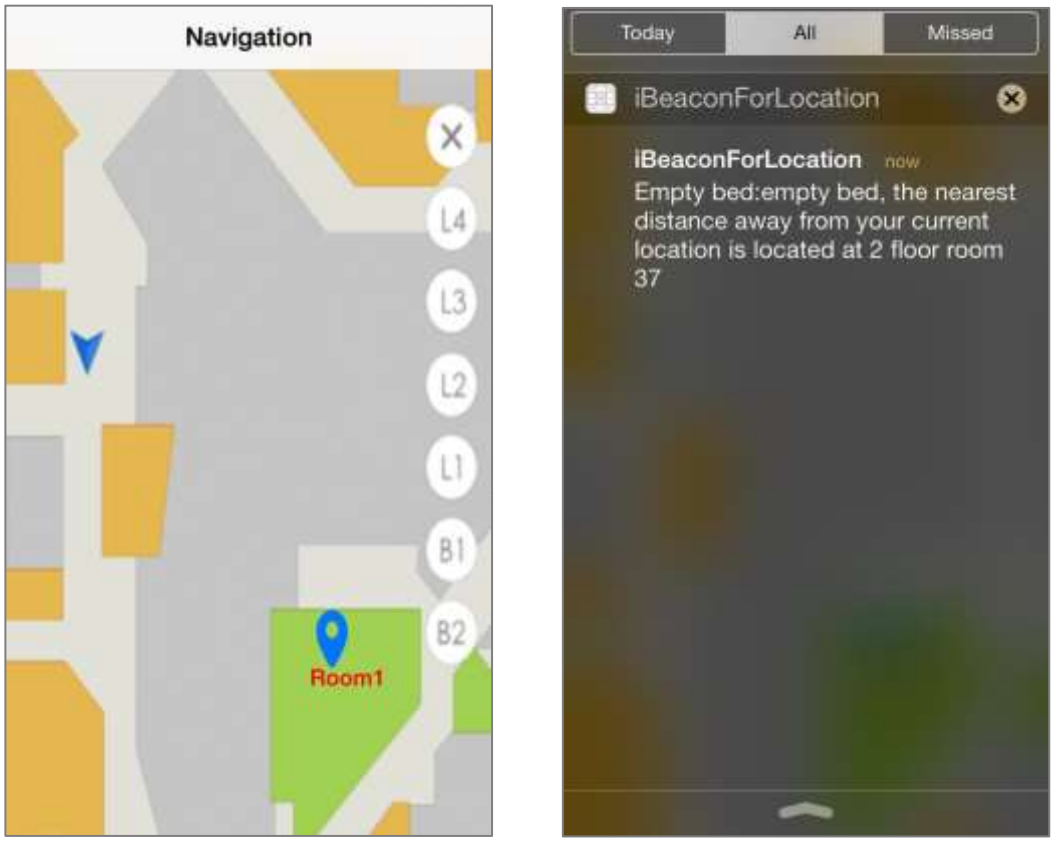


Figure 2-5 Flow Chart of Recommending the Nearest Bed

Source: International Journal of Smart Home, 2015



Figures (2-6)-(2-7) How the iBeacon Works in Mobile Phone

Source: International Journal of Smart Home, 2015

➢ Optimizing the Workflow:

Improving the efficiency of healthcare infrastructures and Biomedical Systems is one of the most challenging goals of modern-day society. In fact, the need of delivering quality care to patients while reducing the healthcare costs, and at the same time, tackling the nursing staff shortage problem is a primary issue.

An alarming statistic from an American Healthcare Organization, that an average of 195,000 people in the USA died in hospitals in each of the years 2000, 2001 and 2002 as a result of potentially preventable in hospital medicals errors. They clarified that, "the problem is not bad people in healthcare, and it is that good people are working in bad systems that need to be made safer".

Recent advances in the design of Internet of Things (IoT) technologies are encouraging the development of smart system to support and improve healthcare and biomedical-related processes.

However, the technologies of identification by radio frequency (RFID) can be used to build a smart hospital which optimizes:

- Business processes.
- Reduces errors.
- Improves patient safety.
- Enhances the quality of services.

It is a fact that the use of RFID can contribute to create the hospital of the future. Here are some of the RFID systems that are already being successfully tested (or deployed) in a number of hospitals (Patrik Fuhrer and Dominique Guinard, 2006):

1. Patient Identification:

Many health professionals are concerned about the growing number of patients who are misidentified before, during or after medical treatment. Indeed, patient identification error may lead to:

- Improper dosage of medicine to patient.
- Having invasive procedure done.

- Inaccurate lab work and results, which might appear in having effects such as misdiagnoses and serious medicine error.

In order to stop the clinical errors, several RFID-based patient identification and tracking projects have been launched during the last decade.

For instance, some RFID systems are applied in New York's Jacobi Medical Centre, Birmingham Heartlands Hospitals and many more.

Basically, all patients admitted to the hospital are given an RFID based wristband with a passive RFID chip in it. This chip stores a unique patient ID number and some relevant medical information such as the patient's blood type, in order to speed treatment.

And, over a wireless LAN connection, the hospital staff can access the patient's encrypted information on which drugs and what dosages the patients will require.

Also, patients will be able to check their own records by scanning their wristband.

Such tracking systems are especially useful for patients whom are suffering from Alzheimer's disease, Diabetes, Cardiovascular disease and other conditions requiring complex treatments.

2. Smart Operating Theaters:

It is a fact that, surgical identification can raise significant problems, according to recent Federal Reports such as The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) declared that the most common reported surgical errors involved surgery on the wrong body part or site, the wrong patient or the wrong surgical procedure.

The aim of this system is to ensure the correct operations are carried out on the right patients.

In the Smart Hospital the patients get a RFID-tagged wristband containing relevant information and a digital picture of them.

- The photograph allows the clinical team to easily confirm that they have the right patient.
- The electronic record ensures that they perform the correct procedure.

If the wrong patients enter the operating room, the medical staff is automatically and instantly warned of the mismatch.

3. Tracking Equipment, Patients, Staff and Documents:

Efficient tracking in a hospital offers plenty of interesting perspectives. Essentially, with taking in mind that our smart hospital is equipped with RFID readers at strategic places such as: main doors, entrances of operating theaters, recovery rooms, exist of the medical histories library, important galleries, etc.

So, with the fact that all the medical histories (and other important documents) are tagged, it enables us to locate them through the use of an assets tracking application like the RFID Locator. This can really help reducing the medical files losses. Nowadays, several documents tracking applications have already been successfully deployed. Most of them have led to a positive ROI (Return on Investment) such as saving 2500 man-hours a year (Patrik Fuhrer and Dominique Guinard, 2006).

Furthermore, using as assets tracking application within the infrastructure deployed for our Smart Hospital gives us:

- The possibility to locate and trace staff members as well as patients efficiently.
- Help improving the workflow of doctors, nurses and other caregivers.
- Help locate them in real-time, which is especially worthy for huge buildings such as hospitals.

Besides, tagging and tracking equipment offers many other use cases such as:

- Finer maintenance scheduling.
- Usage statistics of equipment.
- Placement optimization.
- Fast localization of important material.

4. Avoiding Theft of Medical Equipment:

It is well-known that hospitals own a great number of expensive medical equipment. However, what is not known is, that part of this equipment is stolen on a regular basis, such as wheel chairs and intravascular pumps often disappear from emergency rooms or intensive care units.

According to a survey, more than 155,000 of material were stolen in 2005 in Eleven Hospitals of the United Kingdom.

Yet, this survey does not take into account the side costs of thefts, mean while there are many side effects such as:

- Before being identified as stolen, a piece of equipment would have been searched for hours by hospital's employees.
- The missing material has to be re-ordered by some employees, diverting them from patient care or management tasks.
- The stolen equipment is sometimes vital and its lack may have severe consequences.

Once again, the Radio Frequency Identification can help towards finding a solution to this serious problem. Surely, as RFID tags are planted into the medical equipment of our Smart Hospital (Patrik Fuhrer and Dominique Guinard, 2006), now, we are able to:

- Track and trace all the stolen equipment.
- Reduces risks of the thefts, as the hospital's technical staff is always aware of material's whereabouts within the buildings.
- As for Anti-counterfeiting electronic tagging has a preventative effect can help identifying stolen material.
- RFID gates at the hospital's exits can help notifying the security services that medical equipment is taken out of the building.

➢ Medical gas central piping system:-

The medical gases which used in a hospital are a life-supporting element that gives direct influence in maintaining the life of a patient. Therefore, at the sections where the medical gases are used, the medical gas must be clean, highly pure and supplied under stable pressure (Medical Gas Central Piping System).

The Medical Gas Pipeline System is an infrastructure developed to carry/transport medical gases from its source to end point (consumption/many departments in the hospital), (see the figure below), safely and in best quality (Syed Jawad Shah, 2017).

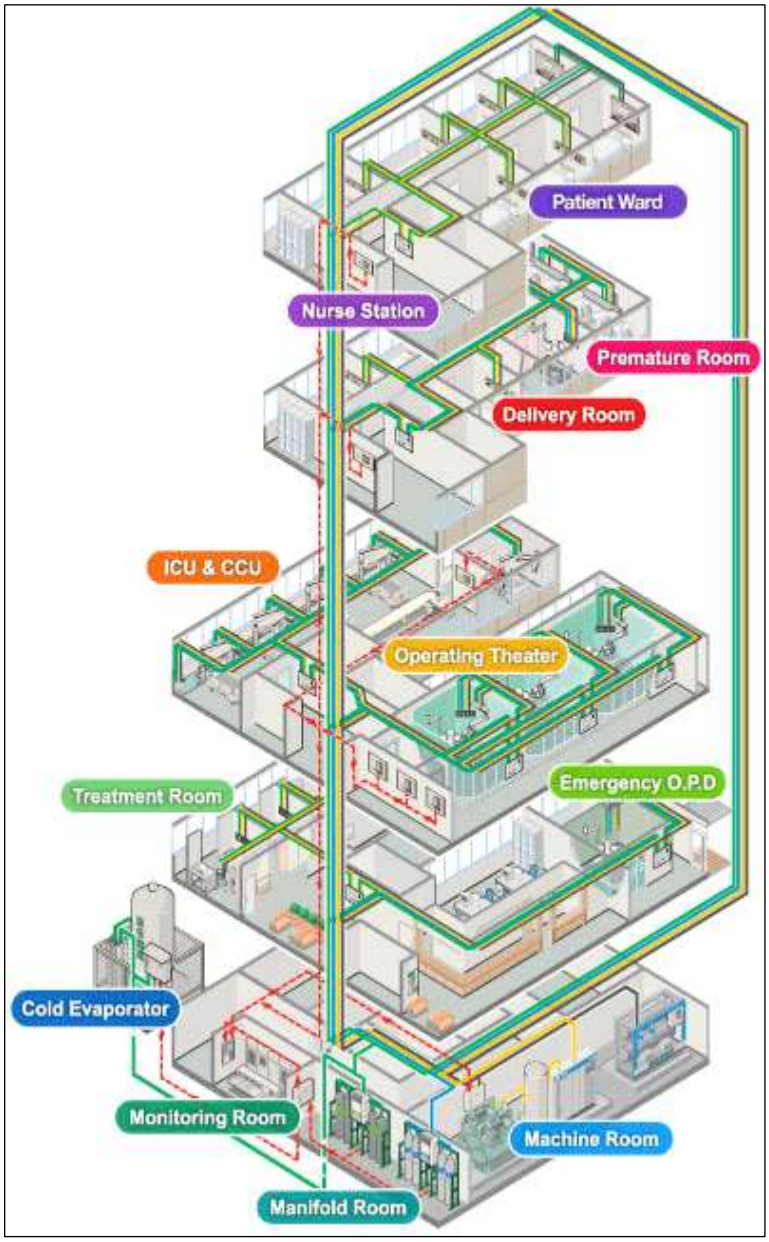


Figure 2-8 Example of distributing the Gas pipe line in a hospital

Source: https://www.medicop.com, 2018

There are many primary

services required for any hospital, its importance increases with the increase in which departments available in the hospital:

Medical Gas Services:

There can be up to 8 services covered under medical gases, there need depends on the application in the respective area or choice of the end user. Some areas in Hospital require all services whereas others may require only one or two of them. The selection of the service for the certain area can also be determined by End User (Syed Jawad Shah, 2017).

Services under Medical Gases are:

1. Medical Oxygen.
2. Medical Air 4 Bar.
3. Surgical Air 7 Bar / Nitrogen.
4. Nitrous Oxide.
5. 50:50 Nitrous and Oxygen Mixture.
6. Vacuum/Suction System.
7. Anaesthetic Gas Scavenging System (AGSS).
8. Carbon Dioxide.

Components of Medical Gas Pipe Line System:

The System is categorized into four segments:

- Source Equipment.
- Copper Tubing/Pipeline.
- Architectural Equipment.
- Monitoring System.

1) Source Equipment:

Which include all the services under medical gases including Vacuum, need some source, from where it should start, this can be whether storage equipment, on-site generation or both. However, the sizing of source storage or equipment is done through scientific flow calculation.

Vacuum and AGSS are suction services, therefore, negative pressure can only be created on site, whereas Oxygen, Air (4 & 7 Bar), can be sourced from storage at the site or produced at sire. Nitrous Oxide and Carbon Dioxide production on the site may be complicated and would not commercially make sense; therefore, these are sourced from the plant and stored at the site (Syed Jawad Shah, 2017).

The variety of this equipment in terms of technologies, design, and sizing are available to choose from in the marketplace. Equipment may include (see figures below):

1. Manifolds (Cylinder Storage and Gas Regulation Mechanism).

2. Vacuumed Insulated Storage.

3. On-Site Generation Plants (For Oxygen, Air, Vacuum, and AGSS).

Figure 2-9

Separate Air Supply Station

Source: https://www.medicop.com, 2018

Figure 2-10

Separate Vacuum Station

Source: https://www.medicop.com, 2018

2) Copper Tubing/Piping:

The copper piping carries contain gases or use to create negative pressure and are connected to outlet points.

Correct sizing of copper piping or tubing is the backbone of the medical gas pipeline system, which is done through scientific calculations and is dependent on the design of the pipeline including its routing. Also the copper tube that used for hospital jobs must be medical grade and ISO certified (Syed Jawad Shah, 2017).

This segment includes:

1. Copper Tube/Pipe.
2. Accessories/Fitting to connect copper tubes.
3. Line Valves and Zone/Area Control Valve Units (figure 2-11/2-12).
4. Fixtures to install these pipes.

Figures (2-11)-(2-12) Example of Valve: Shut off

Source: https://www.medicop.com, 2018

3) Architectural Equipment:

The Patient environment is always very important in any hospital; as they believe that good environment around patient helps in early recovery. Therefore, it is important that the gases that required healing a patient or helping them in recovery should be delivered through beautiful and nice looking devices. These devices include outlet points, bed head panels. A variety of models, colour choice and innovative technologies are available, customization for this equipment is also a very common idea (figures below).

Figure 2-13 Nitrogen Control Units

Source: https://www.medicop.com, 2018

Figure 2-14 Pipes Different Colors

Source: https://www.medicop.com, 2018

4) Monitoring Equipment:

The Medical Gases is a sensitive service for Hospital; it requires monitoring to ensure smooth and reliable supply of medical gases within the Hospital. Therefore, monitoring system including, Alarm Systems and Terminal Units are installed throughout the hospital.

- **Alarm System:**

To maintain a stable supply of medical gases, it is necessary to establish a monitoring system which surely traces the flow of invisible gas from the source of supply through piping to specific space to use the gas.

There are various monitoring systems, which are possible to grasp the information of supply source such as the amount of gas remaining in the source tank and the operating condition of supply station and the pressure of gas supplied at each area of section where the gas is used.

An automatic pressure switch shall be located downstream of the main supply line shut-off valve. A visual and audible alarm should indicate a rise or fall of the main line pressure above or below the nominal line pressure. The alarm should be located where it is continuously monitored. NFPA 99 states (Syed Jawad Shah, 2017). "Area alarms shall be provided for anesthetizing locations and critical care areas. Warning signals shall be provided for all medical gas piping systems supplying these areas…"

- **Terminal Unit:**

The medical gas outlet which the medical staff "such as doctors and nurses" uses for daily medical care must be so designed as not to allow a cross connection to a different medical gas not intended. Furthermore, a visual identification system has been adopted by use of colors respectively designated to the exclusive kind of gas, obtaining a remarkable effect. In order to prevent a cross connection when attaching a medical gas outlet valve at the time of installation or maintenance, a pin guide system is adopted to the valve base of wall type outlet, and some standard is applied to the hose connecting section in the case of reel type and ceiling type outlets.

Station outlets consist of primary and secondary check valves which allow secondary pieces of equipment to be attached to the medical gas line. Station outlets should be used only for the delivery of gases intended for medical use. Each outlet shall be labelled with the name or chemical symbol and the specific colour coding for the gas supplied (see figures below).

Figure 2-15 Main Alarm Panel

Source: https://www.medicop.com

Figure 2-16 Alarm Panel

Source: https://www.medicop.com

Figure 2-17 Wall type Outlet

Source: https://www.medicop.com

Figure 2-18 Ceiling type Outlet

Source: https://www.medicop.com

Figure 2-19 Ceiling type Outlet

Source: https://www.medicop.com

Figure 2-20 Ceiling type Outlet

Source: https://www.medicop.com

➢ Safety and Fire Fighting Control:

Fire safety is one of the most high pressure and significant components of healthcare facility management. The fact is there is no room for error in this matter and we must do everything in our power to keep the patients safe, since the people inside these facilities unlike a shopping mall, school, or sporting arena while in reality they are often sick, disabled, or elderly.

From 2007-2011, there were about 2,600 fires per year in nursing homes and 1,200 more in hospitals. The National Fire Protection Association (NFPA) found that those fires led to 140 injuries per year and three deaths along with nearly $18 million in annual property damage.

Therefore, facility managers must be cautious in keeping their patients safe. Also, giving attention to detail and routine safety checks can help to keep fires under control or prevent them altogether (Pan American Health Organization, 2014). However, here are some of the guidelines that we must put in consideration:

- Safety is always the primary concern.
- Every effort should be made to include evacuation considerations when designing or retrofitting hospital facilities.
- Full evacuation of a hospital should generally be considered as a last resort when mitigation or other emergency response efforts are not expected to maintain a safe care environment.
- Simplicity is the key; the staff will need a simple plan to follow in an emergency.
- Flexibility is vital because the procedures must be adaptable to a variety of situations.
- Self-sufficiency at the unit level is important because timely communication from hospital leaders may be difficult or even impossible; employees at every level must know immediately what to do in their area.
- When difficult choices must be made, leaders and staff must focus on the "greatest good for the greatest number."

However, to find out the most common reasons of hospitals fires, here are some examples of hospitals fires during the past years:

Table 2-1 Data on Hospital Fires

Source: Pan American Health Organization, 2014

May 2010: St. Joseph Mercy Hospital, Georgetown, Guyana—0 Fatalities	
	– The operating theater and administration departments, located in the historic "Colonna House" wooden structure, were completely destroyed. – 66 years of medical records were lost in the fire.
December 2011: AMRI Hospital, Kolkata, India—91 Fatalities	
	– The fire in this hospital started in the basement, where highly flammable medical equipment was illegally stored. – The fire service arrived 90 minutes after the start of the fire. Windows and doors were locked; windows had to be broken to gain access. – Most deaths were a result of smoke inhalation.
April 2013: Psychiatric Hospital, Ramensky, Russia—38 Fatalities	
	– Most windows and doors were locked. – The old wooden structure, without adequate fire suppression and prevention procedures, had almost completely burned down when the fire service arrived.

October 2013: Orthopedic Hospital, Fukuoka, Japan—10 Fatalities	
	– The fire doors on the second and third floors were not closed, resulting in rapid spread of smoke. – The fire station noted that staff did not attempt to put out the fire when it started and that the call was received late.

We can say that there are a number of different materials and types of equipment are major contributors to hospital fires. Now, the eight leading causes of hospital fires in the United States of America are shown in the chart below (these figures are based on data from the National Fire Protection Association), (Pan American Health Organization, 2014):

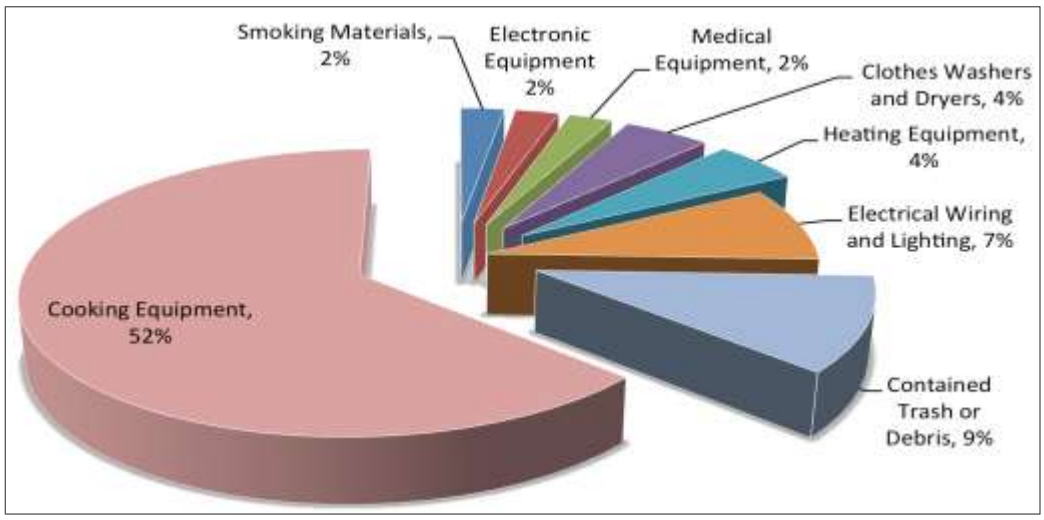


Chart 2-1 Main causes of Hospital Fires

Source: Pan American Health Organization, 2014

According to the previous information, the primary aim of a hospital facility is to **not** evacuate patients unless absolutely necessary. Hence, special attention should be focused on proper prevention and suppression techniques to avoid this worst-case scenario and minimize loss of life. So, the four main sections of firefighting policy are:

- Prevention.
- Suppression.
- Evacuation.
- Evacuation Training Drills.

1. Prevention:

One of the primary considerations in preventing hospital fires is to prohibit the use of combustible structural (e.g., floors, walls, roofs, stairwells, fire escapes) and non-structural (e.g., doors, windows, ceilings, fixtures, facade, insulation, and mechanical and electrical conduits) components in the hospital facility.

- **Construction and Design Considerations:**
  - ✓ **Materials:**

New facilities should be designed using building codes (differ depending on the country) and guidelines for fire prevention, and the materials used should have adequate fire resistance ratings. (These ratings refer to the duration, usually in hours, that a given material can withstand a fire at a specific maximum temperature before losing its integrity, including its strength and insulation capabilities.) In the case of both structural and non-structural components, fire resistance ratings/durations can vary from 30 minutes to over 4 hours (Pan American Health Organization, 2014).

Materials used in the design and construction of hospitals must be:

- Noncombustible/nonflammable.
- Must have adequate fire resistance ratings.
- Should not emit toxic gases/smoke during a fire.

Some examples of materials that emit toxic fumes during a fire and should be avoided are:

- Polystyrene (for example, polystyrene decorative moldings).
- Insulation spray foams, polyurethane.

  - **Existing Medical Facilities:**

- Flammable materials should be protected with fire-retardant paint or other forms of fire-insulating, noncombustible materials or removed altogether. Flammable materials include wood, combustible liquids, electrical equipment and wiring, combustible metals, medical gases (particularly oxygen), and cooking equipment.
- Glass doors and windows should be fire retardant and shatterproof.
- Ceiling tiles and wall and floor finishes (e.g., carpets) should be fire retardant.

- Fire doors and frames should be installed between each fireproof compartment, room and at each landing level of stairwells and fire escapes. It is imperative that fire doors with a minimum fire rating of 20 minutes to 1.5 hours separate each room and section. Fire doors should be self-closing.

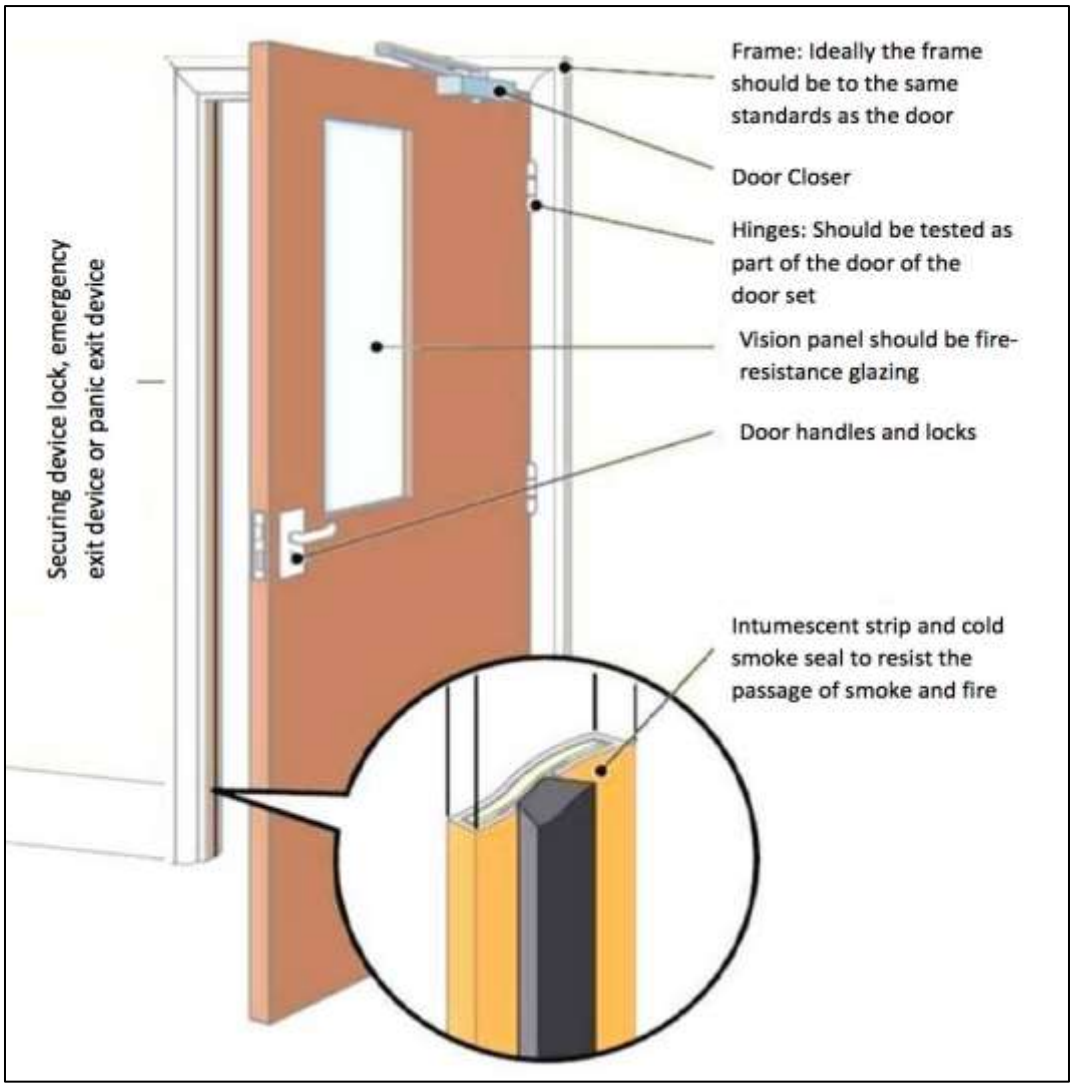


Figure 2-21 Typical Standards for Fire Door

Source: Pan American Health Organization, 2014

✓ **Number of floors:**

- The greater the number of floors, the more complicated the evacuation plan, in terms of both horizontal and vertical movement.
- The need be to reduce the vertical height and number of floors of the building. Single-story, low-rise buildings spread across the site are preferable, as they are easier and quicker to evacuate.

✓ **Egress:**

- There must be a minimum of two independent egress routes and exits on every floor. Also, helicopter landing on site can be provided according to the size of the hospital.
- Exit routes should be located as far away from each other as possible, so that if one exit route is blocked with smoke or fire, the alternate route can be used.
- The width of the corridor leading to the emergency exits (unobstructed) should be at least 2.4 m. This will permit the transportation of hospital beds, mattresses, and so on (Pan American Health Organization, 2014).
- Doors should be of the minimum width necessary to accommodate a stretcher (typically 1.25 m).
- Providing an access for firefighters, for example: In the United States, some hospitals have designated stairwells for firefighters to access the building, to avoid interaction between people evacuating and fire service personnel. In Brazil, some medium - to high-rise buildings provide window access for firefighters to enter the building.
- Evacuation maps should be posted at the hospital's main access points to clearly identify egress routes (figure 2-22).

Figure 2-22 Emergency Signs

Source: Pan American Health Organization, 2014

Figure 2-23 Emergency Stairwells

Source: IFC Life and Fire Safety, International Finance Corporation, 2017

2. Suppression:

The objective of a fire suppression system is to control or extinguish the fire in its early stage. This means suppression can be manual (fire extinguishers, hose reels) or automatic (sprinkler systems, gas extinguishing systems, etc.).

The primary goal of this suppression is to limit property damage and to control the fire.

There are several ways in which fires can be detected. A variety of smoke and heat sensors can be installed as part of a fire alarm system to detect fires (figure 2-24/2-25). The sensors should also be able to pinpoint the location at which the fire was detected; the surrounding doors to that area should be automatically closed in a way of taking control on the fire from spreading to another area.

Figure 2-24 Alarm Sounder

Source: IFC Life and Fire Safety, International Finance Corporation, 2017

Figure 2-25 Smoke Detectors

Source: IFC Life and Fire Safety, International Finance Corporation, 2017

There are many of fire-fighting equipment can be installed in different locations in the hospital, such as:

- **Fire Extinguishers:**

Fire extinguishers are active fire protection devices used to extinguish or control small fires. They are intended to be used by the hospital's first intervention team or by visitors that have the expertise to use them.

Many types of fire extinguishers are available: water, foam, dry chemical, carbon dioxide, etc. All of them have specific advantages and disadvantages and should be selected by professional persons (figure 2-26).

Health, safety officers and hospital staff should be trained on how to use fire suppression devices. Regular training sessions should be undertaken as part of the medical facility's scheduled safety and evacuation simulations.

Figure 2-26 Examples of Fire Extinguishers

Source: Pan American Health Organization, 2014

- **Water Sprinkler System:**

– These systems have a water droplet diameter greater than 1 mm, and the cumulative surface area coverage for 1 liter of water is approximately 3 square meters.
– The sprinkler head is a heat-sensitive valve that releases water once the temperature exceeds a fixed temperature, generally 30^{o}C above the ambient temperature (Pan American Health Organization, 2014).
– Each sprinkler head operates independently and will activate only once sufficient heat reaches the valve. Therefore, only the sprinklers closest to the fire will operate.
– Sprinkler systems cause less water damage than the hoses used by the fire service to combat a fire.

- **Water Hose Reels:**

– Water hose reels should be located on every floor of the hospital, to provide a realistically accessible and controlled supply of water to fight a fire.
– Fire hoses are connected to the main water supply or an independent water storage system.
– Fire hoses are typically 18 m to 36 m in length and have an internal diameter of 13 to 19 mm.
– Hose reels should be checked and signed off monthly.

- **Smoke Extractors:**

One of the means of minimizing the danger of a fire is by incorporating special smoke extraction systems, usually in the initial design of heat, ventilation, and air-conditioning (HVAC) systems (see figure 2-27).

- Smoke extraction systems are mechanical systems that can be manually or automatically activated once the alarm is triggered.
- These systems are designed to remove hazardous smoke from the area of the fire and prevent the spread of smoke to other areas of the building through the closing of specific vents and the high-pressure pumping of air to designated areas to prevent the ingress of smoke.

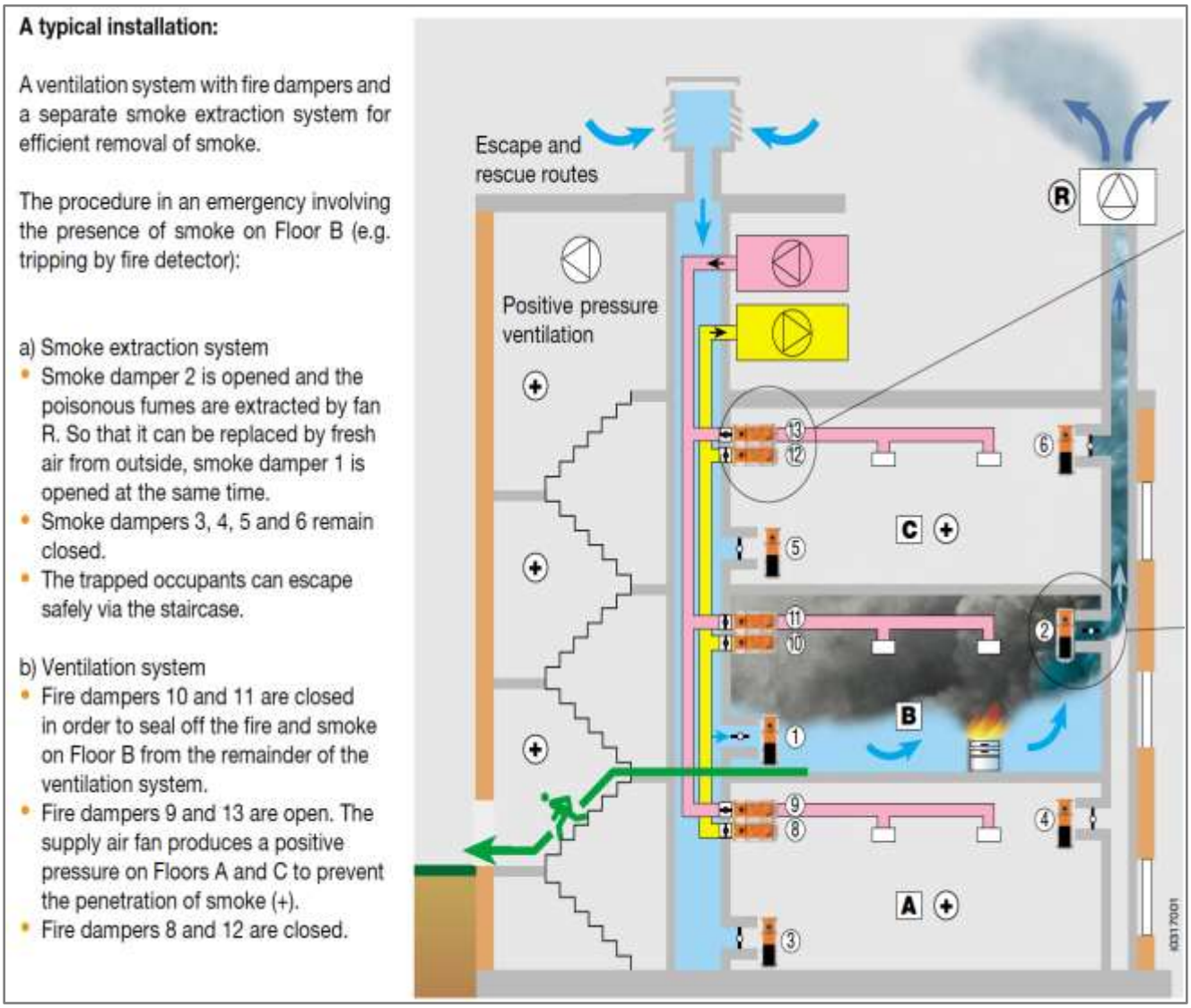


Figure 2-27 How the Smoke Extractors Works

Source: Pan American Health Organization, 2014

3. Evacuation:

It is clear that, evacuation procedures are undertaken only as a final resort action for the hospital. In the case of a fire, evacuation is performed once the preventative and suppression measures have failed to contain the fire.

It is important to note that there is no fixed methodology for evacuations; the procedure will vary for each individual health care facility.

Firstly, if there is a fire threat and the decision to evacuate is made, there should be a selected person responsible for notifying the entire facility of the evacuation order, using appropriate systems such as internal hospital communication systems with loudspeakers. Also the appropriate agencies like The Fire Department must be notified. For instance, consider posting conspicuous notices, at various locations in the hospital, of agencies to be notified, as the following note:

IN CASE OF FIRE
CALL THE FIRE SERVICE AT
{INSERT LOCAL EMERGENCY NUMBER}
ASK THE OPERATOR
"IS THIS THE FIRE SERVICE?"
When the fire service answers, clearly say:
"FIRE"
"AT {INSERT ADDRESS OF FACILITY}"

- **Level of Evacuation:**

The level of evacuation can be:

- Complete evacuation.
- Partial evacuation.

In most emergencies, a full evacuation will not be required. Due to the complex needs and unstable condition of many hospital patients, evacuation is generally considered as a last resort. However, evacuation should be ordered only when absolutely necessary and when there is potential threat to patient/staff safety.

- **Movement:**

The hospital's incident commander determines, based on the fire situation, what type of evacuation is required:

- Horizontal: The primary mode of evacuation, this involves moving patients in immediate danger away from the threat but keeping them on their current floor.
- Vertical: This usually involves the complete evacuation of a specific floor in the hospital. Patients and staff will be evacuated out of the hospital only if necessary.
- Shelter in Place: The staff may be instructed to "shelter in place," that is, remain in their units and wait for further instructions.

- **Patient Classification:**

Prioritizing patients with respect to the limited physical resources available for evacuation (e.g., personnel, elevators, stairwells, transport sleds) is among the most logistically and ethically challenging tasks involved in the evacuation of a hospital (Pan American Health Organization, 2014).

It is important to identify the special needs of patients, some of whom may require additional attention (figure 2-28):

1. Needs of Patients with Disabilities:

- Patients who cannot hear or see or are under anesthetics (unconscious).

2. Medical Care and Equipment Needs:

- Patients may require specific life support equipment (e.g., ventilators) that should accompany them when they evacuate, such as equipment that is battery operated should be regularly checked as part of the hospital's programmed maintenance.
- Specific medications that patients need for treatment should also accompany them when they evacuate.

3. Emotional Support Needs:

- Patients may require psychological support as a result of the stress of the disaster situation.

Typically, medical supplies are stored within the main hospital building; ideally, however, they should be stored in an independent facility.

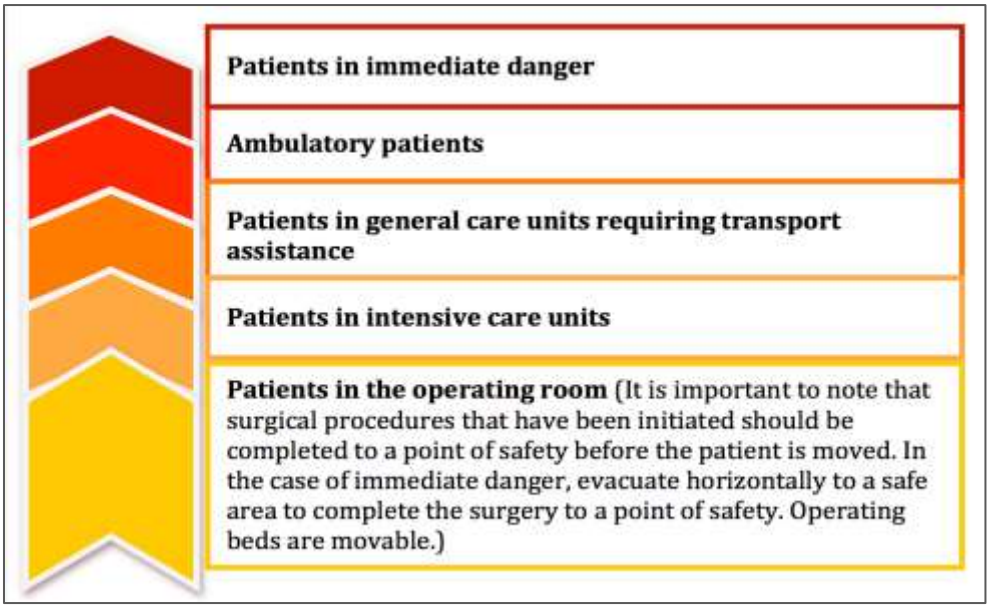


Figure 2-28 the Priority Ratings for Patient Evacuation

Source: Pan American Health Organization, 2014

- **Evacuation Transport Equipment:**

The equipment may include:

- Blankets.
- Wheelchairs.
- Beds.
- Canvas Stretchers/Litters/Gurneys.
- Backboards.
- Sked Stretchers.

Some of the equipment, such as backboards and sked stretchers, is usually not stored in the hospital. These materials may be supplied by the national disaster office or the fire service.

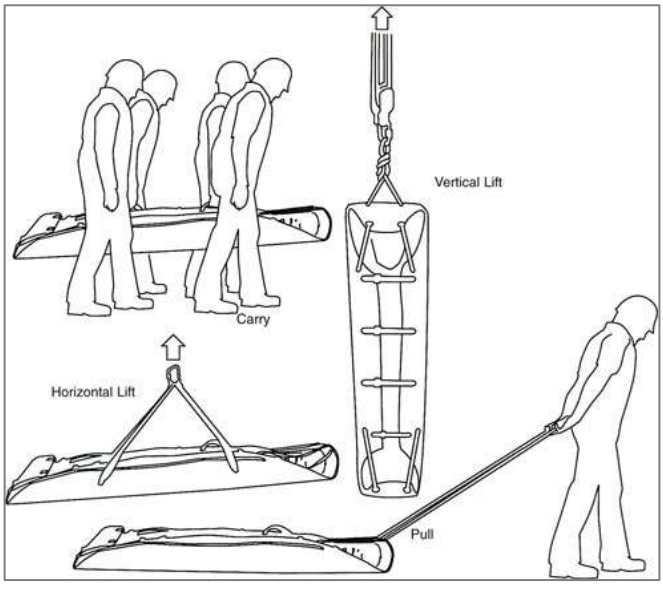


Figure 2-29 Diagrammatic Use of Sked Stretchers

Source: Pan American Health Organization, 2014

4. Evacuation Training Drills:

Upon the sound of the fire alarm, it is expected that hospital staff will activate a practiced system or sequence of activities in response. Each health facility should have a unique system to meet its needs.

An evacuation/response plan should be discussed and developed by the hospital administration, the engineering and medical teams. The plan should include regularly scheduled training for all staff.

General training of all staff should include (Pan American Health Organization, 2014):

1. Training on how to lift and move patients.

2. Training on how to use fire extinguishers.

3. Training on what to do if they see a fire. For example, the **RACE** acronym specifies actions to be taken in a fire (although not in a specific order; the hospital's incident commander determines the appropriate actions to be taken in a given situation):

- **R**: remove anyone endangered by the fire to a safe area.
- **A**: activate the alarm.
- **C**: close all windows and doors; contain the fire.
- **E**: evacuate.

4. Training on what to do if they hear the alarm and see the flashing lights.

Specific training defines the roles and responsibilities of each staff member. For example, in the case of a fire alarm, who notifies the fire service and the rest of the hospital?

➢ Lighting:

In planning hospital environments (whether new or refurbished) cost projections need to take into account these running costs:

- Energy use.
- Ease of maintenance.
- Staff productivity.
- Patient recovery.

Energy efficiency is an increasingly important issue. The use of efficient lamps, ballasts and luminaires, coupled with appropriate lighting controls, can be highly cost effective and help meet the energy targets.

Different areas of the hospital will have a wide variety of color and lighting requirements (Hilary Dalke and David L Loe, 2004). Therefore, we can divides hospital areas into three generic types:

1. <u>General (public) areas:</u>

Consist of entrances, reception area, lobbies and waiting areas, with their associated facilities.

A hospital entrance is where the user first interacts with the building. It needs to be visible from outer approach paths and accessible to all.

In lobbies, patients and visitors obtain the information they need about where to go and how to get there.

Waiting facilities in these areas should provide a relaxing and calming ambience for patients and visitors who may be under stress.

2. <u>Circulation areas:</u>

Include corridors, lifts, staircases and escalators (linking areas).

It is important to have clarity of direction and enough visual interest in these areas to ease the stress of way-finding.

3. <u>Care areas (wards):</u>

Include bedded areas, ward circulation areas, nurses' stations, day rooms, toilets and staff rooms.

Wards should be reassuring; a feeling of excellence of medical care combined with physical and emotional comfort and an ambience that provides a feeling of warmth and relaxation.

A Good Lighting Design will concentrate on:

- The appearance of spaces with enough light on walls and ceilings.
- Spaces will be more pleasant if daylight and views out are available.

Color design and lighting consultants can often pinpoint the reason why a place does not “feel” right. For example, a change of floor color from light to dark or vice-versa can affect a whole area dramatically.

2-4 Previous Studies:

There are many books, previous researches and published papers that discussed the idea of smart systems in health facilities in terms of economic, social, technical and service points of concern, including:

2-4-1 Nahid Ahmed Othman, the Use of Smart Solutions in Building, Sudan University of Science and Technology:

The research dealt with the topic of smart solutions and their use in buildings on general, starting from the definition of intelligence and various concepts, then the definition of artificial intelligence and relationship with architecture, also explains the intelligent buildings and their benefits.

On the other hand, it also discusses different types of smart solutions used in many buildings and dealing with the illustrations and examples.

And Smart solutions in construction in terms of choice of building materials, type and method of building construction.

Also, Artificial intelligence for automation, alarm and remote control systems in different parts is used to reduce power within the building. Some international examples and smart buildings have been studied with an explanation of smart solutions and a reference to the challenges facing the smart building negatively and positively in the next future.

2-4-2 Magdy Shayboub Ali Mahmoud, Development HealthCare System of Smart Hospital, 2014:

The paper spoke about the convergence of information technology systems in health care system building, which is causing us to look at more effective integration of technologies. Facing increased competition, tighter spaces, staff retention and reduced reimbursement, today's traditional hospitals are looking at strategic ways to use technology to manage their systems called smart hospital.

It explained the concept of the smart hospital is a useful system for any hospital, which can be occurs by adding intelligence to the traditional hospital system by covering all resources and locations with patient information. Patient's information considered as an important component of the patient privacy in any health care system that is based on the overall quality of each patient in the health care system.

Eventually, the main commitment for any health care system is to improve the quality of the patient and privacy of patient's information. Therefore, today, there is a need of such computer environment where treatment to patients can be given on the basis of his/her previous medical history at the time of emergency at any time, on any place and anywhere.

The paper is based on the ubiquitous and pervasive computing environment based on UML (Unified Modeling Language) and XML (The Extensible Markup Language) technology, in which these problems has been tried to improve traditional hospital system into smart hospital in the near future.

Finally, the key solution of the smart hospital is online identification of all patients, doctors, nurses, staff, medical equipment, medications, blood bags, surgical tools, blankets, sheets, hospital rooms, etc.

CHAPTER THREE

- Case Study -

I had chosen the Salam Center as a main case study for my research due to this Centre has the highest level of smart systems among the hospitals in Sudan. Furthermore, they had almost approached the worldwide classification of smart system in hospitals.

3-1 Case Study - Salam Centre for Cardiac Surgery:-

The Salam Centre is one of the few cardiac surgery hospitals in Africa, which provide highly specialised, free treatment to patients who are suffering from acquired and congenital cardiovascular diseases.

EMERGENCY Organization provides free, high-quality healthcare to victims of war, poverty and landmines, with it alongside building hospitals and training the local medical staff. The Organization was founded in 1994, since then EMERGENCY has treated 9 million patients in 17 different countries and currently operates in Afghanistan, Central African Republic, Iraq, Italy, Sierra Leone and Sudan.

The Salam Centre in linked to a network of EMERGENCY paediatric centres, where our cardiologists:

- Screen children and adults with heart conditions.
- Identifying those who need to be operated on in Khartoum.
- Providing them with all the necessary post-op care.

3-1-1 Introduction:

1) Location:

The Salam Centre for Cardiac Surgery is located in Soba, 20 kilometers south of Sudan's capital city, Khartoum.

The construction began in October 2004, and ended in March 2007.

The hospital designed and built by EMERGENCY NGO, the Center covers an area of 12Km^2 indoor, and a lot of land of roughly 40,000sqm on the banks of the Blue Nile (figure 3-1).

Figure 3-1 Hospital Location and its Surrounding

Source: Google Map, 2018

Figures (3-2)/(3-3) Hospital Views

2) About Patients:

Source: ARCHNET, 2018

Most patients come by themselves to the Salam Centre, without been referred by physicians or medical facilities. Then, after an initial triage, patients with potential cardiac problems receive further cardiac investigations.

From April 2007 to December 2017, the number of patients whom underwent surgical operations at the Centre for cardiac surgery is about 7,019 and the operative mortality has been calculated and it is approximately about 215 persons, which is about 3%.

3-1-2 The Centre Departments:

The Salam Centre includes all the following (figures 3-4/3-5/3-6):

- Surgical Block: with 3 operating theatres, 16 intensive care units beds, sterilization, catheterization laboratory.
- Diagnostics Block: reception, outpatients' consultation rooms, radiology, ultrasound, laboratory and blood bank, and pharmacy.
- Wards: with 48-beds ward, nurses room, physiotherapy, recreation room for staff and patients, and storage areas.
- Offices: Administration.
- Services Area: laundry, ironing, kitchen, library, conference and teaching room, children's playroom, storage areas and cafeteria.
- Guest House: for relatives of patients coming from outside Khartoum (up to 50 people).
- Technical Area: maintenance services, medical gas system, generator rooms and warehouses.
- Meditation Hall: for patients of all religions.
- Medical Compound: for international staff.

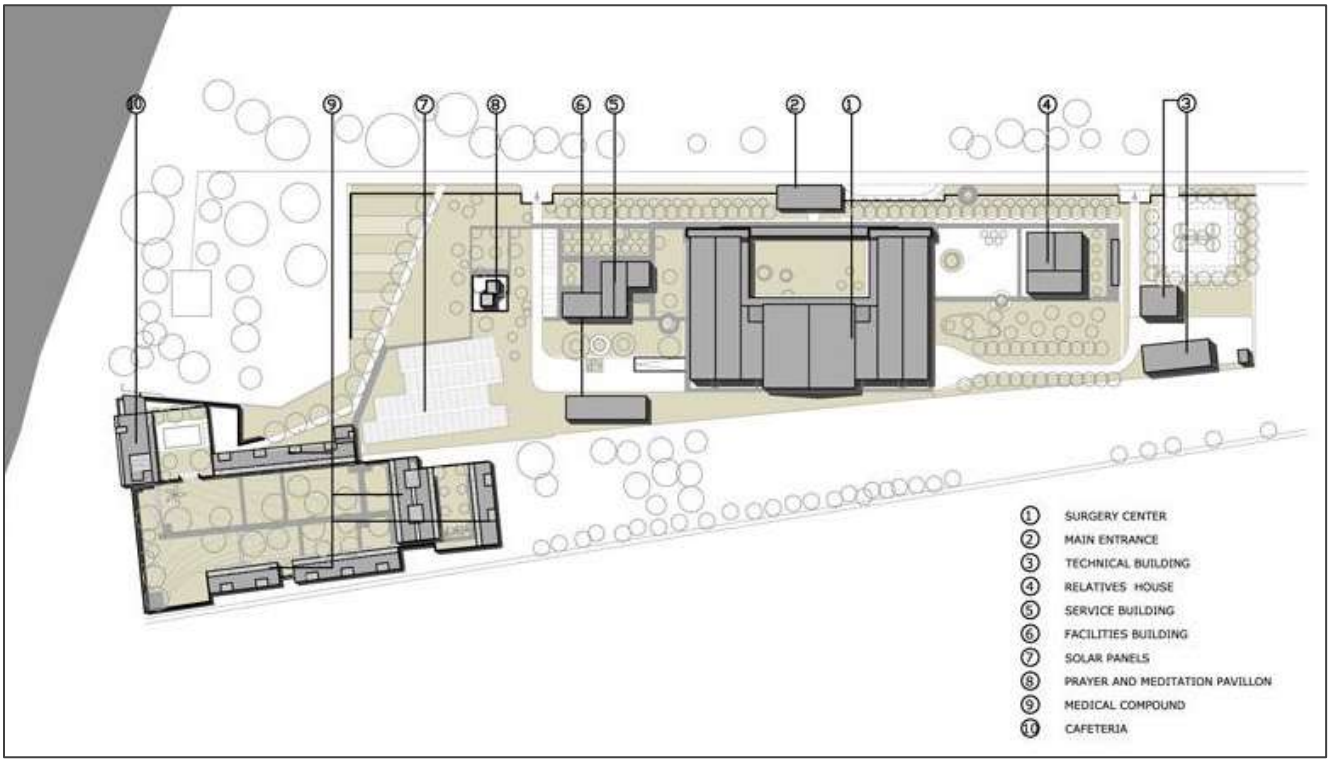


Figure 3-4 Site Plan of the Centre

Source: ARCHNET, 2018

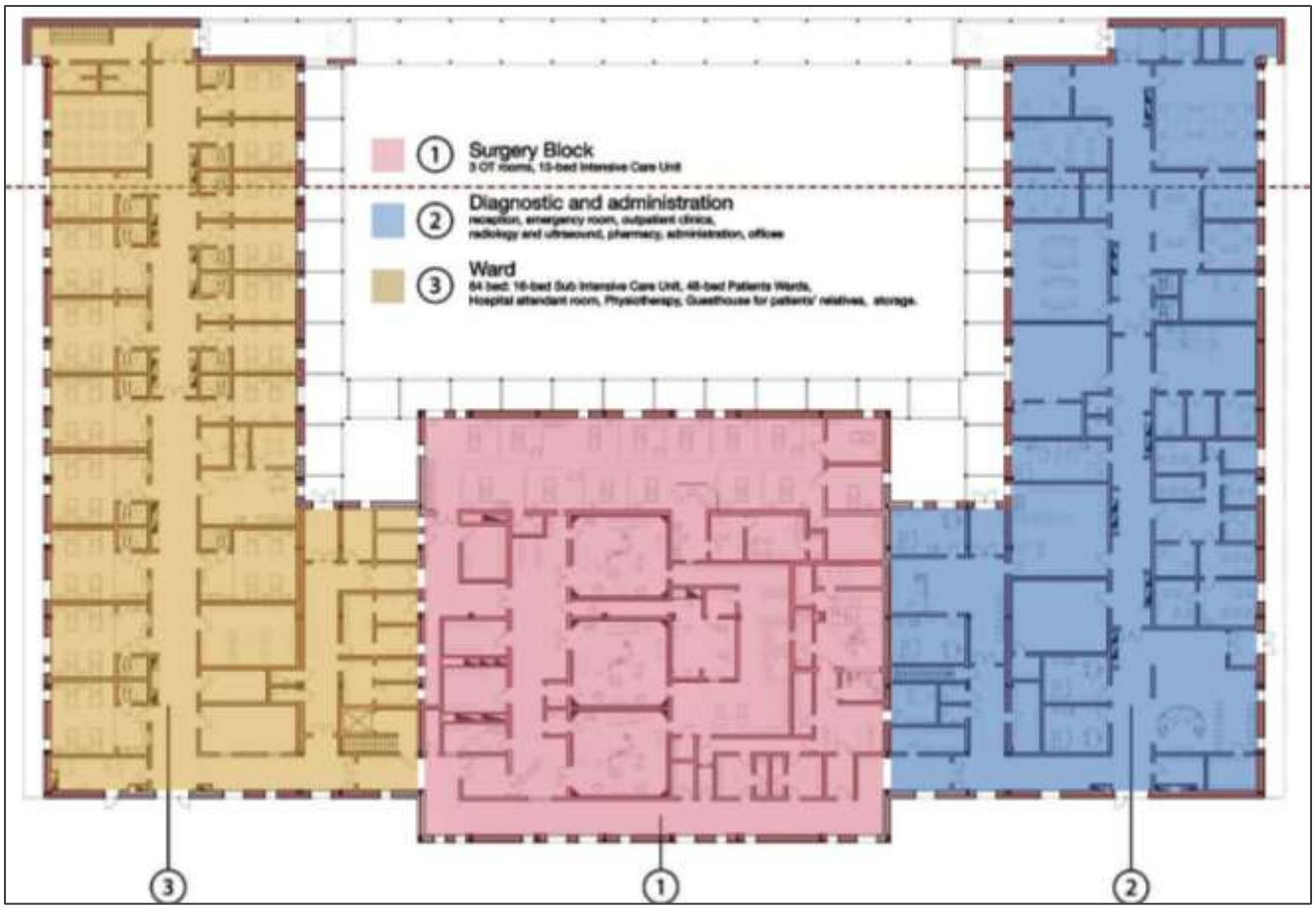


Figure 3-5 Ground Floor Building

Source: ARCHNET, 2018

Figure 3-6 South-East Elevation of the Centre

Source: ARCHNET, 2018

3-1-3 Structural Solutions:

Firstly, *"the design of the structure tries to mitigate the sensation of feeling lost and away from home so typical of hospitals; rather it tries to build a working and healing place where proximity between people and spaces is encouraged".*

The hospital's buildings, that "embrace" the courtyard, have been designed in the form of a pavilion (which is shown in the pictures above).

They reduced the height of the hospital, which inspires the sense of "homeliness" in patients and hospital staff, that is also present in many details and that attempts to reduce the idea of being hospitalised. This is a philosophy that aims to create a cosy space.

Secondly, *according to the high Temperatures in Sudan, which is often exceed 40°C for long periods of time combined with the presence of fine dust generated by the strong desert winds; one of the measures that was taken is, all the Bricks that is used in all the Centre walls in custom made with the workers with specific dimensions. Therefore, all the Centre external walls are built with multiple bricks layers that interspersed with panelled insulated air chambers, to have a total thickness of 60cm (figures 3-7/3-8).*

Figures (3-7)/(3-8) The Hand-made Bricks with Specific Dimension

Source: ArchDaily, 2018

The second thing that was put into consideration is that, performing the walls by making two layers of bricks separated by an insulating air cavity, with small windows. These windows are closed by highly performing glass panels with low emissions. The windows are equipped with double glasses covered with sun-screening films (figures 3-9/3-10).

Figure 3-9 Windows Sample

Source: ARCHNET, 2018

Figure 3-10 Doors Sample

Source: ARCHNET, 2018

The

land around the Salam Centre has been very extensively planted with trees and hedges.

Shrubs and trees were also used to protect the buildings from the heat and to mitigate the effects of the harsh climate. Also a great idea was implemented, which was the use of traditionally crafted roofs for walkways and areas for rest (figure 3-11). This was derived from a traditional technique for bed-making.

Figure (3-11) Building Views

Source: ARCHNET, 2018

Figure (3-12) Building Views

Source: ARCHNET, 2018

Figure (3-13) the Traditional Technique

Source: ARCHNET, 2018

Figure (3-14) Waiting Area

Source: ARCHNET, 2018

Thirdly: A place to pray.

The idea was to create a space that could accommodate the prayer and meditation.

The exterior hosts a large water pool; the pool creates a spiritual separation between the external macrocosm of the hospital/world and the ventral microcosm of the building formed by two unaligned white cubes, which are connected by a semi-transparent cover of palm leaf stalks (see figures below).

Figure 3-15 Prayer Place

Source: ARCHNET, 2018

Figure 3-16 Entrance of the Prayer Place

Source: ARCHNET, 2018

Fourthly: The International Medical Compound with using the concept of recycling and using the containers, which they were used 2007 for transporting the construction materials of the hospital, is now have been converted into living units to the medical compound (figure 3-17).

The main challenge was to transform these destroyed metal boxes into houses. The Compound placed besides the Hospital, in the surroundings of the Nile River.

It consists of 95 (20ft) containers for housing and 7 (40ft) containers for the cafeteria.

Every lodging is 20 sq. and is realized with one and a half containers; the lodging is composed of bedroom, bathroom and a small veranda on the court side (see figures below).

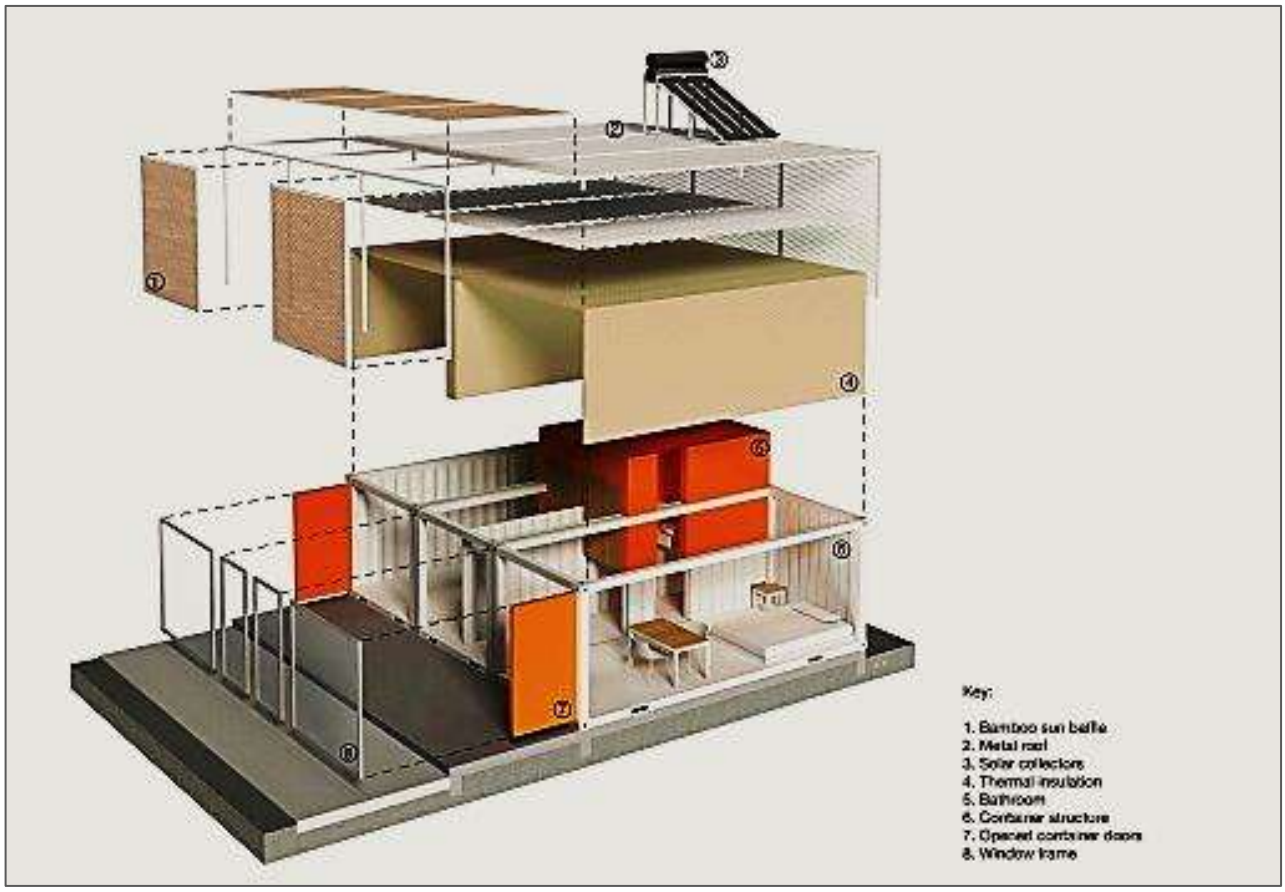


Figure 3-17 Inside Layout of the Container

Source: ARCHNET, 2018

Figure 3-18 Inside Courtyard of the Compound

Source: ARCHNET, 2018

Figures (3-19)/(3-20) The Medical Compound

Source: ARCHNET, 2018

Figure 3-21 Cafeteria of the Medical Compound

Source: ARCHNET, 2018

Figure 3-22 Swimming Pool of the Medical Compound

Source: ARCHNET, 2018

3-1-4 Technical Solutions:

To build a first-rate Centre for cardiac surgery in a climate such as Sudan's, with temperatures above 40 degrees most of the year and frequent sandstorms, the structure must be designed sand-proof as well as heat-proof.

- **Centre Data Base:**

The Centre has designed a specific system to keep all the data of their patients. The system starts from the first visit by giving each patient an ID number, by which all of his examination and results can be viewed in the time of the follow-up by their doctor (figure 2-23).

Each of the IT engineers and International and national doctors can access to the system whenever they want, by a password ID number for each one of them.

Figure 3-23 Salam Centre System

Source: the Researcher, 2018

Results:

- The access to the patients information is only limited to International doctors.
- Not all results and examination is set in the system, some of laboratory department still stored in hard copy, but this is one of their future plans.

- **Air Treatment Units:**

To filter the huge quantity of sand and dust that fill the air, a 60 meters long "sand trap" was built in the basement, by taking advantage of simple mechanical principles (figures 3-24/3-25).

It starts by sucking the air from outside, and forced through that underground tunnel. As the air hits the walls and losses speed, most of the sand and dust are removed and the air starts to cool down, then the air is "washed" and cleaned by vaporized water, which flushing away the smallest particles.

By this process the air dropped 9°C from the outside temperature. Now, this air is ready to enter the Air Handling Units, conditioning systems and water from the Chillier (figures 3-26/3-27).

Figure (3-26)/(3-27) part of the Cooling System with the vaporized water then the other way throw

Source: the Researcher, 2018

Figure 3-28 Chiller

Source: the Researcher, 2018

Figure 3-29 Air Handling Unit

Source: the Researcher, 2018

Figure 3-30 Outlet of Air Supply

Source: the Researcher, 2018

Figure 3-31 Inlet of the Air Supply

Source: the Researcher, 2018

Results:

- The cooling device with the vaporized water is not in used currently (during my field visit), however, it is being maintained since it is not used that much as the weather is frequently cold.
- The conditioning system in the Centre has Three Air Handling Units:
    - The clean area: such as administration and offices section (the system explained above).
    - Wards: as same as the system above, except the retaining air in not filtered and used back in the Air Handling Units (for safety factors).
    - The Surgical Block: as same as the Wards System.
- The Chiller Units have been replaced and maintained few months earlier, which indicate their maintenance schedule is being applied well.

- **Medical Gas System:**

It includes the supply of medical gases within all departments of the Centre, while putting in consideration that, the medical gases must be clean, highly pure and supplied under stable pressure (see figures below).

- The Medical Gas Line is supplied to wards, ICU and operating theater.
- In the Wards Section: above every patient bed, there is a medical gas outlet with Three Opening: medical oxygen, medical air and vacuum.

Figure 3-32 part of the Medical Gas System – in basement

Source: the Researcher, 2018

Figure 3-33 three lines of the system with the controlling valve

Source: the Researcher, 2018

Figure 3-34 Outlet of the system in Wards

Source: the Researcher, 2018

- **Nurse Call System:**

- With every patient bed there is a Request tool in a reach to the patient hand (figure 3-38).
- Outside every ward there is an Alarm with Light, which starts to work when a patient pushes on his request device (figure 3-37).
- Also, in the nurse station, there is a device to indicate which ward is requesting for a help, so the nurse could go to help them (figure 3-39).

Figure 3-37 Alarm Light

Figure 3-38 Patient Request Device

Source: the Researcher, 2018

Figure 3-39 Nurse Station Device

Source: the Researcher, 2018

- **The Fire Fighting System:**

This system (it is an ordinary system) includes distributing all of the following in all departments of the Centre (see figures below):

- Smoke Sensors.
- Water sprinklers.
- Alarm light and signs.
- Fire extinguishers.
- Water hose reel.

Figure 3-40 Smoke Sensor

Source: the Researcher, 2018

Figure 3-41 Alarm Sign

Source: the Researcher, 2018

Figure 3-42 Water Hose Reel

Source: the Researcher, 2018

Figure 3-43 Fire Extinguishers

Source: the Researcher, 2018

Notes:

In 2012, the hospital was on fire, which started from the main store in the basement but it was contained quickly with no life lost just some of their storage supplies.

The outcome of this accident:

- There were no water hose reel in the basement, and the firemen were struggling to put off the fire, according to the huge amount of smoke, lack of fire safety equipment and there were not able to breath, so, they had to put it part by part by going inside the basement to put part off the fire then they ran out of the building to take some breath.
- Their Fire System is not included in the system of the Centre yet; however, they intended to put it the up coming years.
- Doors that near to fire place are closed automatically when the Fire Alarm starts.

- **Electricity:**

The Centre consists on a Power Generator to fulfill all the different needs of areas in the Centre, with two gasoline tanks (figures 3-44/3-45).

It is connected to the system to operate directly when the electricity cut-off, due to the major needs of the power in all medical departments in the Centre.

Figure 3-44 Power Generators

Source: the Researcher, 2018

Figure 3-45 Gasoline Tanks

Source: the Researcher, 2018

- **Solar System:**

The sources of electricity in the Salam Centre can be divided into three:

- The General Electricity.
- The Back-up source from Power Generators.
- The Solar System.

Since, the huge amount of power consumed in the Salam Centre, there are 288 vacuum-sealed solar collectors in the Centre, and the power collected from it is directly attached to the building power (figures 3-46/3-47).

Figure (3-46) Solar System

Source: ARCHNET, 2018

Figure (3-47) Solar System

Source: ARCHNET, 2018

3-1-5 Results:

The future of all buildings is about creating positive experiences for the people that use them. So, for a hospital it must adapt to each patient's differing needs by offering flexible services.

Today, major shifts are occurring in the way buildings are designed, operated and used. Therefore, when visiting the Salam Centre and collecting all the needed information that related to my research and compared them to the international specification of smart systems and devices in hospitals; this table shows to which limit the Salam Center has applied the smart techniques in it.

Technique	To which Degree		
	Full 100% – 75%	**Half 75% – 35%**	**None 35% – 0%**
Clinical Location	85%	–	–
Patient Comfort	90%	–	–
Dispensary Systems	–	75%	–
Equipment Tracking	–	–	30%
HVAC	85%	–	–
Security	95%	–	–

In the field of Equipment Tracking, they still working on it and going to change all the patients' data from hard copy to a soft to ease the way of tracking them when it needed.

In Dispensary Systems Field, the used method of distributing any medical prescription is somehow scheduled but in primitive way and need to be organized by mixing it with a smart devices.

After making this comparison, the Salam Centre is approximately applying the Smart techniques in it with a range of 76.66% which is more than acceptable.

3-1-6 Summary:

Nowadays, the modern architecture is beginning to expand its interests, which is influenced by the variables and special achievements in each fields of knowledge. So, to expand this knowledge, architects have begun to think about the need to follow the latest scientific developments in the field of computers and software and to take advantage of the latest computer simulation techniques for the physical and environmental forces that affect a building to improve the environment to any users of the hospital.

After all this Centre still considered almost in the top of the hospitals in the way of including Smart System in all of his fields, however it's still a working progress to reach the maximum level of using the Artificial Intelligent in it.

So, comparing to the hospitals we have in Sudan, we need to work more on them, to add something new, fill the essential needs, lay down the foundations for how to use the systems in hospitals in the state of Khartoum, and evaluate the existing ones.

Therefore, our Local Architecture needs such changes, which teaches how to design and use intelligent systems in all health facilities.

CHAPTER FOUR

- Results & Recommendations –

Due to the modernity of intelligent control systems in buildings, there are not many architectural studies dealing with this subject in all aspects, in terms of structure, commissioning and feasibility of the systems and how to collect profits from them.

A practical study has been done by looking at examples and models of buildings containing intelligent systems (the case study) and their analysis may be more useful in understanding the systems and how they are installed, and the environmental and economic returns in terms of use.

4-1 Conclusion:

Smart buildings have gone a long way in developing all components of the system in parallel with the developments in the field of electronics, communications and information, consequently by making it very suitable for life and suitability for all age groups (children, senior citizens) and health conditions (healthy, sick, disabled).

However, the idea of a smart building, especially hospitals, is most needed, but it faces obstacles in the lack of recognition of its usefulness in our climate and how to fit it, or the high cost, or lack of experts in this area. Yet, the near future holds many developments in the smart building system, but it is full of optimistic expectations about the low prices of these buildings, which could make them accessible to all.

In spite of all these, there are still things that we can and will be able to achieve, but it is not impossible.

To make a well-designed Hospital with a better health within reach every day.

4-2 Results:

- **Insufficient knowledge:**

About the Case Study: the designers of the Hospital (members of the EMERGENGY NGO) are globally known for designing an ideal building that is suitable to its environment. Therefore, the Salam Centre has won numerous architecture awards for being an innovative building that combine architectural excellence with a positive impact on the quality of life of the surrounding communities.

For example, the building is designed to minimise energy consumption by using vegetation to mitigate the heat and a solar panel system for cooling.

In a General way: We find that most of the engineering companies in Khartoum have sufficient knowledge of the concept of smart buildings, since most engineers in the Labour Market have a background on this subject, but it is not enough because it is limited and not supported by the theoretical study during the periods of study in universities and low experience in the practical side of applying it in a number of buildings.

There are also no adequate studies in the curricula of the universities in this area, and if any, they are very few and are not considered as fact that can be referred to.

Also, the numbers of offices and companies that are interested in this aspect are few and do not reach to where the world has reached in recent times, so we need to have the maximum benefit from foreign expertise, which reached very advanced stages in this area.

- **Implementing the Smart System since the begin of designing:**

About the Case Study: before starting in initiate the Hospital, the designers of the Hospital have done adequate studies about all what matters in designing a healthcare facility in our environment, combining it together with the use of smart system in a way of facilitate it services to their patients and users.

In a General way: We find that when we include design solutions and smart construction in the first stages of construction of a hospital reduces the financial cost when being compared with the attempt to implement and apply smart systems in a building that is already built and used, which will add some additional costs such as modification of systems and linking them to the new system, modify the means of communication used within the hospital, in addition to the possibility of demolition and construction of some walls and ceilings again.

- **Seeking for the patients and users comfort:**

About the Case Study: this point has been put in mind when designing this Hospital. How to comfort their patient since the minute they are being triaged, examined, treated inside the hospital and till the time of their check-ups.

And as for their users, the building is provided with all the comforting ways to make them cosy in it, such as the Guest House for the patient relatives and also the Compound foe the International Medical staff.

In a General way: It is achieved by providing a comfortable internal environment and specific, for example, they do not need to shut down or open the light switch whenever they leave or inter the room, but the system will operate automatically to provide the needed amount of light for users by using some special type of sensors.

- **Patient Information Availability:**

About the Case Study: The Centre has designed a specific system to keep all the data of their patients. The system starts from the first visit by giving each patient an ID number, by which all of his examination and results can be viewed in the time of the follow-up by their doctor.

In a General way: Through the use of programs and applications in phones and laptops, by downloading programs in all available devices and linking them to the system such as the possibility of knowing the existence of available wards or not by telephone without the need to be asset, also the provision of blood transferring procedures to a patient by a device that defines the patient's data and ensure the correct blood type before transfusion to reduce the risks.

- **The speed of safety measures:**

About the Case Study: Their fire safety system includes distributing some fire devices in all departments of the Centre such as: smoke Sensors, water sprinklers, alarm light and signs, fire extinguishers, water hose reel.

Also, the doors that near to fire place are closed automatically when the Fire Alarm starts.

But, Their Fire System is not included in the system of the Centre yet; however, they intended to put it the upcoming years.

In a General way: When a fire occurs in non-smart hospitals, the alarm system picks up the fire, and the machine works automatically. However, there are some procedures that need to be done manually or to aggravate the fire. On the other hand, the signal is sent to the central system of the hospital and from which can control on the whole building, which is going to locks doors automatically that are near to the fire and the opening of other outlets and exits to facilitate the escape of patients and users.

- **It is not necessary to include smart systems in all the buildings:**

About the Case Study: from studying the Salam Centre, it is clear that the use of smart technologies is not included in all parts of the hospital, however, some building were designed and built by using some traditional techniques to make every user of the hospital to not feel lost and away from home (so typical of hospitals).

Adding to that, to protect the buildings from the heat and to mitigate the effects of the harsh climate, the land around the Salam Centre has been very extensively planted with trees and hedges.

In a General way: This requires studying the need for them according to the nature of the building and its size, the surrounding environment and the services provided by the hospital.

4-3 Recommendations:

4-3-1 Case Study Recommendations:

- Till now the Salam Centre is not well known in our society as a place for non-charged healthcare facility, so, as for the Centre they must increase their way of advertising for their well-qualified offered services, and as for us as a community we must break the barriers of fear of change and the idea of everything new within our life.

- As the Salam Centre is designed by a worldwide organization and it is known for their perfectly designed building combined with its environment, our designing and constructing companies should try to work along with NGO organization in designing and the use of smart systems in building, and also try to modernize our old traditional method in designing.

- The Salam Centre designers and our designing companies must try to work with one another to do some courses in creative development and solving the various architectural problems, for both architectural students, local workers and engineers.

- The system that used in the Centre is only limited to International staffs and not all results and examination are set in the system, therefore, it is in need to be updated to include all the Centre departments in it, which will eventually help the doctors to have an access to their patient information (one of the Centre Future Plans).

- Must have a proper maintenance plan in the Centre to all of their Technical system (Medical Gas system, Air Conditioning, Electrical system and the Solar system) to be replaced and maintained every couple months.

4-3-2 General Recommendations:

- Awareness should be given to the importance of the system and the environmental and economic benefits of its use. And keep pace with the creative development in solving the various architectural and descriptive problems and putting them as information and references that are easily accessible and obtainable.

- Adding material to the courses taught to students shows the most important problems and obstacles that accompany the design process from the idea to implementation with the examples of smart solutions that are actually implemented in buildings for easy study when needed.

- It is necessary to break the barriers of fear of change in our society, as the society is still afraid of the idea of everything new and the use of new devices and lifestyles working without interference in either hospitals or buildings in general.

- To think about future generations in terms of the availability of energy sources, therefore, the concepts of sustainability in hospitals must be used. The savings in electricity are followed by savings in water resources and fuels, as well as to minimize damage to the environment.

- The framework of targeting must be expanded, not only at the level of companies but also for all members of society to apply intelligence in all types of buildings, such as making suggestions to the responsible authority when presenting the initial design as a means of spreading technical awareness in Sudan.

- Training the local workers to qualify them for the system design, implementation and the required maintenance. Also to stimulate these workers to ensure their survival and continuity to follow up this type of projects.

- The phenomenon of brain drain in our society today is a major problem for its advancement and the continuation of projects in it and ensure its on-going maintenance, if foreign companies are attracted to construction, it is necessary to train local worker for following-up and maintenance.

- Do not neglect the periodic maintenance and continuous updating of the system, which is a priority to avoid any failure in the future. Therefore, it is necessary to regularly follow all the devices in the building as well as maintenance regularly to avoid faults that may affect the movement of the building and cause serious errors, which leads to resentment and dissatisfaction of users.

- Enact the necessary laws to implement the system on a large scale and the solidarity of the concerned authorities to provide the necessary for investors, these laws will be from the Ministries of Energy and Urban Planning Authority and others.

- Work on coordination between companies which are willing in making workshops and trial courses in designing smart systems for users in various specializations for training and enlightened practice.

List of References

1. G. Abbott. IUSS Health Facility Guides, *Hospital Design Principles*; 2015. P.29.
2. Pan American Health Organization. Hospital Don't Burn. *Hospital Fire Prevention and Evacuation Guide*. Washington. Dc, 2014.
3. IFC Life and Fire Safety. *International Finance Corporation*. Washington. Dc, 2017.
4. Hilary Dalke. David L Loe. Lighting and Colour for Hospital Design. Published by TSO (The Stationery Office), 2004.
5. Gallagher Healthcare. What are the Different Types of Hospital? *Industry Insights Blog* [Online], March 2018. [Accessed 2018].
6. Boyd Philippi. *Factors to Consider in Hospital Design and Construction* [Online], March 2012. [Accessed 2018].
7. European Union Agency for Network and Information Security (EUANIS). Smart Hospitals. *Security and Resilience for Smart Health Service and Infrastructure*; November 2016.
8. International Journal of Smart Home [Online], 2015. [Accessed 2018].
9. Jingjing Yang, Zhihui Wang and Xiao Zhang. International Journal of Smart Home. *An iBeacon - based Indoor Positioning Systems for Hospitals* [Online], 2015. [Accessed 2018].
10. Patrik Fuhrer. Dominique Guinard. *Building a Smart Hospital using RFID technologies: Use Cases and Implementation* [Online], 2006. [Accessed 2018].
11. Syed Jawad Shah. *Introduction to Medical Gas Pipeline System*. [Online], June 2017. [Accessed 2018].
12. Rahul Choudhary. 8 Important Things to Consider when Choosing a Location for the Hospital – Hospital Planning [Online]. Available from: https://www.shareyouressays.com. [Accessed 2018].
13. Guidelines and Main Requirements in the Planning and Design of Hospitals. [Online]. Available from: https://www.linkedin.com. [Accessed 2018].

14. Matias Peluffo. Defining Today's Intelligent Building. [Online]. Available from: https://www.commscope.com. [Accessed 2018].
15. Artificial Intelligence Lays the Foundation of Buildings of the Future. [Online]. Available from: https://www.ibm.com. [Accessed 2018].
16. Medical Gas Central Piping System. [Online]. Available from: https://www.medicop.com. [Accessed 2018].
17. https://blog.encorefireprotection.com. [Accessed 2018].
18. https://www.healthknowledge.org.uk. [Accessed 2018].