A PROCEDURE FOR MINIMIZATION OF NOSOCOMIAL INFECTIONS RISK THROUGH UPGRADING AND RE-ARCHITECTING OF HEALTHCARE FACILITIES

YASAMAN PARSIA

DOCTOR OF PHILOSOPHY

UNIVERSITI MALAYSIA PAHANG

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YASAMAN PARSIA

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ABSTRAK

Sebagai pengurus organisasi seperti hospital, sudah menjadi tanggungjawab bagi organisasi tersebut untuk memastikan tempat kerja adalah selamat daripada pelbagai risiko jangkitan. Jangkitan nosocomial atau (NI) sudah menjadi satu kebiasaan di hospital dan ini boleh mengakibatkan kadar emosi dan kematian. Tambahan pula, pesakit harus berada di hospital pada tempoh yang lebih lama dan seterusnya memberi bebanan kewangan. Adalah mudah untuk NI berjangkit dari satu pesakit ke pesakit yang lain. Oleh yang demikian, adalah amat penting untuk mengenalpasti jabatan yang berisiko dalam mengekang rebaknya jangkitan ini. Berdasarkan tinjaun literatur, belum ada satu model yang dapat mengesan kawalan jangkitan ini secara efektif melalui pengubahsuaian susun atur. Kebanyakan solusi berkisarkan kajian perubatan dan jenis peralatan elektronik bagi warga kerja hospital untuk mengawal kebersihan diri dan mengelakkan daripada risiko jangkitan NI. Menaik taraf atau mengulang semula arkitek hospital boleh membantu para pengurus untuk mengurangkan kadar NI dalam hospital mereka. Oleh itu, objektif pertama dan kedua adalah untuk mewujudkan prosedur membuat keputusan (DM) secara sistematik dengan pendekatan matematik untuk mengawal NI melalui menaik taraf dan atau mengulang semula (rearchitecting) DM. Hibrid ini akan membolehkan hasil ini dapat diintegrasikan melalui kepentingan kriteria kedalam nilai fungsi utiliti. Oleh itu, kaedah weighted sum (WSM), makmal pengujian dan makmal penilaian (DEMATEL), DEMATEL yang diperluaskan atau Expanded DEMATEL bersama teknik kumpulan nominal yang diubahsuai atau (NGT) digunakan untuk membangunkan prosedur. Pemilihan kaedah MADM adalah berdasarkan tanda aras, seperti keupayaan analisis, kemudahan penggunaan dan sebagainya. Objektif pertama dicapai melalui WSM dan DEMATEL. Bagi objektif kedua, DEMATEL dan WSM ditakrifkan. Kesahihan prosedur ditentukan oleh seorang pakar perunding. Kajian kes melalui ujian kebolehlaksanaan dicadangkan untuk menjawab objektif kajian ketiga. 400 katil dan 20 jabatan dari hospital paling besar di Kerman, Iran dijadikan sebagai responden kajian. Pengesahan keputusan telah diperoleh daripada pihak pengurusan hospital tersebut. Secara kesimpulan, prosedur untuk menaik taraf adalah praktikal dan menyumbang kepada pengurangan risiko NI. Ini boleh dijadikan solusi untuk mengatasi cabaran pelbagai susun atur – keputusan pengubahsuaian sejajar dengan pengawalan NI. Prosedur kajian ini boleh menjadi asset bagi kesihatan awam.

ABSTRACT

As manager of each organization such as healthcare facilities (HFs), it is his/her responsibility to maintain a safe and healthy workplace against various risks. Nosocomial infections (NIs), also known as HF cross-infections is one of these risks in HFs. These infections can increase the rate of mortality, morbidity, emotional stress, and prolong hospitalization for patients and also creates additional cost for both patients and HFs across the world, especially in Kerman/Iran as a case of this study. Departments of HFs have a significant effect on transmission of NIs from one patient to other patients and from one department to the other ones. Departments can be source of infections in HFs and it seems so important to find risky departments in controlling NIs. It can be a good decision for HFs managers to find risky and low risky departments to remove or re-architecting/add or upgrading in HF, respectively, to control NIs. Based on literature review there isn't study, if any, by considering this note to control NIs and managers still need more effective models for infection control in healthcare facilities through layout modification decisions. Most of the researchers just try to reduce the risk of this infection through medical study such as introduce new antibiotics or through architecting research by attention to layout design elements for example, type of equipment or through management by preparing some electronical systems to control personnel in fields of personal hygiene. Recognition the risky and/or low risky departments during upgrading and/or re-architecting of HFs can help the managers to reduce the rate of NIs in their HF. Otherwise, less attention to this note during upgrading and re-architecting of HFs can be a factor to increase the risk of NIs. Therefore, the first and second objectives of the current study were to propose a systematic decision-making (DM) procedures with a mathematical approach as a new solution for NI control in HF through upgrading and/or re-architecting DM. It is argued that hybridization of the methods can integrate their results for final DM and create an opportunity of integrating criteria importance into the value of utility function. Thus, Weighted Sum Method (WSM), Decision-making Trial and Evaluation Laboratory (DEMATEL), and Expanded DEMATEL, together with the modified Nominal Group Technique (NGT) for decision data-collection, were adopted for the development of the procedures. Selection of the MADM methods was based on benchmarks, such as their analysis capability, ease-of-use and etcetera. To achieve objective one, WSM with Expanded DEMATEL and for objective two DEMATEL with WSM are defined. An expert consulted to comment validity of the proposed procedures. As third objective, the feasibility test of the proposed procedures, a case study was accomplished. A large size hospital in Kerman/Iran with 400 beds and 20 departments was selected for the case study. The results of the proposed procedures calculated based on the collected data from the case. Lastly, validity and feasibility of the proposed procedures obtained by confirming the results by top management of the case. To conclude the finding of this research, considering the issue of NIs for patients and HFs, the presented decision-making procedures for upgrading and re-architecting of HFs, practically, could contribute to the minimization of NIs risk. They are, theatrically, are novel decision-making procedures for HF managers which can be a considerable solution to overcome challenges of multiple-criteria layout-modification decisions align with controlling the NIs. Last but not least, as a social contribution, the procedures of this study will be an asset for public health.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchical Process
BSI	Blood Stream Infection
DEMATEL	Decision-Making Trial and Evaluation Laboratory
DM	Decision Making
GDM	Group Decision Making
HF	Healthcare Facility
ICU	Intensive Care Unit
MADM	Multi Attribute Decision Making
MCDM	Multiple Criteria Decision Making
MODM	Multiple Objective Decision Making
MOH	Ministry of Health
MRSA	Methicillin Resistant *Staphylococcus aureus*
NGT	Nominal Group Technique
NI	Nosocomial Infection
RTI	Respiratory Tract Infection
SSI	Surgical Site Infection
TOPSIS	Technique for Order Performance by Similarity to Idea
UTI	Urinary Tract Infection
VRE	Vancomycin Resistant *Enterococci*
WS	Weighted Score
WSM	Weighted Scoring Method

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The researcher has explained the dangers occurring due to the existing infections risks in Healthcare Facilities (HFs). This chapter introduces the study, presents the research problem, gap and tries to clarify the statement of the main problem, research objectives and questions, scope and the significance of this study. At the end of this chapter, the structure of the thesis is explained for the readers.

1.2 Background of study

A healthy society is educated, work-centric, can contribute to the different arts and provides many services which are usually unavailable to an ill and unhealthy society (Dima-Cozma & Gavriluta, 2014). Hence, each government has developed mandates for providing better health facilities to all the patients (Phiri, 2014; Wenzel, Bearman, Brewer, & Butzler, 2008). One such measure includes increasing the HFs in the regions and the country, and this could lead to the prosperity of this area and improve the quality of the people's lives (Ahmadi-Javid, Seyedi, & Syam, 2017). Such HFs range from small dispensaries, to doctors' offices, urgent care facilities, clinics and finally, to large hospitals with trauma centres and emergency rooms (Ahmadi-Javid et al., 2017). Hospitals are a formal type of HF which have been developed by the society for providing a diagnostic treatment to the people by an experienced staff (Phiri, 2014). Hospital is an example of a multi-product organisation which offers several services like patient care, health promotion, health personnel education, and even facilitate some health-related research studies (Padgaonkar, 2004; Phiri, 2014)

Every HF building (like the hospital) houses many departments which offer their own services (Abel & Reese, 2015). These include the inpatient, outpatient, medical, accident and emergency unit, and the operating theatres, which are the professional departments, whereas, the non-professional departments include admission, purchasing, personnel, medical record maintenance, laundry, housekeeping, maintenance, mechanical, central sterilisation unit and other such departments (Abel & Reese, 2015). For having an applicable HF, many other parameters like the design quality of the HF layout must also be considered.

The design quality of the HF building is a reflection of an active and healthy society (Phiri, 2014). Also, a proper design of the physical environment within the HFs has many advantages and can lead to improvement in the health and satisfaction levels of the patients, delivery of better medical care, satisfied and cheerful staff along with a reduction in the healthcare costs (Parsia & Puteri, 2018). Furthermore, a good and supportive HF environment prevents additional injuries and also provides help and psychological support to the patients during the recovery process (Hussain & Babalghith, 2014).

On the other hand, evidence shows that a bad design and HF environment could increase the medical-related mistakes, staff injuries, rates of infection, decreases the patient recovery, leads to a higher nursing staff turnover, loss in the work time, added disabilities and the increased costs are other harmful effects of a bad HF environment and design, which must be addressed (Parsia & Puteri, 2018). Some of these problems are more specific to the particular building design, however, greatest of them are observed in many of the HFs (Stockley, Constantine, Orr, & Group, 2006). However, if these issues are recognised during their earlier stages, their effects can be decreased (Stockley et al., 2006). Some of the researchers, such as, Phiri (2014) and Wenzel et al. (2008) described, the main issues related to the strategic designs of the HFs, which were:

i. Sustainability (developing a therapeutic environment, innovative designs, responding to future changes, etcetera), and
ii. Preventing infections and trying to decrease the various NIs (Nosocomial Infections). In general, NIs are defined as the infections affecting the patients during their hospitalisation in HFs (Parsia, Puteri & Sorooshian, 2017).

The physical design of the HF plays a major role in controlling the HF infections and minimising the infection transmission risk (Parsia & Puteri, 2018). Now, it has been accepted that the infection controlling measures must be integrated with the planning and development of the HF buildings along with its operation (Parsia & Puteri, 2018).

After understanding the relationship between the HF construction techniques and the desired result, like the decrease in NIs, a lower mortality rate and etcetera, during the designing of these buildings, the design team must not only focus on the construction costs or meeting the facility space requirements, but must also consider the role played by the physical environment of the HF while providing a better HF (Reis & Chambers, 2009).

According to the US government's mandate, any harm (like NIs) caused to the patients during their stay in the HFs, which are under the control of the Medicare & Medicaid (USA) services, must be treated free of cost (Hughes, 2008). Based on the relationship between the design of the HF building and the HF's agenda for patient safety and improved HFs, the processes like the evidence-based designs are seen to be a common language which enables the communication between the architects, clinicians and the administrators (Reis & Chambers, 2009). The necessary safety risk assessments must be made during the planning stage and should be an iterative process during the design review (Abel & Reese, 2015).

Behnke et al. (2013) said an increase in the use of antimicrobials (modern age of antibiotics) and advancements in the medical practices have led to many invasive procedures being used on the patients, which further increases the threat of new NIs. Weiner, Fridkin, Aponte ‐ Torres, and Avery (2016) and Ohri (2017) stated, there is a lack of adequate systems and infrastructure for infection prevention and control in many HFs contributes to the development of NIs and the spread of resistant pathogens. However, some studies tried to prevent and control the occurance of NIs from different view point, such as, medical and microbiological technique (Meade & Garvey, 2018; Jonokuchi et al., 2018; Alvarez-Marin, Aires-de-Sousa, Nordmann, Kieffer, & Poirel, 2017; İpek, Aktar, Okur, Celik, & Ozbek, 2017; Agarwal & Larson, 2018), HF management (Sitek, Witczak, & Kiedik, 2017; Suner, Oruc, Buke, Ozkaya, &

Kitapcioglu, 2017; Ning, 2014) and architecture which is focus more on design factors such as light, constructive materials and etcetera (Firrantello & Bahnfleth, 2017; Kung et al., 2017; Mehta et al., 2014). But, after about three decades of NI surveillance and control world-wide, it still remains an important problem for HFs today (Samuel, Kayode, Musa, & Nwigwe, 2010; Elliott & Justiz-Vaillant, 2018, Aliyu, Furuya, & Larson, 2019).

1.3 Problem statement

NIs are a worldwide phenomenon, a major cause of mortality and increase the emotional stress levels and the morbidity rates among the hospitalised patients (Ghashghaee, Shahri, Behzadifar, & Seyedin, 2018; Kurutkan, Kara, & Eraslan, 2015; Nazir & Kadri, 2017); or even in the new-borns (Herald, 2017). Totally, NIs are a public health burden, and a threat to patient safety that pervades all healthcare facilities both in developed and developing countries (Shamshiri, Fuh-Suh, Mohammadi, & Amjad, 2015). According to reports from other parts of the world, the incidence of NIs differs within different regions (Hoseini, Abdinia, Ahangarzadeh, & Oskouie, 2014). Even in many of the developed countries like the USA NIs is an important problem and 50-60% of >2 million NIs were caused due to antibiotic-resistant pathogenic microorganisms, only (Mohammed, Mohammed, Mirza, & Ghori, 2014). Although the magnitude of NIs in many developing countries is not clearly understood, it has been estimated that it affects from 5% to 15% of hospitalized patients in departments (Tabatabaei, Pour, & Osmani, 2015). Iran represents one of the developing countries, which faces the issue of NIs imposing a high economic onus, in terms of high costs annually for the Ministry of Health (MoH) and private hospital managers (Ghashghaee, Shahri, Behzadifar, & Seyedin, 2018). In one study, the results from a systematic review of the literature and meta-analysis of the data on the prevalence and causes of NI in Iran published between 1997 and 2010 showed that the best estimate of overall prevalence of NIs in Iran was as high as 30.43% (Tabatabaei et al., 2015). As Zahraei, Eshrati, Masoumi, and Pezeshki (2012) explained, the additional information is needed to determine the country-wide presence of NIs in Iran (Zahraei et al., 2012). In a case-study in Kerman, as one of the biggest provinces in Iran, 33.9% of 1000 hospitalized patients in Shafa hospital of Kerman-Iran had pneumonia infection (a type of NIs) (Saboouri & Ashrafganjuyi, 2015). Musavizade, Yeganeh, and Aghayi (2015) stated, among 400 evaluated patients of three hospital

(Shafa, Afzalipour and Bahonar) in Kerman- Iran, 11% of them were suffering because of NIs. In 2014, the prevalence rate10% of NIs was reported for Bahonar hospital in Kerman-Iran (Afsharipour, Hajipour, & Shahsavari, 2014). During one-year study in Bahonar hospital, 561 patients with NIs were recognized (Rajabi, Abdar, & Rafiei, 2016).

Annually, a lot of deaths occur from NIs, making this the 10th leading cause of death, with projected billions of annual costs (Aliyu et al., 2019; Khazaei, Khazaei, & Ayubi, 2018; Shalini, Vidyasree, Abiselvi, & Gopalakrishnan, 2015). In the current business environment, where the performance of the HFs is responsible for their economic stability and compensation, the administrators of such HFs must focus on making decisions for decreasing the economic burden caused by the avoidable adverse events, like NIs, which increase the expenses incurred by the HFs and their patients/ families (Reis & Chambers, 2009). Stiller, Schröder, Gropmann, & Schwab (2017) mentioned, altering the design of the HFs and the departments housed in these HFs is a strategy which is used for controlling the spread of infections . Construction of the HF buildings is considered to be a dangerous business since any minor design flaw could become a fresh source of infection (Clair & Colatrella, 2013). Many evidence-based studies have shown that the design of the HF , as layout and etcetera, plays a significant role in reducing the morbidity and incidence rates of the NIs , since many infection control measures are included during the design phase of the HF project (Clair & Colatrella, 2013).

However as shown in above paragraphs, the NI risk in HFs exist and it is not a practical solution to close down the existing HFs because of the extremely high costs of rebuilding (Sheth, Price, & Glass, 2010); all existing HFs are at risk of developing NIs for their hospitalized patients (Aliyu et al., 2019). The NIs can transmit among the departments of HF, cross infections, therefore find the risky and low risky departments in field of cross infection can be a good way to decrease the rate of NIs. Unknowledgeable decision making for department configuration in HFs can be the other factor to increase the rate of NIs and their side effects. This study will be a new mean for minimizing NIs risk by considering department configuration during modification of HFs. An extensive search of the different literature databases (such as Web of Science, Scopus and etcetera) together with interviews with professionals of the field reveals that there are very few systematic approaches that can be implemented to modify the existing HFs for NI reduction. Therefore, this study is among pioneers in this area of research.

1.4 Research objectives

The main objective of this study is to propose comprehensive procedures to minimize NI risk through modification of the existing HFs. Below are the sub-objectives of this study:

i. To formulate a department selection procedure to minimiz the NI risks through upgrading of HFs.
ii. To formulate a department selection procedure to minimiz the NI risks through re-architecting of HFs.
iii. To validate the re-architecting/upgrading department selection procedures in a case study.

1.5 Research questions

Based on research objectives, this study is conducted in purport to answer the following questions:

i. How to minimise NIs risks through upgrading of existing HFs?
ii. How to minimise NIs risks through re-architecting of existing HFs?
iii. Is the proposed solution by this research, valid and feasible?

1.6 Scope of study

The superior aim of the research is to minimize NIs risk by proposing systematic layout decision-making procedures for modification of the existing HFs. To make this decision the manager of HF have to attention multiple criteria from different categories. when various alternatives or actions with multiple criteria are ranked and assessed, it becomes very complex and sophisticated methods are then needed (Almulhim, 2014). The Multiple Criteria Decision Making (MCDM) approach focuses on supporting Decision Makings (DMs) who must solve complicated decision problems (Tzeng & Shen, 2017). When upgrading the HF, the DM needs to decide if appropriate new department(s) get added. In a similar manner, the re-architecting of HF requires a decision regarding the selection of department(s) that will be eliminated from the present processes and operations of HF. The departments that are added or deleted will now compete with other alternative department(s) on the basis of the criteria of the decision maker. When there are numerous alternatives to choose from, the process of DM will then need to evaluate the decision criteria to ensure that the right choice is selected (Ansah et al., 2015). Thus, this research uses applied mathematics, especially, MCDM methods to formulate decision-making procedures for department selection in HFs, when upgrading and/or re-architecting of the facility. Therefore, this PhD research, in nature, is a mathematical modelling approach. However, among HFs, this research is focused on hospitals; so, a case-study approach, in a large-size hospital, will be performing the quality test of the proposed procedures. The processes of case selection and it's characteristics will be explained in Sections 4.2 and 4.3.

1.7 Significance of study

This study can be viewed as a body of knowledge which investigated the different academic, practical and methodological perspectives that could be applied in the HFs, and are summarised below:

With regards to an academic perspective, this study has proposed novel decision making (DM) procedures which provides very systematic DM method for upgrading and re-architecting the HFs. Based on the literature review this research is among the very first studies with the aim of enhancing DMs for HFs.

Practically, this study has presented a novel method for solving the problems resulting due to the NIs. The results of this study can be used as a solution for reducing the NIs and their side effects (like additional treatment costs, mortality and etcetera) by department selection for re-architecting and upgrading the design of the HFs.

In addition, the methodological contribution, this research considered hybridization of mathematical decision-making methods in order to create systematic procedures for medication of HFs. The mathematical approach is found to be less studies for HF modification decisions. Therefore, this research will be among the pioneer in developing modification decision making models with mathematical approach.

1.8 Definitions of terms

i. **Healthcare facilities:** Formal organisatiions to present patient care services to person's individual-injured or sick has access to centralized medical technology and knowledge society-it protects the society from widespread of the disruptive effects of caring for the ill in the home and making the problems less disruptive for the whole groups of people (Phiri, 2014).

ii. **Cross infection:** It is the physical transfer or movement of harmful microorganisms from one object, person or place to another, or from one part of the body to another (Krapp, 2006).

iii. **Nosocomial infection:** When the cross infection occurs in a HF or long-term care facility it is called a NI (Krapp, 2006). It is an infection which is achieved in HFs, and are favored by a HF environment, referred to by the term 'nosocomial' have been a huge threat to the public health (Wang & Ruan, 2017).

iv. **Risk:** As defined by the author, risk in this research is reffering to the probabality of appearing any kind of NIs to the hospitalized patients, visitors, HF staff and doctors while they are visiting a HF.

v. **Departments:** Department is a modern name for ward; it is a separate area located to a particular type of patient in HFs, as defined by the author.

vi. **HF upgrading:** As defined by the author, it is planning for activating or adding one (or more) new department(s) in a HF location.

vii. **HF re-architecting:** As defined by the author, it is planning for excluding or omitting one (or more) department(s) in a HF location.

1.9 Structure of the thesis

The problem statement is presented in chapter 1. This chapter has outlined the motivation and objective of the research in the specified scope. The research parameters are further understood through literature review as in chapter 2. The chapter 2 discuss the foundation of this research, NIs and the need for MCDM for department selection in HF modifications. The decision procedures development will be explained further in Chapter 3. The research question 1 and 2 are answered in this chapter. The proposed models and hybridization of them to create decision making procedures, to answer the two research questions are explained in this chapter. Moreover, the formulation of testing the model is presented in this chapter. The finding of a case-study for testing the developed procedures of this study is presented in chapter 4. This will be an answer to research question 3 of this study. The findings will then be further discussed in this chapter. Finally, this study will be concluded in Chapter 5. Chapter 5 will, additionally discus the contributions of this research with some suggestion for future studies to improve this work.

1.10 Summary

This chapter highlights the background of this PhD study, importance of HF layout and its role to control NIs and the need for minimising the infection transmission risk as an important risk of HFs. Therefore, the problem statement has been outlined and justified by the significant of the research effort. Research questions and research objectives had also been stated. In the scope of study mentioned that, this research is a mathematical modelling approach. Then, the chapter continued with the definition of the terms used throughout this study. Finally, the structure of thesis is presented for the readers.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Here, the researcher has reviewed all the available literature regarding the research topic. This chapter will explain all the different areas covered in this research topic for determining the full scope of research, like concept of Healthcare Facilities (HFs) and hospitals, different departments present in a hospital, risky HFs, Nosocomial Infections (NIs) and their subsections, the effect of the HF architecture on controlling the NIs, HF upgradation and re-architecture (based on the department selection), along with the managerial criteria involved in making important HF-related decisions and different types of decision-making (DM) process and finally, decision making for HF upgrading and rearchitecting will be discussed. These are some of the topics that can help to achieve the research objectives in the next chapters.

2.2 Healthcare facilities

World Health Organisation (WHO) is the core of public-health leadership. According to Olden (2014), health is defined as the 'state of complete mental, physical, and social well-being, along with the absence of any infirmity or disease. Healthcare includes all activities, process and measures involved in improving and maintaining the health, living conditions and the working environment of the individual along with his rights for health insurance (Burazeri & Kragelj, 2013; Steele & Cylus, 2012). This field also encompasses the medical and professional measures, processes and activities that can be undertaken for improving the health of the people and preventing/controlling diseases, disorders and infections (Burazeri & Kragelj, 2013; Steele & Cylus, 2012). However, currently, it has become difficult to define the healthcare system and determine where it gets initiated, what is included within its domain and where does it end (Burazeri & Kragelj, 2013).

In one study, Stanfield, Stanfield, Cross, and Hui (2011) stated that the healthcare industries are a complex group comprising of various therapeutic, remedial and preventive services. The healthcare sector aims to deliver efficient service to the patients ('patient' refers to the person who is served in any way by the HF) in variety of it's facilities (Burazeri & Kragelj, 2013; Olden, 2014). Many HFs like the clinics, hospitals, healthcare professionals, governmental or voluntary agencies, medical equipment manufacturers, pharmaceutical industries and the private insurance companies can provide such services to the patients (Stanfield et al., 2011).

In order to provide effective services to the patients, the HFs must satisfy some minimum requirements (Burazeri & Kragelj, 2013):

i. Provide access to good quality services for satisfying acute or chronic health needs;
ii. Provide efficient services for improving health and preventing diseases; and,
iii. Appropriately respond to new health threats (like emerging infectious diseases, increasing burden of the non-communicable diseases, ageing of the population, health problems arising due to global environmental changes).

Ratnapalan and Uleryk (2014) observed that the healthcare systems varied in different countries and were financed by the public or private sector organisations. All the HFs are classified on the basis of their ownership and the motives for their profit (Burazeri & Kragelj, 2013). Parsia, Puteri, and Sorooshian (2017) stated that the HFs include both the inpatient and the outpatient facilities.

a) Out-patient facilities and services

The out-patient care is seen to be an integral component of the healthcare system as it represents the primary contact of the patient with the healthcare professional and is the primary step in ensuring an effective and continuous healthcare (Pouragha & Zarei, 2016). This out-patient service includes providing the 'moving' patient (who are not bed-ridden and do not intend to spend the night in the hospital) with effective services and facilities, as they usually visit for an examination, consultation, treatment or follow-up

(Burazeri & Kragelj, 2013; Smith, 2017). In many cases, they contact the primary health worker, these types of services are provided by the hospitals, community health centres (or clinics), dispensaries or polyclinics (Burazeri & Kragelj, 2013). Usually, the outpatient departments in the hospitals are the primary facilities accessed by the patients and these are still existent (Burazeri & Kragelj, 2013; Pouragha & Zarei, 2016).

b) In-patient care and facilities

The in-patient care involves the admission of the patients into the HFs (like nursing homes, hospital etcetera) (Burazeri & Kragelj, 2013; Venesta, Shapland, & Products, 2006). These services include diagnosis, treatment and rehabilitation of the critically ill patients, as they cannot be completely treated in their homes or the ambulatory-polyclinic facilities and hence, have to be admitted into the hospitals for a certain period of time, which could range from days, weeks to even months (Burazeri & Kragelj, 2013; Smith, 2017). According to Ratnapalan and Uleryk (2014), HFs like the hospitals or academic health centres (including the university-affiliated teaching hospitals) are an important component of the healthcare system, irrespective of their country of origin or the types of funding organisations.

HFs range from small clinics to large complex hospitals (Priyadarsini & Tarek, 2015). Among them, hospitals are the major and most complex type of HF (Priyadarsini & Tarek, 2015). Hospital buildings are unique with regards to purpose, complexity, and size (Olanrewaju, Wai Fang, & Yeow, 2018). Hospital buildings are important for any community and the way the building are designed, constructed and operated have profound impact on users, health and the health of the environment (Olanrewaju et al., 2018). Hospitals are large enterprises and are one of the most challenging buildings to construct and operate (Olanrewaju et al., 2018). In this study, because of the advanced structure, and the long period of patient’s housing, as well as the considerable reports of NIs in hospitals, these HF will be the main concern.

2.3 Concept of hospital

Currently, one of the most important human requirements is the access to a good HF like hospital (Yang, Iqbal, & Ko, 2015). The term 'hospital' originated from the Latin word of '*hospes'* or *'hospitalis'*, which means 'hospitable' (Smith, 2017). Hospitals are a complex form of 24 hours/day HF, which provide medical and nursing care to the injured or ill patients using specialised scientific equipment and a team of well-trained and educated people to treat patients, and also help in the training nurses and doctors (Gecikli, 2014; Hoseinzadeh, Samarghandie, Ghiasian, Alikhani, & Roshanaie, 2013; Phiri, 2014; Saka, Akanbi, Obasa, & Raheem, 2016; Sinclair & Shivagunde, 2014).

2.3.1 History of hospital and hospital management

According to Khan (2013), the medical and surgical practices were available from the beginning of the civilisation, since the diseases preceded the humans on this earth. The medical treatment in the ancient era included many religious and ceremonial activities. Medicine, as an organised form of treatment, was introduced 4000 years ago, in the Southwest Asian region of Mesopotamia, situated between the Tigris and the Euphrates rivers.

According to Van Hoof, Rutten, Struck, Huisman, and Kort (2015), the discussions regarding the importance of building a suitable environment for the HFs were initiated since the period of Hippocrates (400 BC). Hussain and Babalghith (2014), defined 6 historical periods during which there was an evolution in the hospital designs, including the ancient era, medieval period, Renaissance, Nightingale era, Minimalist Mega hospitals and finally, the Virtual Health scope (Hussain & Babalghith, 2014).

For example, Elf, Fröst, Lindahl, and Wijk (2015) stated that in 1861, Nightingle era described different physical factors which promoted the patient health and safety, including temperature, air quality, light and other psychosocial features like the nature and proximity of the patients and the staff. Nightingle era also established a direct relationship between the patient health and the HFs. During the mid-1800s, the hospitals had a healing effect on the patients, and the hospital buildings were usually built in the park-like setting with a lot of greenery and trees.

In field of hospital management, St Thomas Hospital built in 1871, in London, was the first hospital which used the guidelines for planning the architecture and the positions of its departments (Hussain & Babalghith, 2014). Distinct departments were set aside for dissimilar illnesses (like fever, eye conditions, gynaecological disorders, diarrhoea and wounds), which risked the objectification of the patient (Elf et al., 2015; Khan, 2013). Also, the convalescing patients were kept separate from the sick patients and the ambulatory patients were provided with the necessary provisions (Khan, 2013).

Every patient or department in the hospital or any other HF has some specific needs which have to be satisfied by the HF staff or by the other ways (Lucas, 2017). The facility team in the HFs consist of facility engineers who have to work with the other staff including the nurses, physicians, accountants, administrators, etcetera, for ensuring that the HF is able to satisfy and meet with the needs of all the patients. There are different types of hospitals that serve various types of patients and are described below.

2.3.2 Classification of hospitals

Many criteria are used for classifying the hospitals, like the size, level of care, bed capacity, ownership or control, hospital objectives, system and management (Sinclair & Shivagunde, 2014). Alalouch (2009) classified the HF services as:

i. Primary, if they were represented by local doctors at the local level, health centres and in the community hospitals;
ii. Secondary, if they comprised of general hospitals, and;
iii. Tertiary, if they were represented by teaching institutes, specialist hospitals and medical research centres at the regional level.

Figure 2.1 shows the primary, secondary and tertiary healthcare in terms of the services that HFs provide. Appendix A presents the details of categorization of hospitals.

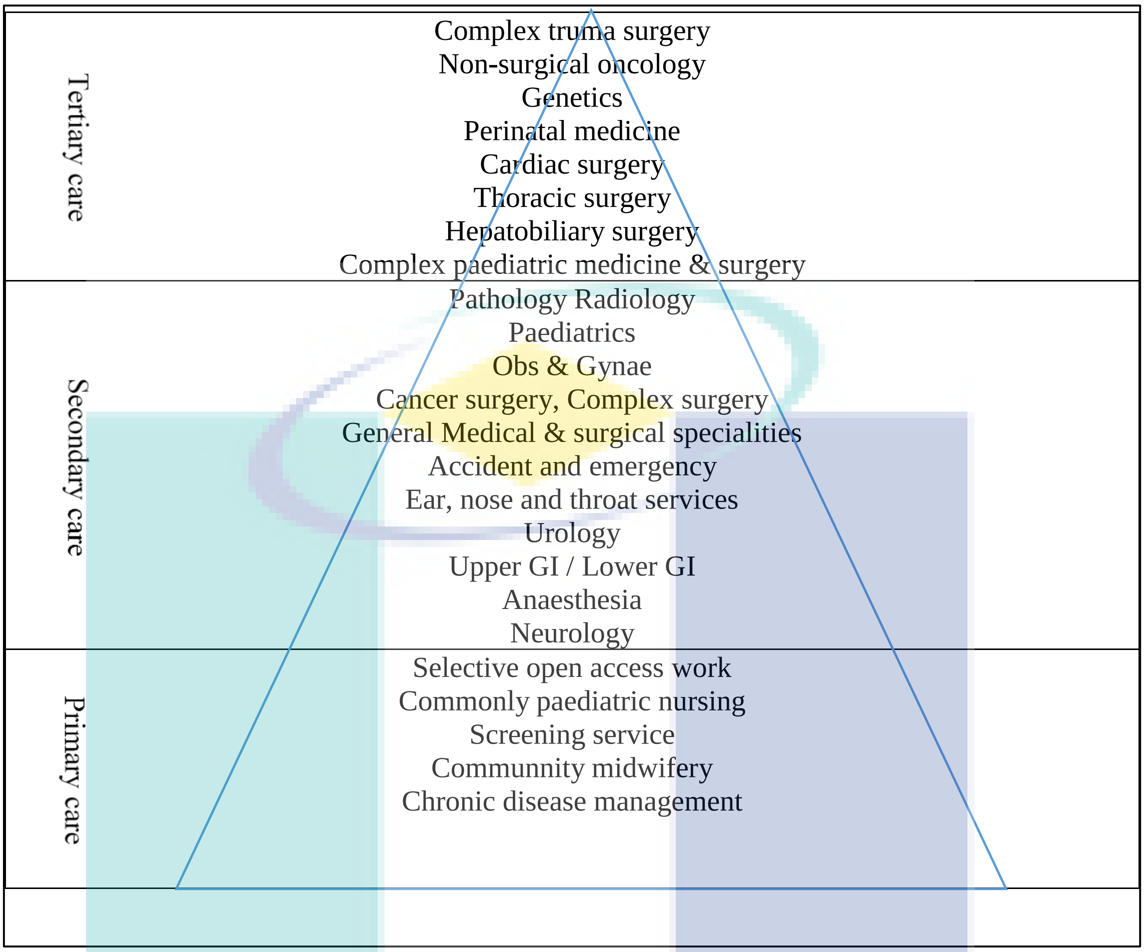

Figure 2.1 Primary, secondary and tertiary healthcare in terms of the services HFs provide

Source: Burazeri & Kragelj (2013).

2.4 Healthcare facilities departments

The different HF departments occupy 50% of the area within the HF and are the single largest element which generate the highest public interest (Alalouch, 2009). The patients spend a lot of time in the departments during their HF stay, and hence, the departments are seen to occupy a lot of floor area. For example, the departments have a significant effect on the design of the hospitals with regards to the size occupied by them and their effect on the patients.

Some studies like Alalouch (2009) and Alalouch, Aspinall, and Smith (2016) stated that the general HFs show a variation in their departments, but generally, the departments are classified into 3 major zones:

i. Support zone.
ii. Treatment and diagnostic zone.
iii. In-patient zone.

On the other hand Alalouch (2009) suggested a very detailed classification system for the HF departments:

iv. Operational areas for providing care;
v. Supply and disposal;
vi. Treatment and examination;
vii. Residential areas;
viii. Research, teaching and service operations;
ix. Administration and technology.

According to Smith (2017), the departments can be classified into the type of patients they serve, as:

i. Out-patients (who stay in the HF for short time, such as, hours).
ii. In-patients (where patients have to be hospitalised for a longer time in the HF).

Based on the published studies, the departments in the hospital (which is the biggest HF) are divided based on the type of patients they serve, the types of services they provide, and etcetera.

2.5 Risky healthcare facilities

The main responsibility which must be fulfilled by the healthcare providers and the various HFs is to 'do no harm' or the 'fundamental human right', and certify that the advantages of the intervention are much better than the risks or the deleterious effects (Jovic-Vranes, Mikanovic, Vukovic, Djikanovic, & Babic, 2014; Slawomirski, Auraaen, & Klazinga, 2017). However, harmful effects have been constantly observed in the healthcare sector (Slawomirski et al., 2017). During the 19th century, the HFs were feared and dreaded, as they were considered to be dangerous places and the sick patients were usually safe if they kept at home. Later, with the advances in the medical technology, there was an improvement in the general status and authority of the medicine and healthcare sector, and thereafter, the HFs were considered safe.

Despite precautions, there are many healthcare errors which lead to mortality and morbidity of the patients (Mohajan, 2018). However, this supposition of safety began to be questioned during the 1980s-90s as healthcare harm was examined in a more structured and scientific manner (Slawomirski et al., 2017). Many patient safety programmes were introduced, which could decrease or prevent the adverse health-related problems amongst the patients (Zsifkovits et al., 2016). Some reports were also introduced like To Err is Human, in 1999, the Quality in Australian Health Care Study ,in 1995, and other European studies, which showed that around 1 in 10 HF patients had to suffer from unnecessary medical errors, and many of these patients ultimately died (Slawomirski et al., 2017). It was stated by the Council of the European Union that many of these adverse events, which occurred in the primary healthcare centres and the HFs, can be prevented (Zsifkovits et al., 2016).

Improper care which results in the patient harm is not simply due to human fallibility but occur principally due to failure in organising or delivering proper care (Kalra & Kopargaonkar, 2017; Slawomirski et al., 2017). One important risk factor in the HFs that can convert them from safe to dangerous places is the high risk of NIs, which is a direct indication of the failure of the healthcare system.

2.6 Nosocomial infections (NIs)

The term ‘Nosocomial’ is derived from the Greek words of ‘*Nosos*’ which means ‘disease’ and ‘*Komeion*’, which means care (Zerganipour, Ajami, Ketabi, & Samimi, 2016). NIs, also known as HF cross-infections, are a type of infection wherein a patient gets infected during his hospitalisation ((Berket, Hemalatha, Getenet, & Wondwossen, 2012; Khan, Baig, & Mehboob, 2017; Lax & Gilbert, 2015; Mohammed et al., 2014; Zerganipour et al., 2016). The term ‘nosocomial’ describes any diseases which are inflicted on the patient when he is being treated for some other ailment or obtaining general medical care (Berket et al., 2012). There are other definitions of this term, published by earlier studies, for instance, it is also referred to systematic or localised conditions which can arise due to a reaction to some infectious agents or toxins (Nautiyal et al., 2015; Zerganipour et al., 2016). According to another definition, NIs refer to the infections contacted because of the prevailing environmental conditions in a HF, for instance, if the HF staff are infected with some infection or if the patients get infected because of other reasons during their hospitalisation (Adamus, 2011; Kouchak & Askarian, 2012; Nautiyal et al., 2015; Tabatabaei et al., 2015). Berket et al. (2012) stated that the NIs are clinically observed when the patient is either still hospitalised or within a few days of his discharge. Some of the significant symptoms of the NIs include inflammation, pain, night sweats, fever, infections, swelling and difficulty in breathing (Nautiyal et al., 2015).

2.6.1 Bases of NIs

The real understanding of cross-infection followed upon the discoveries of Pasteur, Koch and Lister, and the beginning of the ‘Bacteriological Era’. It was then found that microorganisms can transfer from one object/person/place to another (Krapp, 2006). The close of the 19th century saw triumphs of disinfection and asepsis and seemed to herald the final victory over cross-infection, however, the victory was short-lived (Forder, 2007). Furthermore, for the initial theory for this research, the exist of cross-infection in HFs was reported by Cruickshank (1935) when he described the acquisition of *Streptococcus pyogenes* in patients after admission to hospital (Ayliffe and Lilly, 1985). This finding by Cruickshank (1935) is the bases of NI, as well as this research. Even today, hospitals have a concentrated population of seriously ill patients, and an even greater risk of cross infection (Krapp, 2006). This is seen to be a major social, medical and economic problem which affects the developing and the developed countries alike (Adamus, 2011; Farzianpour, Bakhtiari, Mohammadi, & Khosravizadeh, 2014).

In 1941, a memorandum on the prevention of NI in wounds advised that hospitals appoint ‘. . . *full-time special officers to supervise the control of infection* . . .’ (Meers, 1980). In 1944, it was suggested that every hospital should set up a committee representing doctors, nurses, laboratory workers and administrators, to investigate and design measures to control cross infection (Meers, 1980). The pandemic of NI due to *Staphylococcus aureus* in the 1940s and 1950s, led to the production of further advice (Meers, 1980). Jacoby (1944) mentioned, cross infection is a major problem in the management of HF. Fisher (1977) mentioned, decisions should be made on the germicide’s ability (the ability to destroy harmful microorganisms) to fight cross-infection, not on price alone.

With the opening of numerous hospitals for infectious diseases in the 20th century, it was soon realised that infections occurred not only in obstetric and surgical patients (the emphasis in the late 19th century) but in medical patients as well. It was soon realised that many viral, as well as bacterial, infections spread in HFs and cause these infections (Forder, 2007). Even in a recent decades, Hertzberg (2018) alarms, the risk of cross infection in some HF departments are a serious public health concern. The importance of this risk was demonstrated dramatically during the 2003 Severe Acute Respiratory Syndrome (SARS) epidemic, in which 128 cases of SARS could be directly or indirectly linked to exposure to a SARS patient who sat for hours in a community hospital awaiting assignment to a hospital bed (Varia, Wilson, Sarval, & McGeer, 2003). More recently, the presentation of a patient infectious with Ebola virus disease to HFs in Dallas, Texas, resulted in a need to monitor more than 180 individuals, many of them hospital personnel, who were in close contact with this patient or with 2 nurses who became infected after exposure to this patient (Hertzberg, 2018).

Hospital overcrowding, delays in implementing additional precautions, cohorting and crowding patients together with transmissible infections, movement and transfer of patients from one area to another in the hospital, deficiencies in building design and infrastructure, inadequate staff training and shortages of personal protective equipment also contribute to the risk of cross infections (Québec, 2013). Risk of NIs based on transferring of a patient to another facility or hospital or to another department in the same hospital have been reported (Kulshrestha & Singh, 2016). According to Ong, Magrabi, and Post (2013), cross infections can occurred through transmission of microorganisms from patient-to-patient, personnel-to personnel and department to department.

2.6.2 Issues of NIs

The infection from transmission of microorganisms in HF, NIs, cause an undesirable, but a serious threat to the quality of healthcare system in the country (Adamus, 2011; Farzianpour et al., 2014). NIs prolong the HF stay, lead to a long-term disability of the patients, increase the patients' resistance to antimicrobials, can cause mortality, increase the HF costs for the patients and their families and create a huge financial burden on the existing healthcare system in the country (Farzianpour et al., 2014; WHO, 2014; Alvares, Arnoni, & Da Silva, 2019; Labi, Obeng-Nkrumah, Owusu, & Bjerrum, 2019).

Generally, a majority of the infectious diseases can affect the survival of the people (Zhang, Zhang, & Liu, 2015). NIs have been affecting patients since the 18th century or the pre-Listerian era when the environmental conditions in the HFs were unsafe, there was no use of disinfectants, antiseptics, sterilised instruments, dressing of wounds, sterile gowns for the surgeons and no practice of wearing gloves (Pozgar, 2018). The wounds were usually cleaned with a sponge, and the same sponge was used for all the patients, which increased the rate of infection, usually, the mortality after an amputation was also very high, in the other hand, 60% (Pozgar, 2018).

Currently, NIs are responsible for 37,000 deaths annually in Europe , this number could be even higher (WHO, 2014). According to the data reported by the Hospital Infection Surveillance System in Germany and NIDEP-1, a national prevalence study, it was Germany's first prevalence study which investigated the NIs and the use of antibiotics in the representative HFs, annually around 400,000 - 600,000 NIs affected the German patients, resulting in 10,000 – 15,000 deaths (Behnke et al., 2013; Ott, Saathoff, Graf, Schwab, & Chaberny, 2013). According to the report of the Centre for Disease Control and Prevention, 1.7 million patients are affected by NIs in the American HFs every year, which caused 99,000 deaths (Tabatabaei et al., 2015; WHO, 2014; Zhu, Wang, Li, & Yuan, 2019). The Australian HFs reported 180,000 cases of NIs every year, which led to 2 million bed days being occupied (Ampt, Harris, & Maxwell, 2008). Also, 722,000 acute cases of NIs were reported in the US HFs in 2011 (Adamski, Daly, & Dreisig, 2015; Ward, 2015). Based on a report in 2016, that about 247 HFs in Pennsylvania had submitted their data, regarding NIs, to the National Healthcare Safety Network for a 12-month period (Centers-for-disease-control-and-prevention, 2016). In total, these HFs reported that around 22,552 NIs had affected more than 9,757,224 patient days (Centers-for-disease-control-and-prevention, 2016). Also, on any given day, 1 out of every 25 patients in the HFs would be suffering from at least one NI (Adamski et al., 2015; Ward, 2015).

NIs also lead to huge financial losses every year. In Europe, these amount to around €7 billion, which includes the direct costs and leads to an extra 16 million days of the HF stay; also the USA reported a $6.5 billion loss due to NIs (WHO, 2014). WHO (2014) stated, one NI episode in the Mexican ICUs led to an overall cost of US$ 12,155. In the Argentinian ICUs, every catheter-related bloodstream infection or healthcare-related pneumonia infection led to an average cost of US$ 4,888 and US$ 2,255, respectively (WHO, 2014). NIs have existed since the inception of the HFs, and are seen to be a huge and persistent health problem, occurring worldwide, irrespective of the country's levels of income (Berket et al., 2012; Kouchak & Askarian, 2012).

Despite the fact that many countries are making efforts for controlling the NIs, the NIs result in a significant mortality and morbidity rate, which increases the healthcare-associated costs and could cause an economic crisis (Berket et al., 2012). Nowadays, an increase in the use of antimicrobials and advancements in the medical practices have led to many invasive procedures being used on the patients, which further increases the threat of new NIs (Behnke et al., 2013). These infections are still considered a hazard in this day and modern age of antibiotics (Berket et al., 2012; Kouchak & Askarian, 2012). Even in many of the developed countries like the USA 50-60% of >2 million NIs, were caused due to antibiotic-resistant pathogenic microorganisms (Berket et al., 2012; Mohammed et al., 2014). Lax and Gilbert (2015) stated that the exact prevalence of the NI could not be determined as there is no single surveillance system in the US. However, some common NIs have been described below.

2.6.3 Types of NIs

NIs are seen to be a huge problem affecting each level of the healthcare system (Yallew, Kumie, & Yehuala, 2017). The NIs are generally caused by the microbial pathogens in HFs (Khan, Mehboob, & Ahmad, 2015). Ganju, Gupta, Matreja, and Gupta (2016) stated that the NIs could affect the skin, respiratory system, urinary system, digestive system, bloodstream, surgical sites or any other body organ. Many studies, such as, Khan et al. (2015), Berket et al. (2012) and Sharma and Shabir (2017) stated that the National Healthcare Safety Network with the Centre for Disease Control for surveillance classified the NI sites into 13 different types, which comprised of 50 infection sites, based on their clinical and biological criteria. However, the most common NIs were the Urinary

Tract Infections (UTI), Respiratory Tract Infections (RTI) or pneumonia, Surgical Site Infections (SSI) and the Blood Stream Infection (BSI), that contain over than 70% of all NIs, since they pose a huge threat that the health care professionals have to face (Farzianpour et al., 2014; Mohammed et al., 2014; Nautiyal et al., 2015; Sharma & Shabir, 2017; Zahraei et al., 2012).

i. Respiratory Tract Infection (RTI)

According to Little (2008), RTIs are defined as any infection affecting the upper or the lower respiratory tract. The upper RTIs include the common cold, sinusitis, acute rhinitis, pharyngitis/ tonsillitis, acute rhinosinusitis, laryngitis, tracheobronchitis, and the acute otitis media (Little, 2008; Mossad, 2013). The viruses responsible for a majority of the upper RTIs include the *Parainfluenza* virus, *Rhinovirus*, *Adenovirus*, *Coronavirus*, *Coxsackie* virus, respiratory syncytial virus, human *metapneumovirus*, *Influenza* virus and the *Herpes simplex* virus (HSV) accounting for greatest cases (Mossad, 2013). Meanwhile, the bacterial RTIs are caused by the *Corynebacterium diphtheriae*, group C beta-haemolytic *Streptococci*, *Arcanobacterium haemolyticum, Neisseria gonorrhoeae, Mycoplasma pneumonia* and *Chlamydophila* (formerly *Chlamydia*) *pneumoniae* (Mossad, 2013). The lower RTIs include bronchiolitis, pneumonia, acute bronchitis and tracheitis (Little, 2008). Kofteridis et al. (2004) stated that the nosocomial lower RTIs are responsible for ≈50% deaths due to an increase in the drug resistance. These nosocomial RTIs can increase the average HF stay by 5 days (Kofteridis et al., 2004). The lower RTIs are caused commonly by microbes like the *Haemophilus influenzae* and *Streptococcus pneumoniae* (Phin, Cleary, & Hoffman, 2016). The most risky environments which increase the transmission of the RTIs include the clinical settings which practise aerosol-generation procedures in the open or the general patient departments and comprise of facilities which help in caring for the severely immunosuppressed patients (Phin et al., 2016).

ii. Urinary Tract Infection (UTI)

According to Foxman (2014), UTIs affect the urinary tract (in the organs like the urethra, ureters, bladder and kidneys). Deepthi, Gopika, and Samyuktha (2017) stated that the infections in the urinary tract led to several clinical syndromes like cystitis, urethritis, pyelonephritis and prostatitis. Foxman (2014) stated that as urine enables bacterial growth and hence, can increase the microbial growth in the urinary tract. The microbes causing the UTIs, possess characteristic features which help their survival in the urinary tract, like they can form biofilms, toxins or adhesins, or they inhabit an immune-compromised patient if these patients are unable to take measures to remove the bacteria, for example catheter is in place (Foxman, 2014).

Three probable routes used by the microbes to enter the urinary tract include the ascending route [most frequently-used route] the blood-borne route, and the lymphatic route (Deepthi et al., 2017). UTIs are further complicated by the host factors like age, spinal cord injuries, diabetes and catheterisation (Deepthi et al., 2017). The UTIs are common among adults but become serious when the children get affected (especially younger children) (Deepthi et al., 2017; Keren et al., 2015). The UTIs are the second most common urinary tract-related problem affecting children, also bed-wetting (Deepthi et al., 2017). Also, UTIs are more common among women than men because of their structural differences (where females possess shorter urethra compared to the males) (Bosmans, Beerepoot, Prins, ter Riet, & Geerlings, 2014; Deepthi et al., 2017).

Though *Escherichia coli* causes <50% of the nosocomial UTIs, it is responsible for >80% of the community-acquired infections (Deepthi et al., 2017). Foxman (2014) mentioned that the urinary tract was a very common source for bacteraemia, especially *E. coli* bacteraemia. Also, *Klebsiella sp.*, *Enterococcus* sp. and Group B *Streptococci* cause UTIs in the diabetic patients (Deepthi et al., 2017). Flores-Mireles, Walker, Caparon, and Hultgren (2015) stated that *Enterococcus faecalis, Proteus mirabilis, Klebsiella pneumoniae* and *Staphylococcus saprophyticus* are the other common UTI-causing pathogens.

iii. Surgical Site Infection (SSI)

Nel (2014) and Lubega, Joel, and Justina Lucy (2017) stated, this kind of infections occur within 30 days after the surgery or can also be delayed for more than a year after the operation or after an implant has been placed in the body. Alexiou, Drikos, Terzopoulou, and Sikalias (2017) stated, the SSIs were the other most common NI (infected about 14-16%) and primarily the surgical patients. Generally, in some HF, the surgery department is host to most occurrence of NI (Cheng, Li, Kong, & Wang, 2015). Anderson, Sexton, and Harris (2015) and Cheng et al. (2015) observed, amongst the SSI patients, death occurred more than 75% of the patients during their postoperative period. SSIs lead to 38% of the NIs (Anderson et al., 2015). Despite the use of several quality care measures [like prophylactic antibiotics], the SSIs can lead to mortality, morbidity, and are seen to be an economic burden, especially in neurosurgery (Jonokuchi et al., 2018).

These infections are the 2th greatest common kind of NIs mostly caused by *Staphylococcus aureus* which increases the hospital stay and the risk of death (Khan et al., 2017). The other common microbes which cause SSIs include Coag (-) *Staphylococci*, *E. Coli* and *Enterococcus* spp (Alexiou et al., 2017; Dessie, Mulugeta, Fentaw, & Mihret, 2016). Additionally, there has been an increase in the SSIs, due to Methicillin Resistant *Staphylococcus aureus* (MRSA), methicillin-resistant coagulase-negative *Staphylococcus* sp., *Candida albicans*, multidrug-resistant *E. coli*, Vancomycin-Resistant *Enterococcus* (VRE) sp., and the *Acinetobacter* spp. (Alexiou et al., 2017; Dessie et al., 2016). Also, SSIs are caused by the unusual pathogens like *Rhodococcus bronchialis*, *Legionella pneumophilla*, *Clostridium perfrigens*, *Legionella dumoffil*, *Nocardia farcinica*, *Rhizopus orizae* and *Pseudomonas multivorans* (Alexiou et al., 2017). Despite the fact that many preventive measures are implemented in the HFs (for example, improvement in the techniques for preoperative skin antisepsis), the SSIs continue to be a huge burden and affect the healthcare system (Jonokuchi et al., 2018).

iv. Blood stream infection (BSI)

Viscoli (2016) stated, BSIs refer to the presence of harmful and viable microorganisms in the bloodstream (based on the positive blood culture). These microbes elicit an inflammatory response, which alters the laboratory, clinical and other hemodynamic parameters. The BSIs are said to be a major cause of sepsis-related mortality and morbidity in the world (Dat, Vu, Nguyen, & Hoang, 2017). Dat et al. (2017) stated that every year, the nosocomial BSIs affect 575,462 – 677,389 people in North America and 1,213,460 – 1,381,590 people in Europe, which further leads to 79,466 – 93,655 and 57,750 – 276,318 BSI-related deaths, respectively. Viscoli (2016) classified the BSIs into three different groups, in the other hand if occurring:

i. The immunologically-normal hosts, having an intact defence system, are generally infected by *Streptococcus pyogenes* and *Neisseria meningitidis*, while children undergoing native valve endocarditis are infected by viridans *Streptococci*, and the adolescents show positive symptoms for the post-influenza *S. pneumoniae* and *S. aureus* bacteraemias. *Salmonella typhi* and non-typhi also cause infections in many areas of the world.

ii. Patients affected with physiological conditions that impair their immune defences (like the elderly or new-borns) are infected by microorganisms like the *Klebsiella* spp., *E. coli*, Group B *Streptococcus* sp., *Listeria* sp., *Pneumococci* sp., and *Candida* sp.

iii. Patients affected with pharmacological conditions which make them predisposed to infections can become infected by any organisms, like the gram-positive or gram-negative bacteria or fungi.

v. NIs by Antimicrobial-Resistant Bacteria (ARB)

According to Wang and Ruan (2017), the ARB infections are on the rise, which poses a serious threat to the public healthcare system. The patients admitted in the HFs are the primary source of the ARBs (Wang & Ruan, 2017). It was shown that >70% of the hospital pathogens have developed resistance to one or many antibiotics (Krzowska-Firych, Kozłowska, Sukhadia, & Al-Mosawi, 2014). In many of the NIs, the microbes which infect the HF patients, already show resistance to a majority of the antibiotics, used in that similar facility (Fymat, 2017). There has been a significant increase in the ARB-related NIs in the past decades, which is a serious cause of concern (Krzowska-Firych et al., 2014).

The common ARBs, which infect the patients include *S. pneumoniae*, VRE, MRSA or ORSA (in the other hand, MRSA, also known as the oxacillin-resistant *S. aureus*), *Acinetobacter baumannii*, Carbapenem-Resistant *Kelebsiella pneumoniae*, *Pseudomonas aeruginosa* and many *Enterobacteriaceae* sp. and etcetera (Agaba, Tumukunde, Tindimwebwa, & Kwizera, 2017; Fymat, 2017; Krzowska-Firych et al., 2014). Out of all these pathogens, MRSA is a significant cause of morbidity and mortality amongst the patients, and the isolates are resistant to many types of antibiotics (Al-Talib, Yean, Al-Jashamy, & Hasan, 2010; Wang & Ruan, 2017). The patients infected with MRSA generally develop infections (Wang & Ruan, 2017). Several surveillance studies have stated that the incidence of the MRSA strains can vary based on the HF and the country (Šiširak, Zvizdić, & Hukić, 2010). Al-Talib et al. (2010), carried out a cross-sectional study in the Klang Valley in Malaysia, where they investigated 3 institutes, the Hospital Kuala Lumpur, the Hospital Tengku Ampuan Rahimah, Klang and the Bacteriology Division of the Institute for Medical Research. Their results showed that the rate of MRSA incidence showed an overall increase from 25.7% to 28.7%, 27.9% and 33.0% in 1996, 1998, and 2000, respectively (Al-Talib et al., 2010). Many of the studies that were conducted in the USA and European showed that the MRSA strain caused an increase in the morbidity and mortality rates, in comparison to the Methicillin-Susceptible *S. aureus* (MSSA) infections in the critical patients (Al-Talib et al., 2010). Such ARBs can survive for many days/weeks/months, in a dormant state, on the environmental surfaces within the HFs, like the patient gowns, packing equipment or even the computer keyboards, and thereafter, infect the patients (Wang & Ruan, 2017).

vi. Organ transplant

The organ transplant process is carried out surgically in order to replace a diseased or failing organ, such as kidney, liver, lung or heart, with a good and healthy donor organ (Nautiyal et al., 2015). However, infections during the procedure can lead to a higher mortality and morbidity rate amongst the transplant populace (Alalawi, Kosi, Jin, Sharma, & Halawa, 2017). The identification of post-transplant infections in their early stages can be challenging since these patients have a suppressed immunity level, which delays the onset of the characteristic symptoms like rigors, fever, etcetera, till the disease had advanced significantly (Alalawi et al., 2017). Infections are more common during the transplantation of organs from the abdominal cavity like the pancreas and are less common in the heart transplant patients (Nautiyal et al., 2015).

Many of the microbial pathogens like the *Cytomegalovirus*, *Mycobacterium tuberculosis*, and *Trypanosoma cruzi* remain dormant within the donor cells and get transmitted to the organ recipient (Alalawi et al., 2017). Some of the common pathogens that infect the recipient after the organ transplantation process include *S. aureus*, *Enterococcus* sp., and the gram-negative, enteric and non-fermentative bacilli (Nautiyal et al., 2015). Also, many opportunistic bacterial infections are observed between the 2nd and 6th month after the transplantation procedure. The common pathogens which cause opportunistic infections in the transplant recipients include *Nocardia* spp and the *Listeria monocytogenes*. Furthermore, many unusual infections can also be transported from the donors to the recipients like HIV, rabies, choriomeningitis and the West Nile viral infections (Alalawi et al., 2017).

vii. Gastrointestinal endoscopy associated infections

Gastrointestinal endoscopy is generally used for diagnosing, preventing and treating the digestive diseases and even cancer (Petersen et al., 2017). In this procedure, the doctor observes the inner lining of the digestive tract (Nautiyal et al., 2015). Kovaleva, Peters, van der Mei, and Degener (2013) stated, this inner lining can become contaminated by blood, body secretions or microbial pathogens during the endoscopy procedure. In some cases, the researchers also identified the unsterilized irrigation water bottle, which was attached to the endoscope device, as the source for the microbial infection (Nautiyal et al., 2015). Such instruments are very difficult to disinfect and clean since they have a complex design, made of narrow lumens and several internal channels (Kovaleva et al., 2013). Improper cleaning or drying of the elevator and/or air-water channels of the duodenoscopies (are flexible, lighted tubes that are threaded through the mouth, throat, and stomach into the top of the small intestine) can also cause many *Pseudomonas* sp. infections in the recipients (Nautiyal et al., 2015).

viii. Haemodialysis associated infections

Khan, Hamzah, Adnan, and Khan (2014) stated, in the case of the haemodialysis patients, the kidneys lose their function severely and the untreated chronic kidney diseases lead to a final stage renal failure or a chronic kidney failure. The patients with such an end-stage renal failure, especially those undergoing the maintenance haemodialysis, are very susceptible to microbial infections owing to their weak immune system, persistent use of catheters and the presence of comorbidities (Khan et al., 2014). These patients are commonly affected by the BSIs and the UTIs (Nautiyal et al., 2015).

ix. *Clostridium difficile* infection

These patients are commonly affected by the BSIs and the UTIs (Nautiyal et al., 2015). Generally, in these infections, the colon gets inflamed, leading to colitis and antibiotic-associated diarrhoea (Khan et al., 2017). *C. difficile* mostly affects the patients who consume antibiotics, especially, the elderly and the medically-ill patients (Ward, 2015). This organism affects 250,000 hospitalised patients and causes 14,000 deaths annually. Furthermore, the Centre for Disease Control, also, categorised it as a severe threat to the patients.

x. Neonatal infection

Amongst the paediatric patients, the new-born babies are generally affected, especially those neonates who have been hospitalised in the neonatal intensive care units, are administered several antibiotics and are treated using many types of medical devices (Nautiyal et al., 2015; Polin, Denson, & Brady, 2012; Ramasethu, 2017). Due to the improper maturation of the neonatal immune system, they have a higher chance of contracting the NIs, which leads to a higher morbidity and mortality rate and a prolonged HF stay (Nautiyal et al., 2015; Polin et al., 2012; Ramasethu, 2017). According to Ramasethu (2017), the late-onset sepsis, or the sepsis acquired within 72 h of birth (except those caused by the HSV or the group B *Streptococci sp.*) are HF-acquired, especially in the infants who have been hospitalised since birth. The common NIs affecting the neonates include pneumonia, BSIs, skin infections, SSIs, eye infections, UTIs, oral cavity infections, upper RTIs and gastroenteritis (Nautiyal et al., 2015).

xi. Device-associated NIs

Khan et al. (2017) observed, many invasive devices like the ventilators and catheters, used in the HFs, are a major source of infection. The device-associated NIs (for example, infections contracted from infected needles, syringes or other such devices) significantly affect the patient and personnel safety, increase the morbidity and mortality rates, costs, and prolong the patient stay in the hospitals of developing countries (Yepez et al., 2017).

2.6.4 Some causes of arising NIs

The patients are at a higher risk of developing NIs in the HFs (Yallew et al., 2017). According to Yallew et al. (2017) the risk factors for such NIs vary between the specific site infections, due to the complex nature of the HF environment (Yallew et al., 2017). Mehta, Gupta, Todi, and Myatra (2014) stated, many environmental, therapy and patient-related risk factors can lead to the emergence of NIs. Also, some additional precipitating factors that cause NIs in the patients (Mohammed et al., 2014), have been described below in three groups:

i. Patient-related risk factors:

i. Low immunity in the patients (Nautiyal et al., 2015; Tabatabaei et al., 2015).
ii. Age of patients (Nautiyal et al., 2015; Yallew et al., 2017);
iii. Gender (Yallew et al., 2017);
iv. Whether the patient is diabetic (Nautiyal et al., 2015; WHO, 2014);
v. A longer HF stay increases the risk, for instance, admission in the HFs for a severe or multiple health issues (Nautiyal et al., 2015; Tabatabaei et al., 2015).
vi. Lack of personal hygiene by the patients or hospital staff also increases the risk of infection (Nautiyal et al., 2015).

ii. Therapy-related risk factors:

i. Immunosuppressive agents (Nautiyal et al., 2015; WHO, 2014);
ii. Administration of a broad-spectrum antibiotic dose and the emergence of many multidrug-resistant microbial pathogens (Nautiyal et al., 2015);
iii. Patients beings administered chemotherapeutic drugs (Nautiyal et al., 2015);
iv. Intravenous therapies, catheterisation or surgical procedures (Nautiyal et al., 2015; Yallew et al., 2017);
v. Use of invasive devices, such as, urinary catheters (especially for treating and monitoring ICU patients) (Nautiyal et al., 2015; WHO, 2014).
vi. A lack of knowledge and implementation of simple infection-control procedures (WHO, 2014);
vii. High-risk medical and invasive procedures (WHO, 2014);

viii. A lack of knowledge regarding the safety procedures during injection and blood transfusion procedures (WHO, 2014);

ix. A lack of knowledge regarding the spread of infections (Nautiyal et al., 2015);

x. A lack of technology in the HFs also hinders the introduction of safe healthcare waste management systems in the developing countries (Brent, Rogers, Ramabitsa-Siimane, & Rohwer, 2007);

xi. A lack of standard and isolation-related precautions being applied (WHO, 2014).

iii. Environment-related risk factors:

i. The design and layout of the HFs, for instance, larger HF size (Lax & Gilbert, 2015);

ii. Poor infrastructure in the HF (WHO, 2014);

iii. Type of HF (Yallew et al., 2017)

iv. An improper ventilation system in the operation theatres and other departments (Nautiyal et al., 2015);

v. Inadequate environmental hygienic conditions in the HFs along with an improper waste disposal system (Nautiyal et al., 2015);

vi. Lack of clean environmental surfaces (Saka et al., 2016);

vii. Insufficient equipment (WHO, 2014);

viii. Overcrowded HFs (Nautiyal et al., 2015);

Furthermore, an increased use of invasive procedures for the treatment, higher use of antibiotics and diagnostic processes, chemotherapy, immunotherapy, and advancements in the organ transplant procedures have altered the NI distribution sites in the past few years (Nautiyal et al., 2015). For instance, the incidence of the nosocomial pneumonia infection increased from 17% in the early 1990s to 30% in 1995 (Nautiyal et al., 2015).

2.6.5 Pathogens of NIs and general principles of their transmission

HFs are a complex ecosystem and comprise of many dynamical elements like different types of people, microbial pathogens, and HF environments (Adamus, 2011).

The microbes prevailing in the HFs vary depending on the patient population, types of HFs and the environment of the departments where the patients are treated (Khan et al., 2017). NIs can be caused by both the gram-positive and the gram-negative microorganisms and also by other pathogens like the fungi or viruses; however, a majority of the microbial pathogens are gram-negative microorganisms (Berket et al., 2012; Mohammed et al., 2014). Lax and Gilbert (2015) stated, due to the emergence of new NI-causing pathogens, it has become difficult to identify the disease-causing microbial taxa, especially since the antibiotic resistance genes are widespread and are detected even in many remote environments.

Some of the common nosocomial pathogens include *Staphylococcus aureus*, *Escherichia coli*, *Enterococcus* sp. and *P. aeruginosa* (Berket et al., 2012; Khan et al., 2015). Out of these, *E. coli* is the major cause of UTIs and is rarely isolated from other types of infections (Berket et al., 2012). On the other hand, *S. aureus* is seldom isolated from the UTI samples but is commonly detected in other sites (Berket et al., 2012). In the case of the BSIs, the probability of detecting the coagulase-negative *Staphylococcus sp.* is 2-times that of detecting *S. aureus*. The *Enterococcus* spp. are often isolated from the SSIs and the BSIs, but rarely from the RTIs. However, *P. aeruginosa* is seen to be present in 10% of all the infections and infects all the major body sites, except the bloodstream. Mamishi, Pourakbari, Teymuri, Babamahmoodi and Mahmoudi (2014) said that cross transmission would be a main way of infection or colonization for *P. aeruginosa.* The findings showed significant cross transmission of *P. aeruginosa* not only among patients in one department but also among those from dissimilar departments.

The common NI pathogens also possess drug resistance properties like the MRSA, Vancomycin-Resistant *S. aureus* (VRSA), multi-drug resistant *Mycobacterium tuberculosis*, *A. baumanni*, VRE, *Stenotrophomonas maltophilia* and *Burkholderia cepacia* (Bank, 2009; Berket et al., 2012; Breathnach, 2013; Khan et al., 2015; Mohammed et al., 2014). Some other common NI pathogens include:

i. *Staphylococcus aureus* (especially in patients who have undergone some major surgeries) (Berket et al., 2012; Khan et al., 2015; Mohammed et al., 2014; Sharma & Shabir, 2017).
ii. *Acinetobacter baumannii* (Mohammed et al., 2014; Sharma & Shabir, 2017).
iii. *Escherichia coli* (Berket et al., 2012; Khan et al., 2015; Meade & Garvey, 2018; Mohammed et al., 2014; Sharma & Shabir, 2017).
iv. Coagulase negative *Staphylococci* (CNS) (Mohammed et al., 2014).
v. *Pseudomonas aeruginosa* (Berket et al., 2012; Khan et al., 2015; Mohammed et al., 2014; Sharma & Shabir, 2017).
vi. *Legionella* (Khan et al., 2015; Sharma & Shabir, 2017).
vii. *Stenotrophomonas maltophilia* (Sharma & Shabir, 2017).
viii. *Proteus mirabilis* (Khan et al., 2015).
ix. *Mycobacterium tuberculosis* (Sharma & Shabir, 2017).
x. *Clostridium difficile* (Khan et al., 2015; Sharma & Shabir, 2017).
xi. *Salmonella* spp (Berket et al., 2012).
xii. *Serratia marcescens* (Berket et al., 2012; Khan et al., 2015).
xiii. *Klebsiella pneumoniae* (Berket et al., 2012; Khan et al., 2015; Sharma & Shabir, 2017).
xiv. *Streptococcus* spp (Berket et al., 2012).
xv. *Bacillus cereus* (Khan et al., 2015).
xvi. *Enterococci* (Berket et al., 2012; Khan et al., 2015; Mohammed et al., 2014).
xvii. *Candida* sp. (Meade & Garvey, 2018).

Every pathogen produces a different type of infection in the different body parts. Table 2.1 describes some common microbial pathogens along with their infection-causing sites.

Table 2.1: Some of common, less common pathogens and sites of infections

Site of infection	Common pathogens	Less common pathogens
Blood stream	Coagulase-negative *Staphylococci* (CNS) (Mohammed et al., 2014) *Staphylococcus aureus (Breathnach, 2013)* *Pseudomonas aeruginosa (Breathnach, 2013)* *Candida* sp. (Breathnach, 2013)	*Enterococci (Mohammed et al., 2014)* *Klebsiella* sp. (Breathnach, 2013) *Serratia marcescens (Mohammed et al., 2014)* *Enterobacter* sp. (Breathnach, 2013) *Malassezia* sp. (Mohammed et al., 2014)
Pneumonia	CNS (Mohammed et al., 2014) *S.aureus (Mohammed et al., 2014)* *P. aeruginosa (Mohammed et al., 2014)* Respiratory syncytial virus *(Mohammed et al., 2014)* *Oxacillin-sensitive Staphylococcus aureus (Victor, Tambe, Mary, Rahule, & Tabhane, 2017)*	*Enterococci (Mohammed et al., 2014)* *Klebsiella sp. (Mohammed et al., 2014)* *S. marcescens (Mohammed et al., 2014)* *Haemophilus influenza (Victor et al., 2017)*
Skin/soft tissue/surgical site	CNS (Tariq et al., 2017) *S. aureus (Mohammed et al., 2014)* *Pseudomonas aeruginosa (Tariq et al., 2017)* *Klebsiella pneumoniae* (Tariq et al., 2017) *Proteus mirabilis* (Tariq et al., 2017)	*Enterococci (Tariq et al., 2017)* *S. macescens (Mohammed et al., 2014)* *Aspergillus* sp. (Mohammed et al., 2014)
Gastrointestinal tract	*Rotavirus (Mohammed et al., 2014)* *Klebsiella pneumoniae* (Gorrie et al., 2017)	Anaerobic bacteria (Mohammed et al., 2014) *Coronavirus (Mohammed et al., 2014)*
Conjunctivitis/ocular	CNS (Mohammed et al., 2014) *P. aeruginosa (Mohammed et al., 2014)* *Human mastadenovirus (Gonzalez, Aoki, Yawata, & Kitaichi, 2017)*	*S.marcescens (Mohammed et al., 2014)*

Table 2.1 Continued

Site of infection	Common pathogens	Less common pathogens
Urinary tract	gram-negative bacilli (Mohammed et al., 2014) *P.aeruginosa* (Ferreiro et al., 2017) *Enterococci (Mohammed et al., 2014)*	*Candida* sp. (Mohammed et al., 2014)
Endocarditis	CNS (Mohammed et al., 2014) *S. aureus (Baddour et al., 2015)*	*Candida* sp. (Mohammed et al., 2014)
Central nervous system	CNS (Mohammed et al., 2014) *S. aureus (Mohammed et al., 2014)* *Brevibacterium* spp. (Page et al., 2017)	*Candida* sp.(Mohammed et al., 2014) *S.marcescens (Mohammed et al., 2014)* *Enterobacter* sp.(Mohammed et al., 2014)
Osteoarthritis	*S. aureus (Mohammed et al., 2014)* Group B *Streptococci(Mohammed et al., 2014)*	*Candida* sp.(Mohammed et al., 2014) gram-negative bacilli(Mohammed et al., 2014)

Some gram-negative bacteria like *E. coli*, *P. aeruginosa*, *Acinetobacter* sp., *S. marcescens*, *Klebsiella* sp., and *Shigella* sp. are able to survive on the HF surfaces for months (Saka et al., 2016).

2.6.5.1 Viruses

Along with bacteria, some viruses also cause NIs (Khan et al., 2017). The investigation studies revealed that viruses cause about 5% of the total NIs (Khan et al., 2017). Hepatitis NIs are commonly caused by viruses, while Hepatitis B and C are transmitted due to unsanitary injection processes (Breathnach, 2013; Khan et al., 2017). In field of RTIs, viral bronchiolitis (caused by the respiratory syncytial virus or RSV) are common in the children's department suffer from viral infections, while influenza and secondary bacterial pneumonia are seen amongst the elderly HF population (Ducel, Fabry, & Nicolle, 2002). Other NI-causing viruses include HIV, rotavirus, and HSV (Khan et al., 2017).

2.6.5.2 Fungi and parasites

The fungal parasites are opportunistic pathogens which cause NIs in the immune-compromised patients (Khan et al., 2017). Several parasites and fungi (like *Aspergillus* spp., *Cryptosporidium sp.*, *Cryptococcus neoformans*) infect the patients during long antibiotic treatments and when their immune system is suppressed (Ducel et al., 2002; Khan et al., 2017).

2.6.5.3 The modes of transmission pathogens

According to Siegel, Rhinehart, Jackson, and Chiarello (2007), the mode of transmissions of the different pathogens (like bacteria, viruses, parasites, fungi or prions) varies based on the type of organisms. Some of the infectious agents are transmitted by multiple routes, some get transmitted by a direct or indirect contact (like the respiratory syncytial virus, HSV, *S. aureus* etcetera), and others are transmitted by droplets (like the influenza viruses and *Bacillus pertussis*) or through the airborne routes (like *M. tuberculosis*) (Siegel et al., 2007). Some general routes of pathogen transmission are (Siegel et al., 2007):

i. Contact-based transmission.
ii. Droplet transmission.
iii. Common vehicle transmission.
iv. Vector-borne transmission.
v. Airborne transmission.

2.6.6 Risky departments in field of NIs

The environment of the HF is contaminated by many types of pathogenic organisms and also is a reservoir of the nosocomial pathogens that could infect the patients during their HF stay (Akbari, Fattahi, & Fazeli, 2018). Khan et al. (2015) stated, though the infection rates in the different HFs cannot be determined accurately, one can obtain a rough estimation of these infection rates based on many dependent factors like the type of HFs (public or private), service provided by these HFs, etcetera (Khan et al., 2015).

According to a survey, the common sites affected by the NIs were the departments that related to surgical wounds, lower RTIs, UTIs and BSIs (Mohammed et al., 2014). A Canadian study in 2008 showed that UTIs were the most common NIs, followed by the RTIs, SSIs and the BSIs (Wahab, Maning, & Ganeswrie, 2013). Wenzel et al. (2008), stated that the RTIs and the BSIs showed the highest mortality rate (25-30%) in the developed countries. Another Dutch study stated that the SSIs commonly affected the HFs in the Netherlands, followed by the RTIs, UTIs and BSIs (Ward, 2015).

The UTIs were the most common type of NIs (Mohammed et al., 2014). UTIs were generally observed amongst the chronic haemodialysis patients, and they account for ≈47% of all the infections in these patients (Nautiyal et al., 2015). Furthermore, the UTIs largely affect the chronic haemodialysis patients (4.2/1,000 patient-days) compared to the non-chronic haemodialysis patients (0.7/1,000 patient-days) (Nautiyal et al., 2015). The SSIs were the most prevalent and expensive NIs in the USA (160,000-300,000 SSIs/ year) (Ward, 2015). SSIs commonly affected the patients in the developing countries with limited resources (WHO, 2014). These infections infected ≈67% of the operated patients, in the developing countries, with a 9-times higher frequency than those in the developed countries (WHO, 2014).

The infection indicators are commonly used for monitoring the neonatal ICU and the general ICU units since these patients are at a higher risk of developing NIs, which could be fatal (Bank, 2009). The ICU units in the HFs are a high-risk area, where many patients can become infected (Bank, 2009; Nautiyal et al., 2015; Warren & Kollef, 2005). The general incidence of the NIs in the paediatric ICU ranges between 6.1- 29.6% (Kouchak & Askarian, 2012). The proportion of the patients suffering from the ICU-acquired infections ranges between 4.4-88.9% (WHO, 2014). ICUs showed a very high frequency of infection, in the other hand, 42.7 cases every 1000 patient-days (WHO, 2014). These figures are 3-times higher than those observed in the developed countries (WHO, 2014). On the other hand, 25% of the ICU patients in the developed countries and up to 50% ICU patients in the developing countries can acquire the NIs (Zerganipour et al., 2016).

NIs are very common in the neonatal ICUs, as the low-birth-weight infants are generally immune-compromised and susceptible to the opportunistic pathogens (Lax & Gilbert, 2015). Also, the new-born babies in the developing countries show a 3-20 times higher infection rate than those in the developed countries (WHO, 2014). According to the Australian Commission on Safety and Quality in HealthCare, the new-born babies should be constantly monitored for bacterial sepsis during their first week (Bank, 2009). In the case of infants with a low birth weight, the use of common broad-spectrum antibiotics disrupt their microbiome, which lowers the diversity, causes a chaotic flux in the community composition and increases the number of the opportunistic pathogens (Lax & Gilbert, 2015). In one study, the researchers investigated the NIs in the neonatal-ICUs present in the University of Utah Medical Centre, Salt Lake City and in Kuala Lumpur, Malaysia (Hanifah, Lee, & Quah, 2000). They observed that 15.3% of the infants hospitalised in the Utah Medical Centre and 5.2% of the infants who were hospitalised in Kuala Lumpur, for 48 h or more, had acquired NIs (Hanifah et al., 2000).

NIs were the primary cause of neonatal deaths in the developing countries, causing 4- 56% neonatal deaths (WHO, 2014). On the other hand, 75% of the neonatal deaths in the South-East Asian and Sub-Saharan African regions were due to the NIs (WHO, 2014). Also, 65% of the very-low-birth-weight babies had acquired at least one type of NI, while 27% of the neonatal deaths in the neonatal-ICUs were due to the NIs acquired after birth (Lax & Gilbert, 2015). To sum up this section, referring to above issues, this is an evidence for the exits of NI. With reference to the NIs, some departments are affected more than the others, and some can be the causes due to the exist of cross infection. In this research, both cause and effect department are called risky. Thus, risky departments are be different from one HF to another; this can be concluded from Ducel et al. (2002) who justify the impact of level of prevention, strategies, size, type, technology and other factors related to HFs.

2.6.7 Control of NIs

The prevention and the control of the NIs is the primary responsibility of the community and the HFs (Berket et al., 2012). It is stated by Ducel et al. (2002), that the infection control strategies would vary based on their type, need and resources provided by the HFs. Khan et al. (2017) stated that despite all the efforts made for preventing the NIs, more work needs to be carried out to control the infections. Though some improvement was observed, more work has to be carried out. The monitoring of the NIs is an important step for controlling the infections and is also considered as a basic step for preventing the department-specific infections (Berket et al., 2012).

In this study by assessing the literature and review, the researcher acknowledged 61,559 relevant articles by systemically searching on the Scopus Database with the key words "Nosocomial infection" OR "Hospital acquired infection". Articles from the period 1915–2020 were analysed. Figure 2.2 displays specific distribution of article publication over the targeted years particularly belongs in research area of NIs. As it is shown in the Figure 2.2, most of researches in field of NIs published in 2014, 3100 articles, and after that the number is decreased to 2895 articles at the end of 2018 based on the information achieved from Scopus database on September 2019.

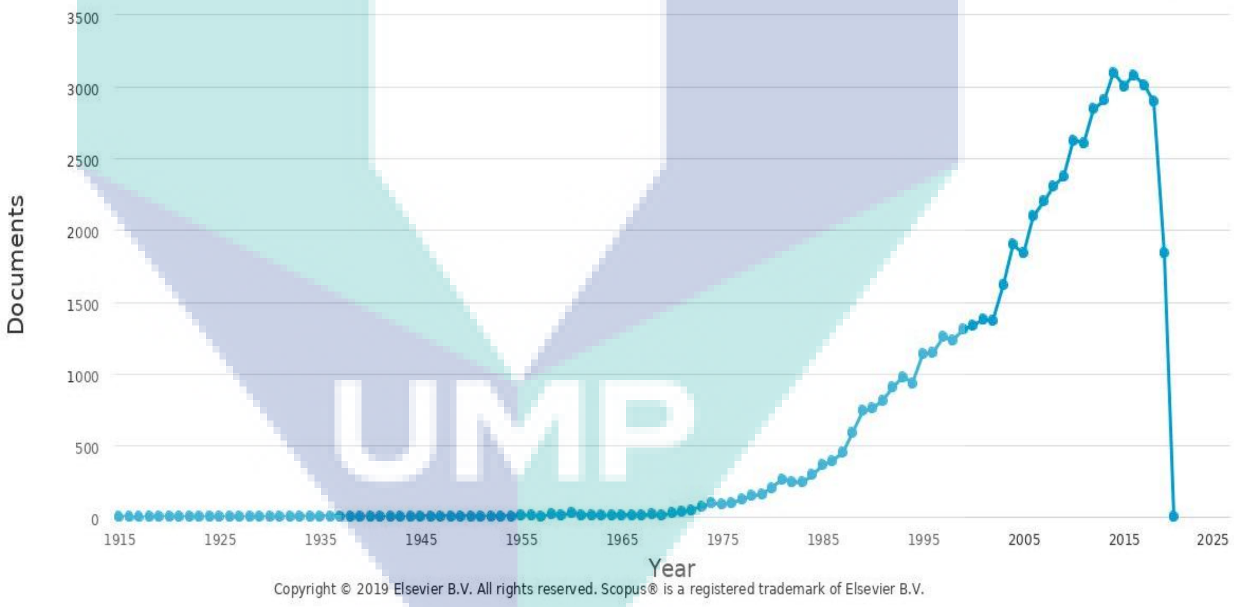

Figure 2.2 Range of published articles in field of NIs from 1915.

Also, the articles analysed based on the publisher country from 1915 to 2020. Referring to the result is shown in Figure 2.3, United States has the most number of published articles, 16,648, following by France and the UK, in the area of NIs.

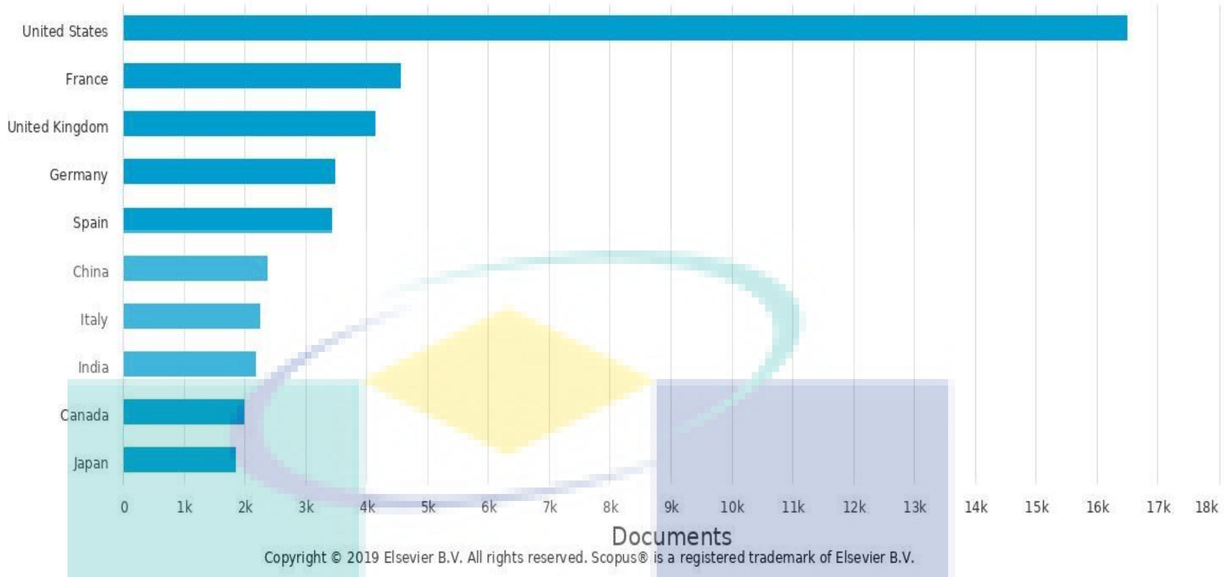

Figure 2.3 The most article publisher country in field of NIs from 1915.

Figure 2.4 shows that how many percentages of articles are published in each subject area, Medicine has highest percentage, with 67.2 % of total subject area, and the lowest percentage belongs to Environmental science and Social science, with 0.7 % of total subject area. However, the subject area Business, management and accounting with 60 articles belongs to the other group in the Figure with percentage of 5% of total subject area. Also, the field of architecture, with 12 articles, belongs to Engineering subject area.

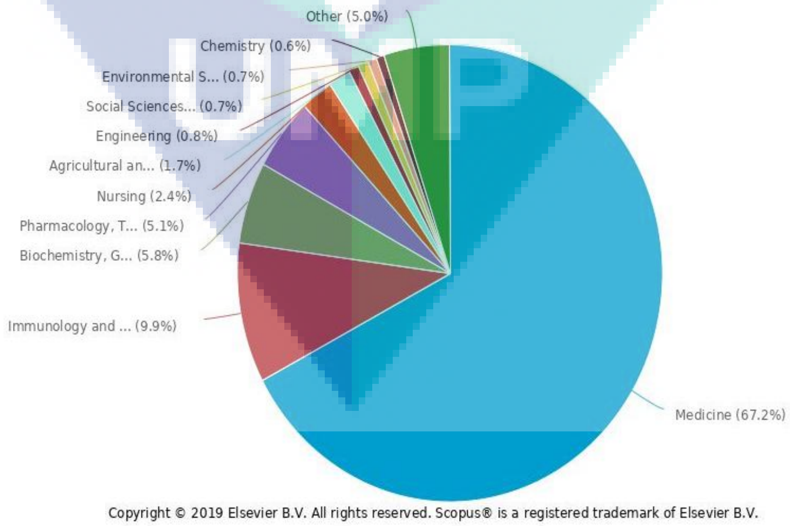

Figure 2.4 The percentages of articles are published in each subject area in field of NIs from 1915.

Furthermore, the research articles were analyzed based on Title, Keywords and Abstract by use of VOSviewer which is a software tool for constructing and visualizing bibliometric networks. In systematic literature review, this software recognized different keywords on the research area. Keywords of “Nosocomial infection” OR “Hospital acquired infection”, in Scopus search engine, shows the connections among the keywords and clustered them. The studies that were found were downloaded into Microsoft Excel in a CSV (comma separated value) format from the year 1915 to the year 2020 to be analysed. Figure 2.5 is the result of the VOSviewer analysing.

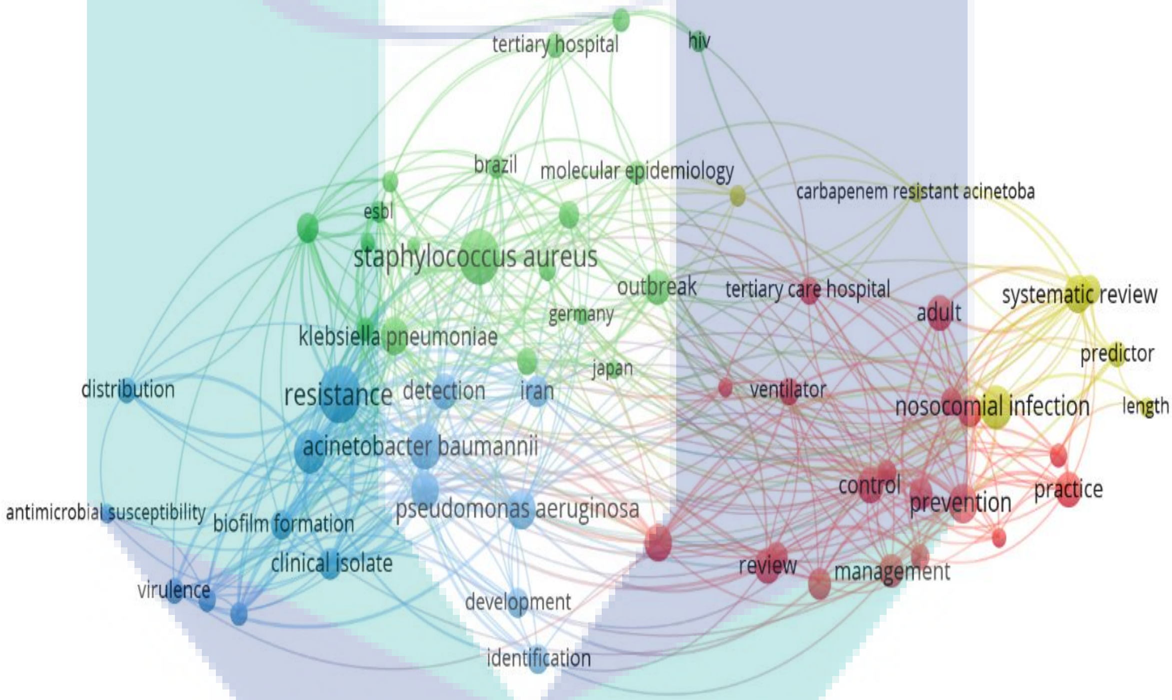

Figure 2.5 The term maps from the 1915.

Table 2.1 The clusters of keywords with the highest connection

No	Cluster 1 (Red color)	Cluster 2 (Green color)	Cluster 3(Blue color)
1	Adult	Draft genome sequence	*Acinetobacter baumannii*
2	Case report	Emergence	Antimicrobial susceptibility
3	*Clostridium*	*Escherichia coli*	Biofilm formation
4	*Clostridium difficile* infection	HIV	Clinical isolate
5	Control	Investigation	Detection
6	Diagnosis	*Klebsiella pneumoniae*	Development
7	Effect	Molecular characterization	Distribution
8	Evidence	Molecular epidemiology	Gene
9	Implementation	Neonotal intencive care unit	Identification
10	Incidence	Nosocomial outbreak	Resistance
11	Management	Outbreak	Virulence factor
12	Occurrence	*Staphylococcus aureus*	
13	Practice		
14	Prevention		
15	Sepsis		
16	Surgical site infection		
17	Tertiary care hospital		
18	Ventilator		

The result is an evidence to prove multidisciplinary nature of NI studies. From the result, the keywords in each cluster, as shown in Table…, have high connection. As it is shows in the Table...., most of the keywords are from to medicine field. The word of management, in cluster 1, is one of the found keywords and it is grouped by keywords, such as, “Control”, “Diagnosis”, “Effect”, “Preventiion” and etcetera which is shown the high connection among these words in research. It can be an evidence to show the considerable relevant of management researches to control NIs. In continue, some recent –published top-cited researches in fields of NIs are discussed.

Some medical researchers have tried to introduce new disinfectants and inhibitors in the area of NIs, for instance, Surendran-Nair, Lau and Liu (2019). They proved that the essential mineral Selenium, could inhibit skin-colonizing and biofilm forming abilities of *Acinetobacter baumannii*, is a multi-drug resistant nosocomial pathogen causing a variety of disease conditions, especially wound infections in humans. However, Cabal, Sevillano and Fernández-García (2019) proved the inhibitory of ZnO glass-filled thermoplastic polyurethane and polydimethyl siloxane composites on biofilm of eight strains of NIs bacteria. Also, Majeed and Al-Aubydi (2019), showed the positive effect of Zinc Oxide nanoparticles against multidrug resistant Kelebsiella pneumonia which was isolated from RTIs. In addition, Khan, Lee and Manivasagan (2019) employed chitosan oligosaccharide for the synthesis of chitosan oligosaccharide-capped gold nanoparticles as an effective inhibitor to biofilm of nosocomial pathogen *Pseudomonas aeruginosa* as well as eradication to pre-existing mature biofilm. Furthermore, Meade and Garvey (2018) present novel chemical disinfectants, peracetic acid and triameen, effectively inactivated all test microbial strains, however, the ARB show resistance to these products.

Meanwhile, the other groups of medical researchers have worked on antibiotics in the area of NIs, such as, Jonokuchi et al. (2018) which test the topical antibiotics on SSIs, in continue Alvarez-Marin, Aires-de-Sousa, Nordmann, Kieffer, and Poirel (2017) and İpek, Aktar, Okur, Celik, and Ozbek (2017) evaluate and use of antibiotics against the multidrug-resistant bacteria. Although, both studies focus on a special group of microorganisms and NIs, however, the rang of NI's pathogens and type of NIs are many. In continue, the other group of researcher try to decline the rate of NIs through some administrative medical protocol, such as, prevention of occur and repeat infections by practicing good hygiene, especially cleaning of hands (Agarwal & Larson, 2018), maintaining aseptic practices after inserting the urinary catheters and similar other urological procedures (Nautiyal et al., 2015).

Although above studies concentrated in a special group of pathogen microorganisms, as it is mentioned in Section 2.6.3, there are many types of NIs with the different responsible group of NIs microorganisms. Therefore, the limitation of the reviewed researches just minimizes the risk of one type of NIs, meanwhile, the procedures of this study tried to decrease the total rate of NIs, for all types of them in each HF around the world.

Next to be studied, a group of the researchers in the area of management have worked on cost effective protocol to decrease the financial load because of NIs, for instance, Lodise and Lapensee (2019) evaluate the cost effect of shortening hospital stay in a group of patient with bacterial pneumonia infection by two healthcare decision models. In addition, the other group of researchers have worked on the satisfactory of staff, for example, Johnson, Nguyen, Groth and White (2018) used secondary survey data and an important indicator of organisational effectiveness in the healthcare sector (in other word rates of NIs). They proved that HFs with higher rate of workplace aggression had higher rates of patients with NIs and that employee engagement was an important mechanism that helped explain this effect. However, Suner, Oruc, Buke, Ozkaya and Kitapcioglu (2017) have done a research to determine the best hand hygiene preference of the infectious diseases and clinical microbiology specialists to prevent transmission of microorganisms from one patient to another. Findings which obtained through two separate decision-making methods, the MAUT and AHP suggest that alcohol-based antiseptic solution has the highest priority and utility among the experts' selections.

Based on findings of a research in 2017, using risk management processes including elements of active surveillance and efficient monitoring can help to minimize the risk of NIs (Sitek, Witczak, & Kiedik, 2017). In addition, Ltifi, Benmohamad, Kloski and Ben-Ayad (2016) by designing and developing visual data mining tools have tried to enhance existing visualization processes by adapting it under the temporal dimension of data, the data mining tasks and the cognitive control aspects. It can help physicians to fight against NIs in the intensive care unit. Moreover, Rozman, Fijan and Turk (2015) stated that inappropriately disinfected hospital textiles can act as a vector for cross transmission of healthcare associated infections, which represent complications in the treatment of patients and cause economic damage. They presented MorapexA device as a better implementation and an adequate substitute for non-destructive textile hygiene testing. In the other study, researchers have introduced ANP as a tool to identify main reasons of NI and, therefore, the performance of doctors can be systematically calculated, which will greatly benefit the hospital management. (Ning, 2014).

Referring to the above discussed studies there are a few which tried to research on NIs by considering a factor of management, such as, cost, satisfaction, hygiene, quality of service, risk management and etcetera. The research gab in these researches in field of NIs through managerial viewpoint is they did not attention to the multi-criteria chief managerial criteria in their study. However, the present study has considered all the managerial criteria based on the viewpoints of managers in each HFs and presented a general procedure in this area to minimize NIs risks.

Last but not least, Gazzarata, Monteverde, Bonetto and Savini (2019) have designed a surveillance system for the Abruzzo Region (Central Italy) to monitor the prevalence of multi drug resistant organisms in both infected and colonized patients, to verify appropriateness of antibiotic prescription in hospitalized patients and to interact with other national and sovra-national networks. Service Oriented Architecture approach, different healthcare service specification project standards, local, national and international terminology and clinical document architecture release 2 were adopted to design the overall architecture of this regional surveillance system. Then, Janowicz (2019) evaluate the relations between architectural actions and epidemiological safety in field of NIs, as well as presenting the need for an on-going assessment of architectural solutions by interdisciplinary teams of specialists.

Furthermore, Firrantello and Bahnfleth (2017) improved the disinfection systems like the air disinfection system by use of ventilation and filtration system and decrease the risk of air transmission of NIs microorganisms. However, Bouvry, Tvardic, Kergourlay and Bittar (2016) tried to develop a generic semantic solution for extracting and structuring medical data by offering a modular architecture that makes a clear distinction between the linguistic rules and the medical expert, in field of NIs, rules for epidemiological analyses or for medical decision-support. This project helped to highlight the value of combining different technologies (natural language processing, terminology, expert systems integration) to allow for the use of unstructured data in epidemiology. Ellouzi, Ltifi and Ben-Ayed (2016) have applied the proposed architecture to develop visual intelligent clinical decision support system for the fight against NIs. They believed on improving coordination and communication between the different system modules to generate the appropriate solution for a specific problem.

However, Mehta et al. (2014) presented a guideline to improve environmental factors and the HF architectural design and layout of HF, by set hand hygiene system in different parts of HF, in order to decline rate of NIs. But, the other group of researchers suggested to use an appropriate architecture hardware and software which helps in monitoring the hand hygiene for decreasing the spread of the NIs (Martínez-Hernández, Pérez-González, Martínez-Pérez, Pérez-González, & Cuevas-Tello, 2010). Although, the mentioned studies in field of architecture tried to solve the problem of NIs. But they didn't pay attention to department configuration and identify the risky department to remove from HF or selected low risky departments for adding. Most of them focus on interior design factors of HF, such as, air disinfection system and etcetera. Although, the present study tried to attention this missed factor, department configuration, during upgrading and rearchitecting of HF to minimize NIs risks.

Recently, many studies were published which stated that the HF environment (like the design and the layout) played an important role in the pathogen transmission within the HFs and any suitable change in the HF design could decrease the infection risk (Zimring et al., 2013). Some recent studies have explored the impact of the HF environment on the type of services provided and the quality of life (Elf et al., 2015). Despite the fact that many researchers established the link between the architecture of the HF and human health, people are still reluctant to alter the structures of those HFs which affect human health, like cause NIs (Kembel et al., 2012). Studies on the evidence-based designs have shown that the HF's physical environment along with its layout can affect human health, decrease the treatment duration, reduce the dosage of the medicines and also relieve the stress which is experienced by the patients, their family and the nursing staff (Elf et al., 2015). However, Shikder and Price (2011) described, the different factors which must be considered while designing an effective healthcare system. A supportive HF environment with a good-quality layout and circulation creates an inviting, engaging, hygienic, calm and productive environment for the patients, their families and the staff (Shikder & Price, 2011).

Hussain and Babalghith (2014) noted, HFs were places where people sought medical treatment, while the HF staff provided a constant support. Hence, creating a calm environment in the HFs, with proper physical aspects was very important (Hussain & Babalghith, 2014). However, Elf et al. (2015) stated, a good implementation of the novel techniques and HF models helped in improving the patient health as the patient-related services were associated with the HF environment (or HF architecture). Decisions regarding the healthcare design and architecture are seen to be very important as these designs affect the people and the work processes for a long time and need a financial commitment from the whole community (Elf et al., 2015).

Many studies recognised the fact that a well-planned HF architecture was beneficial in improving the patient health for many years (Kembel et al., 2012). In addition, Elf et al. (2015) stated that a poor HF architecture could lead to many problems and risks for patients, such as, NIs and dissatisfied patients. Additionally, a poor HF architecture could prove to be very costly and lead to a lack of confidence in the HF's healthcare system (Elf et al., 2015). Also, Dettenkofer, Seegers, Antes, and Motschall (2004) mentioned, the infection controlling measures are also supported by a good HF architecture (for example, they provide enough space for treating and taking proper care of the patients). However, there are many variations in the HF layout designs around the world, and control of infections by applying specific engineering designs, is still a topic of debate (Dettenkofer et al., 2004). The scientific research is focused on determining the manner in which an improved design can reduce the risks in the HFs (Kembel et al., 2012). Hence, the HF design is considered to be an important factor affecting the modern healthcare system and the HFs must be constructed after integrating proper architectural designs, which would further help the patients (Elf et al., 2015). Although, Nowadays, a lot of attention is given to the environment in the HFs and its relationship with patient health, which has led to the development of effective designs (Elf et al., 2015), not enough studies are available to discuss department configuration in HFs.

2.7 Healthcare facilities building design for NIs control

Several researchers have shown an interest in investigating the effect of the HF environment on the health of the patients (Elf et al., 2015). While designing the HFs, the architects must ensure that the HF buildings can be cleaned easily, which could prevent the onslaught of numerous microbes and diseases (Mohd Nawawi, Sapian, Majid, Hanita, & Aripin, 2013). These buildings must be designed so that enable a hygienic control, help in controlling infections, possess adequate space and ability to function, ease of circulation and provide a comfortable and safe environment, which can heal and calm the patients (Mohd Nawawi et al., 2013).

Specialised HF buildings, like the hospitals, require a specific design and must employ knowledgeable clients or advisors (Mohd Nawawi et al., 2013). The HFs comprise of different working environments (like different departments) which consist of specific staff, equipment and type of pathogens (Mohd Nawawi et al., 2013). In departments, the patients are usually more stressed, weak and have a limited control over their surrounding and they are more susceptible to the pathogens acquired from their environment (Alalouch, 2009; Zimring et al., 2013). Though, there is a lot of evidence which links the environment in the HFs to the pathogen transmission, it is scattered amongst various disciplines and is not systematically assessed (Zimring et al., 2013).

According to Stiller et al. (2017), the HF design is seen to play a significant role and is an emerging strategy in controlling the spread of infections and can incorporate infection control measures for minimising the infection transmission risks. Some studies have determined the relationship between the transmission of pathogens or spread of NIs and the layout structure of the hospitals (Parsia & Puteri, 2018; King, 2013; Stiller, Schröder, et al., 2016; Hall & Kamerow, 2013). According to this paragraph and King (2013), evidence based design is widespread in the health care sector relying on best-practice and credible scientific evidence that designing the built environment in such as way can outcome in staff and patient well-being, promote patient healing and cross infection rate reduction.

2.8 Architecting of healthcare facilities

Most architects who worked on healthcare projects have projects in other sectors as well (Dannenberg & Burpee, 2018). Many architectural historians avoid hospitals, perhaps because the HFs' architecture functioned as a normal building, rather than healing; and as a result, hospitals are glaringly absent from standard architectural history texts (Adams, 2016). But recently it is found that by focusing on the health-promoting aspects of design, architects have the opportunity to contribute to solutions to major societal challenges, to lead change, to improve the quality of life for everyone, and to grow the demand for their services (Dannenberg & Burpee, 2018). In the ideal world, architects and their clients will begin to consider the health-promoting aspects of design as routine and desirable as they now consider sustainable elements of design. To reach that stage, architecture students and health science students need to be taught about the health impacts of design. This information should also be incorporated into continuing education courses for both design and health practitioners. By recognizing the importance of the impacts of design on health, architects can further contribute to the quality of life of all people, today and into the future.

While healthy design may incur initial costs, many of the benefits of health-promoting design are long term and may not be realized by building owners or occupants in the early years of building use (Murdoch & Hughes, 2008). Many design, and construction concepts can be applied to achieve a scalable, for example the ability to expand or remodel easily, or adaptable, for instance the ability to adapt space for different or evolving services, HF (Murdoch & Hughes, 2008). The experiences of existing HF environment reveal their poor designs ,for example , the study by the Commission for Architecture in 2004 and the Built Environment in the United Kingdom and Simini in 1999 (Aripin, 2007). About hospital, there has been little work on analyzing layouts for hospitals (Padgaonkar, 2004). A hospital building requires continual maintenance to meet its design and construction functions and to maintain the satisfaction levels of its users (Olanrewaju et al., 2018). The term 'Healing Architecture' is adopted to invoke a sense of a continuous process; in creating an environment physically healthy and psychologically appropriate (Aripin, 2007).

Architects who design HFs should considered the impacts of design on health (Dannenberg & Burpee, 2018). They recognize the value of evidence-based design, which is the process of basing decisions about the built environment on credible research to achieve the best possible outcomes. For example, department configurations and design of layout in HFs can be selected based on evidence of reduced managerial risks or fewer NIs. Hospital departments are fixed or immovable entities (Padgaonkar, 2004).

The prime focus while designing hospital facility layouts is the optimal arrangement of these entities, since the proper placement of departments results in the travel entities having to travel shorter distances, thus reducing the movement cost drastically (Padgaonkar, 2004). To achieve efficient placement of the departments, the interaction between departments should be taken into consideration. The departments having high traffic between them are placed closer to each other than the ones with less traffic. This adjacency requirement thus increases functionality and efficiency.

In this study tried to evaluate departments relationship in field of transmission NIs. About NIs risks, it is recognised that the health care environment is a secondary reservoir for micro-organisms with the potential for infecting patients (Carr, 2017). Studies have suggested that bacteria can exist and survive in the environments with fixtures, fittings and furnishings acting as reservoirs of infection. Therefore, it is essential to ensure that infection control and cleanliness issues are considered and implemented during the planning, designing and final construction stages of all new builds, upgrading and re-architecting, to minimise the cross infection risks that can be associated with the environment.

The Commission for Architecture and the Built Environment (CABE) produced similar findings during the campaign for healthy hospitals in the United Kingdom in November 2003 (Aripin, 2007). They believe that well-designed healthcare buildings can lead to better health outcomes and comments provide a clear outcome on aspects of physical environment to be considered for future HFs (Aripin, 2007). In conclusion, new HFs are needed to design based on the healing architecture concept; however, it is a need for the existing hospitals to be modified based of this concept.

2.9 Modification of healthcare facilities

Modification of an existing building is a successful branch of the construction industry because it provides financial diversification for construction stakeholders (Pope, Marks, Back, & Leopard, 2016). In the inherently dynamic industry of healthcare design and construction, organizations are continually working to achieve balance between customer demands and the need to manage cost, schedule, and quality (Okada, Simons, & Sattineni, 2017). The construction sector covers a wide span of projects from residential complexes to commercial buildings but hospital projects have a special place in this basket (Barakchi, 2017). Meaning, hospital buildings are of importance in every country due to their critical role in healthcare system. Reducing hospital's building costs is among the top priorities. The issue escalates by considering that hospital constructions are often large projects with substantial funding needs. Healthcare projects often deal with dynamic external forces such as market changes, stringent regulation, and a range of stakeholders, all which add variability to the process (Okada et al., 2017). This is the environment where project planners, architects, managers, and constructors work to build the HFs of the future (Okada et al., 2017).

Throughout the design and construction process, project planner teams must be particularly in tune with the changing needs of the owner to ensure that the facility is an effective solution for the end user (Okada et al., 2017). As a project progresses from planning to design and construction, changes are an inevitable part of the process. A change that occurs during the construction phase will most often fit into one of the following time broad categories: unforeseen conditions, design errors and omissions, and owner-requested changes. These changes can solve layout problems.

The hospital facility layout problem has received less attention in the literature compared to manufacturing facilities (Padgaonkar, 2004). Previously, the HF design layout was more focused on the cost/square foot, integration of new technologies, and was also based on the nursing facility models, which, in turn, were derived from the industrial settings that did not consider the problem of infection transmission (Van Enk, 2006). For instance, the nursing facilities usually placed two patients very close to one another, since the nurses had to take lesser steps while attending to the patients and this would decrease the square-footage requirement. In such models, the patients were believed to be a product that was assembled by the nursing staff.

Padgaonkar (2004) mentioned, the layout of hospital based on the placement of departments takes into account the interaction between departments, which depends on the traffic intensity between the two departments. The departments having more interaction are placed closer than the ones having lesser interaction with the aim being the minimization of the distance between them (Padgaonkar, 2004). Hussain and Babalghith (2014) the term 'Healing Architecture', which creates a sense of continuous process and is used for describing a psychologically satisfying and physically healthy environment. A calm and healing environment with the proper physical designs would improve the patient health, decrease their hospital stay, reduce their stress levels, increase patient satisfaction, decrease the risk of infections, etcetera (Hussain & Babalghith, 2014).

To create healing environment in HFs it needs to do some HF layout changes/modification. Padgaonkar (2004) mentioned, hospital facility layout changes/modification can be typically divided into the following four categories:

i. Minor changes in the existing layout.

ii. Rearrangement of existing layout.
iii. Relocating into existing facilities.
iv. Building a new plant.

All changes in above are often based on requests, feedback, and input from the owner, user groups, and project delivery team (Okada et al., 2017). Hence, in this study, the researchers have aimed to improve the HF layout after upgrading and re-architecting the HF structures (based on the department selection) for minimising the risk of NIs and generating a healing HF environment. In this study modification of HFs by upgrading and/or re-architecting is the focus. Reviewing the existing literature and searching the scientific database of Scopus, reveals 4539 published articles since 1981 with the "healthcare" and "architecture" in their article title, abstract, or keywords. However, adding a new key words of either modification, re-architecting, or upgrading, reveals a significant lack of literature in this field. A very same conclusion is achieved by searching other databases like Google Scholar or ISI.

2.9.1 Healthcare facilities upgrading

New building codes are constantly changing, and it is likely that additional requirements have gone into effect since the time the original building was built (Assumpcao, 2016). If you choose to upgrade, you may be required to bring the entire building up to the current code (Assumpcao, 2016). In upgrading processes, the facility will be expanded and number of departments will be increased, in general, minor adjustments will occur to the existing facility (Health-Infrastructure-Branch, 2013). If upgrading is a major component, it would classify as a redevelopment (a redevelopment involves a major partial renewal of the HF). Considerations during upgrading shall include:

i. Assess the impact on existing services systems and identify the potential for extension or expansion.
ii. Establish the capacity of existing facilities and whether these are sufficient or can be extended or augmented.
iii. Where staging of the works is required assess the impacts on operation.
iv. Assess the impacts on operation of existing departments of existing systems.

About HFs, the increasing population along with the increase in the average age of the population indicates that there is a constantly growing need to expand the public services provided by the HFs, which is done as follows (Shikder & Price, 2011):

v. Improving the primary HF layout;
vi. Extension of existing HFs; or
vii. Optimising the existing productivity of the HFs.

Demolishing existing facilities and constructing new facilities are not a feasible solution to provide modern healthcare services and reducing the impacts of healthcare construction industry on the environment (Sheth et al., 2010). Also, the National Health Service's (NHS) focus on new construction in the recent past is responsible for the deteriorating existing building stock (Sheth et al., 2010). According to Hussain and Babalghith (2014), the main aim of improving the healthcare facilities was to maintain the positive aspects of the existing HFs, while trying to improve the weaker aspects. In this area, improving the healthcare quality and decreasing the medical errors are the two top most priorities (Hussain & Babalghith, 2014).

Conventional ways of designing HFs around the delivery of service are moving towards creating a healing environment that can accelerate patient recovery and enhance staff productivity and morale (Shikder & Price, 2011). The understanding of different stakeholders' perspectives on the healthcare environment is providing an effective evidence-base for informed decision making in healthcare planning and design (Shikder & Price, 2011). Considering the size and scale of healthcare facilities, upgrading can arise at any time because of various reasons (Sheth et al., 2010). For instance, the Community Hospital of the Monterey in Peninsula, California was upgraded several times before considering for major refurbishment after 50 years from inception of the facility buildings the presence of asbestos is considered as a driving factor for upgrading and needs to be removed during upgrading (Sheth et al., 2010).

The upgrading cycle is divided in to four main phases (Sheth et al., 2010):
i. Proposal,
ii. Design,

iii. Construction, and
iv. Use.

In phase 1, a pre-construction primary design phase, where most of the decisions related to end product will be taken. This phase will serve as guidance during the development of the upgrading proposal. They also explained that in this phase, various opportunities are provided to consider different options which can have an impact on the overall life-cycle of the facility. The decision-making team members are key actors in this phase.

In field of minimizing infection risks, infection control teams should be consulted from the outset of any new build/ upgrading project and should form part of the planning team (Latta, 2009). During the process of HF upgrading, mutual effect two groups of departments, existing and potentials to be added, are to be considered.

2.9.2 Healthcare facilities re-architecting

Whilst re-architecting is one of a range of strategies that may be implemented to achieve a new structure, it is also a term closely linked with 'restructuring' in the minds of many in the workforce (Sitlington & Marshall, 2009). Re-architecting is a common response to environmental influences, with organisations implementing these changes in order to improve their effectiveness (Clabaugh, 2001). The reasons why, and how, organisations re-architect has a major influence on perceived outcomes (Sitlington & Marshall, 2009). A re-architecting plan should be included in the strategic management plan of all organizations, regardless of whether they plan to re-architect or not (Davis & Savage, 2003). While re-architecting is viewed as a complicated, multifaceted phenomenon, it has generally been adopted either reactively or proactively (Gandolfi, 2008). To put a single re-architecting cause forward is problematic and underrates its inherent complexity (Davis & Savage, 2003). Each re-architecting decision is likely to constitute a combination of company-specific, industry specific, and macroeconomic factors (Davis & Savage, 2003).

Re-architecting in HFs started to become more noticeable in the late 1990s, when the United States was still experiencing a decade of almost unprecedented economic prosperity (Weil, 2003). According to this thesis, section 1.8, re-architecting is defined as the decisions targeting the removal of one or several departments in the HFs. All HFs staff and managers are aware that old structures not only merely fail to serve the patients adequately but fail in what even the most reluctant healthcare providers have come to recognize as a medical marketplace (Haji, Wang, Wong, & Darabi, 2006). The most obvious product in the medical marketplace is excellence in healthcare, and a facility's reputation for excellence is a strong incentive to healthcare consumers to select that institution over another (Haji et al., 2006). The most important factors that influence the potential consumers are the design of the facility and the patient amenities that the design offers. The first advantage of eliminating extra (risky) departments through re-architecting is to maximize the space in order to enhance flexibility and the capability of handling more patients; it also eliminates the unnecessary flows in the clinic area and the second step is to reorganize all the departments. A number of studies have been published that examine the degree to which re-architecting, workforce reductions, re-engineering and resizing effect the delivery of health services and employee morale (Weil, 2003).

The HFs have to re-architecting their structures due to technical or financial limitations. These decisions can also be made due to managerial strategies, medical errors and the rising risk of spreading infections. For many businesses, including those in healthcare, re-architecting means the loss of employees, positions, departments, or product line (Davis & Savage, 2003). Its goal is to cut waste, improve profitability, increase productivity and enhance local, national or international competitiveness (Appelbaum, Everard, & Hung, 1999; Davis & Savage, 2003). For this research we use this method due to minimizing infection risks in HFs. To refocus attention toward the anticipated goal, re-architecting is often called different names such as productivity improvement, growth in reverse, restructuring, or reengineering (Davis & Savage, 2003).

The re-architecting process helps in demolishing the risky departments and is usually sought through:

i. Construction of a new HFs;
ii. Size-decreasing of existing HFs; or
iii. Optimising the specialization of existing HFs.

2.10 Managerial criteria for upgrading and re-architecting healthcare facilities

HF designing can prove to be challenging for the architects (Alalouch et al., 2016). Elf et al. (2015) stated, one of the main challenges affecting the architects involves integrating the requirements of the future HF users with the current design-related decisions. Also, the management must encourage the implementation of those design techniques which balance the effect of the specific, but local requirements with the general knowledge (Elf et al., 2015). The designing of complex structures similar to the HFs requires architects who are able to tackle the numerous design criteria (supported by the different design-supporting models) (Alalouch et al., 2016; Van Hoof et al., 2015). They also have to tackle the complex clinical and functional requirements of the HFs and consider other less tangible and sensitive factors (Alalouch et al., 2016).

Additionally, owing to the functional complexity of the HFs, many standards and guidelines have to be considered by the architects before designing the HFs (Alalouch et al., 2016). For example, in the UK, the Department of Health and National Health Service Estates, published several standards and guidelines which guide and regulate the architects during the HF designing process (Alalouch et al., 2016). The scientists consider the HF surroundings as healthy and safe, if they provide access to transport, better land usage, good architectural design strategies and policies, involve strategic planning, include collaborative designs, etcetera (Zavadskas, Cavallaro, Podvezko, Ubarte, & Kaklauskas, 2017). The architects have to design a healthy and safe HF environment based on the sustainable development principles (Zavadskas et al., 2017).

According to Alalouch et al. (2016), the well-designed architectural buildings affect the recovery times of the patients and improve their satisfaction levels. A proper HF design has many advantages and helps in improving the patient health, increases the satisfaction levels of the staff and the patients, improves the delivery of medical care, and decreases the healthcare costs (Cunney, 2008). Many studies have proved that a faulty HF design increased the number of medical errors, rates of infections, increased the injuries due to falls, decreased the patient recovery rate and led to a higher staff turnover (Reis & Chambers, 2009).

Architects (considered to the key players in the HF designing process) have to often encounter numerous sources who present conflicting design criteria that lack understanding and a clear structure (Alalouch et al., 2016). The HF designing process must be simplified and made more accessible to the architects. However, no study has summarised the design criteria that can be solely controlled by the architects. A few of the general design criteria (called as the managerial decision criteria) based on literatures that must be considered while designing the HF buildings include cost (Nah & Osifo-Dawodu, 2007), customer satisfaction (Rivers & Glover, 2008), sustainability (Mohd Nawawi et al., 2013), construction and design standards (Alalouch, 2009), and safety (Joe, Chu, Banham, & Maclean, 2014). However, these criteria could be different for different HFs and their requirements.

2.11 Decision making for HF upgrading and re-architecting

Decision making (DM) is a part of every person's everyday lives, with numerous personal and business decisions made daily (Almulhim, 2014). However, DM involves the use of knowledge, innovativeness and insight in order to meet basic needs or address certain issues (Ansah, Sorooshian, & Mustafa, 2015). A DM process is typically an easy and intuitive task when decision problems having a single criterion are considered (Almulhim, 2014). However, when various alternatives or actions with multiple criteria are ranked and assessed, it becomes very complex and sophisticated methods are then needed (Almulhim, 2014).

When upgrading the HF, the DM needs to decide if appropriate new department(s) get added. In a similar manner, the re-architecting of HF requires a decision regarding the selection of department(s) that will be eliminated from the present processes and operations of HF. The departments that are added or deleted will now compete with other alternative department(s) on the basis of the criteria of the decision maker. When there are numerous alternatives to choose from, the process of DM will then need to evaluate the decision criteria to ensure that the right choice is selected (Ansah et al., 2015). For the department selection for HFs, two main criteria categories were identified in this study: NIs risk and managerial criteria.

2.11.1 Multiple Criteria Decision Making (MCDM)

According to Aruldoss, Lakshmi, and Venkatesan (2013), many daily decisions are being made from different criteria, thus, one can make a decision by giving weights to these various criteria. Identifying the structure of the problem is vital, as well as the explicit evaluation of multi criteria (Aruldoss et al., 2013). Graham, 2012 stated that DM should begin by identifying the stakeholder(s) and the decision maker(s) for that decision, as a way to lessen the possible disagreement about problem definition goals, requirements, and criteria. A general DM process can then be partitioned into several other steps in order to obtain an optimal outcome (Graham, 2012). Almulhim, 2014 states that one can categorise the DM process into three phases (Figure 2.6):

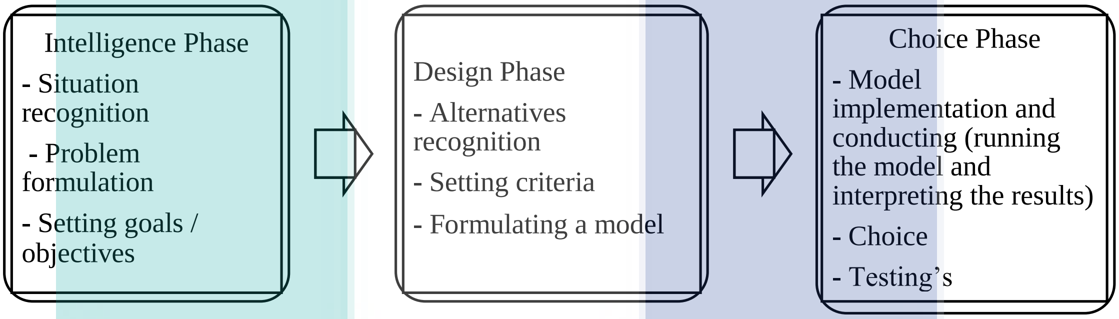

Figure 2.6 Decision making process

Source: Gade & Osuri (2014)

1. Intelligence phase: the decision makers inspect the economic, political, technical, and social environment in order to determine the new situations and conditions that require new decisions and actions. For example, this phase might involve a comparison of the current status of a process or a project with its plan. The decision statement is the final result of the intelligence phase.

2. Design phase: the decision makers develop and design probable modes of action. This process includes formulating a model, looking for alternatives, and setting the criteria for the choice.

3. Choice phase: in traditional terms, it is during this phase where the decision is made. It involves the ranking and assessment of the alternatives that have been formulated in the design phase before selecting one of them. In this phase, the product is an

executable decision; for example, the decision makers choose the superior alternative from a list of them.

According to Ansah et al. (2015) and Almulhim (2014), MCDM is considered as one of the most popular DM branches of over the last thirty years, it has been used to solve decision problems given the existence of multiple alternatives and criteria. The term MCDM serves as an "*umbrella term which outlines an assortment of formal approaches that intend to take formal account of several criteria in aiding individuals or groups explore decisions which are vital*"(Almulhim, 2014). Mardani et al. (2015) stated, MCDM can be considered a generic term for all the existing methods that are used to help people in DM based on their preferences in situations when more than one conflicting criterion.

According to Almulhim (2014) and Zavadskas, Govindan, Antucheviciene, and Turskis (2016), MCDM is now one of the most significant and rapidly growing subfields of management science and operations research, as it combines computational and mathematical tools to subjectively assess the performance criteria by decision-makers. It makes use of a general class of operations research models that take into account the DM problems when there are several decision criteria (Ansah et al., 2015). As explained by Ruotsalainen (2009) MCDM is not responsible for providing the"*right*" answer or giving an "objective" analysis that will serve as replacements for the decision makers as they try to make difficult judgements. The MCDM process assists in the structuring of the problem, and it aims to give significant attention to conflicting and multiple criteria (Ruotsalainen, 2009). Thus, the decision makers now find it easier to learn about the problem in consideration, and learn about their own values and judgments and those of others as well (Aruldoss et al., 2013; Ruotsalainen, 2009). According to Mardani et al. (2015), the utilisation of MCDM may be considered as a way to handle complex problems by breaking down the problems into smaller portions. After considerations and judgements are made about the smaller components, the pieces are reconstructed so that an overall picture can be presented to the decision makers (Mardani et al., 2015). Under MCDM, the models are suitable for assessing and making decisions regarding the best alternatives (options) so that the perfect criteria can be chosen (Ansah et al., 2015).

MCDM problems are generally complex and less structured (Almulhim, 2014). Aruldoss et al. (2013) stated, not only very complex issues involved in multi criteria, but some criteria may also influence other wings. However, in order to obtain an optimum solution, a common criterion must be contained within all the alternatives to help ensure that more informed and better decisions are made (Aruldoss et al., 2013).

2.11.2 Classification of MCDM approaches

There exist very limited uniform classifications for MCDM approach (Almulhim, 2014). Thus, they can be classified in many ways, such as the characteristics of the decision space, the form of the model, or the solution process (Almulhim, 2014). Therefore, Hwang and Yoon (1981) and Zimmermann (1987) gave a general MCDM field classification that includes two categories, the first is based on various purposes and the second is based on various data types (Almulhim, 2014; Ansah et al., 2015; Aziz, Sorooshian, & Mahmud, 2016; Ghazi, Lotfi, Jahanshahloo, & Sanei, 2016; Zavadskas et al., 2016):

i. Multiple Objective Decision Making (MODM).
ii. Multiple Attribute Decision Making (MADM).

MADM and MODM can be distinguished by the fact that the former focuses on the decision space; while the latter concentrates on mathematical programming having several objective functions that also have a continuous decision space (it therefore has no links with problems that have predetermined alternatives) (Almulhim, 2014; Ghazi et al., 2016; Zavareh, 2014). On the other hand, the focus of MADM is on problems that possess discrete decision spaces (it involves the assessment of a definite set of alternatives based on a predefined set of evaluation attributes) (Almulhim, 2014; Ghazi et al., 2016; Zavareh, 2014). Thus, MADM mainly aims to choose the best alternatives, while MODM mainly aims to find the solution that satisfies the objectives (Zavareh, 2014). However, for both MADM and MODM, one should determine the criteria before the decision making process (Zavareh, 2014). Each category has several methods and each method possesses its own characteristics (Ansah et al., 2015).

A MODM problem includes objective functions, a vector of decision variables, and constraints where decision makers are toned to work for the optimisation of the objective functions in terms of the constraints (Ghazi et al., 2016). The primary concern of DM is to design the alternative that shows the most promise in terms of the limited resources (Almulhim, 2014). MODM is utilised to handle a problem or resolve a set of conflicting goals that are not simultaneously achievable (Almulhim, 2014). In this case, the decision making models offer the best circumstances for the decision factors so that the maximum fulfilment of objectives can be achieved (Zavareh, 2014). Some MODM examples include energy management, construction, concept selection, and transportation (Zavareh, 2014).

MADM method is seen as one of the DM support methods and was determined to be the base for DM model (Ansah et al., 2015). The focus of this model is on a list of selected criteria, its parameters, and the variables that an individual wants to inspect in the DM process (Ansah et al., 2015). Moreover, MADMs have determined alternatives, and the decision makers just have to assess and rank the existing alternatives (Zavareh, 2014). Some MADM examples include supplier selection, environmental management, manufacturing, human resource management, and risk management (Zavareh, 2014). To assess an alternative, 'a criterion is established for each of its attributes and the attribute is scrutinised against the criterion' (Almulhim, 2014). According to Triantaphyllou, '*very often, the terms MCDM and MADM are utilised to mean the same category of models (in the other hand, MCDM)*' (Almulhim, 2014).

2.11.3 Multiple attribute decision making

The MADM problems are significant in various fields, including engineering, economics, and management (Robinson & Amirtharaj, 2014). Imprecision comes from various sources like unquantifiable data that results when decision makers have to work with imprecise or vague information regarding the options related to the attributes (Ansah et al., 2015). It is noteworthy that the use of probabilities and statistics for conventional correlation analysis is taken to be inadequate in managing uncertainties that are related to data and modelling failures. Problems in MADM were observed to be far reaching in real life DM situations, furthermore, they focus on finding desirable solutions given a limited amount of feasible alternatives that were assessed on multiple properties, both subjective and quantitative.

According to an article in 2014 over 30 recognised MADM methods exist (Zavareh, 2014); however, considering the trend of generating new, modified, and hybrid MADMs, the number will be more than hundreds. Nevertheless, the amount of MADM methods has not been determined easily, since every method, such as statistical and mathematical methods, that can solve multi-criteria DM is considered as an MADM method (Zavareh, 2014). From the literature review, it was revealed that Mardani et al. (2015) attempted to classify the MADM methods into two categories, recently developed and previously developed methods. Popular previously developed methods include WSM, DEA, TOPSIS, AHP, VIKOR, DEMATEL, ELECTRE, PROMETHEE, etcetera as well as their modifications. Furthermore, recently developed MADM methods include COPRAS, MOORA, ARAS-F, MULTIMOORA, WASPAS, as well as numerous other applied and rapidly developed methods for solving real life problems.

According to Aruldoss et al. (2013) the MADM is utilised in several applications such as warehouse location, performance evaluation, supplier selection, assessment of health-care waste treatment, supply chain management, banking performance, teachers' performance, e-banking, and in different multi choice selection processes. It has been proven that MADM is an effective approach for choosing or ranking at least one alternative given a finite amount of alternatives based on multiple, typically conflicting criteria (Yeh, 2003). Given these definitions, every DM process has a set of alternatives, a decision goal, and a set of decision criteria, additionally, in DM, one can describe these three characteristics as follows (Almulhim, 2014):

i. The decision goal/s presents the things that the decision makers desire.

ii. The alternatives represent the various actions options that the decision makers can evaluate or rank.

iii. The decision criterion refers to a characteristic property that can be used to judge something. These criteria can be classified as either quantitative or qualitative in nature. Furthermore, the precedence that exists between them may have dramatic variations under different situations.

The next chapter will therefore discuss the proposal of an MADM methodology for the selection and ranking of departments (alternatives) for the re-architecting and upgrading of HFs based on the categories of managerial criteria (section 2.11), and the NI risks.

2.12 Summary

The literature review has given proof that NIs are still serious risk problems for patients, HFs, and society. Furthermore, they can introduce various kinds of NI pathogens. It also showed that despite the presence of numerous prevention guides and studies to control and lower the risks of NIs, there is still a worldwide problem and the rates of morbidity, mortality, and financial load have been increasing for patients, HFs, and the rest of the society. The review described the important role of the layout and department selection of HFs in reducing the rates of NIs risks. The review also provided descriptions of the studies conducted in the field of NI prevention by designing HFs layouts that will maximise their purpose. However, there are not many studies concentrating on modification of the HF layouts with the aim of reduction in NI risks. Searching the major literature databases, such as Scopus and WOS, reveals the lack of previous studies to fill this gap. It is also shown in this chapter that a MCDM is needed for department selections in modification of existing HFs. Therefore, this study will introduce the MCDM methods as methods to upgrade and re-architect HFs layout. Based on this literature review, the main classifications of the criteria have been defined, as well as the managerial criteria and NIs risks. For the next chapter, there will be an attempt to introduce and choose convenient methods to conduct MCDM and design new procedures by utilising them to upgrade and re-architect HFs to reduce NIs risks.

CHAPTER 3

PROCEDURES DEVELOPMENT AND RESEARCH METHODOLOGY

3.1 Introduction

As described in Section 2.11.1 in Figure 2.2, decision-making (DM) involves three phases: intelligence, design, and choice. These three phases represent this research flow. The initial phase is defined in the second chapter, while the third chapter aims to attain the second phase. The succeeding chapter is meant to attain the third phase. This part will assist in formulating the thesis so as to attain the first two research objectives as in Section 1.4. This chapter is to explain the methodology and research processes to achieve research objectives and answers of research questions.

3.2 Research paradigm

In the research approaches specially in the social science study, paradigms are positivism, post positivism, critical theory and related ideological positions, and constructivism (Guba & Lincoln, 1994). Paradigms can be seen as a fundamental set of beliefs and assumptions which serves as standards and pattern for actions (Guba & Lincoln, 1989). This research is quantitative in nature, as a quantitative research can be defined as a systematic investigation of phenomena via mathematical, statistical, or computational methods (Bhawna & Gobind, 2015). Hence, as stated by Rouse (1997), the quantitative approach in research is represented by positivist and post-positivist. According to Morgan and Smircich (1980) positivism and post-positivism are the two methodological traditions in social science research.

Positivism posits ontological (the nature of reality) and epistemic (what consistitutes valid knowledge) realism (Gephart, 2013). However, this research is alignwith post-positivism. Post-positivism differs from positivism by criticizing the role of induction wherein universal laws could be derived from a set of particular observations. post-positivism stance amends positivism (Bergman, 2016). While positivists emphasize independence between the researcher and the researched person (or object), post-positivists accept that theories, background, values and knowledge of the researcher can influence what is observed (Robson, 2002). Post-positivists pursue objectivity by recognizing the possible effects of biases (Robson, 2002; Taylor & Lindlof, 2011). While positivists emphasize quantitative methods, post-positivists consider both quantitative and qualitative methods to be valid approaches (Taylor & Lindlof, 2011).

Beyond the paradigms, characterization of this research is another concern. More recently, scholars challenged the normal outlining of social sciences to deal with complex, messy interactive and dynamic social processes (Boisot & McKelvey, 2010). The characteristics of this research is based on modelling multiple-criteria decision-making (MCDM) procedures for minimization of complex issue of Nosocomial Infection (NI). To understand the strengths of MCDM modelling, the difference between statistical and MCDM approaches be distinguish (Tzeng & Shen, 2017). Tzeng and Shen (2017) say that "*the statistical approach puts more emphasis on examining the relationships among the variables for theoretical purposes, whereas the MCDM approach focuses on supporting DMs who must solve complicated decision problems*".

Two underexplored but critical issues must be addressed in MCDM modelings: first, the involved or observed criteria (or attributes) in MCDM research are usually obtained from any of three possible approaches, (i) subjective judgments by researchers; (ii) statistical analysis from historical data; and (iii) theoretical support (Tiesmeier, 2016; Tzeng & Shen, 2017; Vinogradova, Podvezko & Zavadskas, 2018). This research is using the "subjective judgments". The subjective judgment approach is constrained by the limited knowledge and experience of researchers; in addition, real-world problems are becoming ever more complex and complicated; it would be unlikely for researchers to choose the minimal and essential criteria (attributes) when considering numerous plausible attributes by subjective judgments (Jayant & Singh, 2015; Goulart Coelho, Lange & Coelho, 2017). Second, MCDM research should play a more proactive or constructive role in problem solving; to select among a group of inferior options would not help decision makers (DMs) achieve satisfactory outcomes (Shen & Tzeng, 2018).

Traditional MCDM studies have ignored the objective and reliable selection of minimal and representative criteria for forming MCDM models, so complex social or business environments require reasonable approaches to help researchers identify critical attributes (Tzeng & Shen, 2017). In the so-called "Big Data era," human brains (in the other hand, of DMs or researchers) inevitably encounter difficulties when they attempt to process the complex and imprecise patterns behind a complex problem (or information system) (Martins, Vossen & de Lima Neto, 2017). Traditional MCDM models assume that the criteria are independent and hierarchical in structure; however, in most real-world problems, the relationships among criteria or aspects, also called dimensions, are usually interdependent with certain feedback effects (Liou & Tzeng, 2012). Therefore, the emphasis in the research field has shifted from ranking or selection when determining the most preferable approaches to performance improvement of existing methods, the new trend in this issue is hybrid MADM analytical tools (Tsui, Tzeng & Wen, 2015; Tzeng & Shen, 2017).

Usually in hybrid MADM, as one of the MCDM modelling approaches, two or more analytical MADM methods, techniques, are combined or integrated for ranking, selection, and improvement planning, in the context of multiple attributes (Velasquez & Hester, 2013; Mardani et al., 2015; Zavadskas et al., 2016; Rekik, Kallel, Casillas and Alimi, 2016, Tzeng & Shen, 2017). The modelling of new hybrid MCDM may be regarded as a process of transforming data or information, and knowledge or experience from experts or DMs to form understandable decision aids for problem solving (Tzeng & Shen, 2017).

This research attempts to hybrid MADMs to achieve its objectives. There are a few MADM modelling dissertations with hybridization approach are found from PhD dissertations which are used as benchmarks and guides to structure the reporting of the current research; among them "*A Hybrid Multi-criteria Decision Making Method For Risk Assessment Of Public-private Partnership Projects*" by Hadi Sarvari in 2016 from Universiti Teknologi Malaysia, "*Fuzzy dynamic hybrid MCDM method for supplier evaluation and selection*" by Adeleh Asemi Zavareh in 2014 from University Of Malaya Kuala Lumpur, "*Development of a Hybrid Fuzzy Multi-Criteria Decision Making Model for Selection of Group Health Insurance Plans*" by Tarifa Almulhim in 2014 from University of Manchester, also from Universiti Putra Malaysia "*Development of a* *systematic method in Lean Tool Selection for Automotive Industry*" by Alireza Anvari and "*Development of a fuzzy integral group model based on linguistic reasoning for project manager selection*" by Alireza Afshari in 2012, "*Economic Production Quantity Model Based On Extended Cost Parameters for Imperfect Process and Defective Items*" by Mohammad Reza Shahraki and "*Development of Group Decision Making Model Under Fuzzy Environment*" by Mohammad Anisseh in 2011 are mentioned.

3.3 Overall flowchart of study

The overall flowchart processes of this study to achieve objectives is presented in Figure 3.1 and the summarized relevant detail are explained. The description of stages mathematical methods which are used in developing procedures are described at the fallowing sections of this chapter.

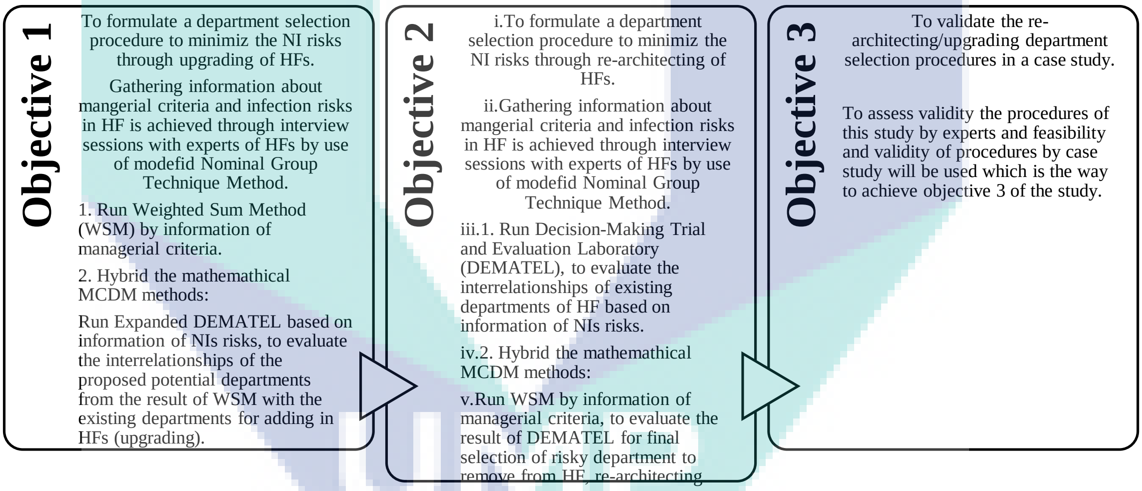

Figure 3.1 Overall flowchart of research

3.4 Methods for department selection

Selecting single or else multiple MCDM methods can be a challenge (Gade & Osuri, 2014). In any case, the appropriate technique progressively manifests during the formulation of the problem and the identification of alternative and criterion stages, since methodical selection can involve on-going processes (Dooley, Sheath, & Smeaton, 2005). Various modelling methods have been proposed for DM theorems and applications (Mardani et al., 2015). Numerous strategies have also been proposed for the modelling of decision aids as well as for the development of alternatives as process complexities are considered (Mardani et al., 2015). Gade and Osuri (2014) stated, selecting specific MCDM methods for evaluation is a vital challenge that comprises logical as well as systematic analyses. The task entails exhaustive, and even unattainable processes that must account for all DM processes, the role of the decision-maker, not to refer the variety number and variety of techniques and available information (Mota, Campos, & Neves-Silva, 2013). Mardani et al. (2015) reported, the choice of solution approaches and schemes will depend on the actors who are engaged during the course of DM, in addition to the desired aims, accessible information, time available, etcetera.

Mardani et al. (2015) noted, there is no uniquely defined decision aiding methodology that can be followed in steps throughout its course. Gade and Osuri (2014) described the key aspects to be considered when selecting methods of MCDM, comprising as follows:

i. Ease-of-use;
ii. Generalised application domain;
iii. Friendly user interface;
iv. Consistent operation;
v. Robust application;
vi. Time needed;
vii. Technical implementation;
viii. DM course results must be accurate;
ix. DM processes necessitate fewer human interventions;
x. Decision models need to apply in sensitivity analyses.

For users who have lesser expertise in maths, the most appropriate technique would be that which requires less knowledge in this field (Sorooshian, 2015).

Accordingly, this study selects three various mathematical levels of techniques which are enumerated as follows.

3.4.1 Weighted Sum Method (WSM)

The Weighted Sum Method, also termed the weighted linear combination, is a broadly popular, widely known and practically used, and readily implemented subjective DM method (Chou, Chang, & Shen, 2008; Salehi and Izadikhah, 2014; Talebanpour and Javadi; 2015; Sorooshian, 2017). Kumar and Suresh (2009) demonstrated, this method involves decision procedures wherein every alternative must be scored based on relevant factors, with each weighed on importance. Methodical application involves the determination of highest scores for all factors (criteria), the determination of the diverse levels of all factors, and the determination of suitable scores for each level (Kumar & Suresh, 2009). Sorooshian (2017) agreed on x alternative (A) and the y decision criterion (C) sets, in that the method can be algorithmically delineated into five phases:

i. First decide priorities for the criteria according to their importance in DM. By focusing on the decided priorities, weightings (W_x) in percentages can be assigned to every criterion so long as the total weight equals 100%.

ii. For each alternative, assign a numeric value (V) based on each criterion at the first column of matrix. With this step, the alternatives set are represented by the decision matrix [V_{ij}], wherein V_{ij} denotes the numeric value that expresses how efficiently alternative A_x could attain criterion C_y. Through this research, the author utilised numeric values within the domain $1 \leq V \leq 100$, even though a different series could be utilised for all values.

iii. The weighted sum (WS) is determined by multiplying the weighting for every criterion by the associated numeric value that is allocated to each alternative, with the resulting values then summed up. This is shown in Eq. 3.1.

$$WS(A_x) = (W_x . V_x) \tag{3.1}$$

iv. Eq. 3.2 shows that for each alternative (A_x), the WS can be determined by summing up the respective resulting values at the last row of the matrix.

$$WS(A_x)= \sum_{y}(WS(Ax)) \tag{3.2}$$

v. Finally by comparing the WS, all alternatives with maximums that match the criteria can be enumerated from most to least preferred option. The alternative featuring the highest WS is superior alternative in terms of selection.

3.4.2 Decision-Making Trial and Evaluation Laboratory (DEMATEL)

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique was applied in 1974 by Duval, Fontela and also Gabus at the Battelle Memorial Institute, Geneva Research Centre, in order to visualise the structure of complex causal relationships via matrices or digraphs (Dasaklis, 2015; Sheng-li, You, Liu, & Huang, 2017; Sheng-li, You, Liu, & Zhang, 2018; Zahidy, 2016). Among the more powerful DM techniques, the methodology is well-suited for the extraction of interdependent relationships and the intensities of interdependencies among the complex parts of a system (Zahidy, 2016, Talebanpour and Javadi, 2015). Talebanpour and Javadi (2015) also arguing that this technique is widly accepted as one of the bests for extracting the cause and effect relationships.

DEMATEL utilises expert knowledge to arrive at a superior understanding of the correlations between factors, in accordance with the relationships and influences among various factors (Zahidy, 2016). DEMATEL stems from the graph theory and the approach involves the conversion of interdependency relationships into cause-and-effect groups using matrices (Dasaklis, 2015; Falatoonitoosi, Ahmed, & Sorooshian, 2014; Sheng-li et al., 2017; Si, You, Liu, & Zhang, 2018; Sorooshian & Falatoonitoosi, 2015). Factors within cause groups can significantly affect on system as well as those factors within the effects group (Falatoonitoosi et al., 2014). The method can also recognise indirect, direct, and interdependent effects between every complex factor, as well as rank each according to long-term DM strategies, all while indicating scope for improvement (Dasaklis, 2015; Falatoonitoosi et al., 2014; Si et al., 2018). With DEMATEL structures, each factor or part may utilise and acquire from a further higher or lower factors (Sorooshian & Falatoonitoosi, 2015). The method is therefore useful for improving the understanding of the specific research problem, clusters of entangled problems, and contributing to the recognition of practical solutions through the use of hierarchical structures (Falatoonitoosi et al., 2014; Zahidy, 2016). Zahidy (2016) recapped the additional advantages of the DEMATEL method to include the following features:

i. Feedbacks can be applied in applications (Falatoonitoosi et al., 2014; Zahidy, 2016);

ii. The value and importance of using the entire factor set in place of particular parameters can be assessed and established (Ilieva, 2017);

iii. Criteria can be prioritised according to relationship types and the severity of mutual influences (Lin, Wang, & Tseng, 2009);

iv. The relationship between criteria in complicated problems can be revealed (Ilieva, 2017);

v. Indirect and direct dependencies between unpredictable attributes can be determined (Ilieva, 2017).

Si et al. (2018) evaluated DEMATEL against some MCDM methods, such as, AHP (analytic hierarchical process), GRA (grey relational analysis), TOPSIS (technique for order performance by similarity to ideal solution), VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje), and ELECTRE (Elimination Et Choix Traduisant la REalit´e) methods. The DEMATEL method has the following benefits:

i. It efficiently analyses the mutual effects (both indirect and direct effects) among various factors and understands the complex cause and effect correlation in the DM problem.

ii. It is able to create a picture of the interrelationships among factors and enable the choice maker to clearly recognise which parameters have mutual effects on one another.

iii. The DEMATEL can be employed not only to establish the ranking of the alternatives but to find out critical assessment criteria and compute the weights of assessment criteria as well.

Ali, Sorooshian, and Kie (2016) clarified that procedures on performing DEMATEL can be summed up as in Figure 3.2. The formulating steps of the DEMATEL can be summed up as follows, which is based on the efforts of a few researchers (Ali et al., 2016; Si et al., 2018):

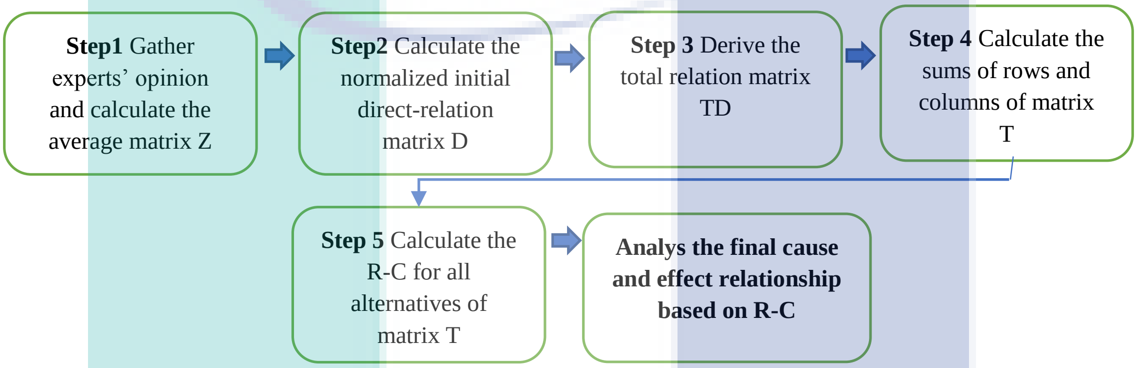

Figure 3.2 DEMATEL steps
Source: Ali et al. (2016).

STEP 1: Gathering expert's opinion and calculating the average matrix Z

As a sample, let us consider a set of m experts and n parameters for this research. Experts are to be allotted a list of factors organised in sets of i and j. They are then to be requested to indicate their assumed degree of impact the factors have on one another (pair-wise comparison); that is, how does factor i affects factor j. The suggestion can be made in the range of 0 to 4; 0 implies no influence, 1 implies low influence, 2 implies moderate influence, 3 implies high influence and 4 implies very high influence. Nonetheless, this scale is only used as an example for this research, or else the rating scale can be according to the researcher's preference. The amount to which the expert's perception of factor i affecting factor j is indicated by X_{ij}. For each expert, an n x n non-negative matrix is created as $X^k = [x^k_{ij}]$, in which k is the number of experts participating in the evaluation procedure with $1 \leq k \leq m$. The mathematical notation can be formulated as Eq. 3.3:

$$X = \begin{bmatrix} 0 & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \dots & 0 \end{bmatrix} \qquad 3.3$$

Thus, we would get X^1 , X^2 , X^3 , …, X^m as the answer matrix acquired from the experts. Every element of the matrix is designated as X_{ij} representing the amount of impact parameter i has on parameter j. An average insight on the experts' answer has to be attained. This could be accomplished by calculating the matrix average which could be termed as an initial direct-relation matrix. This matrix could be represented as matrix $Z = [z_{ij}]$ based on the Eq. 3.4:

$$z_{ij} = \frac{1}{m} \sum_{i=1}^{m} x_{ij}^{k} \qquad 3.4$$

STEP 2: Normalising the initial direct-relation matrix D

In the second step, normalised direct-relation matrix D has to be derived from the average matrix Z. This is accomplished by dividing every element by the biggest row sum of Z, the average matrix. Total direct effect on the influence magnitude of the factor with largest direct influence on the other parameters can be given as follows (Eq. 3.5):

$$\max_{0 \le x \le 1} \sum_{j=1}^{n} z_{ji} \qquad 3.5$$

The value of each element in this normalized direct-relation matrix D would vary between [0,1]. The computation to obtain the matrix is as shown in Eq. 3.6 and Eq. 3.7:

$$D = \frac{Z}{s} \qquad 3.6$$

Where, $S = \max_{0 \le x \le 1} \sum_{j=1}^{n} z_{ji}$ 3.7

STEP 3: Finding the total relation matrix T

The third step would realise the total or direct/indirect relationship between each pair of the system factors. The suppositions are that the matrix of indirect influence converges to the null matrix as displayed in Eq. 3.8:

$$\lim_{k\to\infty} D^k = 0 \qquad 3.8$$

In the case where 0 is the null matrix with I as an n x n identity matrix, the equation given below holds true Eq. 3.9:

$$\lim_{k\to\infty} (I + D + D^2 + \cdots + D^K)^= \ (I - D)^{-1} \qquad 3.9$$

The matrix of total relation T is, therefore, defined as Eq. 3.10:

$$T = D\ (I-D)^{-1} \qquad 3.10$$

STEP 4: Calculating sums of rows and columns of matrix T

Vector R and C denote the sum of rows as well as sum of columns respectively in the matrix of total-influence T. Let vector R be given as n x 1 and C be given as 1 x n. Therefore, the sum of rows Eq. 3.11 and the sum of columns Eq. 3.12 would be determined as:

$$R = [R_i]_{nx1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{nx1} \qquad 3.11$$

$$C = [C_j]_{nx1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{nx1} \qquad 3.12$$

Set R_i be the sum of *i*th row in matrix T. The worth of R_i presents the total given both indirectly and directly effects, that factor i has on the whole factors. Set C_j be the sum of the *j*th column in matrix T. The worth of C_j indicates the total received both indirectly and directly effects, that whole factors have on factor j.

Step 5: Calculate the R-C for all alternatives of matrix T

When $i = j$, the subtract (R_i-C_j) for each factor indicates the net indirect and direct interrelationship that factor i contributes to the system and is given in Eq. 3.13:

$$(R_i - C_j) = \sum_{j=1}^{n} t_{ji} - \sum_{k=1}^{n} t_{ik} \tag{3.13}$$

If ($R_i - C_j$) is positive, the influence factor i is a net cause, while if ($R_i - C_j$) is negative, factor i is a net receiver (effect). Hence, according to Lytras (2008), Chen, Hsu, and Tzeng (2011), Wu (2012) and Dedasht, Mohammad-zin, and Ferwati (2017) the final result of DEMATEL are in two groups:

i. Cause group:

The calculated ($R_i - C_j$) shows the “severity of influence”. Each factor of total matrix with positive ($R_i - C_j$) belongs to this group. These factors can affect the other factors of the system with direct and/or indirect relationships. The factors belong to the cause group will be prioritised based on the result of ($R_i - C_j$); the higher ($R_i - C_j$), the higher influence on other factors. On the opposite side, the factor with the nearest ($R_i - C_j$) to zero has a lower impact on the other factors of the system.

ii. Effect group:

Each factor of total matrix with negative ($R_i - C_j$) belongs to this group. These factors can receive the influence from other factors of the system with direct and/or indirect relationships. The factors belong to the effect group will be prioritised based on their calculated ($R_i - C_j$); the factor with the lower ($R_i - C_j$), receives the higher influence in the system. On the opposite side, the factor with the nearest ($R_i - C_j$) to zero is receiving the lower influence from other factors of the system. Referring to the second objective of this study which is recognize risky departments, cause and/or effect that both are risky, to remove from the HF, therefore DEMATEL known as an upright method in this way.

As in a literature review by Si et al. (2018) stated, there are several MADM methods combined with the DEMATEL in previous modelling. Therefore, DEMATEL is well hybrid able with MADMs. To achieve the second objective of this study, DEMATEL hybridize with WSM in order to remove risky department from the HF, re-architecting, to minimize the risk of NIs.

3.4.3 Expanded DEMATEL

The expanded DEMATEL was initially presented in 2014 (Falatoonitoosi et al., 2014). It facilitates researchers to establish the cause and effect factors in bidirectional relations in networks when the number of rows is not the same as the number of columns among different clusters which consist of several factors (Falatoonitoosi et al., 2014). Expanded DEMATEL is highly applicable and effective for all kinds of networks that are inclusive bidirectional relations because of determining cause and effect factor among separate criteria that have direct influence on each other to improve the system (Aghelie, Mustapha, Sorooshian, & Azizan, 2016; Falatoonitoosi et al., 2014).

Falatoonitoosi et al. (2014) stated, as per the DEMATEL technique, when i $=j$, $[Ri]_{n\times 1} = (\sum_{j=1}^{n} t_{ij})_{n\times 1}$ (total given effects by factor i) and $[C_j]_{1\times n} = (\sum_{i=1}^{n} t_{ij})_{n\times 1}$ (total given effects by factor j) and thus (R – C) will be obtained. But when i ≠ j and elements in rows are distinct from components in columns, computing (r_i - c_i) is not feasible (Falatoonitoosi et al., 2014). If we have two clusters (1 and 2) with different factors and unequal number of factors to evaluate their relationships, the evaluation will be done based on Equations 3.14, 3.15 and 3.16 of Expanded DEMATEL in two different matrices. As it was explained in Section 2.9.1, upgrading HFs involve with two groups of departments:

i) Existing departments in the HF.
ii) Potential department to be added to the HF.

Therefore, Expanded DEMATEL can be an upright method to evaluate the relationships between two groups of departments. Finally, this method beside WSM will be used to develop procedure to make decision in selecting potential department for upgrading of the HFs. The stages of Expanded DEMATEL is as follows:

In first matrix, R (the total effects, both indirect and direct) of cluster 1, based on Eq. 3.14, will be achieved.

$$\left[[R_i]_{i\times 1} = \left(\sum_{j=1}^{i'} t_{ii'}\right)_{i\times 1}\right]_x \tag{3.14}$$

R= shows the total effects, both indirect and direct, given by "m" factors of cluster 1 to the "n" factors of cluster 2.

i= the number of factors in cluster 1.

i'= the number of factors in cluster 2.

x= the name of final matrix which will be achieved.

In second matrix, C (total effects, indirect and direct, received) of cluster 1, based on Eq. 3.15, will be achieved.

$$\left[[C_i]_{1\times i} = \left(\sum_{i=1}^{i'} t_{ii'}\right)_{1\times i}\right]_x \tag{3.15}$$

C= shows the total effects, both indirect and direct, given by "m" factors of cluster 1 from the "n" factors of cluster 2.

i= the number of factors in cluster 1.

i'= the number of factors in cluster 2.

x= the name of final matrix which will be achieved.

Finally, the (R-C) will be achieved based on Eq. 3.16.

$$(R-C)_1 = R_1 - C_1 \tag{3.16}$$

Therefore, same as DEMATEL, considering result of $(R - C)$, dimensions will be partitioned into cause and effect.

3.5 Hybrid MADM method

Latest trend with regards to the use of MCDM method is to integrate two or more methods to make up for shortcomings in any single specific method (hybrid MCDM) (Mardani et al., 2015; Velasquez & Hester, 2013; Zavadskas et al., 2016; Rekik, Kallel, Casillas and Alimi, 2016, Tzeng and Shen, 2017). Karami (2011) suggested, decision-makers generally use more than one DM method to make important decisions. Also, Zahidy (2016) mentioned, hybrid methods research could provide a better understanding of the research problem rather than the use of single method alone. Zavadskas et al. (2016) said, "*because individual MCDM methods can yield different rankings, selecting an appropriate method is a great challenge. It is therefore recommended to use a hybrid approach based on more than one method and to integrate those results for final decision-making. Another advantage of hybrid approaches over individual methods is based on an opportunity of integrating subjective and objective criteria importance into the value of utility function*".

3.5.1 Hybrid decision-making method for HF upgrading

To attain objective 1 of this study, WSM-Expanded DEMATEL should be employed as a hybrid MADM method. With reference to a discussion with the first and the third authors of Expanded DEMATEL and reviewing the MADM literature, no evidence shows a similar hybridization; this attest to a novelty of the presented hybrid MADM method. Initially, WSM will be employed, based on Section 3.4.1, to identify the potential departments/alternatives which can be included in an existing HF depending on the managerial criteria. Next, Expanded DEMATEL, citing Section 3.4.3, could assess the bidirectional relations between various clusters of existing departments and selected potential departments (based on NIs risks) from WSM result, which can be included in the HF. The outcome of the Expanded DEMATEL is the recommended un-risky departments for HF upgrading which can be chosen from the potential list.

3.5.2 Hybrid decision-making methods for HF re-architecting

To attain objective 2 of this study, DEMATEL-WSM will be employed as a hybrid MADM method. Very few attempts, if any, for hybridizations of DEMATEL and

WSM is in the MADM literature. Based on reviewing of the literature in NI and HF management fields, no evidence of previous use of DEMATEL-WSM was found. Hence, the use of this hybrid method for re-architecting of HFs is initiated by this study.

Firstly, DEMATEL will be utilised. As described in Section 3.4.2, DEMATEL is an appropriate technique to assess cause and effect relationships. In this research, it can recognise the risky departments depending on the NIs risks caused by the interrelationship among the existing departments of a HF. Subsequently, selected departments by DEMATEL will be assessed using WSM (Section 3.4.1). WSM can employ the listed managerial criteria of selected department to determine the risky department(s) which should be excluded.

3.6 Group decision making for HF upgrading and re-architecting

Usually, the GDM (Group Decision Making) process involves several stakeholders discussing the issue at hand, listing of alternatives by means of brainstorming and reaching a consensus that produces the final set of decisions (Rekhav & Muccini, 2014). The outcome of multiple-criteria GDM is more precise compared to a single decision-maker (Sorooshian, 2017). This study proposes an integrated method of hybrid MADMs and GDM for the complex DMs of HF re-architecting and upgrading and stakeholders of this studies are HF manager, NI specialist, and modification decision makers.

In GDM, brainstorming is a practice that is created by Alex F. Osborn in the year 1957 and is outlined as a methodical way to permit the mind to generate ideas without getting hindered in trying to determine the worth of those ideas at the same time (Andresen, 2000). The basic steps for group brainstorming comprises of (Wilson, 2013):

i. Choosing a group of 3 to 10 participants with various backgrounds (HF management, microbiologists, infectious diseases and any field of study wich is relevent to NIs and HF architecture and management).

ii. Presenting a clear problem, question, or subject to the group.

iii. Asking the participants to generate ideas or solutions with no disapproval or attempts to restrict the number and type of ideas. This is the "divergent" stage in which it is desirable to have as many ideas as possible with no censorship.

iv. Arguing, evaluating, and possibly prioritising the brainstorming outcomes for later action. This final step is usually called the "convergent" stage where there is a sorting out of all the proposals into the ones that ascertained to be the most appropriate to a problem.

The NGT (nominal group technique) is an adaptation of the brainstorming wherein the DM group suggests their decisions separately (Sorooshian, 2017). In case of NGT, individuals produce ideas anonymously and separately, without interference from others, by noting them down on paper or storing them electronically (Parthasarathy, 2014; Sorooshian, 2017). In the final stage of the NGT session, the content of paper or the electronic contents are combined together to generate the set of ideas from the participants (Parthasarathy, 2014). NGT is a method that can be executed within a fairly short time duration and is easily comprehended by participants (Madden et al., 2017). In NGT researchers can use open-ended and close-ended questions. The GDM method is a feedback technique with a group of experts and referring to a set of qualitative research methods (Zahidy, 2016). It relies on the opinions of individuals who are believed to be experts on the subject under consideration. The GDM method is a highly formalised method of communication that is designed to extract the maximum amount of unbiased information from a panel of experts (Zahidy, 2016). Some experts support the NGT more than the wordiness agreements in brainstorming (Sorooshian, 2017).

The primary benefit of the NGT compared to other strategies is the enhanced opportunity for the whole group to contribute suggestions and reduced domination of the process by more outspoken or confident individuals (Jones, 2004). Other benefits include (Jones, 2004):

i. The creation of a higher number of ideas than other group processes.
ii. The creation of more original ideas than other group processes.

iii. The simplicity of interpreting the outcomes (as ideas are created, voted on/ranked, and assessed at the session itself).

iv. A higher sense of accomplishment for participants (as the outcomes are available instantly after the session).

v. The nominal resource requirements (a place, facilitator, paper, pens and whiteboard).

vi. The comparatively effective use of time.

An advantage of NGT over other group methods includes its practical application in concurrently addressing problem recognition, development of ideas and determining priorities for action (Madden et al., 2017). This research adopts GDM, particularly NGT.

3.6.1 Group decision making with unbalanced expertise

Most GDM and consensus models include a few number of scholars, because usually, important decisions are made by professional, skilled and authorised persons in the firms, administrations or institutions (Kamis, Chiclana, & Levesley, 2017). These scholars have their own viewpoints, knowledge, interests, drives etcetera, all face a universal problem, and all are attempting to arrive at a collective decision (Bilbao-Terol, Jiménez, & Arenas-Parra, 2016). In this research, each HFs have separate clusters and probably not many scholars with different knowledge or non-equal level of expertise in the area of minimising NIs risks, such as, decision manager, infectious disease specialist, microbiologist and others. To achieve feasible and valid results, it is very crucial to know how to give weight to these diverse clusters of experts (or non-equal level) and recognise which opinion has higher impact compared to the other ones. It is difficult to obtain the consensus about all issues in practical group DM processes, so it is a significant research topic how to assess the evaluation level of scholars in group-decision analysis (Xia & Fan, 2007). The multiple-cluster GDM approach is more appropriate when the input claims take the form of various preference relations in several situations due to time pressure, lack of knowledge, and people’s inadequate expertise related with the domain of problem (Sorooshian, 2017, 2018; Xia & Fan, 2007). A synopsis of this research is mentioned below:

Thus, this research attempts to use a solution which was applied by Parsia et al. (2020). They recommended to nominate separate expert clusters with reference to the level of expertise of each committee/cluster. This technique also, taking into account DM panel with poorer level of expertise, could resolve the limitation of expert accessibility in DMs. In case of DM, a different weightage for each cluster may be applied based on the degree of expertise, as demonstrated in Figure 3.3. For instance, opinions from cluster of experts having a high degree of expertise will be considered to have double weightage than opinions of experts from a cluster having a moderate degree of expertise, and it will be three times the weightage of the opinions of cluster of experts having a low degree of expertise. Opinions from experts having a moderate degree of expertise will be given two times more weightage than the opinions of the experts having a lower degree of expertise. The weightage of the opinions of each cluster is determined by the top decision maker(s).

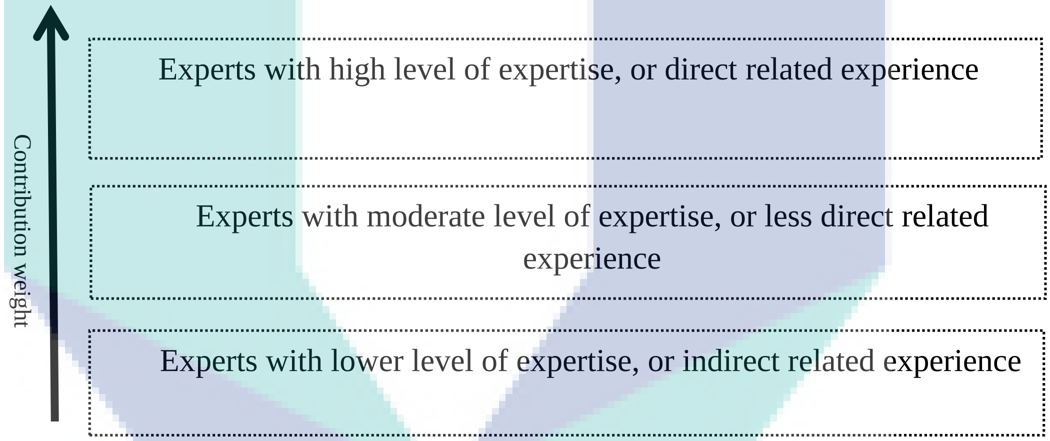

Figure 3.3 Group Decision making with multiple experts
Source: Sorooshian (2018)

This research uses the NGT along with the approaching experts with unbalanced expertise; this is modified NGT, however, from now generally will be called NGT. The goal of research based on qualitative data is not necessarily to collect all or most ideas and themes but to collect the most important ideas and themes. Open-ended questions are used alone or in combination with other interviewing techniques to explore topics in depth, to understand processes, and to identify potential causes of observed correlations. Open-ended questions may produce lists, short answers, or lengthy narratives (Weller, Vickers, Bernard, Blackburn, & Borgatti, 2018). Open-ended questions are questions that allow someone to give a free-form answer.

Closed-ended questions can be answered with "Yes" or "No," or they have a limited set of possible answers (such as: A, B, C, or All of the Above). Closed-ended questions are often good, because gets higher response rates. Also, answers to closed-ended questions can easily be analyzed (Farrell, 2016).

3.7 New procedure for department selections in HF

Through an integration of above hybrid techniques for HF upgrading and re-architecting, this research suggests new DM procedure in order to minimize the NI risks, as given below (illustrated in Figure 3.4):

Step 1: Decision type identification (Upgrading or re-architecting): In case of upgrading move to step 2, or for re-architecting, move to step 8.

Step 2: Alternative (potential departments to be added and the existing departments) identification by use of NGT.

Step 3: Managerial criteria identification by use of NGT.

Step 4: Computation based on WSM for potential departments to be added to get the specified list of them based on managerial criteria.

Step 5: To study interrelationships between alternatives (specified list and existing departments) by use of NGT.

Step 6: Computation by Expanded DEMATEL to select the best potential department based on NIs interrelationship between the best potential department(s) to be added and the existing departments.

Step 7: Move to step 13.

Step 8: Alternative (existing departments) identification by use of NGT.

Step 9: To study interrelationships between alternatives by use of NGT.

Step 10: Computation by DEMATEL to identify and prioritize risky department(s) depending on NIs interrelationships between alternatives.

Step 11: Managerial criteria identification by use of NGT.

Step 12: Computation by WSM to identify department for excluding based on managerial criteria, from step 11, and NI risk, from step 10.

Step 13: Selection of the potential department for upgrading/re-architecting.

This procedure represents the accomplishment of both objective 1 and 2 of this study which was to create decision procedures for HF upgrading and re-architecting in order to minimise the NI risks. The comprehensive procedure of combination of both upgrading and re-architecting procedures is shown in flowchart of Figure 3.4.

To implement the presented procedures of this study, each HF needs to have the information of its two main criteria, managerial and NI risk. Then, use the information in the matrices of the mathematical procedures proposed by this study. Thus, these procedures are general and can be used in any HF.

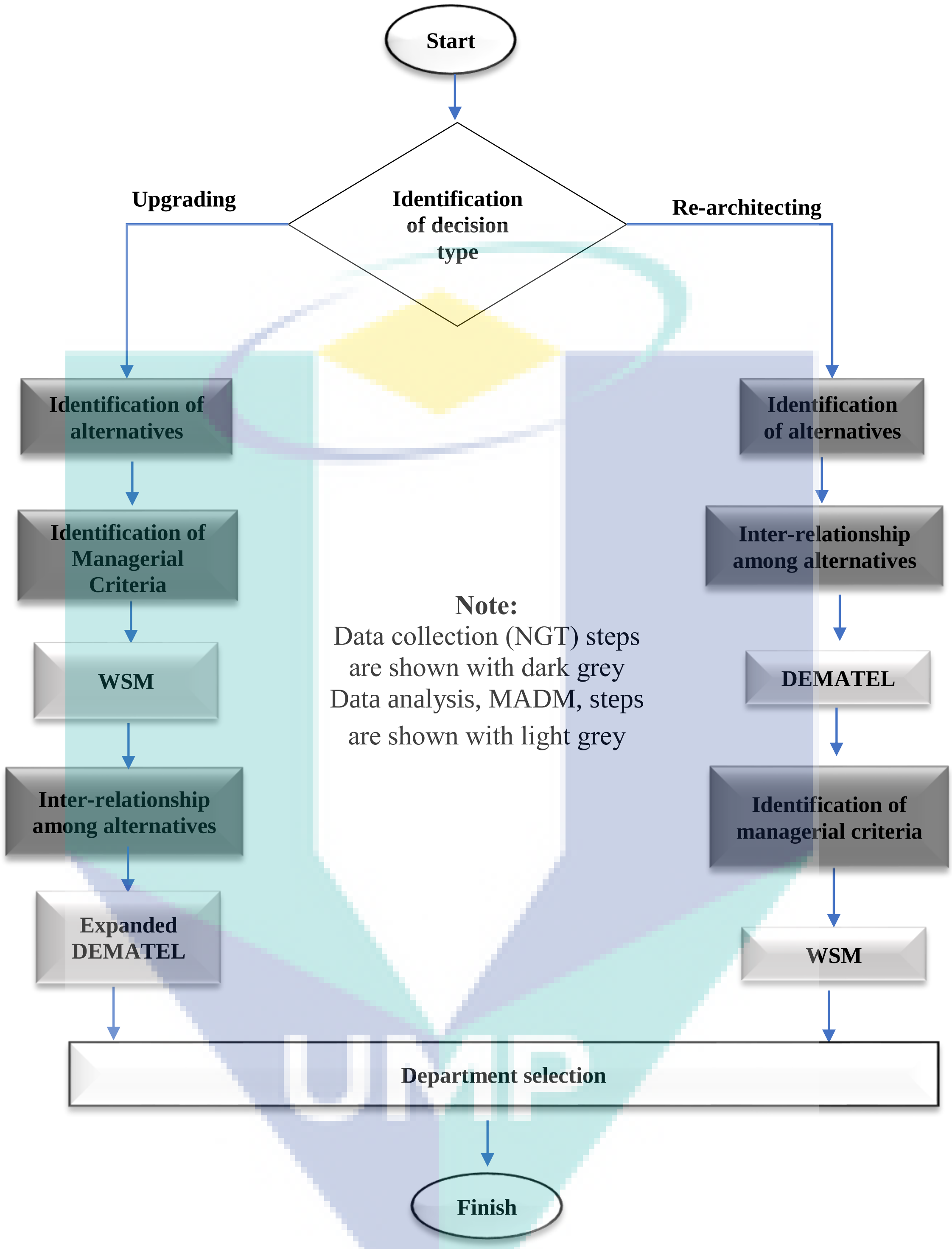

Figure 3.4 Flowchart of new procedure for upgrading and re-architecting hospital layout to minimize NIs risks.

3.8 Validation of procedures

Validity refers to the extent to which a methodology measures what we hope to measure with no or little bias or validation is the method of establishing that the system entirely and accurately represents the domain of problem, and it reaches acceptable levels of performance (Eldrandaly, Ahmed, & AbdelAziz, 2009; Garcia-Hernandez, 2015).

To assess validity of procedures of this study by experts and feasibility and validity of procedures by case study will be used which is the way to achieve objective 3 of the study.

3.8.1 Validation by experts

Expert is defined as '*a person with a high level of knowledge or skill in a field*' (Zahidy, 2016). The expert viewpoint seems to be the best available option to validate the model (Bracke, Spruijt, Metz, & Schouten, 2002). The final confirmation of a methodology is how well it fulfils the expectation of the target, and this can be obtained from the expert's opinions (Bougnol & Dulá, 2006). According to Zahidy (2016), the chosen of expert who have the knowledge and interest on the topic will increase the logical validity of the proposed method or model.

In this study, first of all, the supervisor was consulted to validate the comprehensiveness and ease of use of the procedures. Second the procedures and the flowchart of Figure 3.4 are reviewed with a MCDM expert to ensure they are logically valid and generalizable. The expert was selected based on the following criteria:

i. Understanding of the problem-statemenet, literature and objectives of this reseach.
ii. Knowledgeable in field of the DM methods, including MADM methods.
iii. Experties on at least, the three selected MADM methods of this study (WSM, DEMATEL, Expanded DEMATEL) and GDM processes.
iv. Experiance on modeling and hybridization of decision making methods for problem solutions.

Based on the above criteria, an expert who was an accredited management consultant and an associate professor from a university in Malaysia, has been invited for a session of interview. This research models have been discussed; few of the alternative DM methods have been assessed; the recommended hybrid methods and the procedures have been validated. Additionally, the simplicity of use, user- friendliness of the proposed procedures, easiness of the DM process for HFs, implementation and generalizability of the procedures and accuracy of the possible result have been verified by the expert.

3.8.2 Case study

According to Creswell (2014), a case study is a strategy of inquiry in which the researcher explores in depth a program, event, activity, process, or one or more individuals. Case study method enables a researcher to closely directly examine the data in a specific context (Zainal, 2007). In majority of the cases, a case study method selects a minor geographical area or a very few individuals as the study subjects (Zainal, 2007). The case study is a popular and valid method to test MADM models (Dehe & Bamford, 2015).

Zahidy, 2016 opined that performing a case study is a strategic part of a research, and it aims to settle some logistical concerns such as:

i. Verify that the instructions are clear and feasible.
ii. Verify the quality of results.
iii. Verify the analytical procedures to determine their efficacy.

For the test of validity of MADM modellings, as it is suggested by Anvari (2012), validation can be obtained by employing a case study. According to Debnath and Roy (2017), researchers support a minimum one case study to validate the usefulness of their proposed research framework. They listed 28 studies which used a single case-study to validate their MADM modelling. However, studies with one case study to validate their MADM models are many more; among them, Pourjavad (2011); Krohling and Campanharo (2011); Song-man, Hu-Chen, and Li-en (2017); Gizem and Gülçin (2011); Rezaeisaray and Ebrahimnejad (2016); Shilei, Tallón-Ballesteros, and Pamučar (2016); Wei (2015); Tian, Wang, Wang, and Zhang (2018); Ruonan, Zhang, and Liu (2016);

Tuzov, de Andrés, and Ruiz (2018); Wang, Labella, Rodríguez, Wang, and Martínez (2017).

In addition to opinion of experts, this research uses a case-study to test validity and feasibility of the proposed department selection procedures to minimize NI risk in HFs. Thus, if these procedures can be used on a case study and an outcome can be obtained, the procedures are assumed to be feasible. The case/HF will provide feedback about the quality of the outcome of the procedures. These models will be validated if can be executed and if they establish positive results and are satisfactorily accepted by the case (Anvari, 2012).

After search and evaluate potential HFs to provide a practical validation of the proposed procedures, a hospital confirmed to cooperate and be as a case study of this research, as the selection procedure is explained in the coming chapter 4.

3.8.2.1 Nomination of experts of the case study

As per Zahidy (2016), an expert team must comprise experienced professionals who can give an expert opinion on matters in their particular fields. From this description, it could be realised that the choice of experts is confined to those with a high degree of knowledge and/or experience; the use of experts who have the knowledge/experience and interest on the topic increase the reliability and validity of the case study (Zahidy, 2016).

Experts selected for the case study will be chosen from the case, taking into account their expertise in management of the HF (for managerial criteria) and NI specialists (for NI criteria). The number of the experts will be decided on the recommendation and availability by the hospital/case. Anvari (2012) clarified that usually a sample of 5-6 experts for interview is sufficient. Also Daniel, Yusuff, and Jassbi (2009), Arunraj and Maiti (2010), Hsu, Chen, Hu, and Chang (2012), Abdullah (2013) and Mondal and Pramanik (2014), Al Yami et al. (2017), Abdullah, Adawiyah, and Kamal (2018) used only 4 experts in their research. Noor-E-Alam, Lipi, Hasin, and Ullah (2011) and Anvari (2012) stated, the number of experts as interviewees should not be more than a few as participation of too many experts makes difficult the process of integrating the various opinions. There is no theoretical or experimental confirmation that the size of the expert team affects the outcomes (Lee & Yang, 2017).

For this study, referring to objective 1 and objective 2, two categories of experts are needed: (i) experts with expertise related to managerial criteria, (ii) experts with expertise related to NIs risk. Therefore, to run the upgrading procedure as well as re-architecting procedure, experts from both categories should be invited. Expertise of the experts from category (i) are used for WSM analysis (in upgrading and re-architecting procedures) and expertise of experts from category (ii) are required for DEMATEL (in re-architecting procedure) and Expanded DEMATEL (in upgrading procedure) analysis. Table 3.1 is presenting the use of two defined categories of experts for this case study. Category (i) of experts is shown with black color and category (ii) of experts shown in gray in the Table.

Table 3.1 Expert categories

Upgrading	WSM	Expanded DEMATEL
Re-architecting	DEMATEL	WSM

The GDM-NGT with unbalanced expertise will be utilised for the case. Therefore, based on the meeting with top managers, of the hospital, a few experts for both categories (i) and (ii) will be chosen for participation as panel of this case-study. Experts with different fields will be invited, for instance, in category (ii) different clusters of specialists in NI control and infectious diseases can be considered. Decision weightage (as explained in section 3.6.1) to the contributions of the diverse clusters of experts will be decided in the same meeting with the top managers.

3.8.2.2 Procedure of the case study

For this case study, it is planned to have a few discussion sessions with top manager of the hospital. Prior to the case study, significance of the current study and the potential output as well as the proposed procedures will be discussed and elaborated to the top manager. General documentation about the HF and its layout plan will be collected. Moreover, panel of experts for the case-study and the next data-collection meetings will be planned. Following the steps of this research procedure (Section 3.7) as a case study protocol, to ensure the ability to yield results with minimal variability over repeated implementations, a few rounds of data-collection with experts should be organized.

Therefore, for upgrading, an interview session by top manager (by use of NGT) should be planned to find suitable new departments by use of next assessment (WSM) from the list suggested by manager, based on managerial criteria. In the next step, set interview session with NI specialist scholars to recognised the risky departments (from list of potential departments which are achieved from WSM) by comparing direct and indirect inter-relationship between potential departments and existing ones based on NI risks (for upgrading by use of expanded-DEMATEL). Finally, the low risky potential department(s) have selected to add in hospital.

For re-architecting, the first step will be used NGT to identify alternatives (departments), NIs direct and indirect interrelationship between departments and find risky ones by use of DEMATEL based on opinion of NI experts, then also, planed a session interview with top managers and decision-makers to choose final department(s) to exclude by use of proposed managerial criteria and WSM.

To increase the reliability of a MCDM study, Garcia-Hernandez (2015) said that a face to face interview will provide a better understanding of the questions for the experts and for the researcher to get the true value through of the data; this is endorsement of the reliability. The final round of the case-study, the achieved results from analysis will be presented to the top managers, the results will be verified by their knowledge and practical experiences.

3.9 Summary

This chapter sums up the procedures adopted for carrying out this research endeavour, including choice of methodology, present procedures and their validations. Hybrid methods were picked as the most appreciated approach with reference to this research. Based on the literature of MCDM methods, DEMATEL as well as Expanded DEMATEL are chosen respectively to assess relationships (based on NIs criteria which are significant to prevent risks of NIs and selected them by employment of NGT from expert's attitudes) between existing departments to choose one of them to exclude (for re-architecting HFs), and also new departments (suggested by HF manager) with existing departments to select the most excellent one to add (for upgrading HFs). WSM also decided to rank the selected department(s) based on managerial criteria and alternatives which are significant for HFs managers as expert and recognised by use of NGT for upgrading and re-architecting HFs. Experts in this study will selected from managerial decision maker, HF manager, specialists of NI control and infectious diseases. Finally, in this chapter concluded with the discussion on feasibility and validity of the procedures. The approaches described above establish the cornerstone for the following chapter. The first two objectives of the thesis were attained. Chapter 4 will discuss about the third phase of DM procedure (choice phase) with the help of case studies, in order to achieve the third objective of the research.

CHAPTER 4

CASE STUDY, RESULT AND DISCUSSION

4.1 Introduction

In this chapter, an attempt is made to assess the implementation of the procedure presented in Section 3.7 in case study to analyze their validity and feasibility. Some explanations are provided concerning the case of the study, that is, Bahonar hospital in Kerman – Iran together with the existing departments of the hospital, its manner of functionality as to adding and eliminating department(s) and the NI conditions thereof. The data collection process of hospital experts (management and infection control experts in Bahonar hospital) with respect to the implementation of the procedures including questions and definitions of management criteria obtained from experts to add or eliminate department(s) is stated. The procedures implementation stages to add or eliminate department(s) (in a separate manner, based on the procedure presented in Section 3.7) and the calculations together with the corresponding matrix for each stage are provided and the results are interpreted. The potential departments are presented as the final data of the procedures to be added or eliminated from the hospital. The validity and feasibility of the procedures are assessed.

4.2 Selection of the case

The criterion in selecting the case in Iran is the lack of language barrier, simplicity of giving explanations in medical jargon and complete mutual comprehension (among student and the interviewee due to shared mother tongue), which lead to the enhancement of validity of data collection process and precision of the collected data and consequently, the results. Another reason is complete familiarity with the environment and health centers in Kerman province together with the positive approval of authorities and government for the project as to economic support, etcetera, which accelerated and facilitated the data collection procedure. The hospital was in the middle of modification decision making. The period of obtaining permission to select the case is 4/07/2018 to 24/07/2018. After visiting Ministry of Health and Medical Education, and Kerman University of Medical Science, the approval is obtained from the vice-chancellor in Research Affairs by presenting the introduction letter of Universiti Malaysia Pahang (UMP), Appendix B, and the summary of the proposal. The permission to run more assessment is sent to the vice-chancellor in Treatment who sent a letter to the management of hospitals in Kerman to issue the permit. After the approval of manager, the permission is sent to the security management of the Kerman University of Medical Science. After obtaining their approval, the letter is brought to the Ministry of Health and Medical Education to obtain final approval, Appendix C. Eventually, after obtaining the approval of the ministry and the secretariat, the permission is sent to Afzalipour and Bahonar hospitals.

Afzalipour medical education center as one of the biggest hospitals in Iran is established in 2002. The plan of this hospital constitutes two phases with 540 beds capacity, while only the first phase with 462 beds is active. This project is established on 23 hactare surface with 62000 m² total area, with 90 billion Rials and $2 million expenses on Khomeyni highway, Kerman (Afzalipour, 2018).

By considering the properties of this hospital, the data collection process is run in 25/07/2018. Despite the conversations held, due to heavy workload, the hospital management did not contribute to the data collection process, Appendix D.

After visiting Bahonar hospital in 26/07/2018, the permission as to management approval is obtained. In order to initiate the project, the permission is presented to clinical research unit and after explaining the project content and data collection procedure and presenting the proposal to be assessed by the corresponding authority, the primary approval is obtained. To obtain the next approval, a letter is sent to the education unit of the hospital. The obtained approval is sent to hospital security. After explaining the project content and data collection procedure and presenting the proposal to be assessed by the security authority, the permission is approved, and the initiation permission is issued by the head of Bahonar hospital, Appendix E.

4.3 Bahonar hospital background

According to the official websites of, Tasnim-news (2018), Bahonar-Hospital (2018) and Borna-news (2018), Bahonar hospital is the only accidents and trauma hospital in Kerman, the first public hospital and the founder of public hospitals in Kerman province. This hospital is one of the biggest and oldest accidents and trauma hospitals in South-East Iran. Bahonar hospital with 55000 m^2 area is located on Valiasr crossroad and Gharani Ave. in Kerman. Bahonar hospital is established in 1949 with 80 beds.

Referring to Bahonar-Hospital (2018), todays, Bahonar hospital constitutes 20 diagnostic and therapeutic departments with 400 beds. This hospital with educational, therapeutic and research departments, administers patients from Kerman province and acute patients of other private and public centers. Bahonar hospital consisting of 1,400 medical staff, nurses and personnel and modern equipment run therapeutic services, student training, and research and prevention plans. This center receives and assists about 45,000 and 200,000 inpatients and outpatients, respectively, and runs about 17,200 specialized and subspecialized surgeries on an annual basis.

4.3.1 Diagnostic and therapeutic departments

As tabulated in Table A.1, (Appendix A), Bahonar hospital is categorized as a large public hospital with the objective of general education, specialized in accidents and trauma which runs long-term and tertiary-level care system. Due to appropriate space, expertise and educational and therapeutic equipment, medical and nursing students are being trained in this center.

Bahonar hospital departments and the descriptions about their functionality obtained from the official websites of Bahonar-Hospital (2018), Kerman-Isna (2018) and the interviews run with management office authority and the coordinator of hospital quality improvement committee are tabulated in Table 4.1. Code number for each existing departments of Bahonar hospital which is presented in Table 4.1 will be used in the result matrices in Section 4.6 to make better the presentation of tables. The list is approved by the management.

Table 4.1 Bahonar hospital departments

Code No.	Name of departments	No.	Name of departments
ED_1	Neurology1	ED_{11}	**Haematology/Oncology 2**
ED_2	Neurology2	ED_{12}	**Jaw and face surgery**
ED_3	General Surgery	ED_{13}	**Urology**
ED_4	ICU1	ED_{14}	**Internal surgery**
ED_5	ICU2	ED_{15}	**Emergency**
ED_6	ICU3	ED_{16}	**Laboratory**
ED_7	CCU	ED_{17}	**CT scanning**
ED_8	Orthopaedics (for men)	ED_{18}	**Radiology**
ED_9	Orthopaedics (for women)	ED_{19}	**Pathology**
ED_{10}	Haematology/Oncology 1	ED_{20}	**Physiotherapy**

The following information about the departments are obtained through the interview run with the coordinator of hospital quality improvement committee and the official website of Bahonar-Hospital (2018):

- Neurology 1 & 2 departments

Neurology and spine departments provide specialized brain and subspecialized spinal cord surgeries. It is possible to run closed brain surgery (neuroandoscopic surgery) and navigation in this center. The difference between neurology I and Π departments is in the type of patients. At neurology I department, urgent patients like head bleeding patients are treated, while at neurology Π department ICU patients who need neurology department services and lumbar disc patients are treated.

- General surgery

At this department, in addition to providing services to truma and accident patients, subspecialized services like laparoscopic, colorectal and vascular surgeries are provided. The Transanal Endoscopic Microsurgery device is applied for specific operations of intestine surgery.

- ICU (1, 2 & 3)

Kerman University of Medical Science anesthesia and intensive care group is located in these centeres, providing services with the contribution of professors, assistants, and expert personnel applying developed equipment in ICU, surgery room, emergency and acute and chronic pain control departments. The services in these departments include bronchoscope, ultrasound, portable radiography, ABG wavy mattresses to prevent bedsore, intermittent pneumatic compression to prevent deep vein thrombosis and to assess cardiac output condition, dialysis device and pain control system of patient-controlled analgesia after surgery through the specialized pump. These three departments provide the same services. Their difference is that ICU 1 department administers general surgery, ICU 2 administers brain and neurology surgeries and ICU 3 runs CCU together with providing services to ICU 1 and 2 patients. These departments are located at different areas of the hospital; thus, considered as separate departments in this study.

- CCU

At this department, traumatic patients with primary diagnosis beginning from heart diseases to myocardial infarction are treated in a complete manner through the hospital heart intensive care (consisting all sensitive cares related to patient life).

- Orthopedics (men & women)

At these departments, in addition to common orthopedics surgeries, subspecialized surgeries of hand, shoulder, and knee are run. Due to a different location and a high count of reception at orthopedics departments considering the fact that the hospital is specialized for accident and trauma, the orthopedics department is separated for men and women in order to enhance administration and provide more appropriate and rapid services.

- Hematology/oncology 1 & 2

At these departments, the services related to blood diseases and adult cancer are provided. The difference between I and Π departments is in the type of services. At department I, cancer patients are treated, while in Π the patients with blood diseases like bacteremia (presence of bacteria in the blood) are treated. Due to a weak immune system, the patients at these departments are the most sensitive patients.

- Jaw and face surgery

All the services related to jaw and face including jaw and face breakage surgery, plastic surgeries and face reconstruction are provided at this department.

- Urology

Services like percutaneous nephrolithotomy, radical prostatectomy and specialized surgeries of urology are provided here. Stone and urodynamic units with the supervision of expert technical assistant are operating next to this department.

- Internal surgery

Therapeutic services for patients with kidney, lung, gastrointestinal and endocrine diseases are provided here.

- Emergency

Emergency fulltime expert physicians administer and visit accident injured patients together with other patients like poisoning, internal emergencies, surgery, urology, heart, etcetera and if necessary, these patients are transferred into corresponding departments.

- Laboratory

This department is active 24 h and its microbiology unit is considered as the focal point of South-East Iran. The sub-specialized blood laboratory with flow cytometer device is an outstanding property of this department. All hormone tests are run in this center.

- CT scanning

This department with the capability of running various CT scans like 3D, spiral and CT angiography is providing 24 h services by expert staff.

- Radiology

This department provides services like spinal cord, chest, pelvic and thigh-pelvic joints radiography together with upper and lower body and jaw, mouth, teeth, etcetera radiographies.

- Pathology

This department is providing services to patients and medical practitioners to accelerate the therapeutic process by running tissue tests and cytology based on defined scientific, technical and safety standards through modern devices and methods in an appropriate and safe area for the staff. The services include tissue assessment, body liquid cytology assessment, bone marrow sample assessment, etcetera.

- Physiotherapy

This department provides services to outpatients or inpatients with physical or mental disabilities by running standard tests and providing auxiliary equipment and by considering the type of disability and required training. At this department, patients are assisted to perform daily activities in an independent manner.

4.4 Data collection

In this study, in order to comprehend the transmission of infection to various hospital departments, observation is run. The data collection process is run through interviews with management and infection control experts to determine and analyze the management and infection risk criteria as to adding or eliminating hospital departments. To run interviews, NGT method described in Section 3.6 is applied and the data of every expert is ranked based on the unbalanced expertise method presented in Section 3.6.1. The final data are applied to test the procedure presented in Section 3.7. These data are applied based on the methods related to them and the order of their application in the procedures.

4.4.1 Nomination of experts

In order to determine the experts to collect the data, according to the management guidance, an interview is run with the research authority of Bahonar hospital as the study mentor. The mentor is required to present all the potential experts with minimum 3 years working experience in the hospital and knowledge about management criteria or/and infection risks. A list of sixteen experts is presented to the hospital head and manager for approval. Some names are rejected due to insufficient experience or knowledge. Fourteen experts with positions tabulated in Table 4.2 are approved. The experts of managerial group are named with the code number M_1 to M_7 and the experts of assessing infection risks are called with the code number N_1 to N_7. The experts are assigned ranks based on the correspondence of their expertise to the study case. The highest and lowest numbers constitute 3 and 1, respectively, that is, the level of expertise of the expert at rank 3 is 3 times higher than that of 1. After collecting the matrices of every expert, the rank number of each expert is multiplied into the data of his/her matrix to run further calculations. The rank of every expert is tabulated in this table according to the hospital head and manager. After obtaining the final approval, the experts are interviewed.

Table 4.2 List of experts and their ranking based on unbalance expertise method

Categorization of experts	Code No.	Position	Duration of professional experience	Speciality	Ranking No.
Experts related to collecting management criteria	M1	Head of the hospital	12 years	PhD in Anesthesia and Fellowship Specialist of ICU	3
	M2	Manager of the hospital	15 years	PhD in Internal disease specialist	3
	M3	Hospital development committee coordinator	3 years	B.Sc in Engineering	2
	M4	Hospital quality improvement committee coordinator	7 years	M.Sc. of management	2
	M5	Hospital crisis and hazard committee authority	6 years	M.Sc. of management	2
	M6	Research coordinator	4 years	M.Sc. of Nursing	1
	M7	Training coordinator	4 years	B.Sc. of Nursing	1

Table 4.2 continued

Categorization of experts	Code No.	Position	Duration of professional experience	Speciality	Ranking No.
Experts related to assessing infection risks	N1	Hospital infection expert and member of infection control	7 years	PhD in Infectious disease specialist	3
	N2	Hospital infection control coordinator	8 years	M.Sc. of Nursing	3
	N3	Hospital infection expert and member of infection control	5 years	PhD in Infectious disease specialist	3
	N4	Hospital infection expert and member of infection control	3 years	PhD in Infectious disease specialist	3
	N5	Hospital nursing head	11 years	M.Sc. of Nursing	2
	N6	Hospital quality improvement committee coordinator	7 years	M.Sc. of management	2
	N7	Environment health coordinator	6 years	B.Sc. of environmental health	1

4.4.2 Management criteria and the departments proposed by the management group to be added or eliminated in Bahonar hospital

To collect data, interviews are run through NGT method. In this study, the collection of management criteria and the possible departments to be added to the hospital are run through the open-ended interview. Due to heavy workload and unavailability of mentioned experts, the data collection process is run in one month at the office of each expert. The duration of the interviews is 30 to 60 minutes.
In the first interview the questions consist of:

i. What criteria are considered for adding or eliminating a department in Bahonar hospital?
ii. What department(s) is (are) proposed to be added or eliminated in hospital based on board and related committee meetings? Why?

After completing the criteria collection process, the overlapping data are identified and represented as one criterion. As to adding and eliminating a department in the hospital, 15 and 12 criteria are collected, respectively. The final list is analyzed by experts during the interview to score the criteria (second meeting) and then all experts approved the list. The proposed departments to be added or eliminated in Bahonar hospital are presented in Sections 4.4.3 and 4.4.4.

4.4.2.1 Management criteria as to adding a department(s)

In this part tried to describe managerial criteria for adding department(s) which obtained from management experts of Bahonar hospital as a case study of this research. For analysis process each managerial criterion for upgrading is named by MU_1 to MU_{15}.

i. The possibility of obtaining approval and government permissions to establish a new department (MU_1)

As to this criterion, obtaining a permit is an essential requirement in adding a department in the hospital. After presenting the proposal in boarding and authority committees' meeting, the proposal for adding a department is sent to Medical Sciences University and Ministry of Health (MOH). After obtaining the approval (considering the fact that the hospital has the required conditions for adding a department), the permission is sent to the hospital and the required stages of establishing a new department are initiated.

ii. Correspondence of the new department with hospital expertise and strategies (MU_2)

Due to the fact that the Bahonar hospital is specialized for accidents and trauma, the presented department to be added must correspond to this criterion. For instance, a reconstructive surgery department where the expert physician is always present corresponds to the hospital strategy and the number of patients is so high.

iii. Presence of an expert (physician) with expertise corresponding to the new department (MU_3)

Here, it is revealed that the prerequisite to adding a department is the presence of an expert with expertise corresponding to the department. For instance, at ICU department, the presence of an anesthesiologist is required. If not, the treatment process would become slow and the process may consist prescribing primary medications or the patient may be sent to another medical center to run a part of the treatment and return to the hospital to complete the process.

The count of expert physicians in every department is determined based on MOH approvals. For instance, if it is decided to add a heart department with 5 beds, the given department necessitates a heart expert, a vascular expert, and two heart surgeons. That is, the count of the experts is determined based on the count of the beds in every department.

iv. Presence of appropriate personnel count (nurse, paramedic, etcetera) to provide appropriate services (MU_4)

Presence of personnel with various abilities like a nurse, paramedic, etcetera is essential in maintaining a department. The personnel count should correspond to the count of beds in the department and the hospital so that the department provides appropriate services. The personnel are the supporter of the department.

v. The high financial profitability of department (MU_5)

The financial profitability criterion of the hospital is essential; hence, attempts are made to balance the hospital income. Because the departments fluctuate in financial profitability, it is preferred to add or keep financially profitable departments like orthopedics where the count of patients and surgeries is high.

vi. Lowest expenses of equipment and establishment (MU_6)

Some examples are provided with respect to the expenses of equipment and establishment of a department. By considering the fact that Bahonar hospital is a trauma center, surgeries of hand, for instance, are more profitable compared to other services, especially if the period of running the surgery and hospitalization are not long. In these cases, no expensive equipment is applied, while the opposite holds true for orthopedics. To replace a joint 90 million Rials purchase is required.

vii. Lowest expenses of maintenance of the new department (MU_7)

As to maintenance, it is revealed that a department which does not necessitate an area with expensive equipment and specific constructive conditions for the establishment and does not require high expenses for maintenance like ventilation system, may cause low expenses for the hospital. This type of department is a suitable option for adding or keeping in hospital.

viii. The demand for community and inpatients (MU_8)

The demand of the patient is essential in selecting a department to be added. If the count of the patients of a department is high, the department must proceed to develop. The emergency patients should be taken into consideration and the department to be added should be selected based on their demands. By considering the facts that the hospital is specialized in accidents and trauma and the city of Kerman is developing and the count of streets, vehicles, and consequently accidents are increasing, as long as this hospital is the only one in its categorization in this province, the hospital must develop and increase the count of the departments related to accidents and trauma. For instance, CCU department is added to the hospital because the patients of accidents with heart and blood pressure issues were sent to other hospitals.

ix. Availability of facilities, equipment and medication corresponding to the medical standards (MU_9)

At some departments like hematology/oncology the expenses of purchasing medications are high and in others, advanced equipment is required. In countries like Iran the domestic conditions of producing medication and equipment are not sufficient and consequently, there exists the need to import these items. The import requires expenses related to customs and maintenance, which in turn increases the expenses related to medication and equipment purchase. Political and economic sanctions of Iran complicate the purchase of medications and equipment. It is deduced that the availability of facilities, equipment and medication is an essential criterion in selecting a department to be added.

x. Correspondence of the new department with insurance laws (MU_{10})

In case the new department expenses include insurance laws and the payments are done by insurance, this opportunity would be affordable for both the hospital and the patients. Because the hospital is connected to financially secure insurance companies and consequently, the hospital income is afforded at the time and the financial issues are minimized. At a department where the services include insurance, the count of the patient's increases, which in turn brings profitability to the hospital. This is a great opportunity for specific patients with high treatment expenses.

xi. Appropriate infrastructure condition for establishing a department (MU_{11})

The factors related to appropriate infrastructure are essential in adding a department. In case of lack of facilities (appropriate wastewater and disinfectant system), after adding a department, the hospital would face problems. In case the hospital wastewater, which is an infection resource, is not evacuated in an appropriate manner, the patients and the personnel may face problems. The conditions should be assessed to determine whether there exists the possibility to generate a disinfectant system corresponding to the department and whether the expenses are affordable.

xii. Correspondence of construction conditions (architecture) of the new department with construction standards of hospital (MU_{12})

By considering the fact that every department requires specific construction conditions (architecture), the hospital should assess its current conditions to add a new department. That is, whether the current conditions correspond to that of new department or there exists the necessity to make great modifications and whether these conditions correspond to that of standard construction conditions of hospital. Here, the cost factor is essential. If the construction expenses of a new department would be compensated by the hospital income in future, adding the new department would be considered appropriate in case of observing the required criteria.

xiii. Effectiveness as to training enhancement in order to improve the domestic rank of hospital-based on MOH measures (MU_{13})

The accreditation measure in the realm of hospital consists of 907 articles and focuses on the standards of hospital activities and expertise. In general, there exist three measures of hospital department accreditation:

- Necessary measures: factors that the hospital must have.
- Basic measures: factors that are planned in order to be provided in the future.
- Enhancement measures: factors that are contributive in rating a hospital to determine its quality.

In order to assess these measures, MOH runs interviews with hospital personnel and assesses the documents on annual basis. Based on the mentioned factors, the hospital is rated by the following categories:

- Above 64
- Under 54 to 50
- Under 50

Every rating category constitutes specific tariffs. Above 64 may increase the expenses of services due to high credibility and appropriate conditions recognized by MOH. Referring to this point that, any changes in hospital which can improve the quality of hospital services or improve its objectives, they can improve the rating of hospital.

xiv. Physical conditions required for establishing a new department (MU_{14})

Physical space is essential in developing the existing departments and adding a new department in terms of moving, transportation, parking, equipment store, etcetera. For instance, Bahonar hospital encompasses an appropriate space to establish a new department, which is now serving as the archive of stagnant documents. The management has decided to hire a salon in University of Medical Sciences to archive stagnant documents and establish a new department based on the required standards.

xv. Improvement of the treatment process and service provision in the existing departments after adding a new department (MU_{15})

The new department should be contributive in running the whole treatment process within the hospital so that the patient is not transferred to another hospital. Consequently, the treatment process would be accelerated, and the extensive expenses of transportation would decrease.

4.4.2.2 Collected criteria in eliminating a department(s)

Here, 12 criteria are collected by running interviews with management experts, which contrast the counterpart management criteria as to adding a department to Bahonar hospital. For analysis process each managerial criterion for re-architecting is named by MR_1 to MR_{12}.

i. Lack of the corresponding expert (physician) in the department (MR_1).
ii. Not correspondence of the department with hospital specialization and strategy (MR_2).
iii. Lack of demand and insignificance (MR_3).
iv. Lack of financial profitability (MR_4).

v. High expenses of department maintenance (MR_5).

vi. Insufficient space for establishing and developing the department (MR_6).

vii. Dissatisfaction of patients from services (MR_7).

viii. Unavailability of facilities, equipment and medication corresponding to treatment standards of every department (due to expenses, sanctions, etcetera.) (MR_8).

ix. Lack of personnel (nursing, paramedic, etcetera.) to provide services (MR_9).

x. Lack of correspondence with hospital construction standards (architecture) related to the department (MR_{10}).

xi. Ineffectiveness in enhancing training and research in order to improve hospital ranking based on MOH measures (MR_{11}).

xii. The inappropriateness of infrastructure conditions (wastewater and disinfection systems) as to department maintenance (MR_{12}).

4.4.3 Potential departments to be added according to experts

Thirteen potential departments are proposed to be added to Bahonar hospital according to the interviews conducted with the management group. The list of departments is observed and approved by the management group during the interview to weight the management criteria. Due to limited financial, personnel, equipment, and etcetera potential, the hospital is not capable of establishing all the departments together and prioritizing is necessary, thus:

i. Peripheral vessels angiography:

Vascular surgery and neurology departments require this department so that the patients do not have to be transferred into another hospital to run the treatment process. The profitability of this department is not considered, while the experts and their services are contributive in its profitability. The main objective of adding this department is the social demand. The functionality of this department is in diagnosing vascular or tissue condition of a body organ in order to decide whether the organ should be maintained or cut. Time is essential in this vital diagnosis (golden time).

ii. MRI:

Because this hospital is specialized in accidents and trauma, the services of this department are needed to run the treatment process. Otherwise, the patients are required to attend other therapeutic centers.

iii. Ear, throat and nose surgeries:

Due to the lack of experts and necessary condition to establish this department, the patients are transferred into other therapeutic centers. The existence of this department is essential and corresponds to the hospital specialization.

iv. Eye surgery:

Due to the lack of experts and necessary condition to establish this department, the patients are transferred into other therapeutic centers. The existence of this department is essential and corresponds to the hospital specialization.

v. Reconstructive surgery:

The hospital is making an attempt to establish this department as a focal point to cover patients from Sistan and Balouchestan province. This would lead to an increase in patients' count, profitability and meeting social demand. Bahonar hospital which is a training, research, and therapeutic center, may accept assistants and surgeons to pass their expertise course at this department, which is considered as an accreditation measure. Kerman province is the biggest province in Iran in geographic terms and the second in terms of accident statistics. The highest types of accidents constitute urban and motorcycle accidents, where the possibility of injury as to reconstruction of hand, in specific, is high. By considering the fact that this province is developing with a high count of factories, the possibility of injury which needs reconstruction and surgery services of hand, in specific, is high.

vi. Transplant:

Most patients of Bahonar hospital constitute accident patients; hence, the existence of this department is essential in providing services in case an organ needs to be transplanted through equipment and physicians within the hospital, at an area specialized for this purpose, in an immediate manner.

vii. Surgery 2:

This department is essential because the hospital, in general, and the plastic surgery department, in specific, require more surgery beds (due to lack of a separate department, the patients are merged into other departments).

viii. Hand surgery:

Because most patients are injured in hand area, the hospital needs this department with the corresponding surgeon.

ix. Obstetrics and Gynecology:

The hospital is planning to add this department in order to develop its activities and provide services to pregnant patients.

x. Infection department:

Due to the hospital specialization in accidents and trauma, the count of the patients and the orthopedics surgeries, in specific, is high. These patients may be brought to the hospital with open wounds; hence, the possibility of infection is high and consequently, there exists the need to add an infection department. Bahonar hospital has infection experts.

xi. Chemotherapy:

Due to the existence of hematology/oncology departments in the hospital and the fact that some patients need chemotherapy services and its corresponding medication, this department is considered necessary to be added.

xii. Psychology emergency:

Patients with mental problems who attempt suicide and suffer poisoning are brought to this department to undergo therapeutic services. Attempts are made to resolve their mental problems within the hospital. Due to attempting suicide (for instance through accident, etcetera) or any other attempt, these patients suffer breakages or other injuries and need the services provided by other departments like CCU, physiotherapy, etcetera. Then, they are transferred to other departments.

xiii. Rehabilitation and physical treatment:

Injured patients need rehabilitation services after treatment for complete recovery; thus, this department is essential to be added.

4.4.4 Potential departments to be eliminated according to experts

Four departments are proposed to be eliminated from Bahonar hospital according to the interviews run with the management group.

i. Jaw and face surgery: Here the count of patients is low and it is not essential for accident and trauma patients.

ii. Hematology/Oncology 1 and 2: These departments are not related to the hospital specialization and cause high expenses to patients and the hospital in purchasing medication and specific equipment.

iii. CT scan**:** This department causes financial loss in the hospital because the expenses of personnel and the depreciation of devices are high.

4.5 NIs in Bahonar hospital from the experts' point of view

Because the objective of this study is to provide a procedure to reduce the infection risk during adding or eliminating a department, a brief description of infection criterion in Bahonar hospital is presented here as the case of the study based on experts' point of view about infection control. Data collection process of DEMATEL and expanded DEMATEL matrix tables based on interviews run with infection control experts mentioned in Table 4.2 is initiated in 4/08/2018. The interviews are run through NGT method in the office of every expert and the process and objective of this study are described. A discussion is held with experts about infection risk and the effect of departments to one another in cross infection. According to experts N1 and N2, as to the objective of this study, that is, “*assessing the infection transmission among departments and considering the infection risk as a criterion in adding or eliminating a hospital department, there exists no authority with this respect and due to limited manpower at infection control department, this issue is not assessed in an appropriate manner*”. While, according to experts, “*infection control is an essential factor in selecting a department to be added or eliminated*”. The explanations of the experts about hospital infection, infection risk, the importance of considering this criterion in adding or eliminating a department and the existing and future strategies in controlling infection in Bahonar hospital are described. According to experts N1, N2 and N3, “*HFs infections are of two types:*

i. Community-acquired infection

These infections are brought to the hospital from outside and the patient attending the hospital may be infected previously. In the case of non-diagnosis by a physician and lack of on-time operations to control or treat, the infection may spread throughout the hospital. The microorganisms causing these infections are distinctive from that of the hospital.

ii. Nosocomial infection

According to the descriptions presented in Section 2.6, these infections occur 48-72 hours after patient's hospitalization or discharge. The microorganisms of these infections constitute clinical microbes”.

According to expert N2, “*finding the origin of infections of patients is expensive and time-consuming. While in many developed countries the patient after being discharged is followed by a nursing force to complete infection treatment. Lack of this system leads to incomplete treatment and transmission of infection. In some cases, a patient attends the hospital with an intense infection, which causes high expenses to both the patient and the hospital and increases the death rate. This is the case with Bahonar hospital where the infection origin is not assessed, with the excuse of insufficient manpower in infection control department*”.

"*If the infection test is positive, in case the patient is brought to the hospital recently, it is supposed the patient had the infection before. This holds true for urology patients with a urine infection and internal department patients with blood infection which do not get recorded. Some patients attend the hospital from other therapeutic centers where they get an infection during a surgery process and the infection does not get recorded. Only Bahonar hospital patients get recorded if their infection is proved after 24-48 hours. But the origin and the reason for this infection is not assessed*".

According to experts N1, N3 and N4, "*infection is transmitted due to the training and research purposes of this hospital. The students are moving among the departments without changing their medical gown or observing hand hygiene and other items related to infection control. They enter departments like hematology/oncology, where sensitive patients with the very weak immune system are hospitalized and do not wear a medical gown, change gloves, wash their hands and observe other health items leading to an increase in infection transmission risk*".

"*The hospital physicians move among departments to visit patients and do not observe hand hygiene. For instance, they move from the infectious ICU department to other departments and increase the infection transmission possibility. This holds true for department technicians who move among departments like physiology and radiology*". According to experts N1 and N6, "*in addition to contact transmission, there exists the airborne infection transmission type of tuberculosis, in specific*".

According to all experts, "*a given department is effective in its infection transmission. The transmission of infection within a department is more rapid, because the microorganisms belong to the department and the patients of the department are more sensitive, react rapidly and get an infection. Another factor of infection transmission is the staff of every department who do not observe personal hygiene*".

According to all experts, "*there exists the possibility of infection transmission among departments. ICU department in Bahonar hospital is an example*". According to experts N1, N2, N3 and N4, "*ICU 1, 2 and 3 departments constitute the highest infection rate and are considered the infection resource. This is due to the long hospitalization of patients and the weakening of their immune system due to antibiotics consumption. These patients are prone to bedsore due to long hospitalization which is considered as an* *infection resource*". According to expert N1, "*in a case, a patient in ICU department in Bahonar hospital was suffering difficile diarrhea and another patient in internal department got diarrhea with the positive difficile test. This is an example that difficile infection is transmitted from ICU to the internal department, both patients had a same physician*".

According to experts N1, N2 and N3, "*due to long hospitalization, open surgeries and the necessity to undergo cerebrospinal fluid cultivation in order to obtain negative infection report, neurology patients have to move among various departments; hence, the possibility of infection transmission*".

According to expert N6, "*in cases the hospitalization time of patients increases due to NI, everything related to the patient is affected, expenses, in specific. This is due to the demand for medication, antibiotics in specific, infection consultation and infection visit and in some cases the necessity to undergo surgery, which depends on the infection type. The simpler the infection, the lower the expenses and manpower. In case of acute infections, a patient with osteomyelitis (an infection of the bone) in Bahonar hospital underwent 11 surgeries and did not recover. This is an instance of high expenses as to surgery, medication, equipment, and personnel for both the patient and the hospital because of NIs. If necessary actions are taken to control infection, the suffering and expenses caused by infection may reduce to a considerable extent*".

With respect to the question that how distant is Bahonar hospital from ideal conditions to control infection, the experts' answer is that "*the main problem of the hospital is its construction; the departments are not in standard conditions and no precision is observed as to infection transmission possibility in their construction*". Expert N6 states, "*despite the endeavors of the hospital to control infection, due to the fact that Bahonar hospital is specialized in trauma and accidents. There exists the necessity to run several surgeries in the abdominal area, in specific, and many patients suffer breakages and brain hemorrhage; hence, NI is inevitable*". According to this expert, "*the type of diseases and the physical structure of the hospital together with the arrangement of departments are contributive in generating and transmitting infection*".

According to experts N1, N2 and N6, "*at emergency department where hospitalization time is maximum 6 hours and then the patients are discharged or* *transferred into a department corresponding to their diseases, there exists the possibility to transmit the infection to other departments. Inappropriate venipuncture at emergency department is considered as an infection resource which may transmit into other departments*". Experts N1 and N2 state that "*a patient in Bahonar hospital discovers to have an infection after undergoing a surgery and being discharged. After running assessments, it is revealed that this patient got the infection during the surgery. In order to receive necessary services, patients may have to return to a previous department and based on the intensity of infection, they may need surgeries and therapeutic services of other departments, which in turn leads to an increase in infection transmission possibility*".

With respect to the question that are the hospital strategies effective in NI control in adding or eliminating departments. Expert N1 answers that "*the infection risk criterion is not considered during adding or eliminating a department by the management group and the authoritative committee. For instance, when ICU 3 department was being added, no isolated room was located in the department and infectious patients were hospitalized in a corner separated from other patients. By considering the fact that infection is high in this department which is located next to urology, jaw and face, and orthopedics departments, the possibility to transmit infection into these departments is high. The transference ways of patients are connected to one another and the staff and the students are moving among departments*".

According to experts N1, N2, N3, N4 and N7, "*Bahonar hospital is distant from global standards as to NI control. For instance, despite the fact that every bed needs one nurse to provide services and control infection, in Bahonar hospital one nurse serves 3 beds; hence, the treatment quality is reduced. Due to the heavy workload of the nurse may not observe hygiene conditions, leading to an increase in infection*".

With respect to the question that is emergency condition announced due to high-risk infection reported in Bahonar hospital, the experts expressed their answers. According to expert N6, "*a case of high meningitis in ICU departments and another of pneumonia caused by ventilators in the hospital were reported, where immediate actions to control were taken. Expert N1 states that in a case the encephalitis rabies (100% fatal)* *of a patient was to spread in the hospital and increase the death rate, while a crisis condition was announced to control the infection*".

According to experts N1, N2, N5, N6 and N7 future strategies of Bahonar hospital to control and reduce NI constitute "*increasing supervision and observing personal hygiene by physicians and staff together with enhancing working conscience among personnel*". According to experts N1, N5 and N6 "*assessing infection risk factor is essential together with other criteria in adding or eliminating a department. In public hospitals where addition and elimination process are run through MOH and University of Medical Sciences, this factor is not considered. Hospital managers focus on departments' profitability and the count of experts required for a department. It is stated that the reports on NIs are sometimes dishonest*".

4.6 Procedures implementation

By considering the procedure process presented in Section 3.7, the subsections described in data collection and analysis processes are explained.

4.6.1 Procedure implementation for upgrading of Bahonar hospital

In order to upgrade Bahonar hospital, the processes of implementation procedure are described in below subsections.

4.6.1.1 Data collection for WSM matrix to determine potential departments to be added to Bahonar hospital

The second meeting of interviews with management group of Bahonar hospital is organized by considering the procedure presented in Section 3.7, after determining the management criteria and the departments to be added based on management experts' first interviews. During the second meeting, the interview to weigh the management criteria for potential departments to be added is run. The second interview is run in every expert's office, based on NGT method for 20-40 min. To begin with, the final list of departments and management criteria is provided, and the final approval is obtained from each expert. Then, WSM matrix table is tabulated for every expert, where the management criteria (named as MU_1 to MU_{15}) to add a department are tabulated in first column from left side and the names of new departments to be added are tabulated in first row, as shown in Appendix F, Table F.1. To weigh the management criteria, close-ended questions are asked. By considering the WSM method presented in Section 3.4.1, at the beginning of the interview, each expert is required to weigh each criterion from 0-100 in column “a” of Table 4.3 result of WSM matrix for adding departments, based on the extent to which the criterion is considered essential in selecting a potential department to be added. Then, asked from each expert to weight for each a potential department to state the extent to which each criterion is present in the hospital to add that department. Complete presence is rated 100, while lack of presence is 0.

4.6.1.2 Analysis of WSM matrices obtained from management experts to determine potential department to be added to Bahonar hospital

After collecting WSM matrices, by considering unbalance expertise method described in Section 3.6.1, experts are assigned a rank based on their expertise (how skilled they are in management) and working experience, Table 4.2. The assigned rank of each expert is multiplied into the matrix obtained from him/her. Then, the matrix average of all collected matrices is obtained. The matrix average is applied to run the calculation through WSM method.

WSM analysis is run on the average matrix based on Section 3.4.1 (all the procedures analysis stages of this research are run on Microsoft Excel 2016). Table 4.3 shows the result of running WSM in Bahonar hospital for upgrading. Also, the result of average matrix of WSM is presented at Tables G.1 in Appendix G

Table 4.3 Result of WSM matrix for adding departments

Alternate **Manager Criteria**	**Weigh for each criterion "a"**	**Reconstr uctive surgery**	**Peripheral vessels angiograp**	**MRI**	**Ear, throat and nose surgeries**	**Surgery 2**	**Hand surgery**	**Obstetric and Gynaeco**	**Rehabilitatin , physical treatment**	**Transplan**	**Infection**	**Chemother**	**Psychology emergency**
MU$_{1}$	0.081833061	4.746314	8.019634	8.1833	0.490998	4.90998	4.2553	1.309328	4.582648	0.327332	3.436986	6.873972	0
MU$_{2}$	0.078559738	7.54176	7.54176	7.22752	3.1424	7.22752	6.2848	3.1424	5.65632	2.3568	2.98528	6.59904	0
MU$_{3}$	0.078559738	7.856	7.22752	5.18496	0.31424	7.54176	6.9132	0.7856	4.7136	1.5712	5.97056	7.856	1.25696
MU$_{4}$	0.070376432	2.955792	4.92632	3.941056	0.281504	3.5188	3.5188	0.422256	2.252032	0.563008	1.689024	3.5188	0.140752
MU$_{5}$	0.05400982	2.26842	3.13258	3.2406	3.34862	3.45664	2.4844	2.05238	3.56466	3.56466	2.48446	2.80852	2.05238
MU$_{6}$	0.057283142	3.551546	3.551546	4.124376	3.780678	4.124376	3.0932	2.635018	3.322414	3.322414	2.176754	2.635018	2.405886
MU$_{7}$	0.058919804	4.94928	5.3028	5.42064	4.47792	5.18496	4.4779	4.59576	4.1244	2.71032	1.29624	1.7676	1.53192
MU$_{8}$	0.070376432	4.785568	6.052336	6.474592	2.81504	5.207824	4.3633	2.955792	4.363312	2.955792	3.237296	3.659552	1.829776
MU$_{9}$	0.06710311	3.891974	3.891974	3.891974	4.02618	5.636652	3.8919	4.294592	4.69721	4.428798	3.086738	4.02618	2.01309
MU$_{10}$	0.070376432	4.92632	5.207824	5.489328	4.081808	5.63008	5.0670	4.92632	4.92632	4.644816	5.067072	4.504064	4.92632
MU$_{11}$	0.063829787	4.59576	4.85108	4.85108	3.44682	4.85108	4.2127	2.93618	3.44682	3.44682	2.93618	5.36172	2.80852
MU$_{12}$	0.05400982	1.40426	3.67268	3.67268	1.6203	1.94436	1.1882	1.18822	1.6203	1.40426	0.5401	1.29624	1.0802
MU$_{13}$	0.057283142	3.780678	4.00981	4.353508	2.405886	4.811772	4.0098	1.947622	3.093282	1.71849	2.405886	3.093282	1.603924
Mu$_{14}$	0.065466448	2.61864	4.189824	4.189824	2.094912	2.225844	1.1783	1.440252	2.225844	1.833048	0.65466	1.833048	1.30932
MU$_{15}$	0.072013093	6.193118	6.193118	6.913248	3.744676	6.049092	5.0409	3.888702	5.328962	3.024546	3.60065	4.896884	2.592468
Ws	-	**66.06543**	**77.77081**	**77.15869**	**40.07198**	**72.32074**	**59.980**	**38.52042**	**57.91812**	**37.8723**	**41.56789**	**60.72992**	**25.55152**

In order to perform WSM, the total sums of columns “a” data illustrated in Table 4.3, result of WSM for adding departments is obtained and each column “a” data is divided into this total sum. The result obtained for each criterion in a column “a” represents the criterion weight (Wx) in terms of its priority by management experts as to a criterion to be considered in selecting a new department to be added. Obtained Wx for each criterion is multiplied into the weights the experts assign to each department (for example indicating the extent to which criterion “b” is present for department x in Bahonar hospital) named numeric value (V). The result of multiplication for each alternative is named weighted sum or WS (alternative or A_x). The total sum of WSs with all criteria is obtained for each alternative. The obtained results are compared to one another based on chart in Figure 4.2 and the higher ranks are presented as potential departments to be added to Bahonar hospital according to management experts.

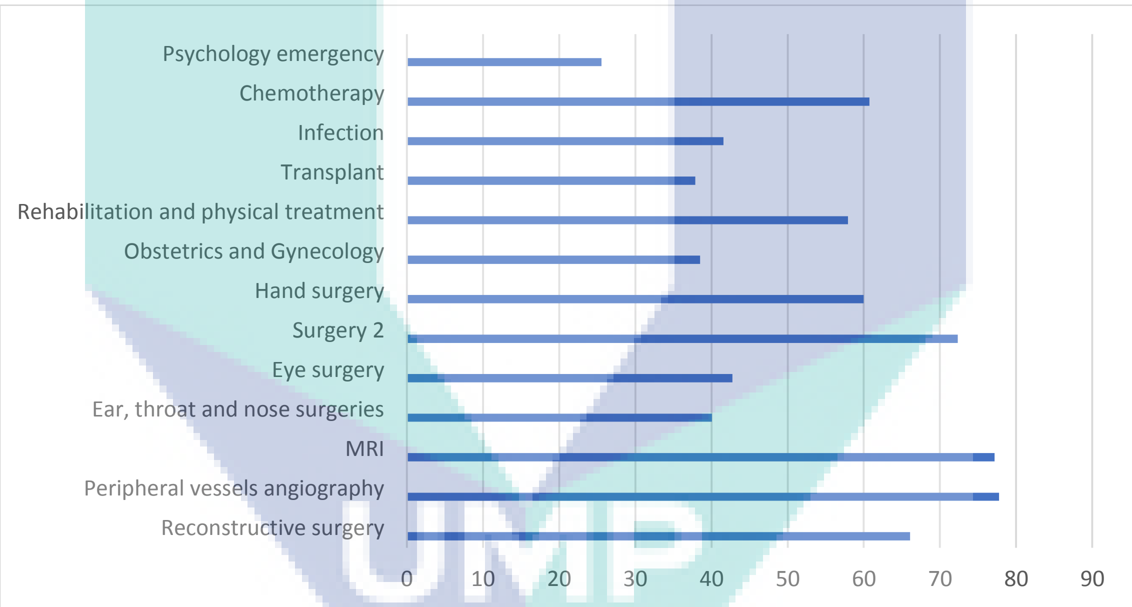

Figure 4.1 Result of WSM matrix from managerial experts for upgrading of Bahonar hospital

Based on Table 4.3, WSM matrix and obtained priorities (higher amount of Ws) in chart Figure 4.1, peripheral vessels angiography, MRI, surgery 2 and reconstructive surgery departments are proposed by managerial experts to be added, respectively. These departments are assessed by infection experts as to infection risk criterion.

4.6.1.3 Expanded DEMATEL implementation method through data collected from infection control experts in Bahonar hospital for upgrading based on infection risk criterion

In a series of meetings, interviews are run with infection control experts presented in Table 4.2. To begin with, the study objectives and the process of procedure are explained to experts based on Section 1.4 and Section 3.7, respectively. Then, the Expanded DEMATEL matrices are collected after they have weighted by experts. The data collection matrices are in Tables F.2 and F.3, Appendix F.

Experts are asked close-ended questions as to weight the criteria through Expanded DEMATEL method based on matrices illustrated in Appendix F. Experts are required to assign rates to the potential departments to be added in matrix Table F.2 of the Appendix F, as to the extent of infection risk effect and infection transmission into existing departments, beginning from 0=no effect to 1=low effect, 2=moderate effect, 3=high effect, and 4=very high effect. After presented matrix Table F.3, experts are required to assign rates to each existing department as to the extent of infection risk effect and infection transmission into the potential department to be added beginning from 0=no effect to 1=low effect, 2=moderate effect, 3=high effect, and 4=very high effect. In the matrices used code number for the names of existing departments of Bahonar hospital based on Table 4.1.

4.6.1.4 Analysis of Expanded DEMATEL matrices obtained from infection control experts in Bahonar hospital for upgrading based on infection risk criterion

By considering Expanded DEMATEL matrices obtained from the interviews run with infection control experts and based on Expanded DEMATEL method described in Section 3.3.3, the data analysis process to obtain a final result and present potential departments to be added are done.

To begin with, the experts are assigned a rank based on duration of professional experience and specialty through unbalance expertise method, Table 4.2. The obtained ranks of experts are multiplied into their matrix data, the matrix average is calculated, and the final matrix (matrix total (T)) is applied for further calculations. Because there exist two matrices in Expanded DEMATEL method:

i. Assessing potential department's infection risk on existing departments, Table 4.4; and
ii. Assessing existing departments' infection risk on the potential department, Table 4.5.

Table 4.4 Matrix of Expanded DEMATEL for interrelationships evaluation of potential department on existing departments based on infection risk for upgrading of Bahonar hospital

Existing department **Potential department**	**ED_{2}**	**ED_{3}**	**ED_{4}**	**ED_{5}**	**ED_{6}**	**ED_{7}**	**ED_{8}**	**ED_{10}**	**ED_{11}**	**ED_{12}**	**ED_{16}**	**ED_{17}**	**ED_{18}**	**ED_{19}**	**ED_{20}**
Reconstructive surgery	0.0202	0.01500	0.01500	0.04480	0.0647	0.0503	0.0556	0.06531	0.06531	0.0405	0.07024	0.07024	0.06995	0.06966	0.06966
Peripheral vessels angiography	0.0148	0.00021	0.00021	0.02977	0.0397	0.0250	0.0444	0.04464	0.04464	0.0297	0.04471	0.04471	0.04470	0.03014	0.03014
MRI	0	0	0	0	0.0095	0.0095	0.0095	0.00956	0.00956	0.0095	0.00956	0.00956	0.00956	0.00956	0.00956
Surgery 2	0.0355	0.03000	0.03000	0.03683	0.0528	0.0814	0.0822	0.08257	0.08257	0.0665	0.08764	0.08764	0.06793	0.06742	0.06742

Table 4.5 Matrix of Expanded DEMATEL for interrelationships evaluation of existing department on potential departments based on infection risk for upgrading of Bahonar hospital

Potential Departments Existing Departments	Reconstructive surgery	Peripheral vessels angiography	MRI	Surgery 2
ED_1	0.022346	0.073772	0.026649	0.068798
ED_2	0.022346	0.073772	0.026649	0.068798
ED_3	0.071351	0.083762	0.02939	0.087829
ED_4	0.096784	0.112131	0.098791	0.111619
ED_5	0.096784	0.112131	0.098791	0.111619
ED_6	0.096784	0.112131	0.098791	0.111619
ED_7	0.04645	0.061278	0.054245	0.056378
ED_8	0.033287	0.041706	0.02352	0.036816
ED_9	0.033287	0.041706	0.02352	0.036816
ED_{10}	0.090707	0.100498	0.088384	0.104671
ED_{11}	0.090707	0.100498	0.088384	0.104671
ED_{12}	0.059515	0.065749	0.017816	0.069901
ED_{13}	0.061287	0.07756	0.028559	0.081698
ED_{14}	0.066042	0.077903	0.028683	0.082018
ED_{15}	0.069029	0.08141	0.071774	0.085695
ED_{16}	0.033846	0.037491	0.032972	0.037313
ED_{17}	0	0	0	0
ED_{18}	0	0	0	0
ED_{19}	0.015928	0.017577	0.002122	0.017431
ED_{20}	0.016378	0.018098	0.002582	0.022601
$C_{\text{Potential Dep.}}$	**1.022857**	**1.289175**	**0.841618**	**1.296289**

The average matrix for each group is obtained, separately, Tables G.2 and G.4 in Appendix G. After calculating matrix total (T) based on equations of Expanded DEMATEL in section 3.4.3, the total sum for each rows (R) in matrix T group 1 (Table 4.4), and the total sum for each columns (C) in matrix T group 2 (Table 4.5), are calculated. These are R and C for potential department to add in Bahonar hospital. By considering Expanded DEMATEL method described in Section 3.4.3, R-C is calculated for potential departments. The results are illustrated in Table matrix 4.6. The results of normal and average matrices, as processes of Expanded DEMATEL, are presented in Appendix G.

Table 4.6 Final analysis of Expanded DEMATEL

	R Potential	**C** Potential	**R_P-C_P**
Reconstructive surgery	1.047274	1.022857	0.024417
Peripheral vessels angiography	0.607485	1.289175	-0.68169
MRI	0.143541	0.841618	-0.698077
Surgery 2	1.292598	1.296289	-0.003691

According to Table 4.6, reconstructive surgery with positive amount of (R-C) is cause. It means that, if this department add to Bahonar hospital, it will have impact on the other factors higher than the they influence on it. The other potential departments are belonged to effect group, because their R-C are negative. Among them, MRI has the lower amount of R-C.

Therefore, it is receiving the higher influence from the other departments of hospital. After MRI, peripheral vessels angiography and surgery 2 have the lower negative amount of R-C, respectively. Therefore, with lowest risk of cross infection, surgery 2 and reconstructive surgery are suggested to be added in Bahonar hospital. Hence, the answer to question 1 which is objective 1 in this study (described in Section 1.4) is implemented and analyzed from the case of the study.

4.6.2 Procedure implementation for re-architecting of Bahonar hospital

In order to re-architect Bahonar hospital, the processes of implementation procedure are described in below subsections.

4.6.2.1 DEMATEL method implementation through data collected from infection experts in Bahonar hospital for re-architecting based on infection risk criterion

In a series of meetings, interviews are run with infection control experts presented in Table 4.2. To run department elimination stages based on the procedure described in Section 3.6, it is necessary to collect data for the DEMATEL method. Thus, experts are asked close-ended questions to weight alternatives. A matrix Table H.1 in Appendix H is presented to experts to assess the effect of existing departments (they named by their code number based on Table 4.1) on one another as to infection transmission based on infection risk criterion. Experts are required to assign rates to each department based on the extent to which the given department is effective in transmitting infection beginning from 0=no effect to 1=low effect, 2=moderate effect, 3=high effect, and 4=very high effect.

4.6.2.2 DEMATEL matrix analysis obtained from infection control experts in Bahonar hospital for re-architecting based on infection risk criterion

By considering DEMATEL matrices obtained from the interviews run with infection control experts, the calculations for DEMATEL are run based on Section 3.4.2 descriptions. To analyze matrix data obtained from experts based on the obtained rank for experts presented in Table 4.2, the rank number of experts is multiplied into the data matrix, and the matrix average is obtained.

Table 4.7 Matrix of DEMATEL to evaluate interrelationships among existing departments based on infection risk for re-architecting of Bahonar

Dep.	ED_{20}	ED_{19}	ED_{18}	ED_{17}	ED_{16}	ED_{14}	ED_{13}	ED_{12}	ED_{11}	ED_{10}	ED_{9}	ED_{8}	ED_{7}	ED_{5}	ED_{4}	ED_{3}	ED_{2}	ED_{1}
ED_{20}	0.01339	0.024757	0.014489	0.013862	0.01556	0.03240	0.03201	0.02998	0.03672	0.03672	0.02832	0.02786	0.03172	0.0456	0.0457	0.0303	0.0306	0.0306
ED_{19}	0.01000	0.021214	0.010962	0.010389	0.02184	0.03951	0.02908	0.01754	0.03044	0.03044	0.01617	0.015769	0.02889	0.0293	0.0293	0.0176	0.0279	0.0279
ED_{18}	0.00944	0.0106	0.013903	0.009848	0.01142	0.03552	0.02517	0.02347	0.02645	0.02645	0.03222	0.021734	0.02493	0.0255	0.0256	0.0238	0.0240	0.02401
ED_{17}	0.00777	0.008583	0.008516	0.011446	0.00914	0.02181	0.02163	0.02034	0.02252	0.02252	0.01933	0.019028	0.02142	0.0218	0.0218	0.0206	0.0207	0.02076
ED_{16}	0.04407	0.047629	0.047147	0.045401	0.06354	0.08969	0.08873	0.08310	0.09934	0.09934	0.07898	0.077516	0.09814	0.0998	0.1000	0.0843	0.0850	0.08504
ED_{15}	0.06376	0.079114	0.081735	0.069053	0.08929	0.12903	0.12741	0.11990	0.13977	0.13977	0.10385	0.101746	0.12647	0.1391	0.1393	0.1108	0.1119	0.11190
ED_{14}	0.05054	0.064956	0.064341	0.052124	0.06771	0.11544	0.10740	0.10115	0.12898	0.12898	0.08591	0.084192	0.10637	0.1151	0.1154	0.0985	0.0994	0.09944
ED_{12}	0.01149	0.012651	0.012542	0.011943	0.01346	0.03239	0.03213	0.03694	0.03343	0.03343	0.02874	0.028296	0.03182	0.0323	0.0324	0.0306	0.0308	0.03086
ED_{11}	0.10509	0.112677	0.111433	0.10786	0.11745	0.18504	0.18278	0.17183	0.19741	0.19406	0.15688	0.153998	0.17460	0.1783	0.1788	0.1669	0.1685	0.16856
ED_{10}	0.10509	0.112677	0.111433	0.10786	0.11745	0.18504	0.18278	0.17183	0.19406	0.19741	0.15688	0.153998	0.17460	0.1783	0.1788	0.1669	0.1685	0.16856
ED_{9}	0.05178	0.05629	0.055751	0.053488	0.06919	0.11763	0.11650	0.09884	0.12143	0.12143	0.09129	0.082827	0.11557	0.1177	0.1180	0.1109	0.1118	0.11180
ED_{8}	0.05178	0.05629	0.055751	0.053488	0.06919	0.11763	0.11650	0.08988	0.12143	0.12143	0.08455	0.089561	0.11557	0.1177	0.1180	0.1109	0.1118	0.11180
ED_{7}	0.04390	0.047606	0.047134	0.0453	0.04980	0.09571	0.09475	0.06930	0.09872	0.09872	0.07513	0.063574	0.09729	0.0957	0.0960	0.0901	0.0909	0.09094
ED_{6}	0.12042	0.129456	0.128058	0.123745	0.13530	0.22483	0.22223	0.20858	0.23173	0.21733	0.19530	0.191754	0.22385	0.2249	0.2255	0.2113	0.2132	0.21327
ED_{5}	0.12067	0.12973	0.128329	0.124007	0.13559	0.22526	0.22266	0.20905	0.23217	0.23217	0.19571	0.192183	0.22093	0.2253	0.2260	0.2117	0.2138	0.21368
ED_{4}	0.12067	0.129731	0.12833	0.124008	0.13559	0.22527	0.22266	0.20905	0.23218	0.23218	0.19571	0.192184	0.22092	0.2286	0.2260	0.2117	0.2136	0.21368
ED_{3}	0.08750	0.093978	0.092957	0.089877	0.09819	0.15983	0.15794	0.14817	0.16472	0.16472	0.14109	0.13857	0.15672	0.1599	0.1670	0.1501	0.1515	0.1515
ED2	0.08757	0.094054	0.093032	0.08995	0.09827	0.15992	0.15803	0.14826	0.16482	0.16482	0.1412	0.138676	0.15682	0.1600	0.1604	0.1502	0.1583	0.15504
ED1	0.08757	0.094054	0.093032	0.08995	0.09827	0.15992	0.15803	0.14826	0.16482	0.16482	0.1412	0.138676	0.15682	0.1600	0.1604	0.1502	0.1550	0.15839
C	**1.24352**	**1.391642**	**1.363872**	**1.296352**	**1.48476**	**2.46761**	**2.42072**	**2.20565**	**2.57179**	**2.57179**	**2.05530**	**1.997102**	**2.39796**	**2.4723**	**2.4824**	**2.2476**	**2.2816**	**2.28169**

After obtaining total matrix at DEMATEL stage 4 (Table 4.7), data total in every row (R) and data total in every column (C) are calculated. For each department, R-C is calculated, and analysis done based on step 5 of DEMATEL. The results of average and normal matrices as processes of DEMATEL are presented in Tables I.1 and I.2 in Appendix I.

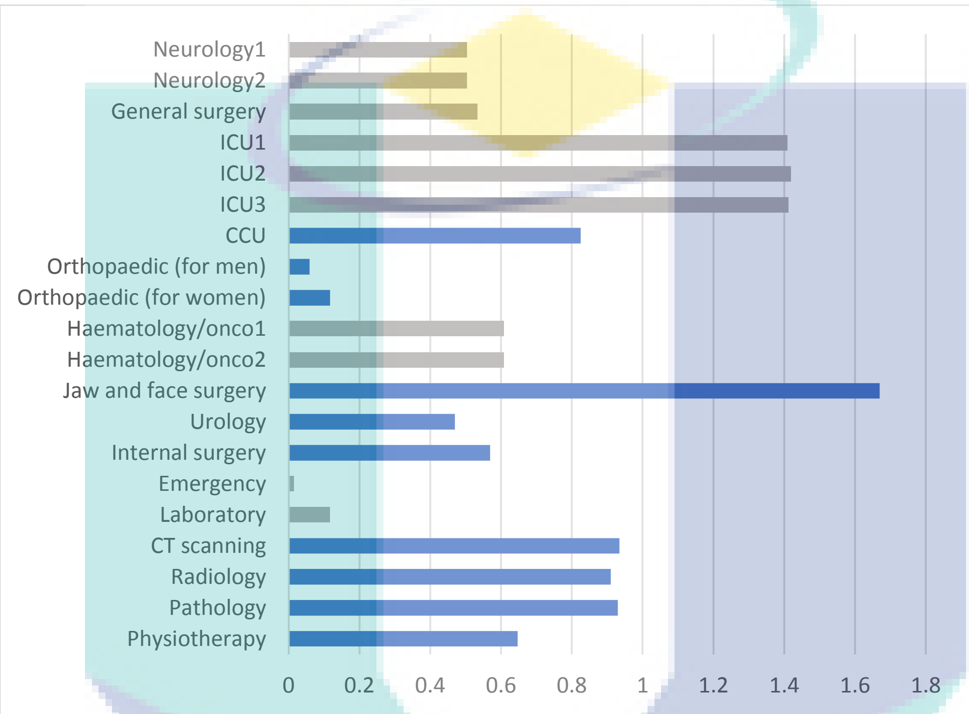

Figure 4.2 Measurement of infection risk for existing departments of Bahonar hospital based DEMATEL result

According to this step, in the cause group, departments which have positive amount of R-C; from high to low, based on Table 4.7 and chart Figure 4.2 (gray bars), they are ICU2 (ED5), ICU3 (ED6), ICU1(ED4), Haematology/oncology1 (ED10) and Haematology/oncology2 (ED11) (with the same amount), General surgery (ED3), Neurology1 (ED1) and Neurology2 (ED2) (with the same amount), Laboratory (ED16), Emergency (ED15), respectively. ICU2 has impact on the other factors higher than the they influence on it, because it has higher positive amount of R-C in comparison to the other departments.

In the effect group, departments with the most negative R-C, based on Table 4.7 and chart Figure 4.2 (black bars), are Jaw and face surgery (ED12), CT scanning (ED17), Pathology (ED19), Radiology (ED18), CCU (ED7), Physiotherapy (ED20), Internal surgery (ED14), Urology (ED13), Orthopaedic (for women) (ED9), Orthopaedic (for men) (ED8), respectively. In the chart the absolute values of the R-C of department are used to draw chart to compare the results well.

Referring to the results, jaw and face surgery is receiving the higher influence from the other factors of system. Because this department has the lower negative amount of R-C in comparison to the other departments.

Therefore, ICU2 from cause group and jaw and face surgery from effect group are presenting as the risky existing departments of Bahonar hospital, in field of cross infection. Also, ICU1 and ICU3 are presented as risky departments, because they have a few different in amount of their R-C in comparison to ICU2. Introducing these departments may be contributive to the hospital and infection control authorities to reinforce infection control actions in these departments.

Based on DEMATEL results, matrix Table 4.7, and chart in Figure 4.2 a criterion of infection risk is considered for each department among 0-100. The numbers are placed in an extensive row at the end of average matrix table of WSM from management group as to eliminating a department. By considering the procedure process described in Section 3.7, it is necessary to run WSM method based on management criteria considered in eliminating a department obtained in interviews run with management experts.

4.6.2.3 WSM method implementation through data collection from management experts in Bahonar hospital for re-architecting based on management criteria

The third meeting of interview run with management group is organized by considering the procedure described in Section 3.6, after determining the management criteria in eliminating a department among the opinions presented by management experts during the first interview. The third interview is run in the office of every expert based on NGT method in 20-40 minutes. To begin with, the management criteria list obtained in the first interview is presented and the final approval is obtained from every expert. WSM matrix table illustrated in Table H.2 of Appendix H is explained for every expert.

Management criteria in eliminating a department obtained from management experts' interview are tabulated in the first column from left side and the existing departments as potential departments are tabulated in the first row to be analyzed as to elimination (they named based on their code number in Table 4.1). Every expert is asked close-ended questions to weight management criteria. By considering the WSM method described in Section 3.4.1, at the beginning of the interview, every expert is required to weigh every criterion from 0-100 in column "a" of matrix Table H.2.

It was based on the extent to which each criterion is essential in selecting the potential department to be eliminated. With respect to the possibility of eliminating the existing departments based on the existing conditions of the hospital, every expert is required to explain the extent to which each criterion is in inappropriate conditions for the department. The weights assigned to every criterion constitute 0-100, in a sense that =100 is the most inappropriate resulting a negative rate and =0 is the most appropriate resulting a positive rate with respect to management criterion. The closer the weight assigned to a criterion to 100, the higher the possibility of eliminating the department.

4.6.2.4 WSM matrix analysis obtained from infection control experts in Bahonar hospital for re-architecting based on management criterion

After collecting matrices, through unbalance expertise method described in Section 3.6.1, the experts are assigned a rank based on their expertise (the extent of their skill in management) and working experience as tabulated in Table 4.2. The assigned rank for each expert is multiplied into the matrix of that expert. The matrix average is calculated and applied for further calculations in WSM method.

Table 4.8 Result of WSM matrix for removing departments

Existing Dep. / Manager Criteria	"a"	ED_{20}	ED_{19}	ED_{18}	ED_{17}	ED_{16}	ED_{15}	ED_{14}	ED_{12}	ED_{10}	ED_{9}	ED_{7}	ED_{6}	ED_{5}	ED_{4}	ED_{3}	ED_{2}	ED_{1}
MR_1	**0.072**	0.86538	0.28846	2.16345	1.87499	2.30768	2.0192	2.1634	0.28846	0.28846	0	0.86538	0	0	0	0	0	0
MR_2	**0.110**	0	0	0	0	0	0	1.76923	0.88461	7.96154	0	1.32692	0	0	0	0	0	0
MR_3	**0.108**	3.02884	0.21634	0	0	1.30768	0	3.89422	4.11057	0.43269	0	0.43269	0	0	0	0	0	0
MR_4	**0.103**	4.1346	4.54806	5.37498	7.23555	5.78844	2.8942	7.02882	1.86057	6.40863	0.41346	4.96152	1.65384	1.65384	1.65384	0.826	0.826	0.8269
MR_5	**0.055**	2.98555	2.7644	5.08649	5.30764	3.75958	2.54324	1.10576	2.98555	2.87497	2.87497	3.53843	4.64419	4.64419	4.64419	2.764	2.874	2.8749
MR_6	**0.069**	3.34617	1.81251	3.90387	3.34617	3.62502	1.67308	2.92790	3.20675	2.78848	2.50963	4.04329	2.23078	2.23078	2.23078	2.788	2.788	2.7884
MR_7	**0.069**	3.62502	1.11539	3.62502	3.62502	1.67308	3.06732	1.39424	1.39424	3.06732	1.95193	0.55769	0.55769	0.55769	0.55769	3.067	1.115	1.1153
MR_8	**0.040**	1.71633	0.73557	2.04325	1.55287	2.20671	1.14422	1.55287	1.38941	3.2692	1.6346	2.12498	1.79806	1.79806	1.79806	1.634	1.798	1.7980
MR_9	**0.064**	3.2452	2.07692	4.41347	3.63462	3.37500	3.89424	2.59616	1.81731	2.20673	2.85577	1.29808	2.33654	2.33654	2.33654	3.245	2.855	2.8557
MR_{10}	**0.408**	3.2692	1.79806	2.77882	2.77882	2.53363	2.61536	2.12498	2.04325	3.51439	2.61536	1.22595	2.28844	2.12498	2.12498	1.471	1.389	1.3894
MR_{11}	**0.098**	2.16827	0.59134	3.35097	3.35097	3.35097	1.57692	1.97116	1.18269	2.36539	1.57692	6.70194	0.78846	0.78846	0.78846	1.971	1.182	1.1826
MR_{12}	**0.045**	1.55288	1.55288	1.82692	2.19230	2.10095	1.82692	2.10095	1.91826	2.37499	2.19230	1.27884	1.82692	2.00961	1.73557	1.461	1.461	1.4615
Infection Risk	**0.120**	6.61056	8.17305	7.69228	8.17305	3.60576	1.20192	5.40864	12.0192	6.0096	3.60576	7.69228	10.0961	10.8172	10.2163	5.408	4.807	4.8076
	Ws	**36.5480**	**25.6730**	**42.2595**	**43.0720**	**36.0576**	**24.4566**	**36.0384**	**35.1009**	**43.5624**	**22.2307**	**36.0480**	**28.2210**	**28.9614**	**28.0864**	**24.63**	**21.10**	**21.100**

After calculating the matrix average, presented in Table I.3 of Appendix I, by considering DEMATEL results and the result of chart Figure 4.2 for each department, the infection risk criterion is applied in the average matrix of WSM together with management criteria to eliminate a department. During the third interview with the management group, the row corresponding to infection risk in the matrix is not presented to experts in order to avoid bias in results. By considering the main objective of this study, that is, reducing NIs and recognizing the importance of NI risk criterion by infection control experts in Bahonar hospital. The weight of this criterion as to its importance in eliminating a department is 100 in WSM matrix first column, “a”. For the remaining departments, based on the chart Figure 4.3, 0-100 weights are assigned in final WSM Table matrix 4.8 (management matrix average).

WSM analysis is run on obtained matrices based on Section 3.4.1. To perform WSM, the sum total of column “a”, data presented in Table 4.8 matrix is obtained and each “a” data is divided into the obtained total. The result of each criterion in a column “a”, represents the weight of the given criterion (W_x) in terms of priority by management experts as to a criterion to be considered in selecting a department to be eliminated. Obtained W_x for each criterion is multiplied into the weights every expert assigned to each department (for instance, indicating the extent to which criterion b is inappropriate for department x in Bahonar hospital) named numeric value (V). The total of WSs into all criteria is obtained for each alternative. The obtained results are compared to one another based on matrix Table 4.8 and chart Figure 4.3 and higher ranks are presented as potential departments to be eliminated from Bahonar hospital according to management experts.

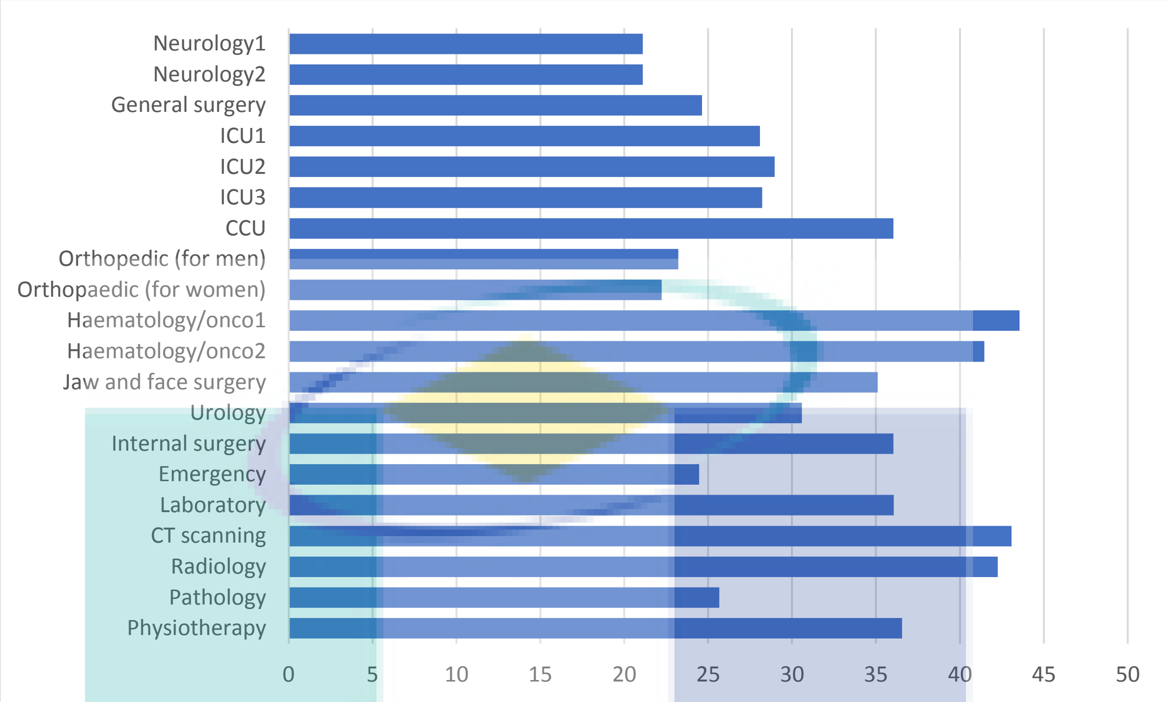

Figure 4.3 Result of WSM matrix from managerial experts for re-architecting of Bahonar hospital

Based on matrix Table 4.8, chart Figure 4.3 and obtained priorities, Haematology/oncology 1 (ED_{10}), CT scanning (ED_{17}), Radiology (ED_{18}) and Haematology/oncology 2 (ED_{11}) are suggested to eliminate from Bahonar hospital, respectively. Hence, the answer to question 2 which is objective 2 in this study (described in Section 1.4) is implemented and analyzed from the case of this study.

4.7 Final analysis of validity and feasibility of results obtained from implementing the procedures in Bahonar hospital as the case of this study

After running the final analysis of all stages in procedures implementation and assessing the obtained results, the final results are assessed by the hospital mentor (research) in 20/08/2018. The expert states that due to the heavy workload of the management group and authorized committees, not much precision is adopted in decision making meetings of selecting a department to be added or eliminated. Moreover, the opinions were contradictory, in some cases, a criterion was missed or not analyzed inappropriate manner and consequently, the proposal was presented in a defected manner.

The results are presented and approved by the head and the manager of the hospital. The head states that the study subject is promising and the methods are comprehensive and reasonable. After observing and assessing the results, the manager expressed his consent about the fact that this study is run on adding and eliminating the process of departments in hospital from a management point of view, by considering NI risk reduction factor (which is missed by most therapeutic centers). The manager referred to the applicability of methods and reasonability of results. The head and the manager expressed that this plan is applicable to all therapeutic centers and due to the fact that these centers require infection control, the procedures presented by this study may be contributive. This study may lead to upgrading and re-architecting HFs to be more precise and to save time.

The results are presented and approved by the hospital improvement and quality coordinator. According to the coordinator, the infection risk factor is not considered in hospital decision making or it is considered with less precision, which may cause problems like increase in NI and consequently, increase in financial burden and death rate. The procedures presented in this study may be contributive in resolving these issues.

Eventually, after the experts approved the results, the validity of the procedures is obtained. The fact that the procedures are analyzed in the case of this study in an appropriate manner and the result is obtained by its implementation, is an approval to the feasibility of these procedures. Hence, the answer to question 3 which is objective 3 in this study is implemented and analyzed and the results are obtained from the experts of the Bahonar hospital. The letter in Appendix J is the evidence that proves the validity and feasibility of the procedures through the experts of the hospital.

4.8 Additional findings from the case study

Through the assessments run in this case study, some issues are revealed regarding the addition and elimination of departments and the current strategies in this hospital. According to the management experts, the issue of adding or eliminating a department is proposed by University of Medical Sciences- Iran standards, the Medical Sciences Department of Kerman University or the hospital physicians, management group or authorized committees. The proposal should be presented to the university research department or hospital development department. Upon the request from the hospital head and manager, a board meeting is arranged with corresponding committees' authorities regarding the addition or elimination of a department in this hospital; this proposal is presented to the Medical Sciences Department of Kerman University and University and Ministry of Health (MOH).

The first criterion considered in this proposal by the management board and the corresponding committees' authorities is the acquisition of a permit from the Medical University and article 20 commission in MOH. Profitability and the extent of correspondence of department specialization with that of the hospital are among the essential factors in adding or eliminating a department in this hospital. According to the hospital quality development committee coordinator, some strategies are adopted regarding adding or eliminating a department to integrate the hospital and the services thereof, thus, making the issues of hospital specialization and the correspondence of the departments with this specialization essential.

Before presenting the proposal of adding or eliminating a department to the MOH, this hospital should assess its conditions in this respect the capability. The MOH commission with the contribution of the Medical University determines whether this hospital is eligible. The infection risk factor is not considered within the criteria related to adding or eliminating a department in many hospitals, while, according to the experts, this issue is essential due to the NIs risk. Due to the fact that focusing on NIs risks as an essential criterion among management criteria regarding decision making in adding or eliminating a department constitutes the main objective of this study and the procedures presented here, the infection risk factor is a confirmation to the significance and innovation of this study.

As to the procedures presented in this study, it is revealed that their structures are comprehensible, which in turn would be contributive in taking actions by the hospital authorities. Through the proposal provided to the MOH, the evaluation process is accelerated in the ministry, the precision is increased, and any ambiguity is resolved in the authorities' decision-making process. Moreover, the extensive correspondences between the ministry and this hospital are minimized and the requested permit is issued in a shorter time. According to the hospital manager, the existence of similar departments in other hospitals in relation to the proposed in Bahonar hospital is not of significance to MOH. The important criterion for MOH is the provision of necessary conditions in this hospital as to establishing a new department with respect to space, beds' count, facilities, human force, geographical location, availability of expert physicians, etcetera. All these factors are assessed based on the descriptions regarding the applicability of the procedures provided in this study.

By assessing the expert's opinion, it is revealed the awarness of the medical groups for infection control within the hospital departments, where attempts are made to control and prevent the outbreak of NIs through applying disinfectants, personnel hygiene, prescribing antibiotics, etcetera. Despite the made advances, NIs are still one of the problems in the HF. By considering the studies run on hospital architecture and management, it is revealed that the focus is on hospital internal design as to environmental factors like lighting, construction materials, etcetera, while the location of departments is not considered as a criterion regarding infection control to prevent inter-departments transmission. In the case study, low collaboration is observed among medical, architectural and management groups, and the procedures presented here consider and assess all the medical and architectural factors.

4.9 Summary

This chapter sums up the implementation of the proposed procedures and the processes to achieve all objectives and questions in the Bahonar hospital as a case study of this thesis. The sections of this chapter are including selection of the case, introducing of the case, the processes of data collection, significance of this study for the case and finally procedures implementation and achieve to validity and feasibility of the results on the case study. Based on the results of implementation of procedures in Bahonar hospital as a case study of this research, the fallowing results are achieved. For upgrading of hospital (objective 1 and research question 1), based on the results of Section 4.6.1, surgery 2 and reconstructive surgery are suggested to add in Bahonar hospital. Also, about re-architecting hospital (objective 2 and research question 2), based on the results of Section 4.6.2, Haematology/oncology 1, CT scanning, Radiology and Haematology/oncology 2 are suggested to be eliminated from Bahonar hospital, respectively. In addition, based on DEMATEL results in Section 4.6.2.2, ICU2, jaw and face surgery, ICU1 and ICU3 are presenting as the risky existing departments of Bahonar hospital, in field of cross infection. Introducing these departments may be contributive to the hospital and infection control authorities to reinforce infection control actions in these departments. Finally, analysis of validity and feasibility of procedures (objective 3 and research question 3) are obtained by confirming the results by head and manager of Bahonar hospital (validity). Feasibility of the procedures achieved through analyzing in the case of this study in a suitable manner and the result is obtained by their implementations, is an endorsement to the feasibility of these procedures.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This thesis is briefed in this chapter in four main sections of: how the objectives of this study are achieved and how this conducted research has responded to the research questions are highlighted in Section 5.2; NI and the contributions in Section 5.3; the limitations of this research are presented in Section 5.4 and the recommendations for future research are presented in Section 5.5.

5.2 Meeting the objectives of the research and addressing the research questions

The review of existing studies of NIs control and the introduction of MCDM methods provide research opportunity to study on minimizing NIs risks by proposing a systematic methodology to minimize the NIs risk through modification of the existing HFs. To accomplish this general objective: i) a department selection procedure is formulated here to minimize the NI risks through upgrading HFs, ii) a department selection procedure is formulated here to minimize the NI risks through re-architecting HFs and iii) a case study to test and validate the proposed re-architecting and upgrading department selection procedures.

By considering the objective of this study described in subsection 1.4, as to the modifications, the terms re-architecting and upgrading are applied for eliminating and adding a department in HFs, respectively, based on consultation with architecture experts.

Due to the fact that this study is run based on management viewpoint(s), attempt is made to provide a scientific solving plan and apply instruments by considering the existence of cross infection. In accordance with the assessments and the descriptions presented in subsection 2.11 and the following subsections, due to the fact that selecting a department to be added or eliminated is a decision-making process and that the HFs are complex organizations with multiple criteria in this respect, MCDM method is selected to accomplish the objectives of this study.

MCDM modellings provide a contributive framework as to drawing complex decisions by devising a platform where all stakeholders can share information, in order to come up with a consensus or find a compromise. The sequence of modelling tasks becomes logical, first, by structuring the problem, next, by modelling the criteria and alternatives and finally by assessment preference and priority of the alternatives or criteria (depends on type of study) leading to the decision to be drawn. Application of MCDM in the healthcare sector is universal in a varied sense, in supporting both clinical and managerial decision-making during complex problem solving (Dehe & Bamford, 2015). This study applied the MADM, from MCDM, to achieve its objectives with the concern of NI criterion.

Based on the criteria described in subsection 3.4 and the approval of experts regarding MADM methods described in subsection 3.8.1, as to selecting a mathematical method among the existing methods of MADM in procedures design, WSM is selected to analyze the management criteria and DEMATEL and expanded DEMATEL are selected to analyze interrelationship among alternatives based on infection risk criterion and NI transmission probability among departments. The processes of each method are described in subsections 3.4.1, 3.4.2 and 3.4.3. The research questions, the research objectives and the methodology applied to respond to each question is briefed below.

5.2.1 Research question and objective 1

The first question: How to minimize NIs risks through upgrading the existing HFs?

In order to decide the direction of this study and adopt first approach for this research, the literature related to the NIs control, HFs' architecting and HFs upgrading is explored in the sections 2.7 and 2.8, and 2.9.1, respectively.

By considering the issues described regarding providing a method in reducing the NIs risk in HFs together with the descriptions provided in subsections 3.4.1 and 3.4.3 as to applying Expanded DEMATEL and WSM methods, they are hybrided in adding a department to HF.

As to the WSM method, realizing this method is not a difficult task, because it does not have a complex structure, consequently, it prevents the generation of any ambiguity in weighing the criteria by the experts (Chou et al., 2008; Sorooshian, 2017). Through the WSM method, the potential departments to be added are assessed with respect to upgrading in terms of management criteria.

Expanded DEMATEL is one of the recent methods applied in MCDM (2014). The direct and indirect correlations based on NIs risk criteria and the possibility of their transmission are assessed through the Expanded DEMATEL method, consequently, the precision of obtained results and the validity of decision making increase. This method is applicable in cases where the rows and columns' counts are not equal in the matrix and the alternatives pertain to two separate groups, of the potential and the existing departments in this case study. The necessary analyses are run according to the Expanded DEMATEL formulas provided in Section 3.4.3. The effect of the potential departments obtained from WSM of management experts' opinions on the existing departments and vise-versa are assessed through this method.

By considering the results obtained in implementing the procedure and its design/plan regarding upgrading described in Section 3.7, by hybridizing the mentioned methods and implementing the WSM and the Expanded DEMATEL methods, respectively, the answer to question 1 is obtained, objective 1.

5.2.2 Research question and objective 2

The second question: How to minimize NIs risks through re-architecting of existing HFs?

About this question, the research began with the literature review, which defined the basic information about the HFs building design for NIs control (Section 2.7), HFs' architecting (Section 2.8) and HFs re-architecting (Section 2.9.2). The findings of this review and based on findings of Hussain and Babalghith (2014) and Stiller et al. (2017) revealed, the selection of potential departments in re-architecting of HFs can be contributive in minimizing NIs risks in HFs.

At this stage, by considering the issues described in relation to providing a method in reducing the NIs risk in HFs and the descriptions provided in subsection 3.5.2 and also based on sub-sections 3.4.1 and 3.4.2, among the methods to be assessed in MCDM subcategories, DEMATEL and WSM are selected for re-architecting.

As to the DEMATEL method, by having the descriptions provided in subsection 3.4.2 in mind and the objective of this study in assessing the interrelationship of departments about NIs transmission in HF, this method is appropriate in assessing interrelationships and answering question 2. DEMATEL method, in addition to assessing the direct correlation between two alternatives, assesses the indirect correlation and effect as well. This issue is not deal with in other methods of MADM, where direct correlations and effects are assessed.

By considering the procedure design provided in Section 3.7 regarding re-architecting, by hybridizing the mentioned methods, the answer to question 2 which is the objective 2 of this study is obtained.

5.2.3 Research question and objective 3

The third question: Is the proposed solution by this research, valid and feasible?

According to the descriptions provided in subsections 3.8.1 and 3.8.2, the procedures are implemented to prove the feasibility and validity of the model. Accidents and trauma specialized Bahonar hospital which is one of the biggest hospitals in Kerman province is the case study here. By considering the descriptions provided in subsection 3.6, attempts are made to enhance the precision of the data collection process during the interviews run through the NGT method and to prevent the generation of bias and brain storming. Based on the descriptions provided in subsection 3.8.2 and the experts' opinions, the validity of procedures is evaluated by implementation in this case study.

The results regarding the approval of these procedures and the experts' opinions, Section 4.7, prove the validity thereof. Hence, the answer to question 3 is obtained.

5.3 NI and the contributions

In spite of the innovations and developments in the field of health sciences and its management, the HFs are still not free of health risks. NIs are one of those HF related health risks that require special attention. As mentioned in section 2.6, NIs constitute one of the main problems of HFs, with a long history. NI is ranked as one of the 10 leading causes of death (Lissovoy, Fraeman, Hutchins, Murphy, & Vaughn, 2009). NI is not limited to be a local issue; it is a worldwide challenge (Parsia, Puteri, & Sorooshian, 2017). NIs can lead to prolonged hospital stays of patients, increase resistance to antimicrobials, increase the patient mortality rates, etcetera (Meng, 2009). The increase in the count of the patients infected by NIs is alarming, and among them many fail to recover from the NIs, thus an increase in the death count (Shalini et al., 2015). Because of the infection risks acquired from the hospital environment, this statement holds true even today that people are safer at home than in some of the HFs (Fabrikant, Kalb, Bucy, Hopson, & Stansel, 2018; Slawomirski et al., 2017). Hospitals' managements and public health authorities around the world are trying to find the most cost-effective strategies and policies to prevent and control NIs (Meng, 2009). According to Khan et al. (2017), although attempts are made to control and prevent NIs, the struggle must continue.

In proposing a solution for the listed problems through NIs, HF layout and departments configurations is a contributive factor. A HF must be designed with fundamental precaution subject to the underlying principle of the ability to be kept clean and off the onslaught of infections, microbes, and diseases. There exist evidence indicating that the HFs plan layout is a major contributive in the transmission of pathogens in HFs and that interventions involving the built environment can mitigate the risks of infections (Stiller, Salm, Bischoff, & Gastmeier, 2016; Zimring, Jacob, et al., 2013).

Many researchers have analyzed and established that proper HF plan layout and management can have a great contribution in controlling NIs. According to Elf et al. (2015), an effective implementation of new models of healthcare and the physical characteristics of the HF architecture will achieve better and safe outcomes. The physical layout of given HFs is contributive in controlling NI, as it incorporates issues of infection control in minimizing the risk of NI transmission (Parsia & Puteri, 2018). That the issue of bad design or layout configuration for HF physical environments may result into increased infection rates, medical errors, and increased injuries rates as a result of either slow patient recovery, high staff turnover, or poor organizational productivity is inevitable, is expressed by Reis & Chambers (2009).

As of now, the consent is on controlling infections as an essential measure during planning and subsequent construction and operation of all HFs (Stockley et al., 2006). The layout architecture is an important factor in contemporary HF, which should be integrated into missions in order to enhance the excellence of care it provides (Elf et al., 2015). One of the emerging NI control strategies involves the HFs redesign and their departments (Stiller et al., 2017). It is revealed that there exists a high extent of infection control when measures are introduced early in the design phase of a healthcare project (Clair & Colatrella, 2013). HFs construction has become a hazardous task as dangers lurk behind walls and ceilings, with the potential to unleash any number of infections sources (Clair & Colatrella, 2013). For the safety and health of the society and less NIs in HFs, it is necessary to have proper selection and organization of departments and right layout design (Hussain & Babalghith, 2014). Although, department selection and layout configuration are very apparent in upgrading and re-architecting of HFs building context and the objective of controlling the NIs, not many researchers have worked on it. Layout configuration of current HFs layout is mostly based on minimizing costs or the inclusion of technologies (Van Enk, 2006). Demolishing existing structures and constructing the new is not a feasible solution to provide modern healthcare services and reduce the impacts of healthcare construction industry on the environment (Sheth et al., 2010). According to Hussain and Babalghith (2014) the main objective of improving the HFs is to maintain the positive aspects of the existing HFs, while trying to improve the weaker aspects thereof.

By considering the importance of HFs design in NIs control described in subsections 2.7 and the cross infection of them among departments described in subsection 2.6.1, it is necessary to assess the HFs as to adding or eliminating a department with respect to infection risk and management criteria in order to prevent and reduce the outbreak of a new infection or the intensification of the existing infections and their transmission among departments. Drawing decision on HF modification is a complex task. There exists very few, if any, systematic decision-making model(s) in this respect, hence, this study, practically, is contributive in healthcare industry to provide this type of model for HF modification in NIs control.

It is highlighted by Tzeng and Shen (2017) the traditional MCDM ignores some important isuues. Therefore, it is argued that the recent trend with regards in MCDM methods is to hybridization of MCDM methods which could simplify solving real-world and complex problems. Thus, as to the theoretical or knowledge contribution of this study, it is revealed that the new hybridizations of the MCDM methods applied in the procedures are run in a manner that the processes of data collection and adding or eliminating a department indicate a logical trend. The hybridizations and decision procedures of this research is among the pioneers of it's kind. In hybridizations, this study has the novelty of introducing DEMATEL-WSM (based on modified NGT) and WSM-Expanded DEMATEL (based on modified NGT) for the very first time. This is valuable, as Tzeng and Shen (2017) explained that new hybrid MCDM, in addition to ranking or selection, are used to improve performance gaps of existing MCDMs and the corresponding aspects.

Hence, through the re-architecting procedure, the existing departments in terms of infection risk based on DEMATEL method is assessed in case of eliminating a department, because the departments are within the HF. After determining the infection risk in every department, the departments are assessed by considering the management criteria based on management experts' viewpoint together with the infection risk criterion.

The process is not the same in case of adding a department, because the departments proposed to be added to HF are not located in the hospital. Hence, it is recommended to evaluate these departments in terms of management criteria by the management experts, so that the departments constituting the conditions necessary in adding one are selected. Otherwise the opposite would occur, if first of all, all proposed departments evaluated based on NIs risk and then assess them based on management criteria. Based on this assessment, some departments maybe selected which their suitable conditions are not existed in HF. It will lead to waste of time and inappropriate viewpoints. Here, first, the WSM is run based on management criteria and next, the selected departments are assessed in terms of infection risk criterion based on Expanded DEMATEL method. Regarding the practical contribution of this study, it is revealed that by providing mathematical decision-making procedures, a solution is provided with respect to the NIs problems for HFs. These procedures are feasible for upgrading and re-architecting decisions which normally is made by the HF top managers.

In addition, with regards to the society contribution of this study, the procedures can help managers to decrease the risk of NIs in their HFs and defiantly in society. This is beneficial to the society and a contribution to public health. Hence, the rate of mortality, financial loads and the other side effects of NIs will be decreased and the level of health in society will be positively effected.

5.4 Limitation of study

The decision models presented in this study are based on the experts' opinions and knowledge essential in running the assessments on NIs in HF. The more scientific their opinions, the higher the validity of the procedures results.

The decision models provided in this study in HFs with tertiary or quaternary level of care (Appendix A) is applicable to a great extent due to the presence of experts with necessary expertise and knowledge in NIs. In other HFs the experts' count with necessary knowledge and experience may be low, therefore, it is necessary to invite experts from other HF's in order to implement the model provided in this study, which in turn would increase expenses. The expert invited from other HF may need time to assess the HF's conditions in a precise manner before implementing these procedures and determine the results thereof.

By considering the importance of NIs in HFs and the risks due to inappropriate control together with the main objective of this proposed model in reducing NIs risks, the existence of experts is essential in this model. Non-scientific opinion leads to false results, thus, an increase in the risks caused by NIs.

5.5 Recommendations for possible future research

By considering the data collection and analyses processes in DEMATEL and Expanded DEMATEL methods, in specific, due to the fact that the weights to be assigned to the alternatives by the infection control experts are within 0-4 range and there exists the possibility for an expert to face an ambiguity as to assigning a weight to an alternative. To clear this ambiguity, the Fuzzy logic can be applied.

Fuzzy logic is a form of multi-value logic where the truth values of variables may be any real number between A and B, and it is applied to handle the concept of partial truth, where the truth value may range between completely true and completely false (Arvapally, Liu, & Baik, 2013). Almost all real-life applications of fuzzy logic involve the use of linguistic variables, a linguistic variable is a variable the values of which are words rather than numbers and they are often used in facilitating the expression of rules and facts (Singh, Gupta, & Meitzler, 2013). Through this fuzzy property, more precise opinions may be collected from the experts, consequently, the validity of the provided model would be high.

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APPENDICES

APPENDIX A

Table A.1 Categorization of hospitals

Criteria	Type of hospital	Characteristic and definition
Size or bed capacity (Sinclair & Shivagunde, 2014)	a) Small size (Sinclair & Shivagunde, 2014)	100 or less beds (Sinclair & Shivagunde, 2014).
	b) Medium size (Sinclair & Shivagunde, 2014)	101 to 300 beds (Sinclair & Shivagunde, 2014).
	c) Large size (Sinclair & Shivagunde, 2014)	301 to 1000 beds (Sinclair & Shivagunde, 2014).
Ownership or control (Sinclair & Shivagunde, 2014)	a)Government or Public (Sinclair & Shivagunde, 2014)	Run by Central or State Governments or local bodies on non-commercial lines (Sinclair & Shivagunde, 2014).
		Funded by the government (Sinclair & Shivagunde, 2014).
	b)Non-Government (Sinclair & Shivagunde, 2014)	Supported by client’s fees, donations, or endowments (Sinclair & Shivagunde, 2014).
		Classified as either proprietary or non–profit organization (Sinclair & Shivagunde, 2014).

Table A.1 Continued

Criteria	Type of hospital	Characteristic and definition
Objectives of the hospital (Sinclair & Shivagunde, 2014)	a)Teaching-Research (Sinclair & Shivagunde, 2014; Sinclair, Shivagunde, & Mishra, 2013)	Training of doctors and researcher (Sinclair & Shivagunde, 2014).
	b)General (Sinclair & Shivagunde, 2014)	Provide medical care (Sinclair & Shivagunde, 2014). Treat common diseases (Sinclair & Shivagunde, 2014). Teaching (Sinclair & Shivagunde, 2014).
	c)Specialized (Sinclair & Shivagunde, 2014; Sinclair et al., 2013)	Giving medical and nursing care in a specific part of body, for example heart hospital (Sinclair & Shivagunde, 2014).
	d)Isolation (Sinclair & Shivagunde, 2014)	When client requiring isolation or suffering from communicable diseases are taken care of (Sinclair & Shivagunde, 2014).
	e)Rural (Sinclair & Shivagunde, 2014; Sinclair et al., 2013)	Located in rural areas permanently staffed by at least one or more physicians (Sinclair & Shivagunde, 2014). Offer inpatient accommodation and provide medical and nursing care (Sinclair & Shivagunde, 2014).
Systems (Sinclair & Shivagunde, 2014)	a)Long – term care or chronic care (Sinclair & Shivagunde, 2014)	The client stays in the hospital for a long time and the disease may be of chronic nature (Sinclair & Shivagunde, 2014).
	b)Short – term care or acute care (Sinclair & Shivagunde, 2014).	The client stay in the hospital for a short period only and the disease is usually of acute nature (Sinclair & Shivagunde, 2014).

Table A.1 Continued

Criteria	Type of hospital	Characteristic and definition
	a)Run by Union Government (Sinclair & Shivagunde, 2014).	Funded by Government , For instance, hospitals run by railways and army (Sinclair & Shivagunde, 2014).
Management (Sinclair & Shivagunde, 2014)	b)Run by State Government	Funded and administered by State Government (Sinclair & Shivagunde, 2014).
	c)Run by local bodies (Sinclair & Shivagunde, 2014)	-
	d)Autonomous bodies (Sinclair & Shivagunde, 2014)	Operational responsibility to the hospital governing board (Sinclair & Shivagunde, 2014). Usually granted by the government (Sinclair & Shivagunde, 2014).
	e)Private (Sinclair & Shivagunde, 2014)	Owned by a profit company or a non-profit organisation (Sinclair & Shivagunde, 2014). Privately funded through payment by patients themselves (Sinclair & Shivagunde, 2014).
	f)Voluntary (Sinclair & Shivagunde, 2014)	Supported in part by voluntary contributions and under the control of a local (Sinclair & Shivagunde, 2014).

Table A.1 Continued

Criteria	Type of hospital	Characteristic and definition
Different Levels Of Care (Sinclair & Shivagunde, 2014)	a) Primary-level (Ch. A. Alalouch, 2009; Jamison et al., 2006; Sinclair & Shivagunde, 2014)	Few specialties or just general practice and limited laboratory services available for general (Jamison et al., 2006). Such as: Rural and general hospital (Jamison et al., 2006).
	b) Secondary-level (Alalouch, 2009; Jamison et al., 2006; Sinclair & Shivagunde, 2014)	5 to10 clinical specialties, 200 to 800 beds and often referred to as a provincial hospital (Jamison et al., 2006). Such as: Regional hospital (Jamison et al., 2006).
	c)Tertiary-level (Jamison et al., 2006; Sinclair & Shivagunde, 2014)	Highly specialized staff and technical equipment, clinical services highly differentiated by function and could have teaching activities (Jamison et al., 2006). Such as: National and central hospital (Jamison et al., 2006).
	d) Quaternary Care (Sinclair & Shivagunde, 2014)	Quaternary care is an extension of tertiary care and is more specialized and highly unusual, therefore every hospital or medical centre cannot offer quaternary care (Sinclair & Shivagunde, 2014). It includes experimental medicine and procedures (Sinclair & Shivagunde, 2014).

APPENDIX B

UMP application letter to obtain information

Universiti Malaysia PAHANG

Fakulti Pengurusan Industri
Faculty of Industrial Management

Fakulti Pengurusan Industri
Universiti Malaysia Pahang
Lebuhraya Tun Razak
26300 Gambang
Pahang Darul Makmur

NO. RUJ : UMP.27.04/13.11/6/1/7 ( )
Tarikh : 5 April 2018

TO WHOM IT MAY CONCERN

Dear Sir,

APPLICATION TO OBTAIN INFORMATION FOR RESEARCH PURPOSES

NAME	:	**YASAMAN PARSIA**
MATRIK NO	:	**PPT17003**
PROJECT TITLE	:	**AN ALGORITHM FOR MINIMAZITAION OF NOSOCOMIAL INFECTIONS RISK THROUGH UPGRADING AND RE-ARCHITECTING OF HEALTHCARE FACILITIES**

2. Please be informed that the above mentioned name is student Doctor of Philosophy of Universiti Malaysia Pahang (UMP), Kuantan, Pahang.

3. We appreciate if you can support and give cooperation to respond to the survey and other related research activities. We assure you that the response will be kept confidential and results to be used for research purposes only.

4. All your assistance is highly appreciated.

"BERKHIDMAT UNTUK NEGARA"
Memasyarakatkan Teknologi

Your Sincerely,

DR. PUTERI FADZLINE BINTI MUHAMAD TAMYEZ
SENIOR LECTURER
FACULTY OF INDUSTRIAL MANAGEMENT
UNIVERSITI MALAYSIA PAHANG
TEL 09-549 2455 FAX 09-549 2167

(DR. PUTERI FADZLINE BINTI MUHAMAD TAMYEZ)
Senior Lecturer
Faculty of Industrial Management
Universiti Malaysia Pahang

Tel : 09-549 2445
Fax : 09-549 2167
Email: : fadzline@ump.edu.my

NNS/Surat/Postgrad

MyGift Green We Care Memasyarakatkan Teknologi Communitising Technology

www.ump.edu.my

APPENDIX C

Permission letter of Ministry of Health and Education to obtain information

بسمه تعالی

وزارت بهداشت، درمان و آموزش پزشکی

دانشگاه علوم پزشکی و خدمات بهداشتی درمانی استان کرمان

معاونت تحقیقات و فناوری

تاریخ: ۱۳۹۷/۴/۱۳

شماره: ۹۷/۱۰/۶۰/۱۳۶۲۲

پیوست:

جناب آقای دکتر هاشمیان

معاون محترم درمان دانشگاه

موضوع نامه: همکاری با انجام پایان نامه

با سلام

احتراماً، به پیوست درخواست سرکار خانم یاسمن پارسیا دانشجوی مقطع دکتری رشته مدیریت صنعتی از دانشگاه پاهنگ مالزی ارسال، خواهشمند است دستور فرمایید در صورت امکان در خصوص جمع‌آوری اطلاعات پایان‌نامه نامبرده با عنوان «الگوریتم ریاضی به‌منظور کاهش خطر عفونت‌های بیمارستانی از طریق توسعه یا کاهش سایز (اصلاح معماری بخش‌ها) مراکز درمانی» همکاری لازم صورت پذیرد. ۹۷/٤/۱۳د

دکتر یونس پرداختی

معاون تحقیقات و فناوری

مدیر محترم حراست دانشگاه

کرمان – چهارراه سمیه (طهماسب آباد) – ابتدای بلوار جهاد – ساختمان ابن سینا

تلفن: ۳۲۲۶۳۸۵۵ , ۳۲۲۶۳۷۸۷

vcr@kmu.ac.ir

این نامه در سیستم اتوماسیون اداری ایجاد شده و امضای الکترونیک همانند امضای اصل معتبر است

APPENDIX D

Permission letter of Afzalipour hospital to obtain information

بسمه تعالی

وزارت بهداشت درمان و آموزش پزشکی
دانشگاه علوم پزشکی و خدمات بهداشتی درمانی استان کرمان
معاونت درمان

تاریخ ۱۳۹۷/۴/۳۰
شماره ۹۷/۱۰/۳/۱۶۱۲۴
پیوست

ریاست محترم بیمارستان ....

ریاست محترم کلینیک ....

موضوع نامه:همکاری با انجام پایان نامه خانم یاسمن پارسیا

باسلام

احتراماً به پیوست نامه ۱۰/۶۰/۱۳۶۲۲ مورخ ۹۷/٤/۱۳در خصوص همکاری با انجام خانم یاسمن پارسیا دانشجو مقطع دکتری رشته مدیریت صنعتی و نظریه مدیریت حراست دانشگاه خدمتتان ارسال می گردد ، مقتضی است در خصوص جمع آوری اطلاعات پایان نامه نامبرده مساعدت لازم مبذول گردد.

دکتر مرتضی هاشمیان
معاون درمان

کرمان-بلوار جمهوری اسلامی،سازمان مرکزی
تلفن : ۳۲۱۱۳۰۱۲ نمابر: ۳۲۱۱۳۱۷۰
vct.kmu.ac.ir - vct@kmu.ac.ir

APPENDIX E

Permission letter of Bahonar hospital to obtain information

بسمه تعالی

وزارت بهداشت، درمان و آموزش پزشکی
دانشگاه علوم پزشکی و خدمات بهداشتی درمانی استان کرمان
معاونت درمان

تاریخ: ۱۳۹۷/۴/۳۰
شماره: ۹۷/۱۰/۳/۱۶۱۲۴
پیوست:

ریاست محترم بیمارستان ....

ریاست محترم کلینیک ....

موضوع نامه: همکاری با انجام پایان نامه خانم یاسمن پارسیا

باسلام

احتراماً به پیوست نامه ۱۰/۶۰/۱۲۶۲۲ مورخ ۹۷/۴/۱۳ در خصوص همکاری با انجام خانم یاسمن پارسیا دانشجو مقطع دکتری رشته مدیریت صنعتی و نظریه مدیریت حراست دانشگاه خدمتتان ارسال می گردد ، مقتضی است در خصوص جمع آوری اطلاعات پایان نامه نامبرده مساعدت لازم مبذول گردد.

دکتر مرتضی هاشمیان
معاون درمان

کرمان – ...
vct.kmu.ac.ir - vct@kmu.ac.ir

APPENDIX F

Matrices for upgrading HFs to minimize NIs risks

i) WSM matrix

Table F.1 WSM matrix for upgrading HFs to minimize NIs risks

Managerial Criteria / Alternatives	Weigh for each criterion "a"	Reconstructive surgery	Peripheral vessels angiography	MRI	Ear, throat and nose surgeries	Eye surgery	Surgery 2	Hand surgery	Obstetrics and Gynaecology	Rehabilitation and physical treatment	Transplant	Infection	Chemotherapy	Psychology emergency
MU1														
MU2														
MU3														
MU4														
MU5														
MU6														
MU7														
MU8														
MU9														
MU10														
MU11														
MU12														
MU13														
Mu14														
MU15														

ii) Expanded DEMATEL matrices

Table F.2 Expanded DEMATEL matrix (potential departments on existing departments) for upgrading HFs to minimize NIs risks

Existing departments / Potential departments	Physiotherapy	Pathology	Radiology	CT scanning	laboratory	emergency	Internal surgery	Urology	Jaw and face surgery	Haematology/oncology 2	Haematology/oncology 1	Orthopaedics (for women)	Orthopaedics (for men)	CCU	ICU3	ICU2	ICU1	General surgery	Neurology2	Neurology1
Reconstructive surgery																				
Peripheral vessels angiography																				
MRI																				
Surgery 2																				

Table F.3 Expanded DEMATEL matrix (existing departments on potential departments) for upgrading HFs to minimize NIs risks

Potential Dep. / Existing Dep.	Reconstructive surgery	Peripheral vessels angiography	MRI	Surgery 2
Neurology1				
Neurology2				
General surgery				
ICU1				
ICU2				
ICU3				
CCU				
Orthopaedic (for men)				
Orthopaedic (for women)				
Haematology/oncology 1				
Haematology/oncology 2				
Jaw and face surgery				
Urology				
Internal surgery				
Emergency				
Laboratory				
CT scanning				
Radiology				
Pathology				
Physiotherapy				

APPENDIX G

Result matrices of case study for upgrading

i) The result of WSM from case study

Table G.1 Result of average matrix of WSM for upgrading the case study

Alternatives / Managerial Criteria	Weigh for each criterion "a"	Reconstructive surgery	Peripheral vessels angiography	MRI	Ear, throat and nose surgeries	Eye surgery	Surgery 2	Hand surgery	Obstetrics and Gynaecology	Rehabilitation and physical treatment	Transplant	Infection	Chemotherapy	Psychology emergency
MU_1	100	58	98	100	6	6	60	52	16	56	4	42	84	0
MU_2	96	96	96	92	40	44	92	80	40	72	30	38	84	0
MU_3	96	100	92	66	4	18	96	88	10	60	20	76	100	16
MU_4	86	42	70	56	4	4	50	50	6	32	8	24	50	2
MU_5	66	42	58	60	62	58	64	46	38	66	66	46	52	38
MU_6	70	62	62	72	66	62	72	54	46	58	58	38	46	42
MU_7	72	84	90	92	76	76	88	76	78	70	46	22	30	26
MU_8	86	68	86	92	40	48	74	62	42	62	42	46	52	26
MU_9	82	58	58	58	60	60	84	58	64	70	66	46	60	30
MU_{10}	86	70	74	78	58	58	80	72	70	70	66	72	64	70
MU_{11}	78	72	76	76	54	54	76	66	46	54	54	46	84	44
MU_{12}	66	26	68	68	30	30	36	22	22	30	26	10	24	20
MU_{13}	70	66	70	76	42	42	84	70	34	54	30	42	54	28
Mu_{14}	80	40	64	64	32	32	34	18	22	34	28	10	28	20
MU_{15}	88	86	86	96	52	68	84	70	54	74	42	50	68	36

ii) The result of Expanded DEMATEL from case study

Table G.2 Result of average matrix of Expanded DEMATEL for interrelationships evaluation of potential department on existing departments based on infection risk for upgrading of the case study

Existing department / **Potential department**	**ED_1**	**ED_2**	**ED_3**	**ED_4**	**ED_5**	**ED_6**	**ED_8**	**ED_9**	**ED_{10}**	**ED_{11}**	**ED_{12}**	**ED_{13}**	**ED_{14}**	**ED_{15}**	**ED_{16}**	**ED_{17}**	**ED_{18}**	**ED_{19}**	**ED_{20}**	**Sum of row**
Reconstruc surgery	0.5	0.666	0.5	0.5	1.5	2.1666	1.8333	2.1666	2.166	2.166	1.333	1.333	2.333	2.333	2.333	2.333	2.3333	2.3333	2.3333	**34.83**
Peripheral vessels angiograph	0.5	0.5	0	0	1	1.3333	1.5	0.3333	1.5	1.5	1	1	1.333	1.5	1.5	1.5	1.5	1	1	**20.33**
MRI	0	0	0	0	0	0.3333	0.3333	0.3333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.3333	0.3333	0.3333	**5**
Surgery 2	1	1.166	1	1	1.1666	1.6666	2.6666	2.1666	2.666	2.666	2.166	2.166	2.666	2.833	2.833	2.833	2.1666	2.1666	2.1666	**41.83**
Sum of column	**2**	**2.333**	**1.5**	**1.5**	**3.6666**	**5.5**	**6.333333**	**5**	**6.666**	**6.666**	**4.833**	**4.833**	**6.666**	**7**	**7**	**7**	**6.3333**	**5.8333**	**5.8333**	

Table G.3 Result of normal matrix of Expanded DEMATEL for interrelationships evaluation of potential department on existing departments based on infection risk for upgrading of the case study

Existing department / Potential department	ED_1	ED_2	ED_3	ED_4	ED_5	ED_6	ED_7	ED_8	ED_9	ED_{11}	ED_{12}	ED_{13}	ED_{14}	ED_{15}	ED_{17}	ED_{18}	ED_{19}	ED_{20}
Reconstruct surgery	0.0143	0.0191	0.0143	0.014	0.043	0.0622	0.047846	0.052631	0.062200	0.0622	0.0382	0.0382	0.0669	0.0669	0.066985	0.066985	0.066985	0.06698
Peripheral vessels angiograph	0.0143	0.0143	0	0	0.0287	0.0382	0.023923	0.043062	0.009569	0.0430	0.0287	0.0287	0.0382	0.0430	0.043062	0.043062	0.028708	0.02870
MRI	0	0	0	0	0	0.0095	0.009569	0.009569	0.009569	0.0095	0.0095	0.0095	0.0095	0.0095	0.009569	0.009569	0.009569	0.00956
Surgery 2	0.0287	0.0334	0.0287	0.028	0.0334	0.0478	0.076555	0.076555	0.062200	0.0765	0.0622	0.0622	0.0765	0.0813	0.081339	0.062200	0.062200	0.06220

Table G.4 Result of average matrix of Expanded DEMATEL for interrelationships evaluation of existing department on potential departments based on infection risk for upgrading of the case study

Potential Departments / Existing Departments	Reconstructive surgery	Peripheral vessels angiography	MRI	Surgery 2	Sum of row
ED_1	0.5	2.166666	0.666666	2	**5.333333**
ED_2	0.5	2.166666	0.666666	2	**5.333333**
ED_3	2.166666	2.333333	0.666666	2.5	**7.666667**
ED_4	2.833333	3	3	3	**11.83333**
ED_5	2.833333	3	3	3	**11.83333**
ED_6	2.833333	3	3	3	**11.83333**
ED_7	1.333333	1.666666	1.666666	1.5	**6.166667**
ED_8	1	1.166666	0.666666	1	**3.833333**
ED_9	1	1.166666	0.666666	1	**3.833333**
ED_{10}	2.666666	2.6666666	2.666666	2.833333	**10.83333**
ED_{11}	2.666666	2.666666	2.666666	2.833333	**10.83333**
ED_{12}	1.833333	1.833333	0.333333	2	**6**
ED_{13}	1.833333	2.166666	0.666666	2.333333	**7**
ED_{14}	2	2.166666	0.666666	2.333333	**7.166667**
ED_{15}	2	2.166666	2.166666	2.333333	**8.666667**
ED_{16}	1	1	1	1	**4**
ED_{17}	0	0	0	0	**0**
ED_{18}	0	0	0	0	**0**
ED_{19}	0.5	0.5	0	0.5	**1.5**
ED_{20}	0.5	0.5	0	0.666666	**1.666667**
Sum of column	**30**	**35.333333**	**24.166666**	**35.833333**	

Table G.5 Result of Normal matrix of Expanded DEMATEL for interrelationships evaluation of existing department on potential departments based on infection risk for upgrading the case study

Potential Departments / Existing Departments	Reconstructive surgery	Peripheral vessels angiography	MRI	Surgery 2
ED_1	0.013954	0.060465	0.018605	0.055814
ED_2	0.013954	0.060465	0.018605	0.055814
ED_3	0.060465	0.065116	0.018605	0.069768
ED_4	0.07907	0.083721	0.083721	0.083721
ED_5	0.07907	0.083721	0.083721	0.083721
ED_6	0.07907	0.083721	0.083721	0.083721
ED_7	0.037209	0.046512	0.046512	0.041861
ED_8	0.027907	0.032558	0.018605	0.027907
ED_9	0.027907	0.032558	0.018605	0.027907
ED_{10}	0.074419	0.074419	0.074419	0.07907
ED_{11}	0.074419	0.074419	0.074419	0.07907
ED_{12}	0.051163	0.051163	0.009302	0.055814
ED_{13}	0.051163	0.060465	0.018605	0.065116
ED_{14}	0.055814	0.060465	0.018605	0.065116
ED_{15}	0.055814	0.060465	0.060465	0.065116
ED_{16}	0.027907	0.027907	0.027907	0.027907
ED_{17}	0	0	0	0
ED_{18}	0	0	0	0
ED_{19}	0.013954	0.013954	0	0.013954
ED_{20}	0.013954	0.013954	0	0.018605

APPENDIX H

Matrices for re-architecting HFs to minimize NIs risks

iii) DEMATEL matrix

Table H.1 DEMATEL matrix for re-architecting HFs to minimize NIs risks

Name of departments	**Physiotherapy**	**Pathology**	**Radiology**	**CT scanning**	**Laboratory**	**Emergency**	**Internal surgery**	**Urology**	**Jaw and face surgery**	**Haematology/onco2**	**Haematology/onco1**	**Orthopaedic (for**	**Orthopaedic (for men)**	**CCU**	**ICU3**	**ICU2**	**ICU1**	**General surgery**	**Neurology2**	**Neurology1**
Physiotherapy																				
Pathology																				
Radiology																				
CT scanning																				
Laboratory																				
Emergency																				
Internal surgery																				
Urology																				
Jaw and face surgery																				
Haematology/ onco2																				
Haematology/ onco1																				
Orthopaedic (for women)																				
Orthopaedic (for men)																				
CCU																				
ICU3																				
ICU2																				
ICU1																				
General surgery																				
Neurology2																				
Neurology1																				

iv) WSM matrix

Table H.2 WSM matrix for re-architecting HFs to minimize NIs risks

Managerial Criterion / Existing Dep.	Weigh for each criterion "a"	Physiotherapy	Pathology	Radiology	CT scanning	Laboratory	Emergency	Internal surgery	Urology	Jaw and face surgery	Haematology/onco2	Haematology/onco1	Orthopaedic (for women)	Orthopaedic (for men)	CCU	ICU3	ICU2	ICU1	General surgery	Neurology2	Neurology1
MR1																					
MR2																					
MR3																					
MR4																					
MR5																					
MR6																					
MR7																					
MR8																					
MR9																					
MR10																					
MR11																					
MR12																					

APPENDIX I

Result matrices of case study for re-architecting

i) Result of DEMATEL from the case study

Table I.1 Result of average matrix of DEMATEL for re-architecting of the case study

Department	ED_{20}	ED_{19}	ED_{18}	ED_{17}	ED_{16}	ED_{12}	ED_{11}	ED_{10}	ED_{9}	ED_{8}	ED_{7}	ED_{6}	ED_{4}	ED_{3}	ED_{2}	ED_{1}	Sum of row
ED_{20}	0	0.5	0	0	0	0.3333	0.5	0.5	0.3333	0.333333	0.3333	1	1	0.3333	0.3333	0.333333	**7.833333**
ED_{19}	0	0	0	0	0.5	0	0.5	0.5	0	0	0.5	0.5	0.5	0	0.5	0.5	**6**
ED_{18}	0	0	0	0	0	0.3333	0.3333	0.3333	0.8333	0.333333	0.3333	0.3333	0.3333	0.3333	0.3333	0.333333	**6.5**
ED_{17}	0	0	0	0	0	0.3333	0.3333	0.3333	0.3333	0.333333	0.3333	0.3333	0.3333	0.3333	0.3333	0.333333	**5**
ED_{16}	0.5	0.5	0.5	0.5	0	1.1666	1.5	1.5	1.1666	1.166667	1.6666	1.6666	1.6666	1.1666	1.1666	1.166667	**22.16667**
ED_{15}	0.833333	1.333333	1.5	1	1.666	1.8333	2.1666	2.1666	1.3333	1.333333	1.8333	2.3333	2.3333	1.3333	1.3333	1.333333	**31.66667**
ED_{14}	0.5	1	1	0.5	1	1.5	2.3333	2.3333	1	1	1.5	1.8333	1.8333	1.3333	1.3333	1.333333	**26**
ED_{13}	0.5	1	1	1	1	1.8333	2.3333	2.3333	1	1	1.8333	1.8333	1.8333	1.3333	1	1	**27.16667**
ED_{12}	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	**6.833333**
ED_{11}	2	2	2	2	2	2.8333	0	3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	**46.66667**
ED_{10}	2	2	2	2	2	2.8333	3	0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	**46.66667**
ED_{9}	0.5	0.5	0.5	0.5	1	0.8333	1.8333	1.8333	0	0.833333	1.8333	1.8333	1.8333	1.8333	1.8333	1.833333	**26.5**
ED_{8}	0.5	0.5	0.5	0.5	1	0.8333	1.8333	1.8333	0.8333	0	1.3333	1.8333	1.8333	1.8333	1.8333	1.833333	**26.5**
ED_{7}	0.5	0.5	0.5	0.5	0.5	0.5	1.5	1.5	1	0.5	0	1.5	1.5	1.5	1.5	1.5	**20.83333**
ED_{6}	2	2	2	2	2	3.3333	3.3333	3.3333	3.1666	3.166667	3.5	0	3.3333	3.3333	3.3333	3.333333	**56.16667**
ED_{5}	2	2	2	2	2	3.3333	3.3333	3.3333	3.1666	3.166667	3.3333	3.5	3.3333	3.3333	3.3333	3.333333	**56.16667**
ED_{4}	2	2	2	2	2	3.3333	3.3333	3.3333	3.1666	3.166667	3.3333	3.3333	0	3.3333	3.3333	3.333333	**56.16667**
ED_{3}	1.5	1.5	1.5	1.5	1.5	2.3333	2.3333	2.3333	2.3333	2.333333	2.3333	2.3333	2.6666	0	2.3333	2.333333	**40.33333**
ED_{2}	1.5	1.5	1.5	1.5	1.5	2.3333	2.3333	2.3333	2.3333	2.333333	2.33333	2.33333	2.33333	2.33333	0	2.5	**40.16667**
ED_{1}	1.5	1.5	1.5	1.5	1.5	2.3333	2.3333	2.3333	2.3333	2.333333	2.3333	2.3333	2.3333	2.3333	2.5	0	**40.16667**
Sum of column	**18.33333**	**20.33333**	**20**	**19**	**21.16**	**32.166**	**35.666**	**35.666**	**29.833**	**28.83333**	**34.666**	**34.333**	**34.5**	**31.5**	**31.833**	**31.83333**	

Table I.2 Result of normal matrix of DEMATEL for re-architecting of the case study

Department	ED$_{20}$	ED$_{19}$	ED$_{18}$	ED$_{17}$	ED$_{16}$	ED$_{12}$	ED$_{11}$	ED$_{10}$	ED$_{9}$	ED$_{8}$	ED$_{7}$	ED$_{6}$	ED$_{4}$	ED$_{3}$	ED$_{2}$	ED$_{1}$	Sum of row
ED$_{20}$	0	0.5	0	0	0	0.3333	0.5	0.5	0.3333	0.333333	0.3333	1	1	0.3333	0.3333	0.333333	**7.833333**
ED$_{19}$	0	0	0	0	0.5	0	0.5	0.5	0	0	0.5	0.5	0.5	0	0.5	0.5	**6**
ED$_{18}$	0	0	0	0	0	0.3333	0.3333	0.3333	0.8333	0.333333	0.3333	0.3333	0.3333	0.3333	0.3333	0.333333	**6.5**
ED$_{17}$	0	0	0	0	0	0.3333	0.3333	0.3333	0.3333	0.333333	0.3333	0.3333	0.3333	0.3333	0.3333	0.333333	**5**
ED$_{16}$	0.5	0.5	0.5	0.5	0	1.1666	1.5	1.5	1.1666	1.166667	1.6666	1.6666	1.6666	1.1666	1.1666	1.166667	**22.16667**
ED$_{15}$	0.833333	1.333333	1.5	1	1.666	1.8333	2.1666	2.1666	1.3333	1.333333	1.8333	2.3333	2.3333	1.3333	1.3333	1.333333	**31.66667**
ED$_{14}$	0.5	1	1	0.5	1	1.5	2.3333	2.3333	1	1	1.5	1.8333	1.8333	1.3333	1.3333	1.333333	**26**
ED$_{13}$	0.5	1	1	1	1	1.8333	2.3333	2.3333	1	1	1.8333	1.8333	1.8333	1.3333	1	1	**27.16667**
ED$_{12}$	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	**6.833333**
ED$_{11}$	2	2	2	2	2	2.8333	0	3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	**46.66667**
ED$_{10}$	2	2	2	2	2	2.8333	3	0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	**46.66667**
ED$_{9}$	0.5	0.5	0.5	0.5	1	0.8333	1.8333	1.8333	0	0.833333	1.8333	1.8333	1.8333	1.8333	1.8333	1.833333	**26.5**
ED$_{8}$	0.5	0.5	0.5	0.5	1	0.8333	1.8333	1.8333	0.8333	0	1.3333	1.8333	1.8333	1.8333	1.8333	1.833333	**26.5**
ED$_{7}$	0.5	0.5	0.5	0.5	0.5	0.5	1.5	1.5	1	0.5	0	1.5	1.5	1.5	1.5	1.5	**20.83333**
ED$_{6}$	2	2	2	2	2	3.3333	3.3333	3.3333	3.1666	3.166667	3.5	0	3.3333	3.3333	3.3333	3.333333	**56.16667**
ED$_{5}$	2	2	2	2	2	3.3333	3.3333	3.3333	3.1666	3.166667	3.3333	3.5	3.3333	3.3333	3.3333	3.333333	**56.16667**
ED$_{4}$	2	2	2	2	2	3.3333	3.3333	3.3333	3.1666	3.166667	3.3333	3.3333	0	3.3333	3.3333	3.333333	**56.16667**
ED$_{3}$	1.5	1.5	1.5	1.5	1.5	2.3333	2.3333	2.3333	2.3333	2.333333	2.3333	2.3333	2.6666	0	2.3333	2.333333	**40.33333**
ED$_{2}$	1.5	1.5	1.5	1.5	1.5	2.3333	2.3333	2.3333	2.3333	2.333333	2.33333	2.33333	2.33333	2.33333	0	2.5	**40.16667**
ED$_{1}$	1.5	1.5	1.5	1.5	1.5	2.3333	2.3333	2.3333	2.3333	2.333333	2.3333	2.3333	2.3333	2.3333	2.5	0	**40.16667**
Sum of column	**18.33333**	**20.33333**	**20**	**19**	**21.16**	**32.166**	**35.666**	**35.666**	**29.833**	**28.83333**	**34.666**	**34.333**	**34.5**	**31.5**	**31.833**	**31.83333**	

ii) The result of WSM from case study

Table I.3 Result of average matrix of WSM for re-architecting of the case study

Existing Departments / Managerial Criterion	Weigh for each criterion "a"	ED_{20}	ED_{19}	ED_{18}	ED_{17}	ED_{16}	ED_{15}	ED_{14}	ED_{13}	ED_{12}	ED_{11}	ED_{10}	ED_9	ED_8	ED_7	ED_6	ED_5	ED_4	ED_3	ED_2	ED_1
MR_1	60	12	4	30	26	32	28	30	0	4	4	4	0	0	12	0	0	0	0	0	0
MR_2	92	0	0	0	0	0	0	16	20	8	72	72	0	0	12	0	0	0	0	0	0
MR_3	90	28	2	0	0	16	0	36	38	38	4	4	0	0	4	0	0	0	0	0	0
MR_4	86	40	44	52	70	56	28	68	10	18	62	62	4	4	48	16	16	16	8	8	8
MR_5	46	54	50	92	96	68	46	20	52	54	52	52	52	52	64	84	84	84	50	52	52
MR_6	58	48	26	56	48	52	24	42	58	46	42	40	36	64	58	32	32	32	40	40	40
MR_7	58	52	16	52	52	24	44	20	24	20	44	44	28	36	8	8	8	8	44	16	16
MR_8	34	42	18	50	38	54	28	38	48	34	80	80	40	44	52	44	44	44	40	44	44
MR_9	54	50	32	68	56	52	60	40	32	28	34	34	44	48	20	36	36	36	50	44	44
MR_{10}	34	80	44	68	68	62	64	52	56	50	58	86	64	46	30	56	52	52	36	34	34
MR_{11}	82	22	6	34	34	34	16	20	16	12	24	24	16	16	68	8	8	8	20	12	12
MR_{12}	38	34	34	40	48	46	40	46	42	42	28	52	48	48	28	40	44	38	32	32	32

APPENDIX J

Approval letter of results from Bahonar hospital

بسمه تعالی

شماره: ۹۷/۱۰/۱۶ / ۳۵۰۴

تاریخ: ۹۷/ ۴/ ۱۱

پیوست:

وزارت بهداشت درمان و آموزش پزشکی
دانشگاه علوم پزشکی و خدمات بهداشتی درمانی استان کرمان
مرکز آموزشی درمانی شهید باهنر

دانشگاه Universiti Malaysia Pahang

باسلام و احترام

بدینوسیله گواهی می گردد که یک نسخه از نتایج کلی تحقیقات سرکار خانم دکتر یاسمن پارسیا در رابطه با الگوریتم ریاضی جهت کاهش نرخ عفونت بیمارستانی در زمینه اضافه یا کاهش بخشهای بیمارستانی تحویل مرکز آموزشی درمانی باهنر کرمان گردید.

دکتر پیمان کریم زاده کارنما
مدیر مرکز آموزشی درمانی شهید باهنر

رونوشت:

-خانم دکترپارسیا جهت استحضار

کرمان – خیابان شهید قرنی-کدپستی:۷۶۱۳۷۴۷۱۸۱
تلفن: ۲۲۳۵۰۱۱ نمابر: ۲۲۶۰۱۰۰سامانه پیامک : ۱۰۰۰۲۲۰۲
bh.kmu.ac.ir-bahonarh@kmu.ac.ir

APPENDIX K
Publications from this research

Parsia, Y., Shahryar, S., & Panjehpour. (2020). A method for finest ward selection for healthcare-facilities. *Quality- access to success*, Dec.

Parsia, Y., Shahryar, S., & Panjehpour. (2019). Infections risks of medical buildings: Perspectives investigation in a case study. *Indian journal of public health research and development*, *10*(12).

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Parsia, Y., & Puteri, F. (2018). Role of Healthcare-Facilities Layout Design, Healing Architecture, on Quality of Services. *International Journal of Civil Engineering and Technology*, *9*(4), 598-601.

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Parsia, Y., & Puteri, F. (2018). Solutions to Overcome Current MCDM Limitations, The 2nd IEOM European International Conference on Industrial Engineering and Operations Management, Paris, France, 415.

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Parsia, Y., Puteri, F., & Shahryar, S. (2017). A framework for hospital characterization. *Research Journal of Medical Sciences*, *11*(1), 46-48.