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Minimization of nosocomial infections risks by a decision algorithm for upgrading of healthcare facilities

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ABSTRACT

Background: Nosocomial infection (NI) increased the rate of mortality, morbidity and financial load for patients and Healthcare Facilities (HFs). Regarding to many advances in controlling NIs, it is still a worldwide problem. Layout of HF (department configuration) has a vital role in controlling NIs, because the pathogen microorganisms can transmit among departments. Some departments can transmit microorganisms much more than the other departments, called cause, and some of them received the microorganisms more than the others, called effect. Both are risky.
Objective: This study attempts to propose a comprehensive algorithm for selecting low risky department(s) for upgrading of HFs by use of Multiple Criteria Decision-Making (MCDM) methods.
Methodology: Among MCDM methods, this study has hybrid WSM and Expanded DEMATEL, beside modified Nominal Group Technique to minimize NIs risk in upgrading of HFs. The resulted decision-making algorithm is validated by implementing in a HF as a case study.
Results: The final proposed algorithm and the resulted low risky departments are approved by head and manager of the HF. Therefore, the algorithm is valid, and the feasibility of algorithm is approved by achieving the result from implementing of algorithm in the case study.
Conclusion: To conclude, the proposed algorithm can be a solution to minimize the risks of NIs, while upgrading, in each HFs and make the decision of HF's managers easier and logic.

Introduction

Despite the fact that healthcare facilities (HFs) are making efforts for controlling Nosocomial Infections (NIs), the NIs result in a significant mortality and morbidity rate, which increases the healthcare-associated costs and could cause an economic crisis [1]. 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 [2]. These infections are considered a hazard in this day and modern age of antibiotics [1,3,4].

Several researchers have shown an interest in investigating the effect of the HF environment on the health of the patients [5]. 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 [6–8]. Some studies have determined the relationship between the transmission of pathogens or spread of NIs and the layout structure of the hospitals [9–13]. The experiences of existing HF environment reveal their poor designs [14], the environment of the HFs is a reservoir of the nosocomial pathogens that could infect the patients during their HF stay [15,16].

These days, 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 [7]. According to Lateef [17], owing to the increased incidence of new and emerging NIs, along with the higher public awareness and expectations, the designing phase of the HF buildings should be paid attention. Even after the completion of the HF building project, the administrators must put into place a systematic plan for constantly modifying the HF infrastructure [17,18].

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 [19]. But, after initial completion of the HFs, a systematic and on-going approach can be adopted to modify, upgrade, the infrastructure [17,18]. An extensive search of the different lit-

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erature databases 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. Padgaonkar [20] mentioned, the prime focus while designing HF 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. However, the cross infection risks is less noticed.

This study tries to evaluate departments' relationship for cross-infection and transmission of NIs. It is essential to ensure that infection prevention is considered and implemented during the planning, designing, construction, and upgrading stages of all new builds to minimise the cross-infection risks that can be associated with the environment.

In upgrading processes, the facility will be expanded and number of departments will be increased [21], improving the primary HF layout, extension of existing HFs, or optimising the existing productivity of the HFs [22].

The upgrading cycle is divided in to four main phases, proposal, design, construction, and use [19]. In the proposal phase, as Sheth et al. [19] explained, 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 (DM) team is key actor in this phase. In 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 [23]. Hence, the objective of this study is to formulate a department selection algorithm for upgrading of HFs, with the ability to minimize the NI risks through upgrading of HFs.

Method

Decision-making and methods used for selecting the HF upgrading

Before upgrading the HFs, the DM decide if any appropriate departments have to be added. Thereafter, the departments that get added compete with the other department(s) based on the criteria defined by the decision maker. If there are multiple options to choose, the DM process must evaluate the different decision criteria for ensuring that the right alternative is selected [24]. In this study, before selecting the departments in the HFs, two criteria clusters were identified, the NI risk and the managerial criteria (like the society need, cost and etcetera). These criteria can differ according to the different HFs and their needs. The HFs are a complex organisation with multiple criteria.

Some HF departments can transmit microorganisms much more than the other departments, called cause, and some of them received the microorganisms more than the others, called effect. In this study, both cause and effect departments are called risky. The risky departments in the HFs are selected using Multiple Criteria Decision-Making (MCDM) techniques. Hence, for selecting the appropriate methods from the various MCDM methods, Gade and Osuri [25] and Parsia [26] suggested that some important aspects must be considered, which are as follows:

i. Generalised application domain;
ii. Ease-of-use;
iii. Consistent operation;
iv. Friendly user interface;
v. Time required;
vi. Robust application;
vii. Technical implementation;
viii. Accurate DM course results;

Hence, in this study, the researchers selected two MCDM methods, described below.

Weighted sum method (WSM)

The Weighted Sum Method is a broadly popular, widely known and practically used, and readily implemented subjective DM method [27,28]. Kumar and Suresh [29] 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 criteria, the determination of the diverse levels of all factors, and the determination of suitable scores for each level [29]. Sorooshian [28] agreed on x alternative (A) and the y decision criterion (C) sets, in that the method can be algorithmically delineated into five phases:

i. By focusing on the decided priorities for the criteria according to their importance in DM, 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. 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 Eq. (1).

$$WS(A_x) = (W_x.V_x) \quad (1)$$

i. Eq. (2) shows that for each alternative (A_x), the WS can be determined by summing up the respective resulting values.

$$WS(A_x) = \sum_{y}(WS(Ax)) \quad (2)$$

i. Finally by comparing the WS, the alternative featuring the highest WS is superior alternative in terms of selection.

Expanded DEMATEL

The expanded DEMATEL was initially presented in 2014 [30]. It facilitates researchers to establish the cause and effect alternatives in bidirectional relations in networks when the number of rows is not the same as the number of columns among different sets which consist of several alternatives [30].

Falatoonitoosi et al. [30] stated, as per the DEMATEL technique, when $i = j$, $[Ri]_{\times 1} = (\sum_{j=1}^{n} t_{ij})_{n\times 1}$ (total given effects by factor i) and $[Cj]_{1\times n} = (\sum_{i=1}^{n} t_{ij})_{n\times 1}$ (total given effects by factor j) and thus $(R - C)$ will be obtained. But when $i \neq j$ and elements in rows are distinct from components in columns, computing $(r_i - c_i)$ is not feasible [30]. 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 Eqs. (3)–(5) of Expanded DEMATEL in two different matrices.

In first matrix, R (the total effects, both indirect and direct) of cluster 1, based on Eq. (3), will be achieved.

$$\left[[R_i]_{i\times 1} = \left(\sum_{j=1}^{i'} t_{ii'} \right)_{i\times 1} \right]_x \tag{3}$$

In second matrix, C (total effects, indirect and direct, received) of cluster 1, based on Eq. (4), will be achieved.

$$\left[[C_i]_{1\times i} = \left(\sum_{i=1}^{i'} t_{ii'} \right)_{1\times i} \right]_x \tag{4}$$

Finally, the (R-C) will be achieved based on Eq. (5).

$$(R-C)_1 = R_1 - C_1 \tag{5}$$

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). Based on some researches, practically, the value of (R – C) is more effective and applicable than (R + C) alternatives prioritization. The component with the highest positive value of (R – C) can be named as the master dispatcher, in the cause group, and the component with the lowest value of (R – C), in the effect group, can be named as the master receiver [31–36].

Hybrid decision-making method for HF upgrading

Latest trend with regards to the use of MCDM method is to hybrid a few methods to make up for shortcomings in any single specific method [37–39]. Karami [40] suggested, decision-makers generally use more than one DM method to make important decisions. Zavadskas et al. [38] 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 DM. 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".

To develop algorithm, WSM-Expanded DEMATEL should be employed as a hybrid MCDM method for this study. Initially, WSM will be employed to identify the potential departments/alternatives which can be included in an existing HF depending on the managerial criteria. Next, Expanded DEMATEL could assess the bidirectional relations between various clusters of existing departments and potential departments, based on NIs risks, which can be included in the HF. The outcome of the Expanded DEMATEL is the recommended low-risky departments for HF upgrading which can be chosen from the potential list of upgrading.

Group decision making for HF upgrading

Usually, the Group Decision Making (GDM) 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 [41]. The outcome of multiple-criteria GDM is more precise compared to a single decision-maker [28]. This study proposes an integrated method of Hybrid MCDMs and GDM for the complex DMs of HF upgrading and stakeholders of this studies are HF manager, NI specialist, and modification decision makers. The Nominal Group Technique (NGT) is an adaptation of the brainstorming wherein the DM group suggests their decisions separately [28].

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 [42]. These scholars have their own viewpoints, knowledge, interests and etcetera which face a universal problem and attempting to arrive at a collective decision [43]. 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. To achieve feasible and valid results, it is very crucial to know how to give weight to these diverse clusters of experts 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 [44]. Thus, this research attempts to use a solution which was proposed recently [28]. It is recommended to nominate separate expert clusters with reference to the level of expertise of each committee. 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. The weightage of the opinions of each cluster is determined by the top decision maker(s) [28].

This research uses the NGT along with the approaching experts with unbalanced expertise; this is modified NGT [28], however, from now generally will be called NGT.

The process of new algorithm for upgrading of healthcare facility

Through an integration of above hybrid techniques for HF upgrading, this research suggests new DM algorithm in order to minimize the NI risks, as given below (illustrated in Fig. 1).

Step 1: Alternative (proposed departments to be added and the existing departments) identification by use of NGT.

Step 2: Managerial criteria identification by use of NGT.

Step 3: Computation based on WSM for potential departments to be added based on managerial criteria.

Step 4: To study interrelationships between alternatives (potential list and existing departments) by use of NGT.

Step 5: Computation by Expanded DEMATEL to select the best potential department based on NIs interrelationship between the departments.

Step 6: Final selection of the potential department for upgrading.

To assess validity of algorithm of this study by experts and feasibility and validity of algorithm by case study will be used.

Case study

The case study is a popular and valid method to test MCDM models [45] Zahidy, and it aims to settle some logistical concerns such as; verify that the instructions are clear and feasible, the quality of results and the analytical procedures to determine their efficacy.

After search and evaluate potential HFs to provide a practical validation of the proposed algorithm, a HF in Iran confirmed to cooperate and be as a case study of this research.

Characteristics of case study in this research

The HF for the case study of this research is established in 1949 and it is the only accidents and trauma HF in Kerman, a province in South-East Iran. Todays, it constitutes 20 diagnostic and therapeutic departments, tabulated in Table 1, with 400 beds and 1,400 medical staff and modern equipment run therapeutic services, student training, research and prevention plans. The HF is categorized as a large public HF with the objective of general education, which runs long-term and tertiary-level care system.

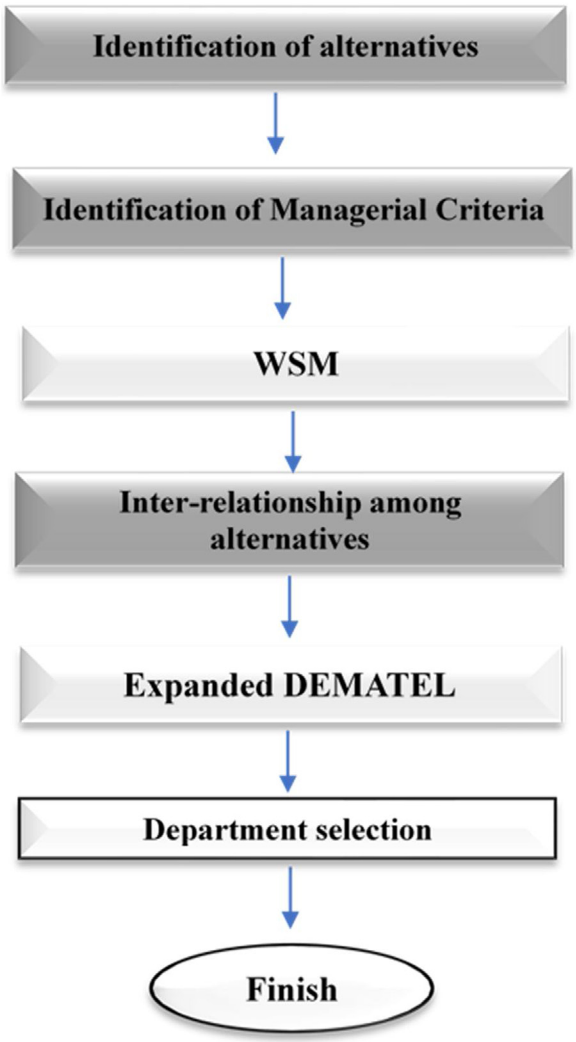

Fig. 1. Flowchart for upgrading a HF.

Table 1
The HF departments.

Name of departments	No.	Name of departments	No.
Haematology/Oncology 2	11	Neurology1	1
Jaw and face surgery	12	Neurology2	2
Urology	13	General Surgery	3
Internal surgery	14	ICU1	4
Emergency	15	ICU2	5
Laboratory	16	ICU3	6
CT scaning	17	CCU	7
Radiology	18	Orthopaedics (for men)	8
Pathology	19	Orthopaedics (for women)	9
Physiotherapy	20	Haematology/Oncology 1	10

In this study, in order to comprehend the transmission of infection to various HF departments, observation is run. The data collection process is run through close-ended interviews with management and infection control experts to determine and analyze the management and infection risk criteria as to select HF departments for upgrading. To run interviews, NGT method is applied and the data of every expert is ranked based on the unbalanced expertise method. The final data are applied to test the proposed HF upgrading algorithm.

Nomination of experts

In order to determine the experts to collect data, according to the management guidance, an interview is run with the research authority of the HF 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. Fourteen experts from the HF with positions tabulated in Table 2 are approved and they assigned ranks based on the correspondence of their expertise to the study case, unbalance expertise method. 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 HF head and manager. After obtaining the final approval, the experts are interviewed.

Results

In order to upgrade the HF, the processes of implementation of the algorithm are described in below subsections.

Management criteria and the departments proposed by the management group for upgrading the HF

Due to heavy workload and unavailability of mentioned experts, the data collection process is run in one month, in 2018, at the office of each expert. The duration of the interviews was 30–60 min.

Thirteen departments are proposed to upgrade the HF according to the interviews conducted with the management group. Then, after completing the criteria collection process, the overlapping data are identified and represented as one criterion. As to adding low risky department(s) in the HF, 15 managerial criteria, and 13 potential departments, shown in Table 3, are collected. The final lists are analyzed by experts during the interview to score the criteria, second meeting, and then all experts approved the lists.

Data collection for WSM matrix to determine potential departments for upgrading to the HF

The second meeting of interviews with management group of the HF is organized 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 (This data also is used for other article by the authors [46]). 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 and to weigh the management criteria, close-ended questions are asked. By considering the WSM method at the beginning of the interview, each expert is required to weigh each criterion from 0 to 100 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.

Analysis of WSM matrixes obtained from management experts to determine potential department for upgrading the HF

After collecting WSM matrices, by considering unbalance expertise method, the assigned rank of each expert is multiplied into the matrix obtained from him/her. Then, the matrix average of

Table 2
List of experts and their ranking based on unbalance expertise method.

Categorization of experts	Position	Duration of professional experience	Speciality	Ranking No.
Experts related to collecting management criteria	Head of the HF	12 years	PhD in Anesthesia and Fellowship Specialist of ICU	3
	Manager of the HF	15 years	PhD in Internal disease specialist	3
	The HF development committee coordinator	3 years	B.Sc in Engineering	2
	The HF quality improvement committee coordinator	7 years	M.Sc. of management	2
	The HF crisis and hazard committee authority	6 years	M.Sc. of management	2
	Research coordinator	4 years	M.Sc. of Nursing	1
	Training coordinator	4 years	B.Sc. of Nursing	1
Experts related to assessing infection risks	The HF infection expert and member of infection control	7 years	PhD in Infectious disease specialist	3
	The HF infection control coordinator	8 years	M.Sc. of Nursing	3
	The HF infection expert and member of infection control	5 years	PhD in Infectious disease specialist	3
	The HF infection expert and member of infection control	3 years	PhD in Infectious disease specialist	3
	The HF nursing head	11 years	M.Sc. of Nursing	2
	The HF quality improvement committee coordinator	7 years	M.Sc. of management	2
	Environment health coordinator	6 years	B.Sc. of environmental health	1

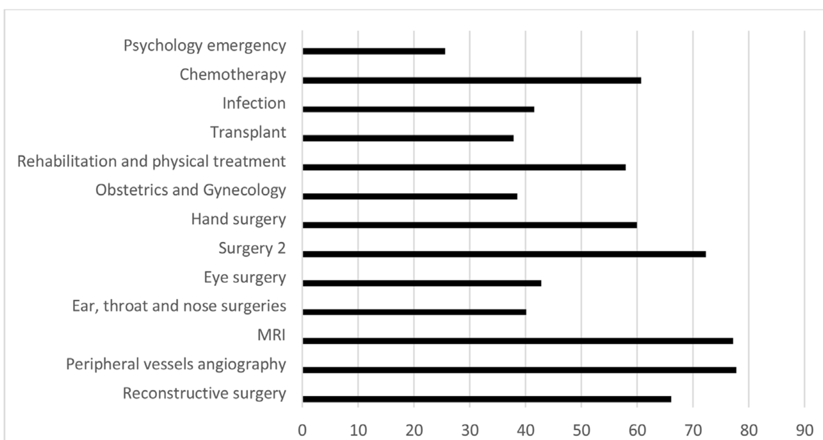

Fig. 2. Result of WSM matrix from managerial experts.

all collected matrices is obtained and applied to run the calculation through WSM method. 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 Fig. 2 and the higher ranks are presented as potential departments; Reconstructive surgery, Peripheral vessels angiography, MRI and Surgery 2; for upgrading the HF according to management experts.

Data collected infection control experts in the HF for upgrading based on infection risk criterion

In a series of meetings, interviews are run with infection control experts presented in Table 2. Experts are asked close-ended questions as to weight the criteria through Expanded DEMATEL method and matrices are collected after they have weighted by experts. Experts are required to assign rates to the potential departments to be added in first matrix, as to the extent of infection risk effect and infection transmission into existing departments, then in the second matrix 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. The rates are beginning from 0 = no effect to 1 = low effect, 2 = moderate effect, 3 = high effect, and 4 = very high effect.

Analysis of Expanded DEMATEL matrices obtained from infection control experts in the HF for upgrading based on infection risk criterion

The obtained ranks of each expert are multiplied into their matrix data, the matrix average is calculated, and the final matrix, total, is applied for further calculations. Because there exist two matrices in Expanded DEMATEL method.

Assessing potential department's infection risk on existing departments; and assessing existing departments' infection risk on the potential department.

According to Table 4, reconstructive surgery is cause. It means that, if this department add to the HF, it will have impact on the other factors higher than the they influence on it. Among other potential departments which are belonged to effect group, 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

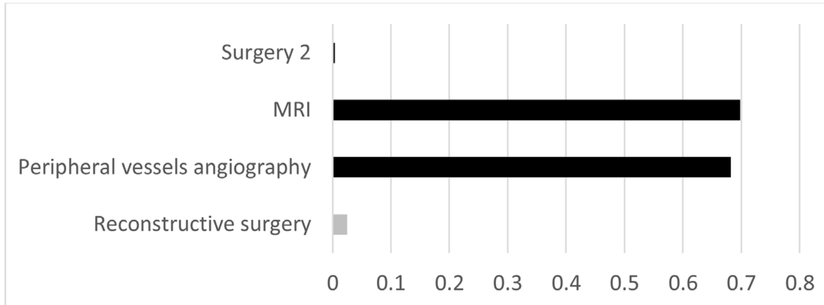

Fig. 3. Measurement of infection risk for potential departments of the HF based Expanded DEMATEL result.

Table 3
Potential departments and selection managerial criteria for upgrading to the HF.

Name of potential departments	Criteria
Peripheral vessels angiography	The possibility of obtaining approval and government permissions to establish a new department
MRI	Correspondence of the new department with hospital expertise and strategies
Ear, throat and nose surgeries	Presence of an expert (physician) with expertise corresponding to the new department
Eye surgery	Presence of appropriate personnel count (nurse, paramedic, etc.) to provide appropriate services
Reconstructive surgery	The high financial profitability of department
Transplant	Lowest expenses of equipment and establishment
Surgery 2	Lowest expenses of maintenance of the new department
Hand surgery	The demand for community and inpatients
Obstetrics and Gynecology	Availability of facilities, equipment and medication corresponding to the medical standards
Infection department	Correspondence of the new department with insurance laws
Chemotherapy	Appropriate infrastructure condition for establishing a department
Psychology emergency	Correspondence of construction conditions (architecture) of the new department with construction standards of hospital
Rehabilitation and physical treatment	Effectiveness as to training enhancement in order to improve the domestic rank of hospital-based on MOH measures
	Physical conditions required for establishing a new department
	Improvement of the treatment process and service provision in the existing departments after adding a new department

Table 4
Final analysis of Expanded DEMATEL.

	$R_{Potential}$	$C_{Potential}$	R-C
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

based on the result of Table 4 and Fig. 3, surgery 2 and reconstructive surgery are suggested for upgrading the HF. 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.

Conclusion

NI is not limited to be a local issue; it is a worldwide challenge [47]. HFs' managements and public health authorities around the world are trying to find the most cost-effective strategies and policies to prevent and control NIs [48]. According to Khan et al. [49], although attempts are made to control and prevent NIs, the struggle must continue.

Layout configuration of current HFs layout is mostly based on minimizing costs or the inclusion of technologies [50]. For the safety and health of the society and less NIs in HFs, it is necessary to have proper selection and organization of HF departments and right layout design [51]. 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 [19]. Although, department selection and layout configuration are very apparent in upgrading of HFs building context and the objective of controlling the NIs, not many researchers have worked on it. Drawing decision on HF modification is a complex task. There exists very few, if any, systematic DM model(s) in this respect, hence, this study, practically, is contributive in providing this type of model for HF modification in NIs control. In hybridizations, this study has the novelty of introducing WSM-Expanded DEMATEL (based on modified NGT) for the very first time. This is valuable, as Tzeng and Shen [52] explained that new hybrid MCDM, in addition to ranking or selection, are used to improve performance gaps of existing MCDMs and the corresponding aspects.

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Competing interests

None declared.

Ethical approval

Not required.

References

[1] Berket W, Hemalatha K, Getenet B, Wondwossen T, Solomon A, Zeynudi A, et al. Update on bacterial nosocomial infections. Eur Rev Med Pharmacol Sci 2012;16:1039–44.
[2] Behnke M, Hensen S, Leistner R, Diaz LA, Gropmann A, Sohr D, et al. Nosocomial infection and antibiotic use: a second national prevalence study in Germany. Dtsch Arztebl Int 2013;110(38):627.
[3] Kouchak F, Askarian M. Nosocomial infections: the definition criteria. Iran J Med Sci 2012;37(2):72–3.
[4] Mohammed M, et al. Nosocomial infections: an overview. Int Res J Pharm 2014;5(1):7–12.

[5] Elf M, Frost P, Lidahl G, Wijk H. Shared decision making in designing new healthcare environments—time to begin improving quality. BMC Health Serv Res 2015;15(1):114.
[6] Rao LCS. Designing hospital for better infection control: an experience. Med J Armed Forces India 2004;60(1):63–6.
[7] Stiller A, Schroder C, Gropmann A, Schwab F, Behnke M, Geffers C, et al. ICU ward design and nosocomial infection rates: a cross-sectional study in Germany. J Hosp Infect 2017;95(1):71–5.
[8] Clair JD, Colatrella S. Opening Pandora's (tool) Box: health care construction and associated risk for nosocomial infection. Infect Disorders Drug 2013;13(3):177–83.
[9] Chaudhury H, Mahmood A. Advantages and disadvantages of single-versus multiple-occupancy rooms in acute care environments. Environ Behav 2005;37(6):760–86.
[10] Dettenkofer M, Seegers S, Antes G, Motschall E. Does the architecture of hospital facilities influence nosocomial infection rates? A systematic review. Infect Control Hosp Epidemiol 2004;25(1):21–5.
[11] King MF. Modelling infection risk due to environmental contamination in hospital single and multi-bed ward accommodation, in school of civil engineering. University of Leeds; 2013. p. 312.
[12] Stiller A, Salm F, Bischoff P, Gastmeier P. Relationship between hospital ward design and healthcare-associated infection rates: a systematic review and meta-analysis. Antimicrob Resist Infect Control 2016;5(1):51.
[13] Ulrich RS, Zimring C, Zhu X. A review of the research literature on evidence-based healthcare design. Health Environ Res Design J 2008;1(3):61–125.
[14] Aripin S. 'Healing architecture': daylight in hospital design. Conference on Sustainable Building South East As 2007:173–81. Malaysia.
[15] Nyamogoba H, Obala AA. Nosocomial infections in developing countries: cost effective control and prevention. East Afr Med J 2002;79(8):435–41.
[16] Carr RF. Hospital; 2017, 04-06-2017.
[17] Lateef F. Hospital design for better infection control. J Emerg Trauma Shock 2009;2(3):175–9.
[18] Bogenstätter U. Prediction and optimization of life-cycle costs in early design. Build Res Inf 2000;28(5–6):376–86.
[19] Sheth AZ, Price ADF, Glass J. A framework for refurbishment of health facilities. In: HaCIRIC International Conference 2010. 2010.
[20] Padgaonkar AS. Modeling and analysis of the hospital facility layout problem. In: Department of industrial and manufacturing engineering. Faculty of New Jersey Institute of Technology; 2004.
[21] Health-Infrastructure-Branch. Architecture and health facility design. In: Queensland health capital infrastructure requirements. The State of Queensland: Queensland Health; 2013.
[22] Shikder SH, Price AD. Design and decision making to improve healthcare infrastructure. School of Civil and Building Engineering, Loughborough University (© Loughborough University); 2011.
[23] Latta J. Health building note 11: facilities for primary and community care services. The Department of Health's Delivering Same-Sex Accommodation (DSSA); 2009.
[24] Ansah RH, Sorooshian S, Mustafa SB. Analytic hierarchy process decision making algorithm. Glob J Pure Appl Math 2015;11(4):2403–10.
[25] Gade PK, Osuri M. Evaluation of multi criteria decision making methods for potential use in application security in electrical engineering. Blekinge Institute of Technology; 2014.
[26] Parsia Y. A procedure for minimization of nosocomial infections risk through upgrading and re-architecting of healthcare facilities. In: Industrial management. Universiti Malaysia Pahang (UMP); 2019.
[27] Chou SY, Chang YH, Shen CY. A fuzzy simple additive weighting system under group decision-making for facility location selection with objective/subjective attributes. Eur J Oper Res 2008;189(1):132–45.
[28] Sorooshian S. Group decision making with unbalanced expertise. J Phys Conf Ser 2018;1028(2018):1–7.
[29] Kumar SA, Suresh N. Operations management. New Age International; 2009.
[30] Falatoonitoosi E, Ahmed S, Sorooshian S. Expanded DEMATEL for determining cause and effect group in bidirectional relations. Sci World J 2014;2014.
[31] Seyed-Hosseini SM, Safaei N, Asgharpour MJ. Reprioritization of failures in a system failure mode an effect analysis by decision making trial and evaluation laboratory technique. Reliab Eng Syst Saf 2006;91(2006):872–81.
[32] Tsai W, Hsu J, Chen C, Lin W, Chen S. An integrated approach for selecting corporate social responsibility programa and costs evaluatin in the international tourist hotel. Int J Hosp Manag 2010;29(2010):385–96.
[33] Tsai W, Hsu J. Coporate social responsibility programs choice and costs assessment in the airline industry—a hybrid model. J Air Transp Manag 2008;14(2008):188–96.
[34] Agustina KA. Coporate social responsibility program selection in hotel business-a case study of East java province, indonasia. In: Department of tourist management. Chinese Culture University; 2013.
[35] Sheryani Y. Project management leadership progression: a conceptual framework for Abu Dhabi. In: School of the built environment. Salford, UK: University of Salford; 2015.
[36] Savara V. A TQM based assessment framework for blended learning environment in higher education sector in school of the built environment. University of Salford; 2015.
[37] Velasquez M, Hester PT. An analysis of multi-criteria decision making methods. Int J Oper Res 2013;10(2):56–66.
[38] Zavadskas EK, Govindan K, Antucheviciene J, Turskis Z. Hybrid multiple criteria decision-making methods: a review of applications for sustainability issues. Ekonomska istraživanja 2016;29(1):857–87.
[39] Mardani A, Jusoh A, Kh. Nor, Khalifah Z, Zakwan N, Valipour A. Multiple criteria decision-making techniques and their applications–a review of the literature from 2000 to 2014. Econ Res Istraživanja 2015;28(1):516–71.
[40] Karami A. Utilization and comparison of multi attribute decision making techniques to rank bayesian network options. University of Skövde; 2011.
[41] Rekhav VS, Muccini H. A study on group decision-making in software architecture. IEEE/IFIP Conference on Software Architecture 2014. IEEE.
[42] Kamis NH, Chiclana F, Levesley J. Preference similarity network structural equivalence clustering based consensus group decision making model. Appl Soft Comput 2017.
[43] Bilbao-Terol A, Jiménez M, Arenas-Parra M. A group decision making model based on goal programming with fuzzy hierarchy: an application to regional forest planning. Ann Oper Res 2016;245(1–2):137–62.
[44] Xia C, Fan ZP. Study on assessment level of experts based on difference preference information. Syst Eng Theory Pract 2007;27(2):27–35.
[45] Dehe B, Bamford D. Development, test and comparison of two Multiple Criteria Decision Analysis (MCDA) models: a case of healthcare infrastructure location. Expert Syst Appl 2015;42(19):6717–27.
[46] Parsia Y, Sorooshian S, Panjehpour. A method for finest ward selection for healthcare-facilities. Qual AccSuc 2020;21(179).
[47] Parsia Y, Puteri FMT, Sorooshian S. Microbial troubles of hospitalization. Int J Pharm Technol 2017;9(1):28447–50.
[48] Meng Y. Application of agent-based simulation to the modelling and management of hospital-acquired infections in warwick business school. University of Warwick; 2009.
[49] Khan HA, Baig FK, Mehboob R. Nosocomial infections: epidemiology, prevention, control and surveillance. Asian Pac J Trop Biomed 2017;7(5):478–82.
[50] Van Enk RA. Modern hospital design for infection control. In: Healthcare design magazine; 2006. Michigan.
[51] Hussain M, Babalghith AO. Quality of hospital design in healthcare industry: history, benefits and future prospect. Impact: Int J Res Appl Nat Soc Sci 2014;2(5):61–8.
[52] Tzeng G, Shen K. New concepts and trends of hybrid multiple criteria decision making. 1 ed. CRC Press-Taylor and Francis Group; 2017.