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Estimating Bed Requirements for Emergency Wards of Qazvin Teaching Hospitals by 2021: Dynamic Systems Modeling

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ABSTRACT

Background: The provision of manpower is one of the effective factors on the improvement in the coverage of health services and the realization of the highest community health level and a considerable part of the health budget is devoted to the production and update on human resources. Therefore, the current study aimed to estimate the number of nurses required in the Emergency Department (ED) of Imam Ali hospital based on the proposed method of the World Health Organization, in which the manpower is calculated based on the workload Workload Indicators of Staffing Need (WISN).

Methods: This was a cross-sectional descriptive study. The study population was all the nurses working in the emergency department of Imam Ali hospital affiliated by Alborz University of Medical Sciences and their duties in the hospital which was performed using the proposed method of the World Health Organization i.e. WISN in 2018. Determination of their duties and the time and number of times for performing them were carried out during the group discussion session through Delphi method.

Results: Based on the research findings, 40 standard nurses were calculated. The studied hospital had 4 nursing staff shortages. The working pressure ratio is 0.91in this study.

Conclusion: In the current study, the nursing staff shortage is observed and this shortage caused a high working pressure on the nurses working in the study area. Considering the vital role of nurses in the emergency department, it is recommended to employ and distribute the manpower based on the requirement and workload in the department.

Key Words: Nurse, Workload, Emergency Department

Citation

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Introduction

Inadequate or inappropriate distribution of hospital beds leads to the inappropriate distribution of all medical equipment and human resource, resulting in inadequate quality of service and health care, long waiting times for patients and clients, and ultimately reduced community trust in the health system services. The high cost of creating and equipping hospital beds along with the time-consuming process of building and establishing a hospital will require careful need analysis and planning of the optimal number of beds for the coming years (1, 2). Proper utilization of these beds will require careful needs analysis over the coming years to ensure that these resources are appropriated and allocated according to the actual need that exists and that they follow scientific and rational principles for appropriate planning (2-4).Obviously, structures designed to respond to health issues in the past are not well suited to meet present needs and certainly future needs, soproper planning and exploitation of costly facilities in this area will require future planning for creating resources to provide health services more effectively and efficiently. This is why in many cases a significant number of beds are left unused due to lack of proper planning and management (5, 6).

It is estimated that the creation of any hospital bed would cost the government between 200 and 600 million Tomans between 2011 to 2015, depending on the type of bed, the type of hospital, and the geographic area. The heavy cost of creating and equipping hospital beds, along with the time-consuming process of building and establishing a hospital, necessitates the careful planning of the optimal number of beds for the coming years. Proper exploitation of these beds will require careful needs assessment over the coming years to ensure that these resources are appropriated and allocated according to the actual existing needs and that they follow scientific and rational principles for appropriate planning (7, 8). The emergency department is known as one of the most complex and sensitive units in the hospital that requires a great deal of coordination in terms of human and material resources. In other words, resource planning is one of the most challenging issues in the field of hospital management. On one hand, the reason can be attributed to the provision of specialized diagnostic and therapeutic services in this sector, and on the other hand, it can be attributed to the high levels of crowdedness and referrals to this sector which emphasized the problems of the emergency department and the necessity of providing its resources appropriately and consistently (7, 8). In recent years, there has been a great deal of research on emergency planning resources, most of which has focused on planning the number of physicians in the emergency department, while the number of beds needed and the need to estimate them is also of great importance to the population covered, and how this decision is made has a significant impact on both the quality of hospital care services and the efficiency of service delivery systems (9-13).In recent years, extensive efforts have been made to design new and comprehensive models to determine optimal hospital bed numbers and a variety of approaches have been used to model and evaluate hospital beds. Some of these approaches include the use of regression modeling, ideal planning model, Poisson flat occupancy model, and simulation models. Meanwhile, simulation models can take into consideration different scenarios for decision making. In other words, a simulation is an appropriate tool for evidence-based decision making in complex, dynamic and changing systems such as the health system, through which an effective, evidence-based solution can provide the appropriate solution to the current situation (14-16).

In the present study, due to the numerous problems caused by the imbalance in the supply of hospital beds in emergency departments, it is decided to conduct a study to estimate the number of beds required in the emergency department of teaching and therapeutic hospital depending on Qazvin University of Medical Sciences by 2021 using dynamic systems modeling.

Materials and Methods

The purpose of this study is to apply simulation modeling using dynamic systems. The research

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setting was the emergency department of Qazvin University of Medical Sciences. The university has 6 teaching hospitals, all of which have active emergency departments and a total of 110 emergency beds with occupancy rates above 80%. In relation to the present study, the sources of information used include Qazvin University of Medical Sciences databases, monthly and annual emergency department reports of the studied hospitals and recorded statistics and information on emergency department performance indicators including mean time assignment of the patients under 6 hours and the average time of patients leaving the emergency department under 12 hours which are recorded in the Quality Improvement Office of these centers as well as additional information recorded in the HIS system of hospitals.Before referring to these sources for data collection, the researcher first reviewed the literature and similar studies on a set of factors affecting demand for hospital emergency department beds in local and foreign databases including SID, IranMedex, Google Scholar, PubMed, and Scopus using keywords such as influencing factors, demand, emergency department, length of stay, and Persian terms including effective factors, demand, emergency department, hospital, bed occupancy and the patient length of stay to get a comprehensive list of factors affecting the number of beds needed which were identified and summarized in various studies and to provide a basis for modeling the dynamic system.After adjusting the list of factors, five professors of health management and policymaking in the health sector were discussed and their views on the relevance and importance of these factors were obtained and applied to the initial list. In this regard, each of the experts was asked to rate the factors identified in the literature review stage on a scale of 1 to 5 on each relevance and importance index. Then, after obtaining all the experts' opinions and summing up the scores, 18 of the top priority were selected and entered the data collection stage of the study.The list was then used by the researcher as a data collection checklist and as a tool for gathering research information. Also, since the modeling criterion is to obtain the required data for at least five years before the start of the study, this checklist has the capability of recording data for each year from 2011 to 2015.At this stage, considering the set of final factors for modeling and the data obtained from them, the possible relationships between the variables in the form of a stock and flow diagram in the Vensim software environment are used to model the dynamical system (17).

The researchers also used a dynamic hypothesis that sought to define the problem to plot the cause-and-effect diagrams of the variables. The research methodology in the first phase of the study consists of the problem definition, hypothesis making, modeling, and validation steps. In other words, the modeling steps in system dynamics analysis are as follows.

- Identification and defining the problem
- Drawing reference charts
- Defining the major variables in the problem
- Defining the relationship between variables
- Drawing cause-and-effect diagrams between variables
- Defining model boundaries
- Building flow-repository charts for models
- Model implementation
- Model validation

After identifying the problem, defining the problem variables, determining the relationship between them and plotting the cause and effect diagram, the researcher drew the stock and flow reference figures. This diagram, as a pattern of the behavioral model, helps to validate the model on one hand, and on the other hand, by recognizing the behavioral pattern of important variables and some accumulations, it could be effective in the process of modeling and selecting variables.The period chosen to evaluate the trend of change in variables was also selected by the researcher for 5 years. Variables for which reference charts are plotted include mean bed occupancy time, usability of current beds, bed return interval, mean age of referral population, bed distribution among different medical specialties, type of hospital, geographical area covered, waiting time for the

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patient, hospital budget, population growth rate, number of dispatches, and emergency department performance indicators.These variables were first determined through literature review and library review and were used as a baseline for studying experts' opinions, including two faculty members of the Department of Health Services Management, two members of executive staff of the Qazvin University of Medical Sciences and an expert from the Ministry of Health and Medical Education, and their opinion were used to assess the importance and necessity of the variables and to add or modify them.Literature review and research background, as well as expert opinions, were used to extract major variables affecting the demand for emergency beds and to determine the relationships between them. Also, at this stage, the researcher, based on the casual loop system of 5 and by the cause-and-effect relationship of the reference behaviors to each other, found out why and how each variable behaved and then completed the relationships among the variables (17).

Then the mathematical relationships in the diagram were made by differential equations which were solved numerically by simulation in the Vensim software. After determining the mathematical relationships in the model and writing the functions and its equations, it was time to run the model. Finally, the model's validity and reliability were tested using a model behavior test. Furthermore, study data was collected from hospitals and curative deputy after receiving the ethical code from ethics committee of Qazvin University of Medical Sciences. This study is the result of a research project with the code of ethics IR.QUMS.REC.1396.268, which has been presented as a thesis in the field of health service management in Qazvin University of Medical Sciences.

Results

The variables of the present study were collected through library studies, review of emergency department reports, and interviews with experts, which have been shown as a cause-and-effect diagram concerning the research problem (18-34). After reviewing the data collection environment and sometimes due to insufficient data in the study period on some of these variables, some of them were removed or replaced by experts as shown in Table 1.

The cause-and-effect diagram of the variables affecting the estimation of beds in the emergency department is illustrated in Figure 1.

As illustrated in Figure 1, hospital goals influence management performance and this factor affect hospital performance indicators. For example, the status of these performance indicators impacts the average patient waiting time and shapes patients' experience of the services and care provided at these centers. In other words, the patient's waiting time is one of the factors affecting his or her satisfaction and the experience he or she receives from the hospital. Here is the accumulation-flow diagram of the research problem.

In this chart, the number of beds needed is considered as a state variable that uses the rate variable of the number of people admitted to the hospital who need to be admitted to the emergency department. The community health variable is also the rate variable for the variable number of clients requiring hospitalization. In this form, the positive/negative sign on each bow indicates an increase or decrease in the relationship between the two variables. The positive sign indicates that the increase in one variable causes the increase in the other variable, while the negative sign indicates that the increase in one variable causes a decrease in the other variable. For example, the higher the budget allocated to the hospital is, the higher the cost will be allocated to the implementation or development of hospital beds, including emergency beds, which can be an effective factor in estimating the number of beds needed in the emergency department. Slow. On the other hand, the number of patients sent to the hospital is directly related to the need for a temporary hospitalized bed to provide emergency services and care for patients and clients.

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Model structure validation

A) Border adequacy test

The question to be considered in the boundary adequacy test is whether all important concepts related to the problem are included in the model. The proposed model of this research has been done based on literature review, investigating each hospital's documents and interviews with experts and all key variables of the model have been reviewed, removed or added and confirmed by their importance in influencing the number of beds needed to enter the model. Also, the importance and the necessity of all the defined variables have been discussed in meetings with the experts that the variables within the model are the result of the final confirmed variables.Another question of the border adequacy test is whether the behavior of the model changes dramatically after deleting the boundary assumptions. To check this case, some variables must be eliminated and the model conditions checked in their absence. Figure 2 illustrates the impact of eliminating the "hospital budget" factor. This factor affects the cost of buying a bed. One of the determinants of the number of beds that can be assigned to each ward is the hospital funding and the higher levels of licensing given to that hospital by the Department of Health and the Ministry of Health. If the hospital needs more beds but the hospital budget does not allow, as well as other funding sources were unable to cooperate, the new bed allocation plan will fail even when needed. On the other hand, the hospital, considering this set of factors, decides whether it wants to maintain or repair the existing bed, which will also affect the number of beds to be provided.As the figure above shows, removing the budget from the system harms the system. The lack of funding, which is one of the main factors needed to create a new bed, can discourage the hospital from doing so.

Figure 3 illustrates the effect of removing the "Hospital Emergency Performance" factor. Not paying attention to the performance of this section and thus not attempting to improve it can have a significant negative impact.

The performance indicators of the emergency department of the hospitals under study have a direct impact on patients' experience and their waiting time. These indices also affect many processes and consequence indices, and can ultimately be a manifestation of bed shortage or overgrowth. These indicators also determine the type of department personnel performance and equipment performance, the efficiency of utilizing the department's facilities, and indicate whether proper planning is occurring or not. Consequently, with the improvement of performance indicators, there is also an expectation for improvement in the overall performance indicators of the hospital, including internal indicators such as the number of beds in different departments.

B) Structure Evaluation Test

The purpose of the structure evaluation test is to check the conformity of the model structure with the knowledge of the system and determine the rationality of the decision-making rules in shaping the behavior of the variables and the correct structure of the model equations. In this model, if there is an increase in the number of hospital visits, an increase in the number of emergency room admissions will occur, which will consequently require more beds to meetthis demand. This increase, in turn, will affect other parts of the hospital, including inpatient rooms, operating rooms, and intensive care units, and will change the planning for proper allocation of resources to these units. Since the model equations in this study are written in the Vensim software environment, the correctness of the model equations structure was verified by the software.

C) Sensitivity analysis test

After simulating and observing the behavior of all the variables and model components in the aforementioned interval, the sensitivity analysis test examines whether the change in the different model variables affects the main variable which is the number of beds required or not. In this section, with the change in bed management factor, the effect on overall hospital performance is examined, and the corresponding results are shown in Figure 4.

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Based on Figure 4, the effect of poor management and, consequently, the poor performance of emergency department performance indicators initially did not show a significant effect. However, from a specific point of time, the malfunction in the management has shown a significant effect and the system has been experiencing a decline in performance. Improper planning and exploitation of the human resource, equipment and facilities are part of the mismanagement that will cause serious problems for the system.

Scenario building

Among the study variables, some of them such as patients' assignment promptly or making appropriate decisions regarding bed management, were considered as scenarios and their effects on the final model were measured.

In Figure 5, five scenarios are plotted (based on the scenarios in Table 2). Considering the above-mentioned contents and the identified compounds for each scenario, scenario 3 was selected with 120. Higher or lower of this number, considering the available space in the emergency department of the hospitals under investigation, and regarding the potential for growth and improvement of service delivery and thus increase hospital productivity, indicated the fact that long-term profitability will not be provided.

Table 1. Factors affecting the number of beds needed in emergency departments

Row	Variable	Definition
1	Average bed occupancy time	The average length of time a bed occupies with a patient
2	Usability of the current bed	To what extent beds available inward are usable and to what extent they are outdated and worn (unusable)
3	Bed fee	The cost of setting up a bed for the investor
4	Bed return interval	The period that the bed is occupied for the hospitalization of one patient until it is provided for the subsequent hospitalization of another patient
5	Emergency department performance indicators	Percentage of assigned patients within 6 hours, Percentage of patients discharged from hospital emergency within 12 hours, Mean duration of triage at each level
6	The population covered by each hospital	The number of people covered by each hospital according to the defined geographic area
7	Hospital diagnostic and paraclinica lfacilities	These are services such as laboratory services, radiology, etc., which require the patient to be hospitalized to do them
8	Type of hospital	The type of hospital is considered as public or specialized
9	Patient waiting time	Due to the lack of an empty bed, the patient has to wait until the bed becomes empty and ready for the patient's hospitalization
10	Population growth rate	Percentage increase in Qazvin population covered by the studied hospitals during the study years
11	Average inpatient admissions in hospital emergency departments understudy	The average number of patients admitted to the emergency department of each hospital studied
12	Number of dispatches	The number of patients being transferred to another hospital for any reason
13	Hospital budget	The number of funds allocated to the hospital
14	Population health rate	Status of health indicators in the region
15	Patient experience	Patient satisfaction or dissatisfaction with hospital services
16	Average population age	The mean age of population referred to hospital emergency department
17	Bed distribution among medical specialties	The status of hospital beds regarding the medical specialties

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Table 2. Impact Factor Research Scenarios

Variable	Scenario 1	Scenario2	Scenario 3	Scenario 4	Scenario 5
Usability of the current bed	0.7	0.8	1	0.9	0.7
Bed fee	600	500	545	570	585
Emergency performance	0.9	0.9	0.87	0.87	0.9
Patient waiting time	3	0	0	1	2
Bed management	1	3	2	2	1

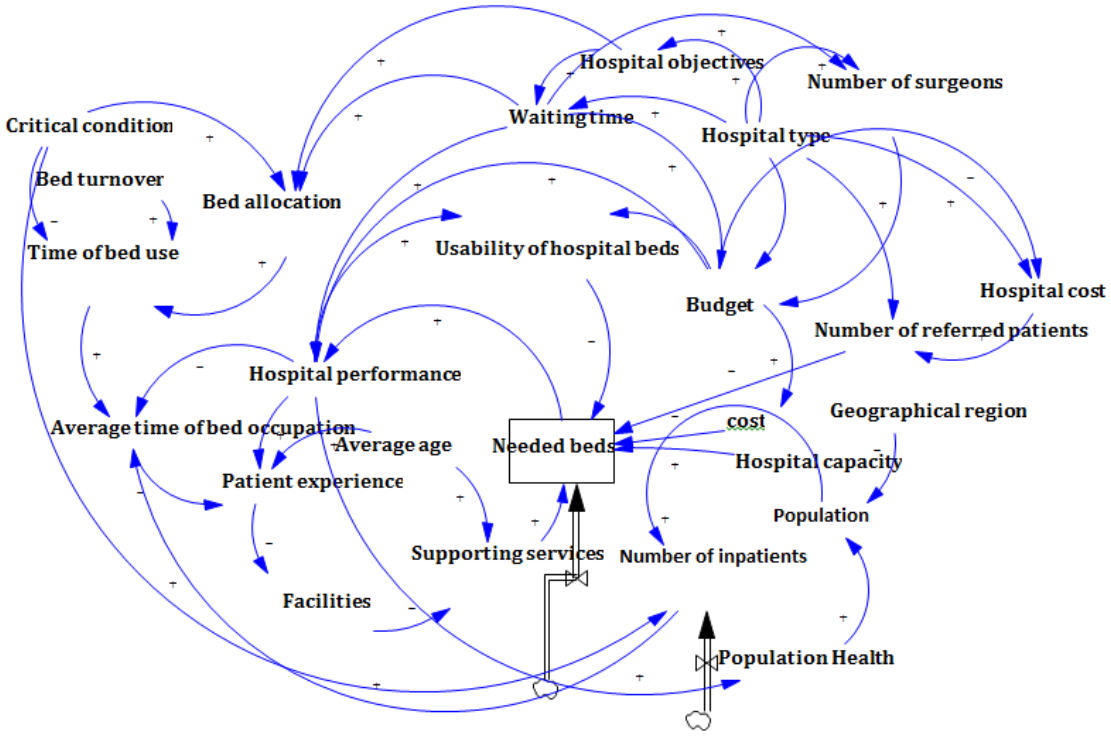


Figure 1. Diagram of the cause and effect of the research problem

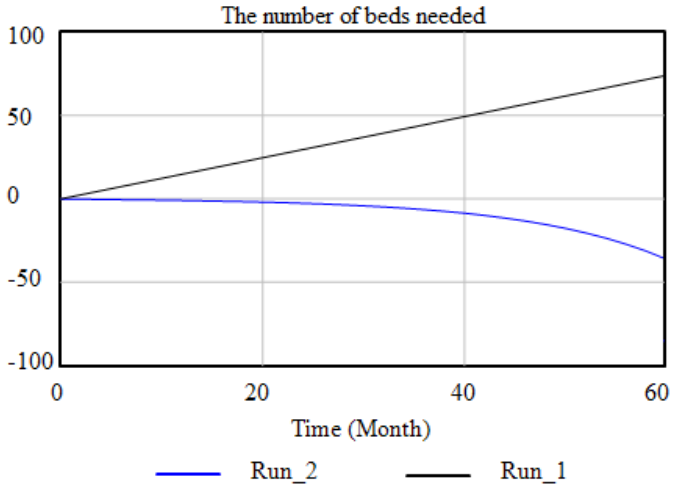


Figure 2. Impact diagram of budget agent removal

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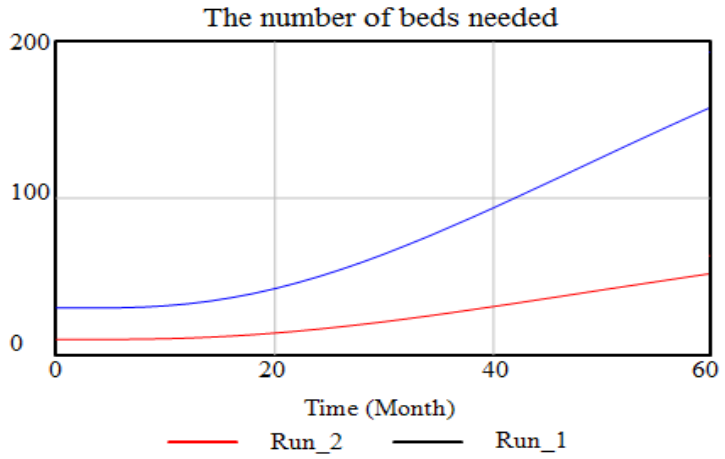


Figure 3. Impact of hospital emergency performance factor elimination

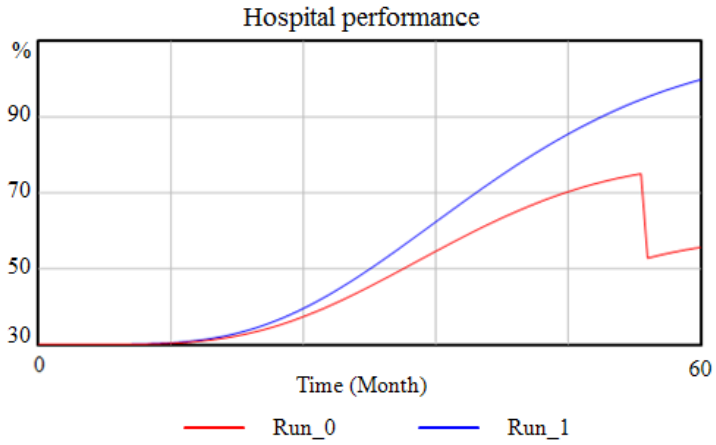


Figure 4. Analysis of hospital performance sensitivity to changes in bed management index

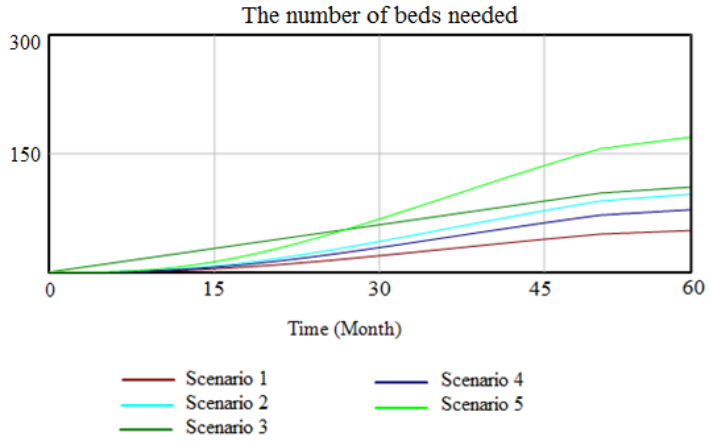


Figure 5. Scenarios tested in the present study

Discussion

In this study, in order to determine the number of beds needed in emergency departments of teaching hospitals in Qazvin by 2021, a scientific and systematic method in line with the up-to-date evidence obtained from other studies and

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researcheswith the same aim done at successful countries in the field of health system and resource estimation has been used. In the present study, the findings of the study indicate the influence of factors such as population of the area covered, patients admitted to different triage levels, patients admitted to the emergency department, patients' waiting time to receive clinical and care services in this ward, management style, a set of emergency department performance indicators, the type of hospital (public or specialized) and the rate of transfer of emergency patients to other parts of the hospital or outpatient dispatches that were included in the modeling. Then, the five different scenarios put forward by the experts were examined as a set of available strategies, and the results showed that it is important to maintain the number of existing beds and improve their usability and their management. Some of the most significant factors include average bed occupancy in the emergency department, usability of current beds, cost of setting up and equipping each bed, bed turnover time, patient waiting time, emergency department performance indicators, number of dispatches to other hospitals and emergency department visits which were all identified as factors affecting the number of beds needed in the emergency department and were recognized at the modeling stage. In a study carried out by Torabipour et al., with the aim of planning to determine the capacity of hospital emergency beds, factors such as length of stay, admission rate, and discharge rate were investigated that was much more limited than the present study, and in other words, the problem of estimating beds has not been looked at in a multi-aspectapproach. In their study, only the use of emergency department services was discussed, with emphasis on patient referral rates and emergency admissions followed by the number of days stayed in the ward (14). Furthermore, in a study conducted by Haghdoost et al, (2015), as the treatment document of Kerman province, calculating the number of beds needed that can be supplied was considered as a function area of two main variables including economic conditions of the area and burden status of the illnesses of the area and for modeling, factors such as bed occupancy rate, the exploitation of the population from bed, average length of stay in hospital was taken into account (15). Compared to these studies, the present study has taken a more comprehensive approach,in a way that bedside considering the index of using emergency services and average length of stay of patients in the emergency room, other factors such as average bed occupancy in the emergency department,usability of the current bed, patient waiting times, compliance with time standards for assignment under 6 hours, and physical departure of patients under 12 hours and referral to emergency departments were also taken into consideration (16). In another study carried out by Babaei et al. (2001), the main variables studied included the number of hospital admissions and the number of beds per day and month, which again emphasized the use of emergency department services and hospital beds existed which did not have the universality of the selective approach (18). Studies conducted with similar purposes in other countries have also identified several effective factors based on which, appropriate estimates have been made. For instance, Starman and Spaman studied the impact of demographic, socioeconomic, and economic characteristics on hospital beds throughout the United States and sought to examine the impact of each of these groups on hospital beds by adopting a holistic approach. (19). Moreover, in a study done by Bogust et al. average patient length of stay and number of admissions were among the factors influencing the demand for hospital beds (20). Similarly, a similar study conducted by Kumar and Mo in Singapore showed that to estimate the number of beds needed and allocate the desired number to the population, length of stay in the emergency department, and data from patient admission rates are among effective factors. In other words, paying attention to these factors and engaging them in making estimations has benefited uswith easier obtaining information about them and can be more effectively monitored and evaluated over time (21).However, an estimate is highly reliable when it comes to a multifaceted

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approach at the issue of determining the resources needed for the health sector, in a way that in addition to the extent of using health care services or resources in the health sector, it could consider the health needs of the target community, the characteristics of the target community in terms of age and sex pattern, the types of diseases predominant in them, the type of hospital policies and management practices in the hospital (21-25).

As stated above, the present study sought to use the dynamic systems simulation model to estimate the number of beds available in the emergency departmentto benefit university managers and authorities making decisions about resource allocation and annual budgeting practices in emergency departments of 5 hospitals under study by2021. According to the set of scenarios presented in the findings section and using the optimal combination of the variables identified in the study, the results showed that the effective use of the existing equipment in the way that they can be utilized appropriately alongside the approved hospital beds, and also rational planning to improve emergency department performance indicators, such as assigning patients under 6 hours and leaving them physically under 12 hours, using existing beds appropriately to reduce the unrealistic need for costly hospital resources including hospital beds and proper bed management so that the admitted patients who have a real need for emergency care and temporary hospitalization services are all among the factors which require serious thought in this regard.

Various studies have been conducted concerning the estimation of the number of hospital beds which all have provided feasible findings (26). Similar research has been conducted in the country or abroad, using other methods for estimating hospital beds. The reason for the more limited application of dynamic systems modeling in the field of health care can be attributed to the relative complexity of the model and the lack of sufficient expertise in this field to make scientific estimates, due to the fact that it was first started in the industry and was mostly used in the industry. As the advantages mentioned for this method include the possibility of considering a diverse set of variables together in a model as well as considering the dynamics of these variables over time, it could be applicable in the country health estimations and can yield profitable results for the policymakers and decision-makers in this field (27).

In general, various studies have shown that in each region, depending on the conditions and the set of policies governing the health care service center, sometimes the required action to achieve the standard level in terms of optimal bed numbers is reducing the number of beds or sometimes it is increasing the number of beds or it is even maintaining the existing beds. But what is needed in all circumstances is proper planning for all health resources, especially hospital resources and hospital beds, in which a significant amount of funding is allocated to them (28, 29). Concerning the present study, the results showed that there is a gap between supply and demand in the number of hospital emergency beds. Considering this gap is especially important in times of crisis. Patients' waiting line and lack of satisfaction with the services received due to delays all indicate that there is a problem in responding to patients because of imbalances in supply and demand in the number of beds available. All of this requires scientific and evidence-based managerial thinking to effectively address existing weaknesses. In this regard, several studies have been carried out within the country, each of which has suggested strategies for optimal utilization of hospital resources, especially inpatient beds (30-34).

In this regard, using scientific tools and methods such as computer modeling and simulation along with taking into account a set of factors that can affect the estimation of the number of beds needed, including those in the hospital emergency department, make a fact-based assessment in the software which helps in practical, effective decision-making and prevents many adverse effects that ultimately lead to a decline in community health (21).

One of the strengths of this study is the application of a dynamic and systematic method of

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estimating the number of beds needed in the emergency department that can provide close-to-reality estimations by considering a set of variables simultaneously and considering their changes over time. However, the limitation of this method is that it is necessary to have the correct data for each of the variables in the time frame defined in the research to achieve accurate estimates. However, in some cases, this was not entirely possible and the research team decided to remove those variables or in some cases estimate their data in years that no accurate information was recorded.

Conclusion

Given the improvement in the performance indicators of the emergency department of the hospitals studied and the reduction of patients' waiting time in these units, fewer beds will be needed by the end of 2021. This highlights the need for special attention to the issue of principle-based planning and scientific methods. Making such decisions, in which the importance of several factors are taken into account and interferes with the estimates, will result in the effective allocation of hospital beds.In other words, establishing hospital beds does not necessarily mean efficiency and improvement of the level of health of the community, so the researcher's suggestion, based on the findings, would be using the existing resources rationally and practically with a health-centered approach rather than a disease-centered approach, following the rule of the referral and grading system of services, strengthening the first level of health care services and estimating the actual health needs of the population which are crucial for deciding whether to build and operate hospital beds.

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Conflict of interests

The authors declare no conflict of interests concerning the present study.

Authors' contributions

Rafiei S designed research; Shakuna M collected and analyzed data; and Rafiei S wrote manuscript. All authors read and approved the final manuscript.

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