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Research Article

Hospital cost reduction modeling thorough scenario planning in system dynamics

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Abstract
Background and objectives: Hospital costs as part of the in-hospital cash flow are affected by a large number of variables that change over time and interact with each other. This study aimed to provide a model for hospital costs based on the internal behavior of the system in order to control costs.
Methods: The research method of the paper is descriptive-analytical. Considering the complex and dynamic nature of the system, a model was designed and presented using the system dynamics approach. Data were collected using interview methods and reviewing past studies. To run the proposed model the computer software (Vensim DSS 6.4E) was employed. After testing the model, six scenarios were defined based on the presented model and its subsystems (financial flow, patient flow and employed nurses) to reduce costs, which include: reducing the average length of stay, increasing the staff productivity, reducing the intensity of hospital care, reducing clothing consumption, modifying the hospital nutrition process and finally the simultaneous implementation of all the above. This system dynamics model integrates all of these subsystem's effects rather than considering them individually which is the strength of system dynamics modeling.
Results: The first scenario, while reducing the total cost by 3.8%, increased the bed admission ratio by 6.5%. It should be noted that this scenario increased the hoteling cost by 2%. The second scenario resulted in a 10% reduction in total cost. The third scenario saved 9% of the total cost. The fourth and fifth scenarios reduced costs 1.5% and 7.5%, respectively by reducing overhead costs. The results showed that the sixth scenario is the most effective policy. It reduced the total cost and the hoteling cost by 26% and 22%, respectively.
Conclusion: Findings indicate that the hospital will face a reduction in cost compared to the current situation by using any of the scenarios but it will see a further reduction with the simultaneous implementation of the scenarios while controlling the cost of hoteling. Based on the results any development in surgery department capacity must be accompanied by a suitable cost control policy.
Keywords: Hospital Administration, Hospital Costs, Cost Control, System Dynamics Analysis

Background and objectives

Nowadays, the health system is globally one of the largest and most important parts of the economy and service. Almost 50-80% of the health sector's total budget and a large share of the educated and expert workforce have been allocated to the hospitals[1]. Hospitals accounted for the highest proportion (36.4 %) of healthcare expenditure in 2019 in the EU[2] and the United States spent $3,795.4 billion on health care in 2019 which 31.4 percent assigned to hospital care[3]. Many studies have examined hospital costs from different aspects and identified the factors affecting it. The cost scope of researches conducted in this field can be divided into three categories: costs linked to the clinical services provided as well as to supporting services, in recent years, the hospital revenues was following cost increases, in other words, the hospital gross margin hasn't significantly increased[4].

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only clinical services excluding supporting services and variable costs which increase proportionally with changes in activity levels of some variables[5]. The identified variables as cost drivers included hospital size[4,6], length of stay[7-10], technology level[11], intensity of care[12] and rules, regulations and tariffs[13,14]. These studies used a variety of methods such as regression, descriptive statistics or accounting methods. Some researches introduced the system dynamics approach to control costs[15,16].

System dynamics is one of the approaches in simulation methods. The benefits of using simulation models are learning about complex problems and testing different interventions[17]. The main advantages of system dynamics simulation are discovering the emergent properties and characteristics of a system, creating quantitative analysis for qualitative problems, identifying the most important system parameters, predicting the long-term effects of decisions, and helping stakeholders learn about the nature of their problems[18]. In recent years, especially since 2013, using the system dynamics approach as a solution to existing problems in health systems has increased[19]. This approach has been used in fields like hospital supply chain[20], patient flow[21-23], patient satisfaction in healthcare[24], the insurance expenditures of health system[25,26], bed allocation[27] and human resources management and service quality control[28,29].

Despite previous researches on hospital costs, the widespread use of system dynamics approach in solving various problems in healthcare and using this approach as a tool of cost control, there is still no research on controlling health costs from the perspective of the hospital using system dynamics. This study tries to cover the existing research gap by examining how to use this approach in cost management and proposing hospital cost control strategies. In this research, after identifying the problem variables, a system dynamics model is presented for analyzing and understanding the behavior of the hospital system. The purpose of this research is providing strategies to control hospitalization costs through the suggested scenarios according to the internal structure of the hospital.

Methods

After reviewing related papers and references, variables and items of the model recognized and initial conceptual model were obtained. In the next step, by interviewing hospital managers and experts in financial units, medical records and human resources, the initial conceptual model was developed and the proposed casual diagram of the model was prepared. Then, the stock-flow diagram was created and formulated in Vensim software. The model was simulated using the collected data from papers and official published reports, and some scenarios were applied and presented for the research goal (control and reduction of costs).

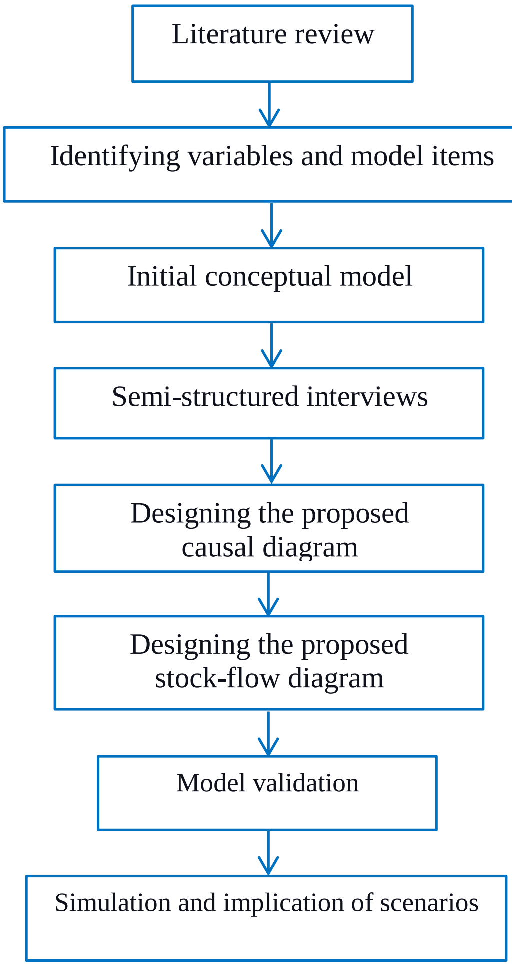

Figure 1. Research process

The research model has been designed to simulate the costs of hospitalization in a hospital with almost 450 beds in Tehran province. The presented model is a practical model for representing the future costs behavior of such hospitals. The collected data is related to early 1397, and the considered time horizon for this simulation is 36 months, which means 3 years. In this research, step times for the simulation have been considered monthly.

The designed model has three sections including financial flow, patient flow, and employed nurses. The subsystem of financial flow (Fig.2) includes variables of costs, revenue, and financial savings. And it represents the primitive conceptual model, which developed in the next stage and its subsystems extended. This section includes three positive loops and three negative loops. Hospital costs are categorized into three classes of hospitalization cost (including overhead costs, administrative cost, and nursing services), drug and supply cost, and uncompensated cost. The hospitalization cost is used in hoteling cost (bed day) calculation. The Ministry of Health signifies the maximum expense of hoteling, and its surplus imposes to the hospital as an uncompensated cost. This cost can be determined by dividing the hoteling cost by the occupied bed day. To respond to the admission demand, the hospital develops its bed but this development will face environmental limits. Also, hospital admission means more revenue for the hospital, in which revenue items are bed revenue (including bed day revenue and nursery services), patient's attendant revenue, patient's bag revenue, inpatient pharmacy revenue, medical equipment, and surgery revenues.

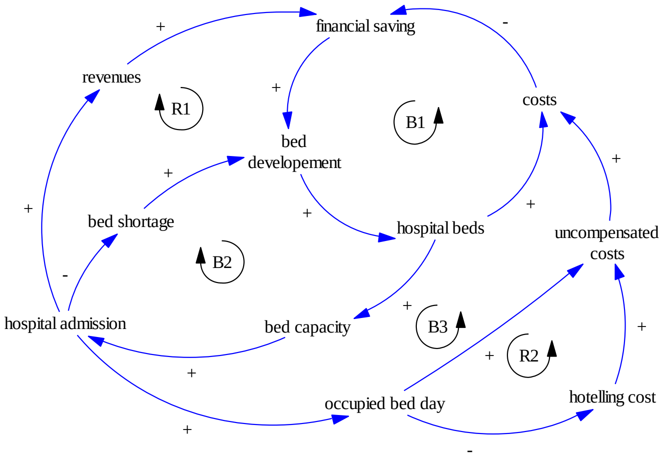

Figure 2. Financial flow

The patient flow subsystem consists of surgery and other inpatients, composed of two negative loops and a positive loop. Because the patients in the surgical department had different length of stay and referral structure, they were separated from each other. The clients of the surgical department are the applicants of elective surgery and hospitalized patients of the other wards, admitted in the surgical department by transmission from the other wards. The first group is seen in the model as elective surgery and the second one is seen as the in-hospital demand. In this subsystem, the represented model in previous study has been modified and utilized[21]. Inpatient admission capacity has been modeled according to the monthly request rate and the inpatient discharge rate and admission rate. Based on the target average length of stay, the hospital estimated its admission capacity and modified the length of stay based on the request rate. When the potential bed occupancy rate is increasing, bed managers will increase the discharge rate by decreasing the occupied bed day and reduce the accumulation. With discharge increasing and hospitalized patients decreasing, the occupied bed decreases, and the rate of admission increases. And with more admission, the hospital can decrease the bed shortage (Fig3). In the surgical department, in addition to this mechanism, the capacity of surgeries is effective in determining the admission capacity.

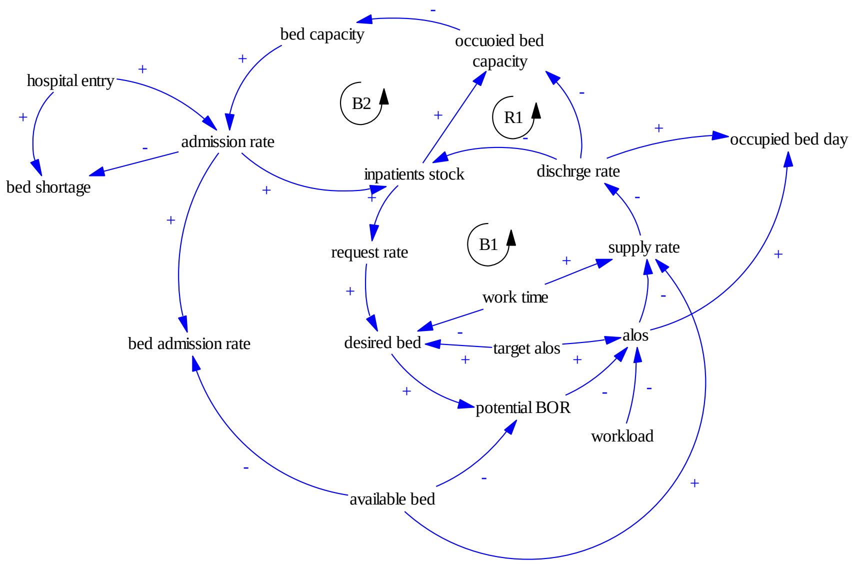

Figure 3- Patient flow

As the figure 4 shows the employed nurses subsystem, composed of two loops. Nurses work time (for difficult jobs) is 25 years, a coefficient embedded into the model as monthly work left and recruitment time is considered 6 months. Based on the care intensity policy, the hospital has a desired nurse per bed ratio and evaluates the desired nurses based on the available bed. On the other hand, the workload due to the employed and desired nurse gap caused decreasing in the stay time of each patient and connects this subsystem to the patient flow subsystem.

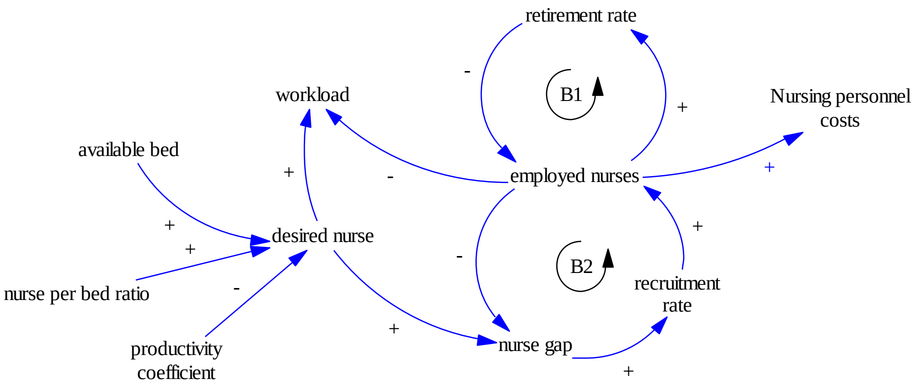

Figure 4- Employed nurses

The proposed stock and flow diagram

The proposed stock and flow diagram is shown in figure 5.

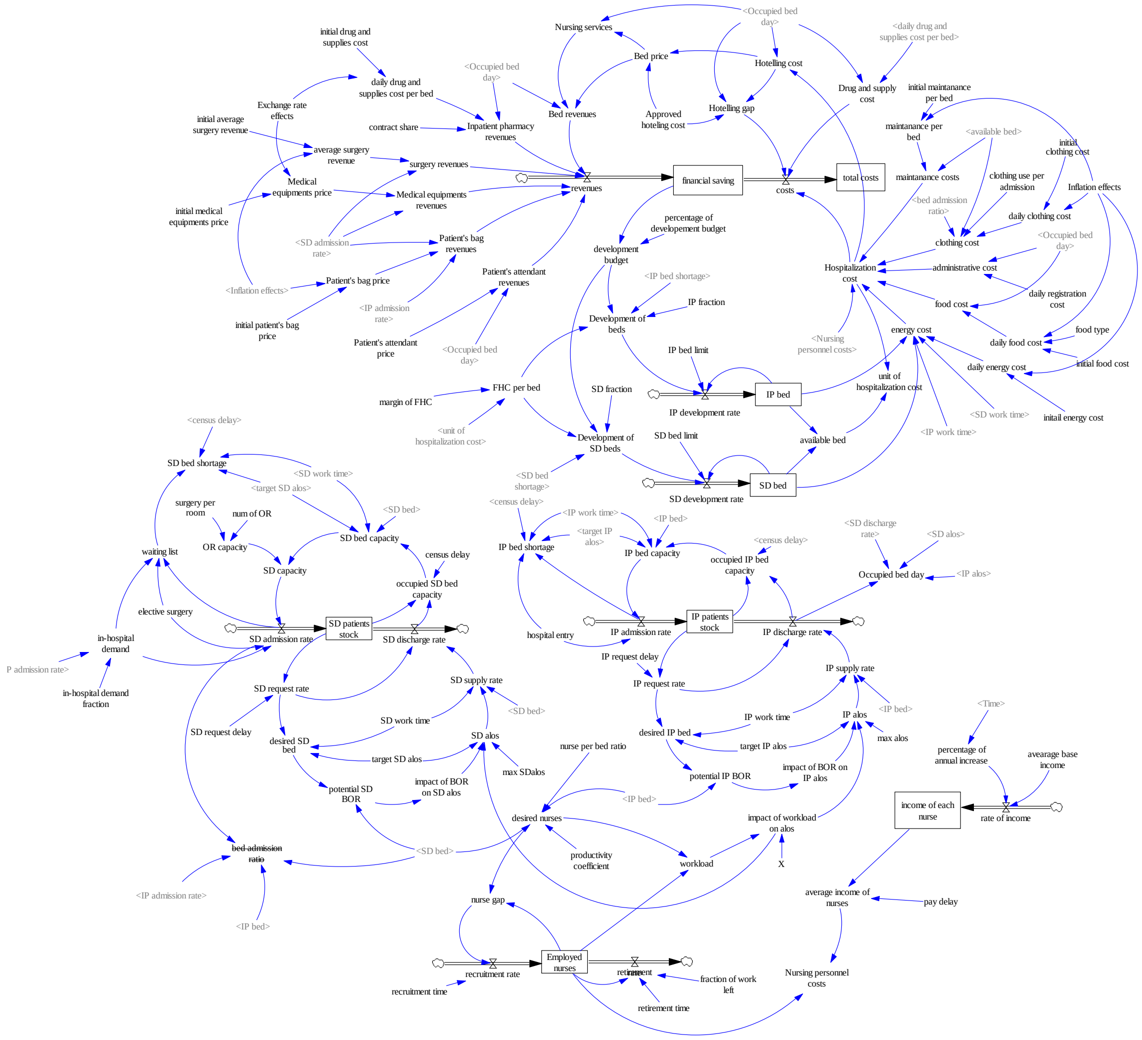

Figure 5. Stock and flow diagram

Results

To validate this model, we used three tests: extreme test, dimension test and structure test. The extreme test is done in three extreme conditions. The left diagram in figure 6 shows the patient flow subsystem behavior, when the patient visits is decreased to 20 people per month. As expected, the admission rate decreased significantly, the occupied bed day is less than 200 days, hoteling cost increased, and bed shortage will be zero. The second diagram shows that by decreasing the average length of stay to half of a day, which is unrealistic but possible, the admission rate increased. In this case, the bed shortage in the model is zero, both of these conditions show the sensibility and correct performance of the model. In the third extreme condition, by increasing the recruitment time to 30 months, which is possible but very unrealistic, we see that the recruitment rate has significantly decreased.

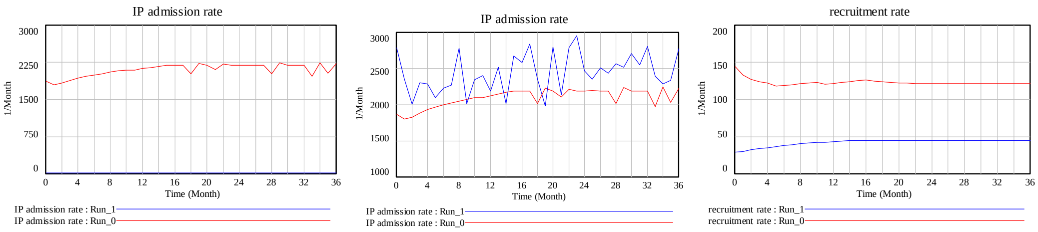

Figure 6. Extreme test

The second test is the dimensional test, which evaluates the equivalency of all variables on both sides of the equations. This test was confirmed by software for the model.

In the structure test, the behavior of defined variables and their effect on the model's behavior adjusted to reality, and this test was validated by examining the behavior of the model and experts opinion.

The next step after validation is the model simulation and applying different policies. The first scenario (scenario 0) was the simulation of the created model and six scenarios have been proposed for reducing the costs based on that. The impacts of these scenarios on the key variables of the system include total cost, hoteling cost, occupied bed day, employed nurses, bed admission ratio, and the available bed has been examined. The behaviors of all scenarios are compared in Fig 7. In the following, the scenarios will be discussed.

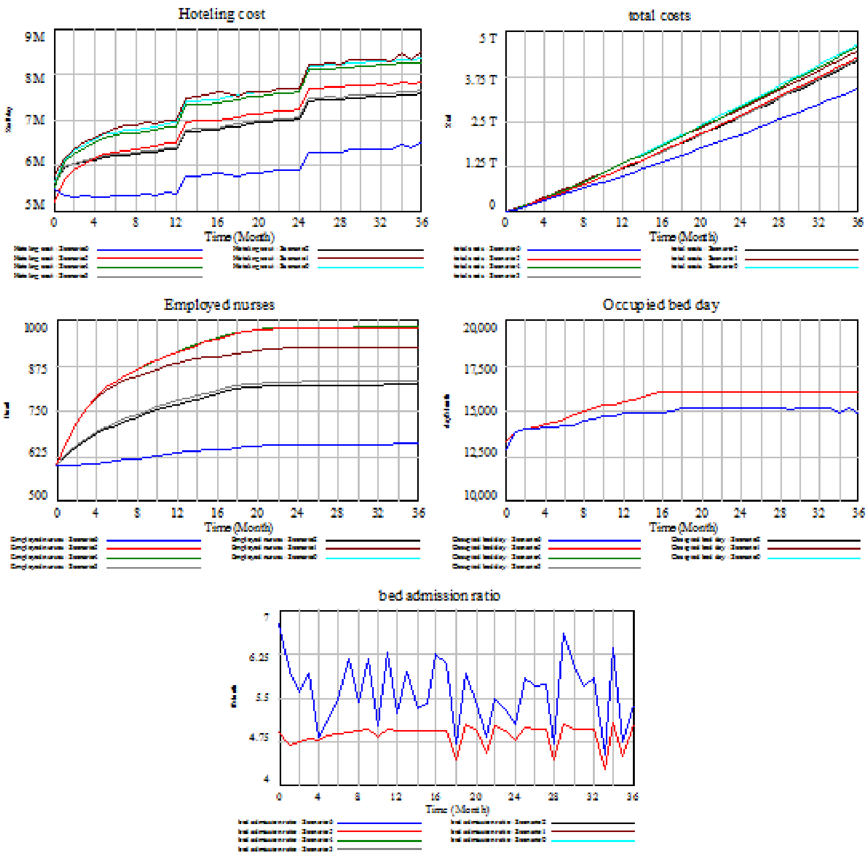

Figure 7. Comparison of different scenarios

Zero scenarios: Continuing the current situation

If the exogenous variables such as intensity of care, length of stay, number of served food, personnel productivity, and clothing cost are constant, the behavior model is according to scenario 0. As it is clear in Fig 7, the simulation results of the base model show that the total cost and the cost of hoteling are. Also, occupied bed days and hospital beds are increasing and after that, they remain constant. The bed admission ratio has been fluctuating around 4.8 and the number of employed nurses is increasing and will be constant after 24 months.

First Scenario: Reducing the average length of stay

In the literature, this factor is a high priority in the strategic, financial, human resources and physical resources planning of the hospital. It is also said that reducing the length of stay can increase productivity, reduce costs and reduce the depreciation of hospital resources[30]. The goal of this scenario is to reduce the average length of stay by 20% and assess its effect on the costs.

In this scenario the admission has increased due to the length of stay reduction, so the bed shortage and available bed decrease and the admission bed ratio increase. But due to decrease in occupied bed day, the bed cost (hoteling) has been increased. Because the hoteling cost is not exceeded the approved amount, the uncompensated cost is not imposed to the hospital.

Second scenario: Increasing the staff productivity

In this scenario, in order to reduce human resource, we increased the productivity coefficient by 15%. By implementing programs to improve the productivity of medical staff, the hospital can be run at a lower cost.

Third scenario: Reducing the intensity of hospital care

In this model, the nurse per bed ratio has been used as the measurement index of hospital care intensity. In the third scenario, to reduce the intensity of hospital care, the desired nurse per bed ratio has been decreased by 15%. Due to this variable reduction, the employed nurses of the hospital have been decreased and with no influence on admission flow and occupied bed day causes the hospitalization costs reduction.

Fourth scenario: Reducing clothing consumption

In this scenario, the clothing coefficient per admission reduced. As a result, with no effect on the elements of the patient flow subsystem, the hospitalization cost decreased.

Fifth scenario: Modifying the hospital nutrition process

To manage the food cost, the food menu reduced from 3 types to 2 types. Due to this policy the hospitalization costs decreased, and with no change in occupied bed day one can reduce the total cost.

Sixth scenario: Applying all the scenarios simultaneously

In this scenario, all the proposed scenarios applied simultaneously.

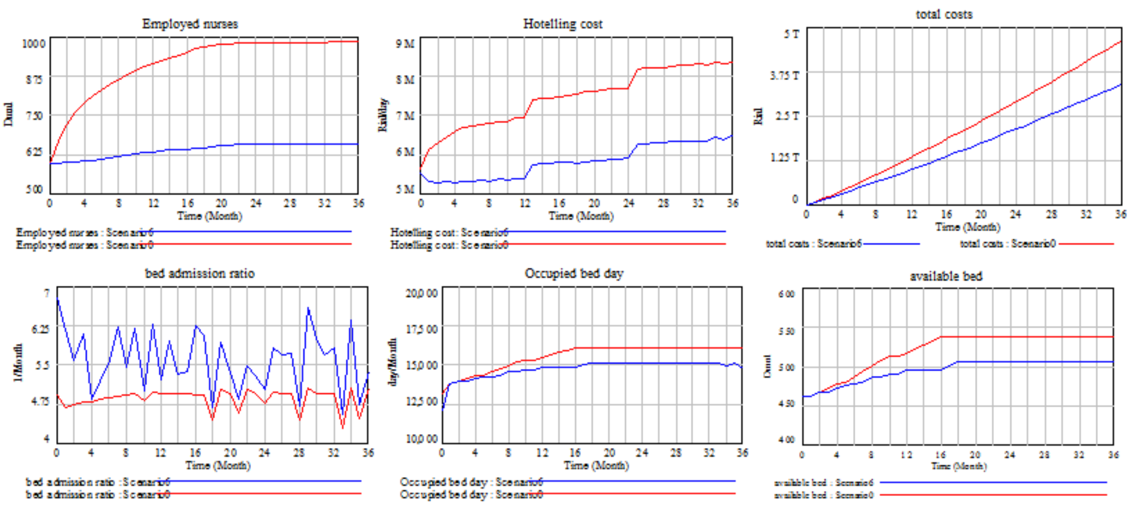

Figure 8. Impact of Scenario 6 on costs and other variables

As represented in figure 8, the total costs, hoteling cost, and the number of nurses decreased and the hospital can be managed with more admission and fewer beds until the end of the simulation horizon.

Discussion

Increasing hospital costs is a global challenge that absorbs the health manager of every country's attention. Hospital costs are a large part of the healthcare system expenditure, and hospital managers always search for ways to present health services with fewer prices and more efficiency. As[31] pointed out, hospitals should pay more attention to cost control in order to have higher cost efficiency which can provide more information about the internal structure of hospitals.

This research has been designed to present a dynamic model to control and reduce hospitalization costs by identifying of the system variables, their relations, and structures. The dynamic model of this research consists of three subsystems of financial flow, patient flow, human resources, and their interactions. After designing the initial conceptual model and its development, the relations and the stock-flow diagram obtained. After validation, the simulated model and different scenarios were implemented. The results showed that with the current trends, hospital costs are increasing. The hospital increased the available bed to meet the demand of its clients, but it is still facing a shortage of beds.

In order to reduce the hospital costs by considering the improvement of system performance, six scenarios were proposed based on the simulation results. The first scenario in addition to cost control, improved flow management of the hospital and increased admission bed ratio. In this scenario, the bed cost index has been increased but along with the improvement of other performance indexes, can be an appropriate policy to control total cost. The second scenario showed that with the productivity improvement, one controls the personnel costs, which is a major part of the expenses. The third scenario succeed to control the cost without any effect on the admission rate and patient flow, by the reduction hospital care intensity as a motivation for hospital costs. The fourth and fifth Scenarios are the policies that can reduce hospital overhead costs and control the cost of inpatients without affecting the patient flow. The sixth scenario has been mentioned as applying all scenarios simultaneously, which consists of all three types of policies of overhead cost, human resources and bed management controlling. In this policy, along with the total cost reduction, indexes of bed day cost, length of stay and bed admission ratio improved, bed shortage decreased, and the hospital can provide more services with fewer beds. The impact of each scenario on the cost and key variable of the model and the priority of the proposed scenarios based on the cost reduction is shown in Table 1.

Table .- Impact of Scenarios on variables and their priority

Scenarios	**Total cost**	**Hoteling cost**	**Hospitalization cost**	**Drug and supply cost**	**Employed nurses**	**Available bed**	**Occupied bed day**	**Bed admission ratio**	**Priority based on cost efficiency**
Scenario1	3.8% decrease	2% increase	6% decrease	8% decrease	5.5% decrease	6% decrease	8% decrease	6.5% increase	Scenario6
Scenario2	10% decrease	9% decrease	9% decrease	-	16% decrease	-	-	-	Scenario2
Scenario3	9% decrease	8.5% decrease	8.7% decrease	-	15% decrease	-	-	-	Scenario3
Scenario4	1.5% decrease	1.1% decrease	1.8% decrease	-	-	-	-	-	Scenario5
Scenario5	7.5% decrease	6% decrease	6% decrease	-	-	-	-	-	Scenario1
Scenario6	26% decrease	22% decrease	28% decrease	8% decrease	32% decrease	6% decrease	8% decrease	6.5% increase	Scenario4

In the created model with an increase in surgery capacity (which is possible through both reductions in length of stay and increase in surgery rooms), the admission increases, and bed manager decreases the length of stay of each patient to respond to hospital entry. This increase in admission and decrease in length of stay eventually offset each other, and the occupied bed day variable remains almost constant. However, overhead costs and consequently hospitalization costs increase so does the hoteling cost and the total cost. Therefore, if the hospital managers intend to develop this department, it is recommended to combine it with one of the cost control policies that has not affected the patient flow in order to avoid the increase in development costs. According to what was said, the effects of the length of stay reduction in each department as a possible cost reduction policy should be examined before implementation regard to the special conditions of that department.

The results of this research showed that, as claimed in previous researches, paying attention to overhead costs along with direct care costs can slow down the growth rate of hospital costs[32]. Also findings showed that longer stays in the form of more bed days may lead to increased costs as stated in many researches[6,9,10,33] so the hospital can consider a strategy to reduce the length of stay[8,34], though according to this research's findings, the unique conditions of each department should be considered before implementing this policy. Another study found that using a more modern surgical procedure, despite reducing the length of stay could lead to higher total hospital costs due to increase in personnel and supply costs[35]. Therefore, the findings of this research are consistent with the results of previous study. In addition, since length of stay and admission bed ratio are known to be indicators of hospital efficiency, this study confirms the claim that improving efficiency reduces costs[4] although the bed cost index is another performance indicator that can be in conflict with the mentioned indicators. On the other hand, by improving bed management, the hospital will be able to reduce the number of available beds, in other words, control its costs by controlling the cost of capital equipment as stated in past study[36].

Conclusion

This research showed that to control the hospital costs, applying all the scenarios simultaneously with the most reduction in costs, is the best policy. After that, increasing the productivity of human resources, reducing the intensity of hospital care, modifying nutrition process, reducing the average length of stay, and reducing clothing consumption are suggested as cost control policies, respectively. As the findings showed, the proposed strategies and their results are in line with previous studies.

Due to the limitations of research in time and data collection, considering outpatient departments, and developing the nurses subsystem into three categories of rookie nurses, experienced nurses and supervisors for having an endogenous productivity variable recommended for future research.

Competing interests

The authors declare no competing interests.

Authors' contributions

The authors are the same

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