



A National Decentralized Approach to Online Monitoring System from Admission and Triage to Discharge and Bed Management

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Abstract

Background and objectives: Hospital management issues have been one of the most important concerns of governments. These challenges involve medical staff and health policymakers more than ever during crises such as the Covid-19 epidemic. Lack of hospital beds and special-care facilities, medical staff shortage, and immediate reduction of drug inventory is among the most important problems in critical situations. Designing technological management solutions and using existing potentials to evaluate the condition of hospitals at the macro level can greatly reduce the incidence of such problems.

Methods: In this study, an attempt is made to prevent the aforementioned problems using a technological solution in Hospital Information Systems (HISs), where a directorial analysis in evaluating the facilities and limitations of medical and healthcare centers on the one hand, and the architecture of the Electronic Health Record (EHR), on the other hand, is performed. Launching an online system transferring the live status of beds between the HIS and EHR systems is the first step, and adopting macro-management approaches to use the available treatment capacities for optimal patient coverage is the second step.

Results: This system is launched nationally based on the current platform of Iran's EHR at a low cost. Collecting patient data during the stages of admission, treatment, and discharge, while facilitating the monitoring of the hospital beds, helps to enrich the content of the EHR, as well as the launch of online management-monitoring dashboards.

Conclusion: Patient status monitoring, bed vacancy, and the discharge rate of hospitals could be monitored offline and lately, and we improved it by providing a novel model.

Keywords: Hospital Administration, Electronic Health Records, Hospital Bed Capacity, Medical Decision Making

Background and objectives

Lack of access to hospital facilities and delay in receiving special inpatient care in some patients can lead to their death, and the number of such deaths will increase drastically in special circumstances such as epidemics of infectious diseases and natural disasters. Studies show that for every hour of waiting for the allocation of intensive care, the patient's risk of death will increase by 1.5%. The problem of not having enough hospital beds to accommodate injured people in accidents that lead to mass injuries have involved the healthcare systems with difficulties. Therefore, there is a significant relationship between the time of admission and the possibility of saving the patient's life, and timely admission of the patient to intensive care wards will improve treatment results¹.

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In addition, the lack of hospital beds in many cases leads to early discharge of the patient and a decrease in the quality of the treatment process.

In Iran, due to some issues, there is a serious challenge to save the lives of hospital patients:

- The limitation of hospital beds,
- Insufficient information about the bed status (especially intensive beds),
- The hospital not accepting patients with verbal inquiry (due to the risk of needing to allocate a lot of resources),
- Reserving intensive care ward beds for patients who are in the surgery rooms.

On the other hand, the emergency unit, which provides pre-hospital emergency services, sometimes needs to transfer and admit patients to intensive care units. This case is especially seen in heart and brain stroke patients who are transported by ambulance, and because of the multitude of these cases, many annual deaths happen due to the lack of information about hospitals with empty beds where the ambulances refer to hospitals without empty beds and finally, the non-acceptance of the patient is reported. In the meantime, the ambulances are forced to move between hospitals to find an empty ICU, CCU or surgical department and surgery room, which means losing the golden time to save human lives, especially in certain patients such as heart and brain patients²⁻⁶.

On the other hand, the difficulties caused by the epidemic of infectious diseases have increased the complications related to the lack of hospital resources. Since the end of 2018, all countries, including Iran, have faced the challenge of the COVID-19 epidemic, and the need for ICU beds as an important executive pillar in the treatment system for critically patients has become more important.

Unfortunately, due to the existence of some old approaches at the level of universities of medical sciences and the relevant ministry, accurate and up-to-date statistics of the occupancy status of these beds are not available, and usually, the statistics are gathered with telephone calls in a non-dynamic manner. Finally, the user enters statistical reports manually in an offline statistics system, which usually is not relied upon for intelligent and timely operations due to some reasons such as human faults and instability.

In this research, to provide a solution to improve the monitoring of hospital admission statistics as well as online monitoring of hospital beds toward the optimal management of medical resources, a new model for analyzing hospital data has been presented. The current infrastructure of hospital procedures, the multiplicity of information systems used in hospitals, the distinction of local coding, and the diversity of hospital processes according to the medical specialty types have caused complications. We want to present an architectural model based on the electronic health record system and propose a data exchange method between hospital information systems to overcome this deficiency. Designing a live national monitoring system based on HIS information for patient monitoring in the treatment process is the main part of the proposed solution, which controls inter-hospital referrals to obviate the lack of empty bed and the number of admission and discharge. Also, the implemented solution based on this model will be used to manage the hospitalization of injured people in natural disasters such as floods, and earthquakes, or searching for missing persons as secondary goals^{4,5}.

Literature survey

In recent years, and especially after 2010, extensive studies have been conducted regarding the monitoring of hospital processes to avoid the lack of medical resources. The studies conducted in the field of hospital bed management pay attention to making bed monitoring smart. In this regard, at the same time as the increase in the average age of society, the increase in accidents and the growth of hospital admissions, the need to design smart sensors on beds has been felt. In order to provide smart equipment for hospital bed management, many efforts have been taken in advanced countries⁷⁻¹¹. Also, in some studies, the issue of waiting time for allocating a hospital bed to a patient in critical wards such as the intensive care wards or the pediatric department has been discussed. The results of some research show that more than 70% of the patient waiting time in the hospital is only spent on transfer from the emergency department to the related ward and the allocation of a bed and hospitalization¹².

In the following, some of the existing studies are evaluated, which are conducted based on the experiences of the healthcare systems in advanced countries. These systems are developed on hospital bed management solutions for the optimal distribution of internal resources and minimizing the waiting time of patients in need of treatment¹³. In some research works conducted in this field, the optimal management of special hospital beds such as burn and emergency beds has been examined as a necessity, especially in crisis events times¹⁴. In the literature, the evaluation of reports on the condition of hospital beds has not been evaluated. However, the category of online monitoring and analysis of the bed condition, as a new approach, requires the production of useful reports for real-time decision-making.

In study of Delamater¹⁵, the relationship between the availability of hospital beds and the optimal use of medical resources is evaluated to utilize hospital facilities optimally. In the United States, hospitals provide behavioral health services to patients to treat mental disorders and the problems caused by drug use¹⁶. This category of patients may present a threat to their health or others when they go to the psychiatric emergency room or the centers related to drug use complications, so they need hospitalization and 24-hour medical supervision¹⁷. Because the number of psychiatric hospital beds has not increased in recent years, it has become more difficult to find an available bed, which leads to longer waiting times in emergency wards. As a result, the states in the US are increasingly establishing online bed tracking systems to improve access to relevant information promptly^{18,19}. In an operational program, case tracking systems have been set up by various states, some of which have been successful and others unsuccessful. The important point in these efforts made was that the data entry in such systems has been done manually, and consequently in many hospitals information is sent with a delay, and some hospitals with a high workload did not participate in the program at all.

In 2019 a study of 17 states found that many states did not publish information about the performance of their online hospital bed monitoring system, and in some cases which they did, the information was collected manually²⁰.

According to the evaluation of the country's health information technology field, one of the treatment requirements at different levels is the possibility of monitoring the admission of patients in the hospitals (including government, private, charity and armed forces) which has been noteworthy of health policymakers in the

past years. Also, monitoring the condition of hospital beds, especially in the intensive care wards, which have limited resources and facilities in the country, is considered one of the most important needs of the health system.

In recent years, guiding and distributing patients to hospitals and medical centers has been done traditionally. Emergency and also personal clients usually refer to the nearest medical center with related specialties. In Iran, there is no systematic evaluation method and nationwide control for the allocation and distribution of patients to hospitals, and sometimes in times of crisis, the triage department of hospitals is not able to respond to a large volume of patients. The patient guidance staff in medical universities has a static mechanism and it is not possible to distribute patients based on the available facilities and capacities, and on the other hand, inefficiency in the distribution and guidance of patients can lead to many disasters. The online monitoring system of hospital beds will be able to evaluate the current situation and make real-time decisions to direct patients to medical centers that have the empty capacity to accept new cases, by gathering information from hospitals all around the country. By designing and implementing this system in the central headquarters of the Ministry of Health and Medical Education and using dynamic guidance based on current conditions, it will be prevented from creating a heavy burden of clients to several centers and leaving the capacities of other centers unused.

From the economic efficiency perspective and by the sake of improving the economic conditions of medical centers is one of the most important priorities of the country's health and treatment system. Evaluating and monitoring the situation of hospital beds, analyzing the load of the patient's admission in hospitals, knowing

about the available capacities, and making real-time decisions in medical centers can improve the financial situation of the hospitals. The Ministry of Health and Medical Education, as a governance and decision-making authority among healthcare organizations, can promote the economic conditions of the hospitals by optimally distributing the budget, considering the capacity and service level. The management dashboards can provide a comprehensive and accurate view for health and treatment managers and will help them in making decisions about budget sharing.

Methods

This study was conducted to improve inpatient services and treatment processes at the country level in Iran, focusing on the city of Tehran. In this regard, first, a comparative model has been presented, and then the necessary studies regarding its implementation have been carried out. This research was conducted between 1397 and 1401.

In this section, the proposed model for online hospital monitoring is described in the following three areas:

- Designing online electronic services based on API to receive online information about the occupied or empty status of hospital beds.
- Establishing a system for receiving and aggregating patient information in the electronic health record at the central headquarters of the Ministry of Health and Medical Education, based on online patient information at the time of admission and discharge.
- Discovering and extracting key performance indicators to produce meaningful reports for triage management and decision-making at macro levels of the healthcare system.

Hospital beds are one of the most critical sources of the treatment process that play a very important role in our proposed model. The most important property of the bed-oriented approach is that during the hospitalization of the patient, only the information related to the status of one bed is sent in each transaction, so the bandwidth occupied in the backbone of the electronic

health record system and the processing time of the message packet sent to the center will be less than the other messages. The bed status feature in hospital bed information is a key feature in the bed data model. This attribute specifies whether a bed is occupied or not, the values considered for this attribute are shown in Table 1.

Table 1. Bed status property

Code	Status	Comment
1	Occupied	The bed is not empty
2	Ready to admission	.The bed is empty and ready to accept the patient
3	Out of service	.The bed cannot be used for reasons such as being damaged
4	Reserved	.The bed is reserved for a patient
5	The patient is being transferred.	The patient has been transferred to another department, but the destination department has not yet announced acceptance
6	The patient is being discharged	The order to settle the patient's account has been issued by the doctor and the patient has been settled. The bed will be .vacated soon

Since this model has been seen for implementation in the global electronic health record system, the DV_CODED_TEXT concept

from the OpenEHR standard has been used. The diagram of the proposed service model is shown in Figure 1.

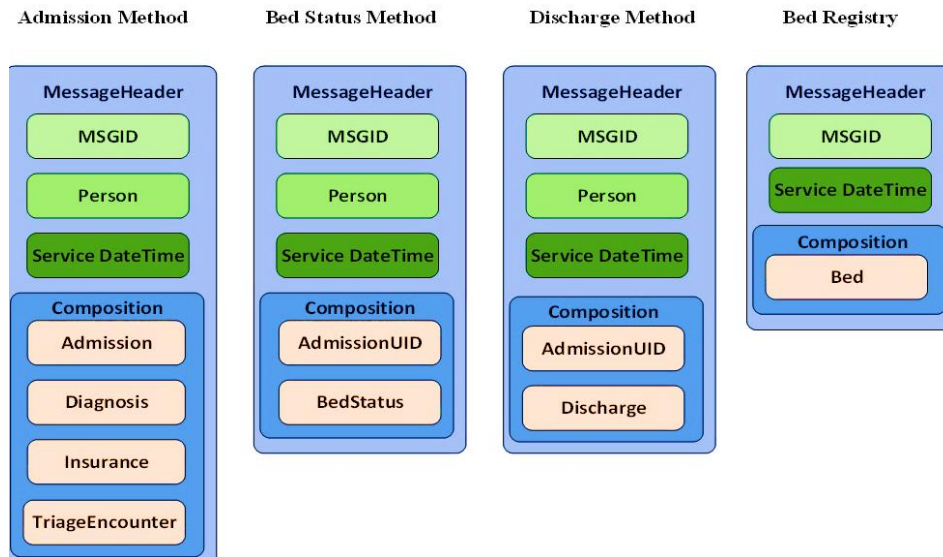


Figure 1. Class diagram of the data model of online hospital monitoring services

A hospital bed status transfer model is designed, which is embedded in existing hospital management systems. This model is an interface for collecting data from the hospitals and will be implemented based on an adopted standard (20). The sending data includes information about the geographic location of the hospital, the hospital wards, the types of beds available in each ward, and finally the status of each occupied or empty bed. The most important point of this system is the direct sending of bed status information from the hospital's information management system to the electronic health record without user intervention. Many hospital staff refuse to accept accidental patients in critical condition who need special care. Having an online system for changing bed status is very valuable to inform the treatment system staff of new conditions.

The information related to the triage department of hospitals has great importance in this system. There is a large volume of requests for the allocation of triage department facilities in crisis and natural disasters in hospitals, and the existing restriction for such requests leads to an increase in deaths and other injuries. Hospital emergency department staff are responsible for

the distribution of patients in different wards of the hospital, which sometimes do not have correct statistics about the bed's status. The lack of this information is more manifest at higher levels and among the all hospitals of a city, and the need for it is felt more. Aggregation of bed status statistics, distribution of patients in wards and management decision-making in these conditions are the benefits of the proposed system.

The data model related to the gathered information from the triage department and other hospital departments has been designed according to Figure 1. This data model has been suggested to software companies developing hospital information systems (HISs).

In recent years, the electronic health record has been considered as the most important information reference in our health system. The information related to people's admission to the medical centers is recorded and organized at four levels in the electronic health record system. Patient identity information, medical diagnosis, all services performed for patients and the received fees are sent in the form of message packages by the hospital management

systems and a medical file is created in the Ministry of Health and Medical Education servers for each patient and after validating the content of the package in the Iranian EHR system (locally called SEPAS) it will be recorded.

SEPAS has been implemented by a collection of web service applications in the Statistics and Information Technology Center of the Ministry of Health and Medical Education of Iran, which creates a data warehouse of information sent from the hospitals. The hospital bed management system has the facility of receiving data about the status of hospital beds from all hospitals across the country. The model of data received in this service is different from the previous data model. In the services related to the online monitoring system of hospital beds, data is prepared and sent to the center based on the bed status. In other words, the main focus in the data model of this service is the condition of hospital beds, in such a way that we can use the aggregation of these data to monitor and control a load of referrals to medical centers, especially in times of crisis.

Table 2 shows the codes sent from hospital information management systems in the proposed data model for monitoring the condition of beds.

Table 2. Status code of bed hospitals

Status Code	Status name
1	Occupied
2	Ready to admission
3	Out of service
6	Reserved
7	Transferring
8	Discharging
9	Return from discharging

In the proposed data model for collecting data on hospital beds the hospital bed types are also shown in Table 3 by their corresponding codes,

so that if a specific type of hospital bed is needed according to the patient's treatment process, it is possible to search it by type.

Table 3. Name and type code of hospital beds

Type Code	Bed name
1	Single bed
2	Two beds
3	Three or more beds
4	Healthy baby bed
5	Incubator patient's baby bed
6	CCU ward bed
6.1	Post-CCU ward bed
7	ICU ward bed
7.1	NICU ward bed
7.2	Post-ICU ward bed
7.4	RICU ward bed

The key performance indicators of the online monitoring system of hospital beds have been investigated and extracted. To evaluate the performance of the proposed system, a set of performance indicators is considered, and its performance is analyzed by measuring these indicators. In the online monitoring system of hospital beds, efficiency, productivity and effectiveness are evaluated by extracting a set of indicators. At first glance, these indicators are divided into the following three categories:

- Connection evaluation: These indicators are intended to evaluate the implementation of online monitoring services at the hospital level.
- Bed evaluation: This group of indicators has been developed to evaluate hospital beds.
- Infrastructure evaluation indicators: This category of indicators has been prepared to evaluate the infrastructure of the hospitals.

Results

Sending data modules related to the online hospital bed monitoring system have been implemented and launched in the hospital information system in several hospitals in Iran. Also, in the central headquarters of the Ministry of Health and Medical Education, web services for receiving and validating these data have been designed and implemented in the electronic health record system, and finally, a large amount of information focusing on the hospital bed status is sent to the central system. The web service implemented through the following four methods transfers hospital status data including admission load, bed status, and hospital discharge.

- **BedRegistry:** This method is used to get the bed ID when a new bed is added.
- **Admission:** This method is called to admit a new patient in triage.
- **BedStatus:** This method is called when the patient's bed is changed.
- **Discharge:** This method is used when the patient is discharged.

The performance result of the hospital monitoring system has been evaluated and analyzed based on the indicators mentioned in the methods section. Table 4 shows the designed evaluation indicators.

Table 4. Evaluation indicators designed for the online monitoring system of hospital beds.

Index	Indicator	Comment	Indicator group
1	The number of connected hospitals	The ratio of the number of hospitals sending information to the total number of hospitals in the country	Connection evaluation
2	The number of connected beds	The percentage of beds with changed status compared to all registered hospital beds	Connection evaluation
3	Bed circulation	The number of patients using a hospital bed, in a certain period. This rate shows the number of occupied and vacated beds in a certain period and indicates the average number of patients who use a certain type of bed during a time interval.	Bed assessment
4	The average length of hospitalization or patient stay	The total number of occupied day beds in a certain period to the total number of discharged patients and deaths in the same period. The duration of hospitalization reflects the medical decision regarding the patient's stay in the hospital.	Bed assessment
5	Bed occupancy rate	A ratio of occupied day beds to active day beds in each period	Bed assessment
6	Registration bed	It is the number of beds whose information has been sent to the center in exchange for the bed registration service.	Bed assessment
7	Approved bed	The number of beds approved by the hospital based on the operating license	Bed assessment
8	The difference between the approved bed and the registered bed	The difference between the number of approved beds and the number of registered hospital beds.	Bed assessment

Index	Indicator	Comment	Indicator group
9	Percentage of patient admission information for each bed	The percentage ratio of the number of sent common file numbers to the total number of sent file numbers	Bed assessment
10	Percentage of correct flat turning process	Percentage of correct bed position rotation process based on standard bed rotation structure	Bed assessment
11	Average time to send information per minute	It is the average delay created in sending information, which is obtained from the difference in the time of sending information and changing the state of the bed in the information packets. If the date of changing the bed status is entered after the time of sending the information, this number is negative, which is usually due to the hospital server clock not being set.	Infrastructure assessment
12	Average last updated beds so far	The average time to receive information packets and the time to change the state of the bed are recorded in the sent information packets	Infrastructure assessment
13	Average change of bed position per day	The average number of bed changes per day	Bed assessment

The data received about hospital bed status in the electronic health record system has a good potential for producing management reports. By defining a management dashboard at the headquarters level, meaningful reports of the situation and performance of several hospitals

where the designed system has been launched were created, which are shown in Figures 2 and 3. As can be seen in these figures, it is possible to monitor the bed status at the level of hospitals, universities of medical sciences and finally at the level of the country.



Figure 2. A view of the management dashboard of the online monitoring system for the status of hospital beds



Figure 3. A view of the management dashboard of the online monitoring system for the status of hospital beds

In the end, it is demonstrated obviously that the management of the patient's treatment process is improved in hospitals. The hospital has faced a significant reduction in patient waiting time and the number of clients who failed to be admitted to the hospital has decreased. Finally, the level of satisfaction of employees, nurses, doctors and patients with the successful treatment process has increased.

The adaptive assessment carried out in this research can be examined from three points of view: the limitations of the problem investigated in the studies, the evaluation criteria and the suggested bed management strategies. In Table 5, the studies conducted on inpatient bed management programs are categorized according to different inpatient wards and the departments where the patient was present before admission.

Table 5. The result of a comparative evaluation conducted among studies related to hospital bed management.

Study	Research Objective			Internal Wards			Hospitalization wards			
	Operational Decision Support	Strategic Management	IT Implement	PACU	OR	ED	General Inpatient Units	Medical/Surgical Units	Stepdown	ICU
Hagen et al ²¹	■				■					■
Crawford et al ²²	■					■	■			
Montgomery et al ²³	■					■		■	■	■
Holm et al ²⁴	■						■			
Schmidt et al ²⁵	■						■			
Mackay et al ²⁶	■					■		■	■	

Study	Research Objective			Internal Wards			Hospitalization wards			
	Operational	Strategic	IT	PACU	OR	ED	General Inpatient	Medical/Surgical	Stepdown	ICU
	Decision Support	Management	Implement				Units	Units		
Johar et al ²⁷	■				■	■	■			
Tortorella et al ²⁸			■				■			
Athawale et al ²⁹		■	■				■			
Abraham and Reddy ³⁰		■				■		■		
Cypress ³¹	■							■		■
Bing-Hua ³²	■			■		■				■
Kembe et al ³³	■								■	
Wonget al ³⁴	■		■		■	■	■			
Takagi et al ³⁵	■							■		
Zhecheng ³⁶	■						■			
Tsai and Lin ³⁷	■				■	■	■	■		■
Veloso et al ³⁸	■									■
Landa et al ³⁹	■					■	■			
Blom et al ⁴⁰	■					■	■			
This study	■	■	■	■	■	■	■	■	■	■

Discussion

In this study, it is tried to design a system for the optimal management of hospital beds and patient transmission in treatment departments. After that, the proposed model has been evaluated according to the background and facilities available in the health and treatment system in Iran. In the next step, based on the existing facilities and limitations, the technical details of the system implementation are documented and finally the mentioned system is applied and launched in several hospitals. The implementation of this model clearly shows that the strategic and integrated management of the patient admission process at the country level

has led to an increase in the performance of the hospitals and healthcare centers and improved the satisfaction of the clients. Systems with similar goals have been designed and implemented in some advanced countries of the world. In a comparison of the proposed model with some other similar works in the world, the following results have been demonstrated:

- ✓ The proposed model is designed in four levels: hospital bed registration, admission, bed status and discharge. Therefore, from the beginning of the hospital operations, beds are managed at four different levels, and the performance of the treatment system has

been affected by considering the situations and facilities of hospitalization in all stages. Whilst in similar systems this process has been managed at only one level.

- ✓ Due to the variety of services provided in the proposed model, in this research work economic productivity, optimal use of the facilities of the treatment systems at the country level, patient satisfaction, and optimal management of the patients during the epidemic of infectious diseases have been considered. In other similar systems, only one aspect of the abovementioned objectives is considered.
- ✓ The designed system is directly connected to the patient's electronic health record and can also use the patient's medical records to improve services to the patients.

Conclusion

The evaluation indicators mentioned in the findings section have been designed and finally measured to analyze the performance of the proposed model. The evaluation indicators help us to monitor the implementation quality of each component of the system. This evaluation shows that by increasing the number of hospitals equipped with the HIS-Live software components, a significant amount of useful information about the hospital bed status has been successfully gathered in the center. Meaningful reports can be generated from this data to make management decisions.

Competing Interests

The authors declare no competing interests

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Reference

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