

## An Emergency Patient Bedding System for Smarter Hospitalization

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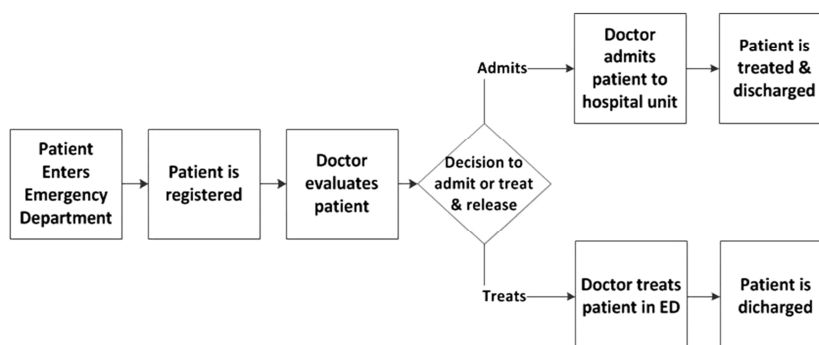
### ABSTRACT

This paper aims to target prevailing problems of emergency department / room (ED / ER) with bottom-up research methodology. Today, many ER related challenges and prevailing solutions in terms of patents and protocols have been discussed thoroughly. Later, a solution is observed through bottom-up research methodology as a special patient bedding system. This emergency patient bedding system (EPBS) is a comprehensive design of a light-weight, smart patient bed specially designed for ED. Its ergonomic design follows the ED protocols and de-facto health care safety standards such that, it can be used out of the hospitals, in mobile vehicles for providing urgent and immediate medical healthcare. The unique combination of active and passive segments in the modular design of EPBS makes it unique, a handy and manageable bedding system. The design features of EPBS are compared to a number of recent but relevant European patents in this paper. The design analysis based is performed on the basis of nurses' manual labor Full Time Equivalent (FTE). The development and use of EPBS specifically, in ED can be very useful for a preoperative environment. EPBS can also be helpful as preoperative (registration, an entry checkup), post-operative and instantaneous care strategy for patients.

**KEYWORDS:** Healthcare, Patient care, Emergency department.

### 1. INTRODUCTION

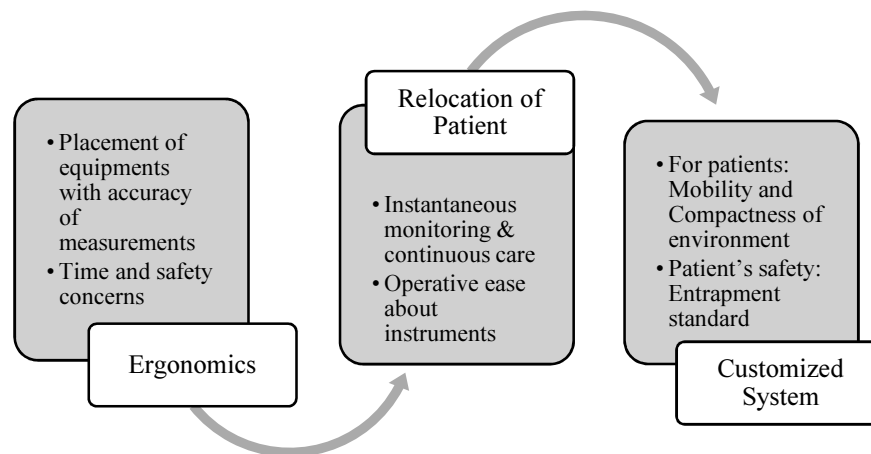
Emergency is defined as: a sudden, severe and often risky situation requiring urgent action [1]. Emergency department (ED) provides services for critically ill patients without earlier appointment, Emergency departments (ED) are right inside the front door of every hospital. As shown in the Fig. 1, the ED provides first aid treatment initially for wide-ranging acute cases and injuries including life-threatening and need urgent attention. ED serves 24 hours a day. ER makes available instant patient care services at every moment further a timely elimination of positioning for the patient to the next point of definitive care.



**Fig. 1.**Hospital emergency department patient admission

When a patient comes to an ER, he needs to be registered in parallel to the treatment by some medical professional who assesses the patient's condition. Further decisions for treatment and stay of the patient are based on this assessment. The efficiency in this registration and assessment process is considered as a critical factor in any ER.

It is necessary to have an appropriate design of ER which allowing immediate access to the patient and administrated the treatment along with the proper medical approach. With particular attention and care, life-saving equipment must be placed where instant and ease is accessible [2]. Following basic tasks for ill and/or injured people in the Emergency Room Department are shown in figure 2. There are three main steps involved as Assessment, Diagnosis and treatment.



**Fig. 2.**Major requirements of an ideal emergency room

A lot of challenges are there to enhance the emergency patient care in the emergency department. There is still a need to create solutions to reduce the gaps between the patient care and the tools used during in such an environment. A patient comes to ER but due to administration formalities delay may occur which may create not only time consumption, but also it may miss a patient's physiological data and the urgent care. Sometimes patient just have to lay over a stretcher in the hospital waiting to get bed without any proper place and without medical equipment and other necessary medical devices, waiting to get his turn in ER if available in such critical conditions else patient needs to move or shift to another hospital. Due to burden of patients in the ER there is also necessary to follow strictly Standard Operating Procedures (SOPs) or Standard Protocols (SP).

It is alarming that the mortality ratio to the increasing rate of population, despite of advancement in healthcare technology, is proportional. One of the major global issues is also overcrowding in emergency treatment [3] [4]. This paper covers the mentioned obstacles in the context of standard protocols successful implementation.

## 2. Motivation

The profound observation about global techniques and medical technologies in ER realizes that lots of things are yet to be done even in implementing to standard protocols. The implementation gap is widened in ERs of the developing and underserved regions. Whereas, in medically advanced countries, the friendliness to the ER system is quite absent today, which is evident from mishaps reported time by time from ER [5] [6] [7]. As biomedical engineer (instrumentation), during the research work, various lethal issues have been observed that motivated for finding any compact solution for medical care and the patient's safety in the area of patient care services. Additionally, solutions aim to provide an ease ergonomically for a paramedical staff while treating patients in ER in terms of time, space and efficiency of medical treatment. The solution also aims efficient processing of medical devices with quality care. This paper summarizes technological resources; we have integrated those technological resources in a single system as per need of an individual. In other words, the proposed solution is based on 'Responsive Smart System'.

## 3. Problem Formulation

Apart from processes during the ER entry of the patient which includes, registration (personal data, cause of emergency, etc.) the ER protocols, in particular, are difficult to implement. Usually, Pre ER-entry steps are avoided in hospitals based on the condition of patients, however, it bring sometimes unnecessary delay in launching swift treatment [8] [9] [10]. This situation may cause critical challenges, summarized below.

- Delay during ER treatment can be incurable (e.g., vital signs of the subject can be lost for any reason).
- Patient can go into unrecoverable conditions due to over-crowding (patients, visitors, etc.) or engaging patients in trivial formalities.
- Relocation of patients from the Medical Emergency Unit (MEU) is challenging due to following factors (i- Instantaneous monitoring & continuous care is required for the period of patient transfer, ii-Improper handling of equipment attached for patient monitoring sometimes creates malfunctioning)
- Customization of healthcare services / resources (i-Patient's safety: Entrapment standards needs to follow, ii-For patients: Mobility and Compactness of the environment for a patient, iii-For training staff: Operative ease about instruments and their handling)
- On-site effective training / assistance about the equipment (i-Multimedia base trainings of a new staff, ii-Provision of highly interactive operating environment)

This emerges a need for such a contiguous system that may not only be helpful for implementing ER protocols but, can also get sync with the ER facilities. Only this way, the aforementioned challenges can be solved. By analyzing the processes, equipment handling, surveys, and advancement in patient treatment, in our strong opinion there is a need of a comprehensive bedding systems. The next section covers the related work and the latest developments in the same direction i.e., patient bed development and scope.

### 3. Related Work

In this section, we provide the latest research and patent work on patient bedding, in general and emergency, in particular.

#### 3.1. Real-time weighing device for use with hospital bed

Weighing appliance for interactive measurement of 'U.S. Patent no. 5,086,856' is designed to calculate the patient's body weight efficiently without the movement of the patient, but this patent unable to give information regarding interactive patient monitoring on a device [10][11]. Real-time weighing device made up of load cells, carrying a plate, electrical processing elements. This assembly of hardware calculates the weight with the elements integrated within the bed frame. Then it drives the data about a patient's body mass and center of gravity as shown in the Fig. 3.

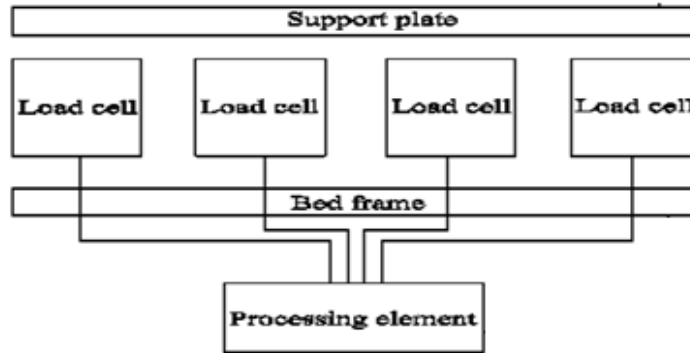


Fig. 3. Load cells uniformly distributed between bed frame & support plate

The elements of the bed are shown next as active and passive elements of the patent are separated in the table 1 [10].

Table 1. Active & passive elements of weighing device

Active Elements	Passive Elements
Load Cells	Bed Frame
Processing Element	Support Plate

#### Drawback of patent

One of the disadvantages of the above patent is that it doesn't have the real time monitoring of the patient. This pitfall creates a less worthiness of the design and not perfectly suitable for the patient in critical cases [11][12][13].

#### 3.2. Intelligent Hospital Bed & Operating Method

Invention of intelligent hospital bed facilitates with the cure and the drug administration to the patient. During stay of patient on a bed, staff needs to change the position of patient for cleaning purpose. To perform this action, staff needs to do it manually. Such service sometimes has need for an extended period of time. By performing this, physical posture of the staff may cause back pain problems[14][15][16]. The invention of intelligent hospital bed provides facility to do it intelligently as shown in the Fig. 4.

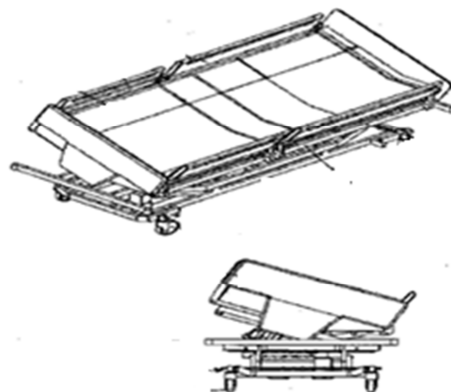


Fig. 4. Invention of intelligent hospital bed illustration

Arrangements of internal elements make it possible to work efficiently, including the following parts:

- i) a lower main frame
- ii) An upper frame

- iii) Plurality of sensors arranged along the mattress capable of measuring the initial force on the point at which the corresponding sensor is arranged.
- iv) Data multiplex system is organized with sensors which control servo motors utilized to move the changeable component of the upper frame in a way that a sensor perceives a signal of movement in real time, a servo motor linked with a related sensor moving one of the changeable parts of the mentioned upper frame is put into action.

The sensor produces pressure images of the object which are evaluated in real time with particular intelligent software supported an automatic learning and image processing techniques for the purpose of interpretation to get even very little movements of the object [17][18][19]. Again, the active and passive elements of above patent are given in Table 2.

**Table 2.** Active and passive elements of intelligent hospital bed

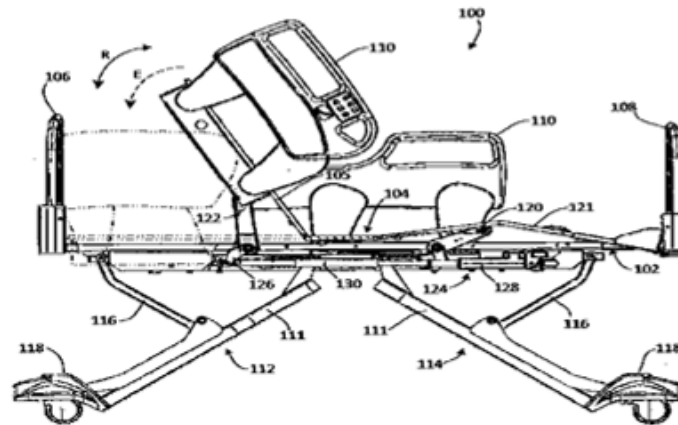
Active elements	Passive elements
Plurality of Sensors	Upper & Lower Main Frames
Data multiplexing system	Servo motors
Intelligent software	Internal wiring

### Drawback of the patent

The patent, no doubt, is providing help in the changing of a patient's position according to the need of a patient situation at that time but the smart way of dealing in some critical cases is missing such as if a patient is in hypotension or in hypertension system need to generate an emergency alarm by sensing the patient's current medical conditions and provide the changing in position initially to provide assistance to make the position up or down respectively in both cases mentioned above. For example, in case if a patient with secretions and fits then there is a need to change in tilted position similarly if a patient is in hypertension, then there is a need to keep the patient's head up at the 45 degree. A patient requires straight position in hypotension.

### 3.3. Patient Support Overload or Obstruction Detection

Hospital beds comprising of many tilt positions depending upon the requirements of the bed posture during treatment. Backrest with prone and raised positions tilted as per need of the patient. Such tilt positions organized electrically by one or more actuators technically. By using actuator sensor, bed is technically controlled by such sensors and generates an alarm while having any obstruction or overloading at the backrest region of the bed. Referring to [12], the patent is shown for illustration in the Fig. 5.



**Fig. 5.** Patient support-overload detection illustration

The active and passive elements of the figure above are shown in Table 3.

**Table 3.** Active and passive elements of overload detection

Active elements	Passive elements
Backrest sensor	Bed frame
Actuator sensor	Controller with actuator
Intelligent software	Internal wiring

### Drawback of patent

This patent is no doubt provides the safety for the patient as well as the hospital bed, but it is precisely covered the safety of the bed. It should be that intelligent that also covers the entrapment issues while the patient is unconscious. Issues of entrapment are one of the basic problems while the patient needs more and more care from healthcare professionals. So

the bed should be that smart enough to overcome above mentioned challenge. One can use actuator sensor in the same manner to detect the obstruction (obstruction of any kind like if a cable of a patient monitor gets stuck between the gap areas of bed) when this condition occurs an alarm will generate and a system gets shut in order to prevent the system of bed. In the light of thorough research, it is highly required to propose a compact solution as hardware (patient bedding or module) for ease of a patient's treatment, record, monitoring. Also, the patient bedding should give ergonomics touch for each of treatment by the paramedical staff. The next section describes the proposal of such a solution as the Emergency Patient Bedding System (EPBS).

### 3.4. Tele-Link

Experts are with Telemedicine mobile system with the aim to allow them to patients from the moment they turn up at the critical center. It can also be observed that the Tele-link is independently connected to Medicare patient as given in Fig. 6. Also it consumes extra space, labor and portability issues along with the patient.



Fig. 6. Image Courtesy of In Touch Technologies

Hence, the lack of technological aid challenges on a hospital bed in terms of emergency. It includes patient's continuous monitoring as an integral part of some advanced bedding system. The bedding system is desired that can help to record and monitor the patient's vital data.

## 4. Proposed Design of Emergency Patient Bedding

Proposed design of the EPBS is created as a bottom-up approach as it can be with the devices integrated with the bed as particular and measured. We keep the standards of the Food and Drug Administration (FDA) for avoiding entrapment issues as well as follow the rules of OSHA to avoid certain issues related in terms of ergonomics of bed. EPBS comprises of two segments and technically its assembly consisting of two main and dynamic parts I) Active II) Passive. In the active region, mainly it consisting of electrodes, a modular system, probes, main processing layer, protective fiber layer. In the Passive part it comprises of two divisions I) Passive Part of Segment 1 and Passive Part of segment 2. In the Passive part of segment 1, mainly it contains Surface technology, a patient monitoring system and control panel of bed. In the passive part of a segment 2 it basically contains the inner assembly of the patient bed, refer to Fig. 7.

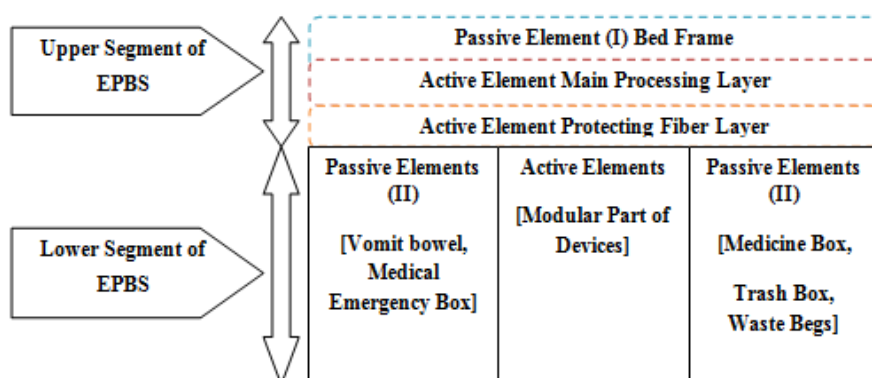
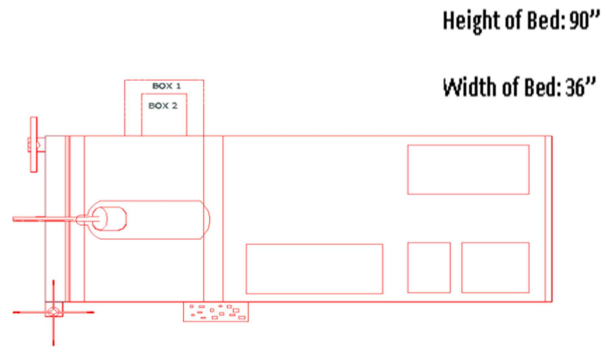


Fig. 7. Active & passive components of the EPBS

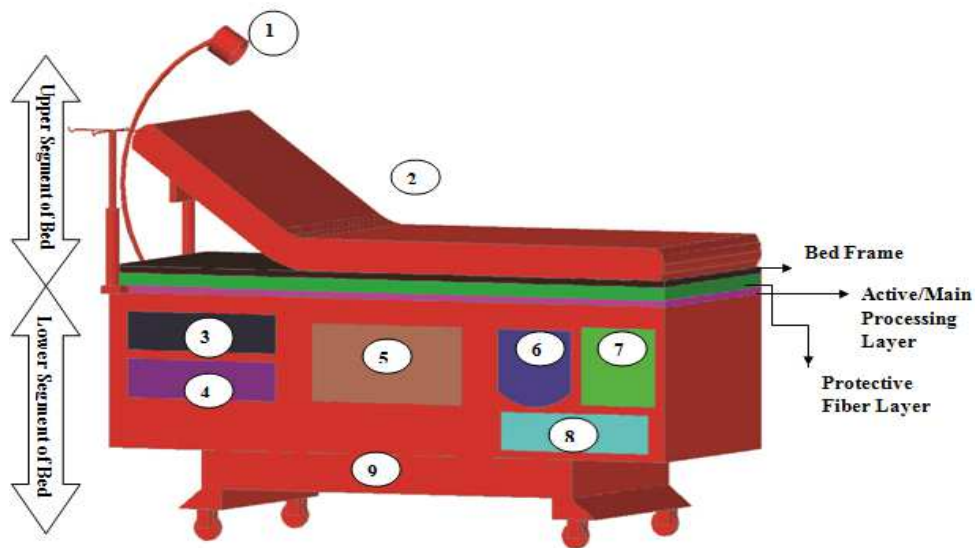
### 4.1. Parameters of Smartness in EPBS

In the Fig. 8, the top view of the bed has different sections with the desired medical tools for emergency conditions. Also, in the Fig 8, there are different sections. Oxygen cylinder is kept near to a patient's face. In the same section, vomit bowel is kept in case of a patient's secretions.



**Fig. 8.**Top view of EPBS

Design of a patient bedding system for treating the patient smartly within a limited space in order to access the healthcare facilities is the basic task of this project. For the Emergency patient bedding system (EPBS) design, smart hospital is created to stay with the standards of dimensions as well as the needs of the medical devices according to the different patient's medical conditions. With two segments (Upper & Lower) bed has its distinctiveness with separate portions which can be detachable when needed. The structure of the EPBS would be of perforated metal for durability so that it provides the safety from any electronic interference. Medical devices modules are kept in a position according to the needs of the patients from mild to severe conditions. Also, in life-threatening conditions, devices would provide support to the patient. Examination light, camera and alarm are also integrated at the head part of the bed so that it won't create any disturbance between the patient to the doctors and paramedical staff. Also, a camera will do observation from all the surrounding of the bed and notice the entire patient's activity during his/her stay on the bed as shown in the Fig. 9.



**Fig. 9.**Side view of EPBS

**Table 4.**Description of EPBS side view objects

1	Patient examination light
2	Bed mattress area
3	Emergency cupboard (B-1)
4	Vomit bowl (B-2)
5	Medical devices interfacing module
6	Waste bag (concealed)
7	Medicine / drug storage box
8	Trash for waste
9	Lower part (base structure and wheels)

## 4.2 Analysis of EPBS

EPBS will be all available for the patients at the door of the hospital. In an emergency, a patient doesn't need to wait for the triage process nor for administrative procedures.

### 4.2.1 Managing inefficiency in terms of patient delay during ER treatment

A patient comes with critical condition in ER, the EPBS is available. From admission to monitoring of a patient's data, all procedures (assessment, diagnosis, treatment) will be done on the EPBS without any delay. No need to take the conventional methods to treat the patient via paramedical staff.

### 4.2.2 Managing inefficiency in terms of equipment mishandling

To avoid the equipment's malfunctioning and to save the space around patient, all the physiological parameters can be measured by a single modular system that is integrated within a bed and detachable with the concealed region for different probes at the bed's frame part. A modular system not only reduce the space around a patient also minimizes the circuitry found in a conventional modular system. A modular system can easily operate. Mishandling by the paramedical staff can overcome in this way as well as equipment safety is for sure.

### 4.2.3 Customization & mobility assistance

EPBS can easily move within a hospital as well as to the ambulance. It's customize characteristic makes it unique as it can continuously measure patients vital data, provides life- threatening treatment and support during mobility.

### 4.2.4 Smart patient bed

EPBS holding the smartness in terms of compactness, mobility of bed along with a monitoring, collection of patient's data and observation of a patient's condition during critical conditions.

### 4.2.5 Managing uncertainty via centralized monitoring system

EPBS come up with the high tech monitoring environment also integrated with the EPBS in such a way that the patient data is centralized anywhere in the healthcare unit. Speaking alarm indicator is synchronized with the patient physiological parameters (ECG, SPO<sub>2</sub>, NIBP and HR) so that patient vital can easily under observation over a distance. This smart platform can solve many challenges regarding patient's safety, security and monitoring.

## 4.3 Ergonomics

*Control of workplace investigation:* Discover the obtainable and potential workplace hazards and to seek ways to make them right such hazardous evolution of the activities that are done in the working environment involves certain parameters that are at risk of pain or injury that may involve missing of patients medical data, treatment responsibilities, patient position over bed, entrapment issues. EPBS will be responsible for taking care of such issues with the designed parameters in the upper and lower segments of the smart bedding system.

*Training for risk assessment and management:* EPBS provides highly interactive environment with having smart surface technology, continuing medical education and training sessions to junior doctors and paramedics. These features make available for better health care services according to the need of a workplace, injuries, diseases, and the main tasks holding during emergencies.

*Time management:* In the context of a patient with EPBS this includes alerts generated by the EPBS on preset timings and to give medicines to the patients provides a high level of care along with the time management. Additionally, a reminder of visits by a doctor to the patient is on time is noticed.

*Hardware interfacing communication (BT, Wi-Fi, 3G or NG networks):* By having communication link via hardware tools such as mobile phones, telephones, central work stations certain issues can be observed and maintain via video conference link or tele-link to improve patient care by enabling medical professionals to increase effectiveness by giving patients save, easy and rapid access. Patient can have the tele-link at the time of need if medical experts aren't available at the critical situation. EPBS can save many mishaps expectedly done by paramedics or junior doctors by taking the experts in an interactive mode opinion at the time of urgent need. Standard protocols: Objective to accomplish for standard protocols is to set point layout for working to specialized medical team members, administrators, paramedical personals, junior doctors, patient care as well as working of other diverse departments and divisions of the healthcare industry. To follow the main theme of the preset points for patients during emergencies is necessary to carry out in a hospital environment. Points to follow under protocols are including: Notes and evolution, admissions, procedure notes, discharges, sign outs, death/Expirations, occupational risks, accountability, ethical Issues, confidentiality of a patient's data, senior consultation and consultations from other Departments / Urgent Scans with the pre designed rules in the standard protocols. EPBS efficiently handles these protocols as every procedure taken by the healthcare professional will be recorded and signature by the staff.

## 5. Statistical Analysis

According to World Health Organization, the nurses are responsible for taking care of individuals, families and groups to aim certain goals within the challenging context of the environment in which they are working and living. It's due on them to promote and maintain health services as well as to prevent illness of health of an individual with the proper planning and implementation of care during illness. It is claimed that nurses have the standard working of 37.5 hours[13]. This means they have to give 7.5 hours a day in five days in a week, the EPBS can work well-organized manner for the nurses. To utilize services by the nurses in terms of time saving as well as performance by the nurses will be increased in patient attending duration. Moreover, the entire patient's data will be saved within the memory attached to the digital system of the EPBS. Hence less paper work will be required and a large amount of data can be saved and easily accessed within the system of EPBS.



## 6. Conclusion

Emergency Patient Bedding System for Smart Hospitalization (EPBS) can hold tremendous advantages for the patient from monitoring to treatment prospective during the emergency conditions. In addition, EPBS also covers the capability of providing light weight, a smart patient bed for ED patients. The distinctive arrangement of active and passive parts of a modular design makes it exclusive, multipurpose and convenient for the patient as well as for healthcare providers. In addition, the design features of EPBS are compared to a number of recent but relevant European patents in this paper and improved the existing patents to some extents in comparison with EPBS according to the challenges mentioned in this paper following under the rules of Food and Drug Administration (FDA) to improve to some extent the accuracy of monitoring, sensitivity of patient treatment with the analysis based is performed on the basis of nurses' manual labor Full Time Equivalent (FTE), provides portability and customization of the system along with the patient.

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