MODELING DECISIONS FOR HOSPITAL BED MANAGEMENT
A Review

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Abstract: With today's hospital demands and financial constraints, hospital inpatient bed management is becoming increasingly complex. The use of decision support systems could enable hospital staff and health decision makers to perform more focused management of the hospital inpatient beds, thus potentially reducing costs and inpatient length of stay. A literature review was carry out on both PubMed and ISI Web of Knowledge in order to identify studies evaluating the use of decision support systems when applied to hospital inpatient bed management. Two different approaches were identified: one approach based on the use of mathematical models to support the planning and allocation of hospital inpatient beds and another approach consisting in the utilization of information technologies to support timely inpatient placement. It was perceived that mathematical models could be safely used to model annual patient arrival rates and bed occupancy, thus forecasting hospital/department bed demand and underlying cost structures/revenues. It was also perceived that the use of bed management information systems provides hospital staff (administrative clerk, clinicians and housekeepers) with the necessary information to timely assess performance measures based on the hospital/department activity thus increasing resource effectiveness, optimizing established clinical pathways, reducing inpatient length of stay and associated costs.

1 RATIONALE

With today's hospital demands and increasing financial constraints, efficient hospital inpatient bed planning and allocation is becoming increasingly difficult. In recent years, hospitals have engaged in various cost-cutting efforts that include department downsizing, the consolidation of small services and the decrease of the average inpatient length of stay (ALoS). The number of hospital inpatient beds is usually determined by the hospital or by associated health authorities using methods based on ratios and/or target bed occupancy rates (Green and Nguyen, 2001; National Audit Office, 2000; Nguyen et al., 2005; Kokangul, 2008; Mackay and Lee, 2005; Millard et al., 2000). The optimal number of hospital/department inpatient beds can be defined as the number for which the following three criteria are met (Nguyen et al., 2005):

- The number of unoccupied beds is not excessive, to avoid resource misuse thus levering the efficiency and maximizing revenues (productivity);
- The number of patients transferred to other departments or other hospitals because of lack of available bed is not excessive (security). Transfers to other hospitals result in a lost of revenues while transfers to other departments may cause the placement in less appropriate units, compromising the quality of care and possibly resulting in a increase of costs (e.g. need for additional staff);
- One or more beds are available for unscheduled admissions (accessibility).

The introduction/development of decision support information systems, either based on mathematical models or based on information systems, could allow bed managers (and other staff that hold responsibilities in the inpatient bed management process) to perform a more focused management of the hospital inpatient beds, either by providing new planning forecast tools and/or tools capable to timely-inform about current bed occupancy/utilization, short-term levels of planned

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elective admissions, likely emergency inpatient admissions and likely inpatient discharges.

2 METHODS

A literature search was performed in December 2009 with the goal of identifying studies evaluating the use of decision support systems when applied to hospital inpatient bed management. The search was conducted both on PubMed and ISI Web of Knowledge resulting in a base data collection of 65 studies. Thirteen studies were excluded by lack of available abstract or full text and 38 studies were excluded after abstract and/or full text review (e.g. studies that didn't address explicitly hospital bed capacity and/or hospital bed allocation management subjects). The final size of the overall data collection was of 14 studies. Ten studies (~71,4%) addressed the use of mathematical models to forecast and/or plan hospital bed capacity (Green and Nguyen, 2001; Nguyen et al., 2005, 2007; Kokangul, 2008; Mackay and Lee, 2005; Millard et al., 2000; Cochran and Roche, 2008; Gorunescu, McClean and Millard, 2002; Belien and Demeulemeester, 2007; Ridge et al., 1998). Four studies (~28,6%) addressed the use of information technologies to support inpatient bed management, currently under use (Blair, 2005; Szabo, 2003; Reuille, 2004) or under evaluation (Kannry et al., 2007). One literature source with publication date in the current decade (National Audit Office, 2000) was handpicked and added to the overall data collection in order to support theoretical and practical concepts surrounding the bed management subject.

3 FINDINGS

From the analysis of the selected data collection from both PubMed and ISI Web of Knowledge, it was perceived that the subject under revision (the use of decision support systems for hospital inpatient bed management) can be undertaken by two distinctive approaches. One approach is based on the use of mathematical models to support the planning and allocation of hospital inpatient beds. Another approach consists on the utilization of information technologies to support the timely-decision/timely-action of the hospital staff (administrative clerk, clinicians and housekeepers) in order to facilitate inpatient placement thus optimizing the bed management process. The main conclusions and recommendations extracted from the reviewed studies are sketched in table 1.

The studies that addressed the planning and allocation of inpatient beds by means of mathematical models covered such diverse techniques as: queuing models, stochastic models, flow models and other general proposed models.

Different distributions of patient arrival/department service rates were analyzed for different department/unit profiles: geriatric department (Gorunescu, McClean and Millard, 2002), intensive care unit (Ridge et al., 1998; Cochran and Roche, 2008), intermediate care, obstetrics/gynaecology and surgical departments (Cochran and Roche, 2008) and paediatric intensive care unit (Kokangul, 2008).

Mathematical distributions were originated from data collections as diverse as: department historical patient arrival rate/LoS, midnight census by department, midnight bed holds by department and patient billed nights by level of care. All of the analyzed studies point out advantages in the use of mathematical models to forecast department demands in terms of allocating the right number of beds. It was concluded that the mathematical models also provide better information concerning cost structures and revenue characteristics and how these affect capacity and resource allocation decisions.

Given accurate data about the actual costs of occupied and empty beds, modelling could be used to balance the cost of providing excess standby beds (accessibility), with the costs associated with rejecting patients. Thus, the modelling approach facilitates the provision of cost efficient and cost effective services.

Four studies addressed the use of information technologies to support and facilitate inpatient placement. Reuille (2004) proposed a centralized bed management system (Bed Control Report) based on five Excel spreadsheets, dispersed by four departments, were information was inputted by the target department staff. Szabo (2003) describes the use of the Bed Tracking System, developed by Tele-Tracking Technologies, to support the bed placement workflow and centralize bed status information (bed released, bed in maintenance and bed available), that is entered into the system by the hospital staff (administrative clerk, clinicians and housekeepers) using specific coded calls. A very similar approach is described by Blair (2005) were the BedCentral system, developed by MediLogistics, is also used to centralize bed status information entered by the hospital staff. Unlike the Bed Tracking System, the information is inputted on both

patient admission and patient discharge. Mobile staff members use PDAs to generate, transmit and receive information about bed status while other members use department workplaces and/or an electronic dashboard. It was concluded that the use of Bed Tracking System resulted in a door-to-bed improvement by nearly 30 percent and that the use of BedCentral resulted in a reduction of the time needed to perform bed maintenance from nearly two hours to about 45 minutes reducing FTEs by 25 percent. The last analyzed study evaluated the use of RFID technology to accelerate identification of empty beds by assigning to each discharged patient a unique RFID tag number that was read at the patient departure time (the effective physical discharge). It was concluded that the proposed system enabled the identification of empty beds within an average of 25 minutes earlier when compared with the pre-existing process (manual information recording in the ADT system).

4 CONCLUSIONS

The analyzed mathematical models were in general complex and didn't address numerous internal and external factors that may affect the provision of hospital/department inpatient services, such as staffing levels, multi-profile beds, requirements for isolated beds and clinical pathways that are cross-departmental (e.g. multi-department beds). As such, the models should be augmented by other information to ensure a more comprehensive understanding of the dynamics that arise from an analyzed hospital/department. For general planning and cost structures/revenue purposes, an annual model of patient arrival rates and bed occupancy (department service) may be sufficient. Models of shorter duration, however, may be necessary to reflect the changes in bed occupancy that occur throughout the year.

Table 1: Main conclusions and recommendations extracted from the analyzed studies.

Information technologies	Mathematical models	
BedCentral has helped St. Luke's Episcopal Hospital to maximize its existing resources, e.g. ICU capacity tuning, telemetry/high-dollar beds swift filling and minimization of the time required to clean rooms and transport patients (Blair 2005)	The use of target occupancy levels, such as the average length of stay (LoS), as the primary determinant of bed capacity is inadequate due to the unpredictable nature and distribution of hospital admission rates and patient LoS over time (Green & Nguyen 2001; Nguyen et al. 2005, 2007; Kokangul 2008; Mackay & Lee 2005; Millard et al. 2000; Ridge et al. 1998)	More sophisticated methodologies should be considered to support decisions that involve bed capacity, e.g. methodologies that capture population structure, organization and resource use (Green & Nguyen 2001; Mackay & Lee 2005)
Bed Tracking System has improved door-to-bed time and reduced the "hold-time" by nearly 30%. It also lengthened the time clinicians can spend with patients instead of trying to locate a empty bed (Szabo 2003)	Stochastic and flow models could be used to determine the optimum size of bed requirement, the size of additional required resources (e.g. workforce or facility planning) or to capture the variation in bed occupancy (Kokangul 2008; Mackay & Lee 2005)	Models should consider elective patient scheduling, different levels of care (e.g. ICU and HDU beds) and semi-automated historical data (Ridge et al. 1998)
The proposed RFID-based system identified empty beds within an average of 25 minutes earlier when compared with the pre-existing process - manual information recording in the ADT system (Kannry et al. 2007)	Posterior financial/billing data, rather than the census data commonly relied upon, yields the true hospital bed demand as it estimates true demand for service rather than merely the service available to be offered (Cochran & Roche 2008)	Seasonal bed demand patterns should be considered when evaluating bed management models (Kokangul 2008, Cochran & Roche 2008)
	There is a clear need to address both the issue of capacity planning at each different level of care within individual hospitals and also relative levels of care across different hospitals in a region (Ridge et al. 1998)	Additional parameters should be included such as population rate, staff/equipment requirements and budget constraints, in order to universalize stochastic models (Kokangul 2008)
Conclusions		Recommendations

Bed management systems based on information technologies, supply hospital staff with the information necessary to timely assess performance measures based on the department activity, thus increasing resource effectiveness, optimizing established clinical pathways, reducing inpatient length of stay and associated costs. However performance measures could be biased because of the implied cross reliance on hospital staff to timely input patient/bed status information. The analyzed systems rely too much on timely inputted information in order to proper track hospital/department bed status – current bed status may not be the real bed status. In this sense, it is recommended that these systems be integrated with the hospital ADT (Admission/Discharge/Transfer) information system in order to reduce human interaction to the minimum. Yet, even after performing this kind of integration, another problem would still exist in the patient discharge process – the time de-synchronization between the patient department discharge and the manual recording of that information in the ADT system. The suggested RFID approach could provide a simple solution for this problem.

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