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The *Intelligent BedTracker*™: Enhancing Inpatient Ward Efficiency and Emergency Department Flow in Low-Resource Health Systems

A Narrative Review

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Abstract: Emergency Department (ED) overcrowding represents a critical challenge within public healthcare systems globally; stemming largely from systemic inefficiencies in inpatient bed management, ineffective capacity monitoring by the ED and clinical managers, along with ED workflow bottlenecks. Traditional manual approaches to inpatient bed monitoring are frequently characterized by a lack of real-time visibility leading to significant delays in patient transfers and suboptimal resource utilization. This paper examines the transformative potential of a real-time hospital-wide bed tracking dashboard, one driven by live ED status data and inpatient bed demand metrics. By integrating real-time ED occupancy, patient acuity and anticipated admissions, the system enables proactive bed allocation for improved patient flow management and surge planning. This innovation addresses critical bottlenecks in hospital operations, reduces delays in care and supports data-driven decision-making that optimizes resource utilization. Designed specifically for low-resource healthcare systems which lack Electronic Health Records (EHRs) infrastructure, this solution addresses long-standing challenges in patient flow, bed allocation, and operational efficiency. Its flexible architecture not only functions independently in EHR-deprived environments but is also capable of seamlessly integrating and scaling within existing EHR-enabled settings, thus making it a versatile tool for diverse healthcare contexts. This descriptive review demonstrates how such systems, through their comprehensive features and intelligent design, can greatly enhance organizational efficiency, elevate workforce productivity, optimize patient flow, and ultimately promote patient-centered outcomes. Furthermore, it explores how its implementation and special features align with broader global healthcare objectives including digital transformation, health equity and the delivery of high-quality care. It also considers future opportunities for scalability and integration with EHRs technologies and advanced Artificial Intelligence (AI) for proactive surge planning.

Key words - Real-time bed tracking; Emergency Department overcrowding; Patient flow optimization; Digital health; Health service efficiency; Data-driven decisions in healthcare; Healthcare information systems; Digital Transformation; Value-Based Care; Patient-centered care

I. INTRODUCTION

Emergency Departments worldwide struggle with the persistent issue of overcrowding, a phenomenon defined by the American College of Emergency Physicians (ACEP) as a situation where the demand for emergency services surpasses the available resources within the ED, the hospital, or both (American College of Emergency Physicians, 2013). This topic is timely since the scope of practice in Emergency Medicine has expanded to include prolonged observational stays, more complex diagnostic workups, and increased critical care within the ED, thus making the strain of an overcrowded department more evident (McKenna, P., Heslin, S. M., Viccellio, P., et al., 2019). This universal issue is often an indicator of broader health system dysfunction and the core of it often lies in the bottleneck created by admitted patients awaiting transfer to an inpatient bed. This phenomenon is commonly referred to as "boarding" (McKenna, P., Heslin, S. M., Viccellio, P., et al., 2019).

The systemic nature of ED overcrowding contributes to inefficiencies across the entire hospital enterprise. According to McKenna, P., Heslin, S. M., Viccellio, P., et al. (2019), within the ED, overcrowding contributes to significant financial and operational impacts including lost revenue from patients who leave without being seen (LWBS) in the case of paid systems, increased ambulance diversions and prolonged overall patient length of stay (LOS). Beyond financial implications, the sustained pressure of an overcrowded ED inflicts substantial physical and moral harm upon ED staff which contributes to burnout and reduced job satisfaction (Kelen, G. D., Wolfe, R., D'Onofrio, et al., 2021). A primary cause of ED overcrowding is the significant delays in transferring admitted patients from the ED to appropriate inpatient floors. When this occurs, the appropriate and timely delivery of patient care is impeded. Factors contributing to these transfer delays are multifaceted, including the availability of hospital beds, staffing and the efficiency with which consulting physicians can facilitate admissions (Kelen, G. D., Wolfe, R., D'Onofrio, et al., 2021). Furthermore, the unpredictable nature of patient demand coupled with the varied health conditions requiring admission, often lead to peak service periods that overwhelm existing capacity and force hospitals to resort to the use of extra beds and

stretchers in ED corridors (Trzeciak S, Gaughan JP, Bosire J, et al., 2017). The problem of ED overcrowding is frequently misdiagnosed as an ED-specific operational issue; however, it functions as an indicator of overall health system performance, reflecting broader hospital-wide capacity challenges (Kelen, G. D., Wolfe, R., D'Onofrio, et al., 2021). This perspective denotes that effective solutions must be holistic and span the entire hospital rather than being confined to a single department.

A central factor reinforcing these inefficiencies and delays is the lack of real-time visibility into bed availability across the entire hospital system (McKenna, P., Heslin, S. M., Viccellio, P., et al., 2019). Without an accurate understanding of bed status, effective coordination and innovative systems, the management of bed capacity and patient surges would remain challenging. Furthermore, this absence of real-time comprehensive information would allow hospitals to remain in a reactive rather than proactive state, constantly struggling to match demand with available resources.

II. CONSEQUENCES OF ED OVERCROWDING ON PATIENT CARE AND HOSPITAL OPERATIONS

The repercussions of ED overcrowding extend far beyond mere inconvenience, imposing severe consequences on both patient care and hospital operations. For patients, overcrowding directly causes delays in care and affects the critically ill (McKenna, P., Heslin, S. M., Viccellio, P., et al., 2019). The unfavorable environment contributes to an increased rate of patients leaving without being seen (LWBS), including those with serious illnesses. For such patients, this often leads to a progressive worsening of their health conditions and subsequent return visits in a more critical state that require a higher level of care (McKenna, P., Heslin, S. M., Viccellio, P., et al., 2019). Additional negative patient outcomes include an elevated risk of adverse events such as hospital-acquired infections, misdiagnoses and medical errors (Mostafa, R., & El-Atawi, K., 2024). Furthermore, McKenna, P., Heslin, S. M., Viccellio, P., et al. (2019), along with other studies, have demonstrated a direct link between prolonged ED boarding and higher 10- and 30-day mortality rates.

Emergency Department overcrowding significantly impacts hospital efficiency and financial stability. Overcrowding has proven to increase the total hospital LOS by at least one day, with the longest boarded patients experiencing an increase of up to three days (McKenna, P., Heslin, S. M., Viccellio, P., et al., 2019). This then leads to a phenomenon known as "hospital exit block." When this occurs, patients ready for transfer from the ED are unable to access inpatient beds. This then intensifies ED crowding and is seen as a symptom of a "sick" health system (Sartini, M., Carbone, A., Demartini, A., et al., 2022). Furthermore, in paying systems, the financial ramifications are substantial as boarding contributes to increased costs and a reduction in revenue due to walkouts and diversions (McKenna, P., Heslin, S. M., Viccellio, P., et al., 2019). Beyond the financial strain, ED staff experience heightened workload, stress and burnout, which then negatively impacts job satisfaction and contributes to high levels of staff turnover (Kelen, G. D., Wolfe, R., D'Onofrio, at al., 2021).

The cascading effect of ED overcrowding is often evident. For example, a bottleneck in one area such as "Triage" or "Awaiting Transfer to Ward" creates ripple effects that destabilize the entire hospital system. This impacts not only patient safety, but financial viability and staff well-being. Managing ED occupancy is a pivotal aspect of healthcare quality (Al-Qahtani, M. F., & Khubrani, F. Y., 2021) and its complexity demands an integrated, customizable, real-time and system specific solution that provides a holistic view of bed capacity across the entire organization.

III. FROM TRADITIONAL TO DIGITAL APPROACHES

ED crowding is seen as a measure of operational efficiency. It also highlights the need for optimal resource allocation and efficient patient flow management systems both within the department (Mostafa, R., & El-Atawi, K., 2024) and between ward transfers. Within hospitals, bed management often operates as an unseen background process, rarely attracting attention until disruptions occur - a point when patient and staff dissatisfaction quickly become apparent (Balaji, R., & Brownlee, M., 2018). Ineffective bed management can trigger a cascade of negative consequences including reduced admission capacity, prolonged ED boarding, and the loss of valuable ED beds for critically ill patients. These limitations not only compromise timely treatment but also strain overall hospital operations and patient flow.

In many low-resource settings, the challenges of department bed monitoring have long been exacerbated by the limitations of predominantly manual conventional methods. These outdated approaches often fail to provide reliable, real-time data necessary for timely and proactive decision-making, thereby disrupting ED operations and impeding optimal patient flow. The transition from manual to digital bed management solutions marks a significant shift, offering the potential to overcome these inefficiencies and enhance the responsiveness, accuracy and effectiveness of patient care coordination particularly in low-resource settings.

Digital transformation in hospital bed management has demonstrated concrete benefits across diverse contexts. In a private general hospital in Brazil, implementing digital tools yielded greater operational efficiency, real-time information access, and improved staff and patient satisfaction even during challenges such as systems integration, real-time data availability, and cultural adaptation (Freitas, R., & Araújo, C., 2024). Internet of Things (IoT)-based bed tracking systems have also shown promising results in the Philippines where an IoT-driven monitoring solution using optical sensors achieved reliable, consistent results, garnering favorable evaluations from healthcare users (Corpuz, R S., Usa, J., Obaña, J., et al., 2024). These findings underscore the potential of practical, adaptable digital innovations to overcome the deep-rooted inefficiencies of manual bed management in resource-constrained health systems.

IV. LIMITIONS OF TRADITIONAL AND MANUAL BED MANAGEMENT METHODS

Traditional manual bed management systems are inefficient and prone to errors, relying on paper records, whiteboards, and fragmented communication channels; this approach limits real-time visibility into hospital-wide bed availability and patient status (Balaji, R., & Brownlee, M., 2018). Information is often outdated or inaccurate, leading to misallocations, prolonged patient wait times and significant delays in bed turnover (Mukherjee, S., Chakraborty, A., Barua, S. et al 2025).

Resource mismanagement is another significant drawback. Inefficient allocation of resources such as an undersized patient transport team, a shortage of nursing staff or limited access to other critical resources, directly delay patient transfers, bed preparation and timely bed reoccupation. Manual checks and reporting are time-consuming and susceptible to human error, further hindering efficient bed preparation and patient transfers (Shaare, M., Zin, M., Isa, A., et al., 2024). The absence of an integrated, end-to-end process view, coupled with the fragmentation of critical activities across departments creates a disjointed operational framework that undermines coordination, delays decision-making, reinforcing systemic bottlenecks.

When unpredictable bed demand is managed through manual methods, hospitals often resort to the use of extra beds and stretchers in ED corridors. This approach compromises patient privacy and safety, worsens overcrowding and strains staff, ultimately diminishing care quality. These outcomes stem directly from manual systems' inability to adapt to dynamic demand or deliver the real-time data and predictive insights needed for proactive management.

V. CAPABILITIES AND GAPS IN EXISTING DIGITAL BED MANAGEMENT SYSTEMS

The adoption of digital transformation in patient admission and bed tracking systems has significantly influenced hospital efficiency and patient care (Mukherjee, S., Chakraborty, A., Barua, S., et al., 2025). Modern digital bed management systems provide real-time visibility into bed availability and patient placement, with some harnessing predictive analytics to anticipate demand and optimize resource allocation. Integrating live operational data with forecasting enables timely, evidence-based decisions that improve patient flow, reduce delays, and enhance hospital efficiency. Core functions include structured queue and waitlist management, automated transfers and discharges, and continuous real-time monitoring of bed occupancy. Some advanced systems integrate with Real-Time Locating Systems (RTLS) to provide enhanced visibility of equipment and patient movement (Overmann, K. M., Wu, D. T. Y., Xu, C. T., et al., 2021).

Despite their advantages, existing digital systems face notable challenges including high upfront costs for technology, integration, and staff training. Many solutions also struggle to integrate seamlessly across diverse healthcare technologies, hindering providers' ability to obtain a unified view of patient health and weakening care coordination. (Cecconi, M., Hutanu, A. L., Beard, J., et al., 2025).

A common discomfort with many management systems is information overload and alarm fatigue, where frequent alarms can desensitize healthcare providers and lead to delayed responses or overlooked critical alerts (Cecconi, M., Hutanu, A. L., Beard, J., et al., 2025). This reinforces that the quality and intelligent presentation of real-time data are crucial, an essential quality of the *Intelligent Bed Tracker™*

Resistance to change among healthcare staff and clinical managers poses another significant hurdle. Technology adoption is not solely a technical problem but a socio-technical one, where successful implementation requires robust training and active stakeholder engagement. Transitioning from familiar manual processes to unfamiliar digital tools necessitates a profound cultural shift and sustained commitment. While digital tools offer significant automation, the importance of maintaining some manual oversight for unforeseen circumstances such as system downtimes or technical glitches is crucial. This is another key feature at the heart of the *Intelligent Bed Tracker™* design, that is, to ensure resilience and continuity of hospital operations.

VI. THE *Intelligent BedTracker™*: A NOVEL REAL-TIME CAPACITY MANAGEMENT SYSTEM

In response to the challenges and limitations identified in both traditional and existing digital bed management practices, the *Intelligent BedTracker™* emerges as a novel real-time solution, especially suited for low resource settings and those without existing Electronic Health Record Systems. This system is specifically designed to provide comprehensive visibility of inpatient bed resources, thereby mitigating overcrowding in public hospital emergency departments by enhancing overall proactive operational efficiency. The following section outlines some of the core features of the *Intelligent BedTracker™*

1. Comprehensive Bed Visibility and Management

The *Intelligent BedTracker™* features a suite of core features designed to deliver comprehensive, real-time visibility into hospital bed status. Its central capability lies in continuously tracking bed availability across multiple wards. This hospital-wide scope enables rapid identification of capacity by the ED and clinical managers, supports timely patient placement and facilitates proactive resource management across diverse clinical settings.

Conventional manual methods are often reliant on phone calls and paper logs that are prone to delays, data inaccuracies, and fragmented communication between departments. These limitations hinder the hospital's ability to respond promptly to surges in demand, lead to prolonged ED boarding, delay admissions, and facilitate suboptimal use of available resources. In low resource

settings, by replacing these outdated processes with a continuously updated digital dashboard system that is driven by the real-time demands of the ED, systems like the *Intelligent BedTracker*™ not only improves operational efficiency, but also enhances patient flow, reduces wait times and strengthens coordination across the entire hospital.

The system also provides clinical managers with real-time visibility of hospital-wide capacity from their offices, including ED patients awaiting transfer or inpatient bed availability (See Fig.1). Since the display also includes each patient's respective wait times, by eliminating reliance on manual rounds and phone calls, the system enables rapid responses to surges and crises with early detection of bottlenecks and timely interventions to optimize resources and improve patient flow.

Additionally, the system provides instantaneous updates on when a bed becomes available across all units, enabling rapid identification of suitable beds for patient admission. Also, because it is continuously updated with admitted patients in real time by the Emergency Department, ward staff gain real-time visibility into all admissions for their respective units including each patient's diagnosis, clinical status (critical or stable), wait times, and other essential information needed for a smooth handover and timely care. This advanced notice allows wards to prepare beds, allocate necessary equipment and coordinate staffing in advance, thereby reducing admission delays, improving patient flow and care efficiency. By fostering transparency between the ED and inpatient units, the system minimizes uncertainty and supports proactive planning, thereby enhancing overall hospital throughput.

2. Accountability and Audit Readiness

Ensuring accountability and enabling robust auditing are core functions embedded in the design of the *Intelligent BedTracker*™, aligning with best practices in healthcare operations and digital health governance. The system maintains comprehensive, time-stamped activity logs for all actions with a dashboard that integrates user login and employee identification with each activity. This feature ensures that only authorized personnel can access and modify sensitive bed and patient status information, thereby enhancing data security and enabling precise tracking of individual responsibilities within the system. User permissions allow for management of access levels and roles, ensuring that each staff member interacts with the system according to his/her designated responsibilities. The combination of timestamped activity logs and secure user login transforms capacity management from a potentially chaotic process into a transparent, auditable workflow. This not only bolsters accountability but also provides invaluable historical data for retrospective analysis, continuous process improvement and the identification of subtle inefficiencies that might otherwise remain obscured.

For emergency department staff, key activities include admitting patients into the system and assigning each one to suitable wards after approval by the admitting team. ED staff are also able to update patient status, modify patient details or priority levels, record updates to diagnoses that require ward attention, and document relevant information in the notes section.
Such granular audit trails are widely recognized as critical for operational transparency, regulatory compliance, medico-legal accountability and continuous quality improvement.

3. Capacity Management

The "Discharge" Button

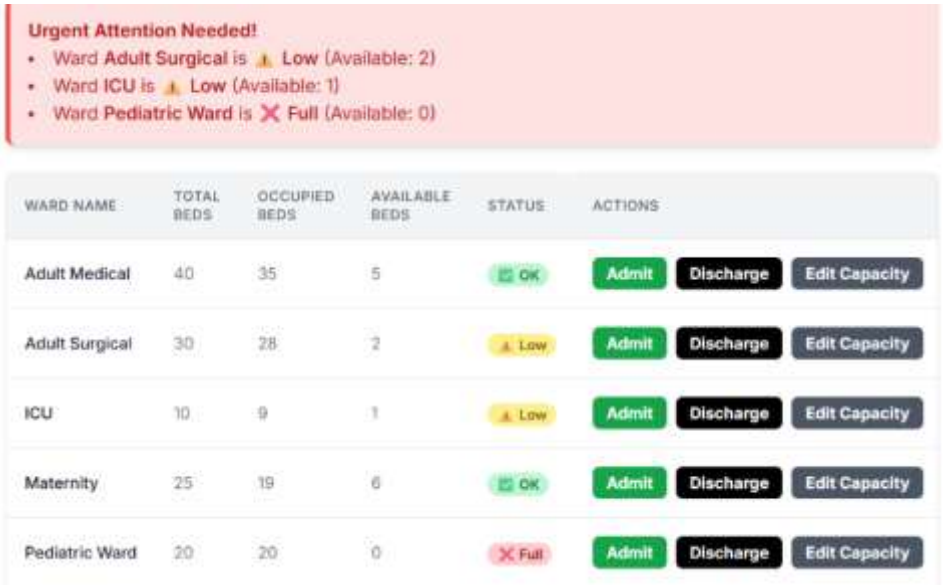
As shown in Fig. 1 below, this function enables ward staff to discharge a patient from the system after physician approval or if they discharge against medical advice (DAMA). Emergency department staff may also apply this function for patients categorized under "Awaiting Transfer to Ward" or "Awaiting Inpatient Bed Availability" (Figure 2), in circumstances such as DAMA, or in the event of an unexpected death while in the ED. Each discharge entry includes a built-in "*Notes*" section that enables clear documentation of the reason for discharge in order to support follow-up and quality audits. This functionality enhances transparency and positions the *Intelligent BedTracker*™ as an effective quality management tool.

One thoughtful design feature of the "Discharge" button when applied by ward staff is the automatic alert it generates on the ED dashboard, immediately indicating that a bed has become available. The alert remains visible for 30 minutes before the bed is automatically reclassified into the general pool of available beds. This design ensures that critical updates are prioritized during periods of high bed demand while preventing dashboard overcrowding. Timely, automated alerts of this nature support resource allocation, reduce avoidable delays, and help prevent overcrowding-related safety risks which have been linked to increased morbidity and mortality within ED settings (Singer, A. J., Thode, H. C., Viccellio, P., et al. 2011).

The "Edit Capacity" button

Access to this function is limited to clinical management or other authorized personnel. Shown in Figure 1 below, it enables staff to modify ward capacity by increasing bed availability when extra corridor beds or other facilities are added during periods of heightened demand or reduce capacity in response to unforeseen constraints. This flexibility therefore ensures accurate and responsive capacity management.

Fig. 1 Partial dashboard view of the *Intelligent BedTracker*™ prototype



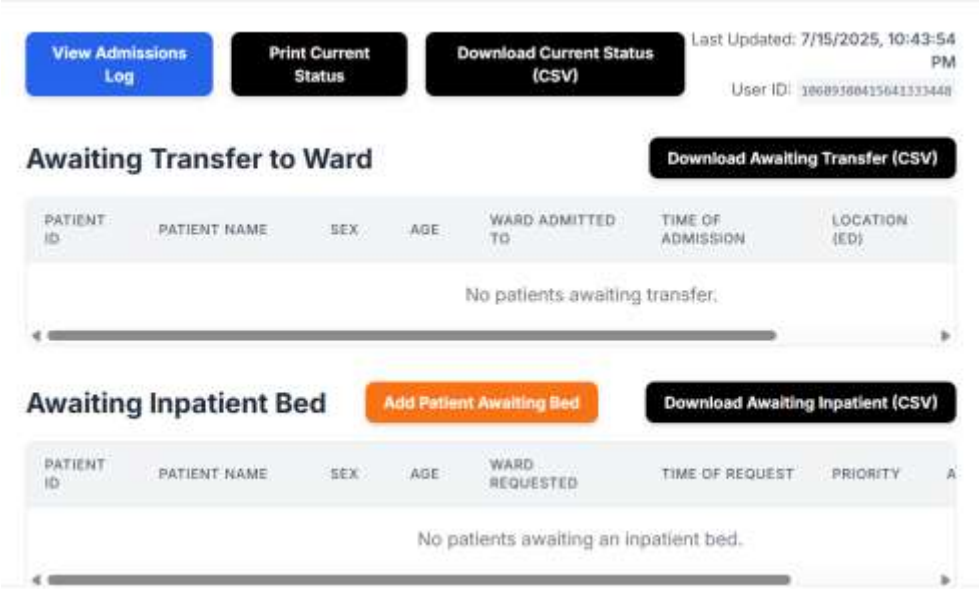
4. Simple Layout and Visual Cues

The *Intelligent BedTracker*™ leverages intuitive visual cues to improve situational awareness and accelerate decision-making. The emphasis on boldness and clarity is among the defining features that make this system unique, ensuring that critical information is not only visible but immediately understood by all relevant stakeholders. Discharge reasons are also color-coded for instant recognition. For example, "DAMA" appears in red, drawing immediate attention to cases requiring follow-up or special handling by Social Workers or Case Managers.

This visual framework extends to real-time bed availability where distinct colors represent specific capacity thresholds. To elaborate, a ward with a high number of available beds is highlighted in green indicating readiness to receive patients. However, if availability falls below five beds, the ward then turns yellow signaling the need for heightened monitoring and proactive measures to prevent ED congestion. Additionally, a ward at full capacity is marked in red, serving as a high-priority alert to both ward and ED teams. These features are displayed Figure 1 and the settings could be customized to the institution's bed capacity and pre-determined alert thresholds.

By combining discharge-specific color codes with dynamic bed status indicators, the *Intelligent BedTracker*™ transforms raw operational data into actionable intelligence. Such meticulous application of data visualization principles reduces cognitive load, enables rapid prioritization, and supports timely interventions. These are critical advantages in the high-pressure environment of emergency care and are crucial for rapid decision-making. It has been established that overly complex interfaces can lead to information overload and delayed interventions (Arnold, M., Goldschmitt, M., & Rigotti, T., 2023). This is common among some existing digital dashboard systems. The design of the *Intelligent BedTracker*™ is intentionally preventive, ensuring wards rarely reach critical capacity levels through early detection and coordinated action. Furthermore, studies confirm that bold, color-coded interfaces significantly improve the speed and accuracy of decision-making in clinical settings, particularly when information must be interpreted rapidly under stress (Harle, C. A., DiIulio, J., Downs, S. M., et al. 2019).

Fig 2. Partial dashboard view of the *Intelligent BedTracker*™ waiting windows and key functionalities



5. Reporting and Data Export Functionality

Although the *Intelligent BedTracker*™ is an advanced digital system, its design incorporates data exportation and printing for physical documentation and reporting. This approach acknowledges that, despite the efficiency and accuracy of real-time digital tracking, many healthcare settings still rely on paper-based records for regulatory compliance, archiving, as well as contingency measures during system downtime. By maintaining compatibility with both digital and physical workflows, the system ensures continuity of operations, supports diverse institutional needs, and promotes seamless adoption in facilities with varying levels of digital infrastructure.

The robust export functionality allows data to be transferred to formats such as Spreadsheets, Character Separated Values (CSV), or Portable Document Format (PDF) (Figure 2). This capability is crucial and allows for the following: enabling in-depth data analysis for research purposes; comprehensive policy reviews; detailed retrospective audits of bed utilization patterns; patient flow dynamics; overall operational performance and system modelling. This feature generates comprehensive census reports that provide detailed insights into bed occupancy rates and trends. These visuals are essential for strategic decision-making and long-term capacity planning within the hospital.

Beyond its export features, the dashboard displays a distinct button labelled “Print Current Status.” This functionality enables the generation of physical reports detailing the institution’s current bed occupancy and patient flow at a specific point in time. Such printouts are invaluable for critical operational activities including shift handovers, emergency planning meetings and fulfilling regulatory compliance requirements where physical documentation remains necessary. This demonstrates a thoughtful and practical design approach that caters to diverse operational needs.

Table 1 summarizes the key features of the *Intelligent BedTracker* ™ and the direct benefits to hospital operations and patient care

VII. THE TRANSFORMATIVE IMPACT OF REAL-TIME MONITORING

The implementation of real-time bed management systems fundamentally transforms hospital operations and patient care by addressing critical pain points and fostering a more efficient, productive and patient-centered environment.

1. Enhancing Workforce Productivity

Real-time systems substantially improve workforce productivity and facilitate clearer communication among staff, which is critical in dynamic healthcare environments. By automating repetitive administrative tasks such as bed tracking, these systems reduce the administrative burden on healthcare professionals, freeing up valuable time that can be redirected towards direct patient care. This shift in focus can lead to a measurable reduction in staff stress levels and burnout, ultimately improving morale and retention within the healthcare workforce.

Table 1. Key Features of the *Intelligent BedTracker™*

Features	**Benefits**
Real-time availability tracking across multiple wards	Optimized bed utilization, reduced patient wait times, enhanced coordination across departments, holistic view of hospital capacity.
Dedicated sections for Awaiting Transfer and Awaiting Bed Availability	Clear identification of ED boarding bottlenecks, improved patient throughput, proactive management of patient flow, faster decompression of ED.
Time-stamped activity logs	Enhanced accountability, audit readiness, detailed historical data for process analysis, improved compliance.
User login and employee identification features	Secure access, tracking individual responsibilities, data integrity, improved security and compliance.
Color-coded discharge reasons (e.g., "Discharge Against Medical Advice" in red)	Instant visual identification of critical patient statuses, reduced cognitive load for staff, rapid prioritization of actions.
Export functionality	Enables in-depth research, policy review, retrospective audits, data-driven strategic planning, and performance analysis.

2. Financial Benefits

The financial benefits of this optimized efficiency are substantial. By reducing unnecessary patient days and improving patient throughput, hospitals can realize significant annual savings through the reduction of wasted time and unnecessary spending, thereby increasing their capacity to serve more patients without the need for costly physical infrastructure expansion. This positions real-time bed management not merely as a clinical enhancement but as a strategic financial multiplier for public hospitals.

3. Reduction in Patient Delays

The availability of real-time data allows hospitals to precisely identify where delays occur and accurately estimate patient volumes and anticipate surges. This empowers clinical managers to respond rapidly by adjusting staffing levels or reallocating resources to high-demand areas.

Empirical evidence underscores the operational and clinical benefits of real-time, data-driven bed management systems. For instance, a leading healthcare facility integrated an Internet-of-Things (IoT)-enabled bed tracking platform within its Electronic Health Record (EHR) system and the hospital experienced a 30% reduction in patient wait times, along with a 20% increase in bed turnover efficiency, highlighting the platform's ability to streamline patient flow and optimize resource utilization (Mukherjee, S., Chakraborty, A., Barua, S., et al., 2025). This occurred within the first year. In a separate case study, an institution employed predictive analytics to identify patients at high risk of readmission and implemented targeted interventions accordingly. This strategy yielded a 15% reduction in readmission rates, demonstrating how predictive data-informed approaches can simultaneously improve care quality and enhance operational performance (Mukherjee, S., Chakraborty, A., Barua, S., et al., 2025).

Added to that, the reduction in "door-to-doc" time (the duration between a patient's arrival in the ED and the moment a physician begins the medical screening or consultation) facilitated by real-time visibility and streamlined processes, emerges as a powerful measure for improving overall patient outcomes and reducing the number of patients who leave without being seen (Nyce, A., Gandhi, S., Freeze, B., et al., 2021). This facilitates a fundamental shift from merely tracking patients to actively accelerating their journey through the healthcare system. Door-to-doc time is a Key Performance Indicator (KPI) in healthcare systems.

4. Patient-Centered Outcomes and Satisfaction

The benefits of real-time bed management extend directly to patient-centered outcomes and overall satisfaction. Reduced wait times are strongly correlated with increased patient satisfaction (Nyce, A., Gandhi, S., Freeze, B., et al., 2021). Beyond actual wait times, real-time communication that provides operational transparency such as updates on workflow status, queue position, or estimated wait times, can significantly decrease perceived wait times and alleviate patient stress and frustration even when actual wait times do not change drastically (Soremekun, O., Takayesu, J., and Bohan, J., 2011). This implies that patient satisfaction is not solely dependent on the duration of the wait, but also on the perception of waiting and the quality of communication received during that period.

Multiple studies demonstrate that higher levels of patient satisfaction are strongly associated with improved clinical and organizational outcomes. Evidence links greater patient satisfaction to reduced mortality rates (Glickman, S. W., Boulding, W., Manary, M., et al., 2010); lower hospital readmission rates (Boulding, W., Glickman, S. W., Manary, M. P., et al., 2022); improved adherence to treatment regimens [(Jha, A. K., Orav, E. J., Zheng, J., et al., 2008) and (Nyce, A., Gandhi, S., Freeze, B., et al., 2021)]; fewer malpractice claims (Stelfox, H. T., Gandhi, T. K., Orav, E. J., et al., 2005); and decreased overall healthcare costs [(Trzeciak S, Gaughan JP, Bosire J, et al., 2017) and (Nyce, A., Gandhi, S., Freeze, B., et al., 2021)].
These findings indicate that designs such as the *Intelligent BedTracker*™ which prioritize real-time transparency and communication, can have a profound positive impact on patient experience.

In addition, under the Hospital Value-Based Purchasing (VBP) program established by the Affordable Care Act, hospitals with higher patient experience scores receive higher reimbursement (Huang, Q., Thind, A., Dreyer, J. F., 2010). This policy framework not only reinforces the importance of patient-centered care but also creates a direct financial incentive for healthcare organizations to prioritize and continuously enhance patient experience.

Lastly, by alleviating overcrowding and streamlining patient flow, thoughtfully designed real-time tracking systems play a crucial role in ensuring patient safety by reducing the risk of hospital-acquired infections and lowering the likelihood of medical errors that often arise in crowded or chaotic environments (Simbo A., 2025).

Table 2 below summarizes the impact of real-time bed management systems on key performance indicators.

Table 2: Impact of Real-Time Bed Management on Key Performance Indicators (KPIs)

KPI	**Measurable Impact**
Organizational Efficiency	Faster bed turnover, reduced bottlenecks, optimized resource utilization, increased throughput, significant cost savings.
Workforce Productivity	Clearer communication, proactive planning, reduced administrative burden, less staff burnout, increased time for direct patient care.
Patient Flow	Fewer delays in admissions, better ED-to-ward transitions, reduced ED length of stay, smoother patient journey.
Patient-Centered Outcomes	Increased patient satisfaction, reduced perceived and actual ED wait times, enhanced patient safety, reduced hospital-acquired infections.

VIII. THE *Intelligent BedTracker*™ AND GLOBAL HEALTH STRATEGY

The advent of real-time emergency department inpatient bed trackers signifies a pivotal advancement in healthcare management. Their impact extends beyond immediate operational improvements by influencing broader national healthcare goals. The *Intelligent BedTracker*™ aligns strongly with contemporary global healthcare goals, particularly those focused on digital transformation, health equity and the delivery of high-quality care [(Pan American Health Organization, n.d.), (World Health Organization, 2021) and (NHS England, n.d.)].

1.Digital Transformation

The system itself is a direct manifestation of digital transformation in healthcare, leveraging real-time information and advanced technology to optimize bed management processes. It contributes fundamentally to the digitization of health records and operational processes which are foundational elements for building a more efficient and responsive healthcare system. This contribution to digital transformation extends beyond mere technological adoption; it facilitates a fundamental shift in business models, strategic approaches, structural processes, and organizational culture within hospitals. The dashboard is not just a tool, but an enabler of systemic change necessary in modern healthcare.

2. Health Equity

In terms of equity, by increasing hospital capacity through optimized bed turnover and improving patient flow, the *Intelligent BedTracker*™ can significantly expand population access to hospital admissions. This is crucial in developing countries or underserved regions where limited bed availability poses a substantial barrier to equitable care as seen in Brazil where the average number of beds per 1,000 inhabitants is 2.3 - a number that is not consistent with the World Health Organization recommendation of three beds per 1,000 inhabitants (Freitas, R., & Araújo, C., 2024). According to the Centers for Medicare & Medicaid Services

(n.d.), reducing wait times and streamlining patient flow can directly address health disparities by ensuring timely access to care for all individuals irrespective of socioeconomic status, geography, or other factors that traditionally impede access.

3. Quality Care

Similarly, the system directly influences quality of care by improving patient safety and service standards. This is achieved by reducing overcrowding, minimizing wait times and improving overall efficiency. Faster diagnoses, a reduction in medical errors, and the provision of more personalized care are also direct outcomes of improved operational efficiency and real-time data access (Mulukuntla, S. and Pamulaparthyvenkata, S., et al 2020). The system also supports a patient-centric culture by enabling healthcare professionals to dedicate more time to direct patient interactions rather than administrative tasks.

4. Scalability and Future Planning Opportunities

The future trajectory of real-time bed management systems emphasizes scalability and deeper integration with existing and emerging healthcare technologies. The *Intelligent BedTracker*™ is designed with scalability as a core principle by employing modular frameworks that allow for the easy addition, removal or adjustments of components to meet the evolving needs of various hospital environments. Such solutions inherently offer this scalability, enabling healthcare organizations to effortlessly expand their software usage to accommodate growing patient demand across multi-hospital systems or regional implementations without requiring significant upfront infrastructure investments. This adaptability is crucial for meeting diverse needs and for supporting larger, more complex health systems.

5. Electronic Health Records (EHR) Systems Integration

A critical opportunity for the *Intelligent BedTracker*™ lies in its integration with Electronic Health Record (EHR) systems. Seamless integration allows for the bidirectional flow of comprehensive clinical data that could inform admission and treatment decisions, while ensuring that data-driven insights and streamlined information exchange.

6. Artificial Intelligence and Predictive Analytics

Further enhancements within an EHR are the incorporation of AI-based alerting for overcrowding and surge planning based on individual patient demographics and unique historical health data. The power of predictive analytics and AI take conventional ED triage classification systems such as the Emergency Severity Index (ESI) and the Canadian Triage and Acuity Scale to an entirely new level. AI and machine learning algorithms can be leveraged for sophisticated predictive analytics, enabling hospitals to forecast patient demand, predict admissions and anticipate patient behavioral patterns. This predictive capability allows for proactive allocation of staff and equipment, thus maximizing efficiency. AI can identify subtle patterns in resource utilization and trigger automated alerts for room availability, thus helping to prevent overcrowding before it becomes critical.

7. Surge Planning

Whether during public health crises like pandemics or in response to sudden and unexpected increases in patient volume, predictive models can forecast bed occupancy and resource requirements with greater accuracy. This foresight enables hospitals to allocate staff, equipment and space proactively, ensuring that critical resources are in place when they are required. The integration of AI for predictive analytics transforms bed management from a reactive or proactive system into a prescriptive one. This allows hospitals to anticipate and mitigate problems like overcrowding and resource shortages, representing a significant leap in operational intelligence.

IX. CHALLENGES

It is important to acknowledge that while AI offers immense potential, challenges exist that must be addressed early in development. These include:

1. Privacy concerns

AI technologies rely on vast amounts of sensitive health data, making privacy a top ethical concern. Risks include unauthorized access, data breaches and data misuse despite regulations. The system addresses such factors by incorporating features such as authorized access entry and signature time stamping activities.

2. Algorithmic Bias

AI systems are only as unbiased as the data they learn from. Biased datasets can lead to healthcare disparities and perpetuate unequal treatment for marginalized populations. Sources of bias include non-representative data and historical inequities embedded in medical records. This can result in unequal treatment such as inappropriate prioritization for certain groups and can erode trust. By training the model on diverse data sets, this issue could be avoided.

3. Transparency

Many AI algorithms operate as "black boxes," making it difficult for clinicians to understand how decisions are reached and to identify potential sources of error. Lack of transparency can undermine trust, limit adoption and pose patient safety risks. To address these challenges, it is essential to clearly define system characteristics, implement interpretable models and provide explainable outputs that allow users to trace decision pathways (Mathew, D.E., Ebem, D.U., Ikegwu, A.C. et al. 2025). The explainability of AI (referred to as Explainable AI or XAI) is important when critical decisions are required such as during patient prioritization, treatment planning and ethical considerations. Furthermore, integrating rigorous validation, continuous monitoring, and feedback mechanisms can help detect errors early and ensure that AI tools support safe, accountable, evidence-based clinical decision-making. By prioritizing transparency and interpretability, healthcare organizations can leverage AI more effectively while maintaining clinician confidence in the technology being applied.

4. Accountability

Questions arise regarding who is responsible when AI systems make errors, highlighting a need for clear frameworks. Particula rly within public hospital settings that serve diverse populations, future development and integration must prioritize ethical AI design and robust data governance frameworks to foster user trust and ensure equitable and safe implementation. Solutions include inclusive data collection; continuous monitoring of AI output; collaborative oversight involving policymakers, healthcare professionals and tech developers; and patient-centered policies with clear consent processes. According to Pham T. (2025), establishing clear and enforceable guidelines for responsibility and liability is essential to safeguard patients and ensure that healthcare systems remain fully accountable for the outcomes of AI-assisted care. Such frameworks help define the roles of clinicians, developers and institutions, provide transparency, build trust and promote the safe integration of AI into clinical practice.

X. CONCLUSION

Evaluation of real-time bed trackers reveals their transformational impact on modern healthcare. These systems are not merely technological upgrades but are strategic investments that fundamentally reshape how public hospitals manage critical resources and deliver patient care. By providing unprecedented real-time visibility into bed availability and patient flow, systems like the *Intelligent BedTracker*™ directly address the deep-seated challenges of ED overcrowding such as inefficient patient transfers and suboptimal resource utilization. With such systems in place, workforce productivity is significantly improved as administrative burdens are reduced and clinicians could dedicate more time to direct patient care. In addition, patient flow is streamlined, resulting in fewer delays in admissions and smoother transitions between departments.

Importantly, with such systems in place, patient-centered outcomes are enhanced through reduced wait times, increased patient satisfaction and improved safety measures including a lower risk of hospital-acquired infections and medical errors. The ultimate success of the *Intelligent BedTracker*™ hinges on a holistic approach that integrates technology with fundamental shifts in organizational culture, training programs for staff, and strong alignment with broader global healthcare objectives. Furthermore, recognizing that technology alone is insufficient without addressing the human and systemic factors that influence its adoption and effectiveness, the system represents a socio-technical transformation. In modern healthcare, intelligently designed real-time capacity monitoring is vital to reducing ED overcrowding and ensuring the delivery of high-quality, equitable, and sustainable care.

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