
Improving patient flow and hospital capacity through governance-oriented Lean bed management: an action research study

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Abstract

Background: Emergency department overcrowding and prolonged boarding times are widely recognised as manifestations of systemic failures in hospital flow governance rather than physical capacity constraints. Despite growing evidence supporting Lean-based approaches, most published interventions focus on isolated processes, with limited attention to governance redesign at a system level. This study examines a governance-oriented intervention aimed at improving patient flow through the redesign of bed management structures.

Methods: A single-centre action research study with a before-and-after design was conducted in a public Portuguese hospital between March and October 2025. The intervention focused on redesigning bed management processes and governance structures through four interconnected domains: structured diagnosis, standardisation of critical pathways, active bed management, and organisational governance redesign. Operational indicators were analysed using routinely collected monthly data, comparing pre-intervention (March–April 2025) and post-intervention (September–October 2025) periods.

Results: The intervention was associated with directionally consistent improvements in hospital flow across all eight monitored indicators, although the short monthly time series (eight observations) did not meet formal criteria for statistical significance or run chart signal. Time to admission decreased from 808.5 to 652 minutes (−19.4%), boarding time from 348 to 188 minutes (−46.0%), and bed turnover interval from 515 to 429 minutes (−16.7%), while discharges completed by 12:00 increased from 10% to 15% (+50.0%). These improvements occurred without bed capacity expansion, despite rising emergency department demand (+4.3%). Secondary indicators, including overall length of stay and emergency department length of stay for non-admitted patients, remained stable, suggesting genuine improvements in flow coordination rather than changes in case mix or premature discharge.

Conclusions: Lean-based interventions structured around governance redesign may be associated with improvements in hospital flow performance without expansion of physical capacity, even in the face of increasing demand, although the short observation window precludes firm causal attribution. Positioning bed management as a strategic organisational function, supported by formal governance structures, real-time coordination, and cross-functional accountability, represents an underutilised lever for improving hospital performance and patient safety. These findings suggest that governance redesign may represent an important and underexplored strategy, alongside traditional capacity-expansion approaches, in efforts to address hospital flow dysfunction.

Keywords: Lean healthcare; bed management; patient flow; hospital governance; emergency department; boarding; action research

1. Background

Healthcare systems worldwide face escalating pressure to improve efficiency, optimise resource use, and respond to growing demand without proportional expansion of physical capacity. Within hospitals, these challenges are fundamentally organisational, reflecting how resources, decisions, and responsibilities are coordinated across complex care systems, often under conditions of uncertainty and interdependence.¹

Patient flow constitutes the organisational backbone of hospital efficiency, relying on coordination between services, resources, and teams. Disruptions to this flow produce care bottlenecks, unnecessary prolongation of hospital stays, and systemic performance degradation. These disruptions are therefore not only operational failures but manifestations of misaligned organisational coordination and governance.¹ Emergency department (ED) overcrowding is a critical manifestation of these dysfunctions and has been recognised as a global public health concern, linked to poorer patient outcomes, reduced access to care, and healthcare professional burnout.^{2,3,4} Crucially, overcrowding is increasingly understood not as a problem originating within the ED itself, but as a systemic expression of failures in the governance of hospital flow, a so-called “input–throughput–output” challenge that requires system-level intervention.³

Hospital bed management occupies a central position in this system. It can be defined as the set of organisational functions responsible for planning, allocating, and coordinating bed capacity, integrating real-time demand and resource availability to support efficient patient flow and institutional performance.⁵ International evidence consistently indicates that failures in bed management governance, rather than physical bed shortages alone, are primary determinants of prolonged boarding (the time elapsed between the clinical decision to admit a patient and their physical transfer to an inpatient

bed), delayed hospital admissions, and ED congestion.^{6,7} The absence of a system-wide and cross-functional perspective on hospital occupancy often results in reactive and siloed decision-making, as individual departments manage capacity in isolation rather than as part of an integrated organisational system.⁷ This reinforces that bed management should be understood not merely as an operational function, but as a core organisational capability linked to hospital governance.^{6,7} Delays in transfer to inpatient beds have been associated with increased mortality, higher rates of adverse events, and delayed definitive treatment, particularly among critically ill patients.^{8–11} These findings underscore that boarding is not merely an operational inconvenience but a patient safety concern with direct clinical consequences.

From a theoretical standpoint, understanding why bed management failures persist requires engaging with organisational and governance theory. Hospitals are complex organisations in which clinical and managerial responsibilities are distributed across multiple actors, physicians, nurses, bed managers, and administrators, who operate with different information sets, different incentive structures, and limited shared visibility over system-level performance. This structural fragmentation tends to produce reactive and department-centred responses to occupancy pressures, in which each service manages its own capacity in isolation rather than as part of a coordinated whole.^{6,7} The result is what the literature has described as a governance deficit in patient flow management: the absence of formalised accountability mechanisms, real-time information flows, and cross-functional coordination structures capable of sustaining prospective, system-wide oversight of hospital capacity.⁷ Repositioning bed management as a strategic institutional function, with explicit governance structures, defined roles, and

integrated information systems, represents a theoretically grounded response to this deficit that goes beyond the deployment of operational tools. Addressing this governance deficit therefore requires not only process improvement, but also the redesign of organisational structures, accountability mechanisms, and decision-making pathways.

Lean Healthcare, derived from the Toyota Production System, provides a complementary operational framework for addressing these governance failures. It has been progressively adopted in healthcare settings to eliminate waste, reduce variability, and improve care outcomes.¹² Evidence demonstrates reductions in waiting times, improved discharge predictability, and optimised resource utilisation.¹³⁻¹⁵ However, a persistent limitation of many published Lean interventions is their focus on isolated departmental processes, without addressing the structural reorganisation of bed management governance at a system level.¹² Effective bed management requires more than a collection of operational tools, it depends on a governance architecture that integrates demand forecasting, cross-functional coordination, role clarity, and real-time decision-making. Without this foundation, Lean tools risk producing localised improvements that are not sustained or scaled.¹⁵ Sustainable improvements therefore require not only the deployment of operational tools, but the redesign of the organisational structures and accountability mechanisms within which those tools operate, a premise that underpins the governance-centred design of the present intervention. In this sense, Lean is positioned not merely as a set of improvement tools, but as an enabler of organisational transformation.

Given these theoretical considerations, action research offers a particularly appropriate methodology for designing and evaluating governance-oriented interventions

in healthcare organisations. It enables implementation in real-world settings through active involvement of researchers and healthcare professionals, supporting iterative learning, context-specific adaptation, and the co-production of knowledge between practitioners and researchers.¹⁶ This participatory approach is well-suited to the complexity of organisational change in healthcare, where interventions must be adapted to institutional cultures, power dynamics, and operational constraints that are not fully knowable in advance.

This study aimed to implement and evaluate a Lean-based bed management intervention, structured around an organisational governance framework, using an action research approach in a public hospital. Specifically, we examined its impact on patient flow and hospital operational performance, including time spent in the emergency department until admission to an inpatient bed, boarding time, discharge predictability, and bed utilisation efficiency. In addition, we explored the mechanisms through which organisational redesign, rather than capacity expansion, can improve system-level performance and support more coordinated and integrated hospital management.

2. Methods

2.1 Study design and setting

This study was designed as an applied investigation using an action research approach with a before-and-after design. The study was explicitly framed as an organisational intervention aimed at redesigning coordination structures and operational mechanisms related to hospital bed management and patient flow. Action research was selected because it enables the co-production of knowledge through iterative cycles of

diagnosis, planning, action, observation, and reflection, conducted collaboratively by researchers and practitioners,¹⁶ an approach that has been applied to bed management and patient flow improvement in hospital settings.¹⁷ This methodology is particularly appropriate for complex organisational interventions in healthcare, where the intervention itself evolves in response to emergent institutional learning and contextual factors.

The study was conducted in a public Portuguese hospital operating within the National Health Service (Serviço Nacional de Saúde – SNS), providing medium- to high-complexity care to a mixed urban-rural catchment population. At baseline, the hospital faced persistent challenges in patient flow management, including elevated ED occupancy rates, lengthy boarding times, and limited system-wide visibility over bed availability. These characteristics are representative of pressures faced by many public hospitals in Southern European health systems, where high demand, constrained physical capacity, and coordination challenges in patient flow management are well documented,¹⁸ and informed the selection of this setting and the potential transferability of findings to analogous contexts. These contextual characteristics also reflect organisational challenges in coordinating capacity and decision-making across hospital units, supporting the broader relevance of the intervention beyond the study setting.

The study involved the integrated participation of researchers and healthcare professionals across all stages: organisational diagnosis, intervention planning and implementation, indicator monitoring, and evaluation. Ethical approval was obtained from the Ethics Committee for Health of Unidade Local de Saúde do Alto Ave (ULSAAVE), Guimarães, Portugal (Approval no. 51/2025–CAF), approved on 23 May 2025. The study was conducted in accordance with the principles of the Declaration of Helsinki. As the

study used routinely collected, anonymised operational data and did not involve direct patient contact or identifiable patient-level data, the requirement for individual informed consent was waived by the Ethics Committee for Health of ULSAAVE.

2.2 Action research cycles and implementation process

The intervention was conducted between March and October 2025, structured into four sequential action research cycles, each corresponding to one of the four operational domains of the framework. Implementation activities took place between May and August 2025, followed by a consolidation and monitoring period between September and October 2025. For analytical purposes, March to April 2025 was defined as the pre-intervention baseline period, and September to October 2025 as the post-intervention period.

Each cycle followed the canonical structure of action research: a diagnostic phase to identify problems and causal mechanisms; a planning phase to design context-specific responses; an action phase to implement changes; and an observation and reflection phase to assess effects and inform subsequent cycles.¹⁶ This iterative structure supported not only process improvement but also progressive organisational alignment and structural redesign across hospital units.

Implementation included five on-site visits of approximately 40 hours each, complemented by eight remote follow-up sessions of approximately two hours. These activities supported implementation fidelity, monitored progress against indicators, and maintained researcher–practitioner dialogue throughout the study period. The active participation of frontline healthcare professionals, middle managers, and hospital directors across all stages was a defining feature of the methodology, consistent with the

participatory principles of action research, and enabled alignment between operational practices and organisational structures.

Although the four intervention domains were defined as the project's guiding structure, their implementation occurred iteratively, in successive cycles of diagnosis, action, observation, and reflection. One example of this adaptation was the decision not to systematically implement daily team huddles, which had initially been planned and trained as part of the intervention: implementation experience suggested cultural and operational constraints that made this specific tool impractical in the local context, without compromising the remaining components of the intervention. This adaptation is consistent with the action research principle of continuously learning from and adjusting solutions to the institutional context, rather than simply executing predefined changes.

2.3 Diagnostic phase

The diagnostic phase, conducted during the first action research cycle, involved an integrated analysis of the emergency department, inpatient units (wards and intensive care units), operating theatres, and hospital discharge processes. Data were collected through direct observation (*gemba* walks covering the ED, inpatient wards, ICU, and surgical centre), document review of institutional protocols and performance reports, and structured discussions with key clinical and managerial stakeholders.

Lean tools were applied systematically: value stream mapping was used to trace patient flow from ED arrival through inpatient admission to discharge, identifying handover delays, communication gaps, and structural bottlenecks; root cause analysis (Ishikawa diagram and 5 Whys technique) was applied to identify the underlying determinants of prolonged boarding time and bed turnover inefficiency; and bed management team self-

assessment sessions were conducted to evaluate organisational readiness and identify gaps in role clarity and accountability structures.^{12,19}

A central diagnostic finding was the configuration of the Bed Management Team (BMT). Although an institutional policy regulating the BMT was in place, its organisational structure was physically and managerially embedded within the emergency department, resulting in a predominantly reactive and department-centred approach to bed allocation. This configuration limited system-wide visibility over hospital occupancy, reduced prospective coordination capacity, and positioned the BMT as a responder to crises rather than as a proactive manager of flow. This finding directly informed the structural redesign dimension of the intervention, highlighting that patient flow inefficiencies were rooted in organisational and structural determinants rather than operational or capacity constraints alone.

This configuration was identified repeatedly throughout the diagnostic phase: prior to the creation of a formal, independent Bed Management Team, bed allocation was monitored informally by a nurse physically based in the emergency department and hierarchically reporting to its head of department. This structural configuration tended to favour patients coming from the emergency department in bed allocation, to the detriment of patients scheduled for elective surgery and of transfers between inpatient units (ward-to-ward, ward-to-ICU, ICU-to-ward, recovery unit-to-ward/ICU), constituting a structural conflict in bed allocation priorities that was widely identified by the inpatient unit and surgical centre teams during the diagnosis. In the absence of a truly independent coordination function, effective responsibility for allocating patients to beds fell to the

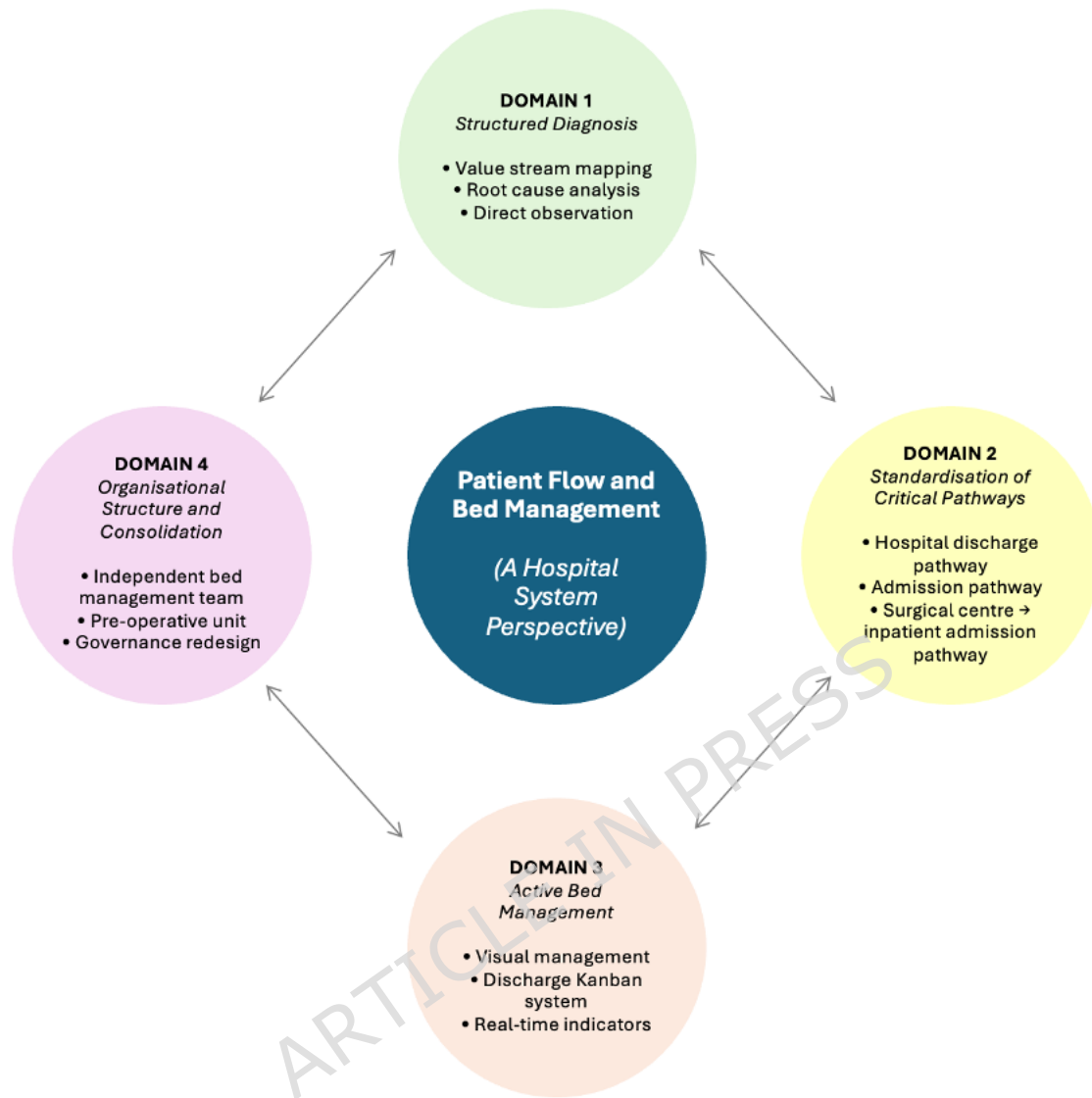
nurses on each shift in the inpatient units, who dealt daily with conflicts between admitting elective and emergency department patients to the same surgical beds.

2.4 Process redesign and intervention domains

The choice of these four domains followed directly from the diagnosis described in Section 2.3: the fragmentation of bed management across departments, the absence of formal coordination mechanisms, and limited visibility over hospital occupancy were identified as the main organisational determinants of flow, rather than the physical unavailability of beds. The interventions were defined collaboratively with the professionals and managers involved, prioritising the problems they considered most critical, and were continuously reviewed throughout implementation.

Based on diagnostic findings, the intervention was structured around four interconnected operational domains, each addressed through a dedicated action research cycle (Figure 1). It was designed as an integrated organisational strategy, aimed at addressing both process-level inefficiencies and underlying governance limitations identified in the diagnostic phase.

Figure 1. Four-domain intervention structure for governance-oriented Lean bed management.



The figure illustrates the four interconnected operational domains of the intervention: Domain 1 (Structured Diagnosis), Domain 2 (Standardisation of Critical Pathways), Domain 3 (Active Bed Management), and Domain 4 (Organisational Structure and Governance Redesign). Arrows indicate the cyclical and reinforcing relationships between domains, operating within a hospital system perspective.

Domain 1 (Structured Diagnosis): This foundational domain produced the organisational diagnosis described above, establishing the evidence base for subsequent intervention domains. It included value stream mapping, root cause analysis, and a comprehensive mapping of the hospital's current patient flow system.

Domain 2 (Standardisation of Critical Pathways): Before the intervention, there was no bed management function that impartially weighed the full set of competing demands for the same resource, emergency admissions, elective surgeries, and transfers between services, which generated daily friction between the inpatient unit teams and the emergency department. The absence of clear, hospital-wide discharge criteria contributed to the recurrent delay of elective surgeries due to unavailable beds, and hospital discharges were neither anticipated nor prioritised throughout the day, occurring mostly in the late afternoon and in a heterogeneous manner both among physicians within the same service and between different inpatient services; beds were also frequently occupied by patients with a clinical profile different from the unit's usual profile ("ectopic" patients). Introducing criteria-led discharge protocols and an institutionally standardised, communicated flow required successive joint meetings between the Bed Management Team and the heads of each service, during which discharge and bed-reoccupation pathways were progressively built and refined collaboratively based on the problems identified, with a focus on reducing steps and optimising time. Throughout this process, the Bed Management Team began systematically monitoring adherence to the new pathways and promoting continuous feedback cycles with the services involved. Critical pathways were redesigned to standardise and expedite key transitions in the patient flow: the hospital discharge pathway (including criteria-led discharge protocols and structured interdisciplinary discharge planning processes), the ED-to-inpatient admission pathway (including standardised bed request and allocation procedures), and the surgical centre-to-inpatient admission pathway.^{13,20} A structured multiprofessional training programme was delivered, comprising theoretical sessions, practical workshops, and simulation

exercises, aimed at aligning practices and strengthening shared accountability for flow management across clinical services.¹²

Domain 3 (Active Bed Management): Before the introduction of these tools, information on bed availability was found to circulate mainly by telephone between the nurse then assigned to the bed management function and the nurses of each inpatient unit, without regular in-person verification or real-time updating: it was not uncommon for a bed to remain recorded as occupied in the system for several hours after the patient's actual discharge, owing to a lack of active information-seeking, a problem compounded by the pressure of high emergency department demand. With the creation of the Bed Management Team, clearer communication channels were established, the importance of real-time system updates was reinforced, active information-seeking on bed status was instituted, and regular visits to inpatient units began, including participation in medical rounds, following an institutionally approved bed prioritisation and occupancy flow. Inpatient units also began using a Kanban board of admitted patients, showing the expected discharge date and the expected average length of stay for each patient, information independently monitored by the Bed Management Team during its visits. This domain introduced real-time visual management tools to increase system-wide visibility over bed availability and discharge status. A Kanban-based discharge management system (digital Kamishibai) was implemented across inpatient wards, enabling bed managers and ward teams to monitor discharge progress in real time.^{12,14} Communication routines between the BMT and clinical services were standardised, including structured daily briefings and a cumulative indicator monitoring framework. These changes

transformed the BMT's operational mode from reactive bed-finding to proactive flow orchestration, reinforcing its role as a central organisational coordination function.⁷

Domain 4 (Organisational Structure and Governance Redesign): This domain addressed the structural determinants of the coordination failures identified in the diagnostic phase. Following the diagnostic phase, within the first month of the study, the findings were presented to the hospital's board of directors, together with the project's local focal point, and were met with immediate support for the improvement opportunities identified; discussions and agreements regarding the design of the new bed management structure were then conducted progressively with all involved stakeholders throughout the project, without resistance from hospital leadership. Key changes included the formal organisational restructuring of the BMT, removing it from its embedded position within the ED and repositioning it as an independent, cross-functional unit with system-wide oversight responsibilities.^{6,7} The Bed Management Team was formally instituted in September 2025, with a fixed staffing roster and an independent physical location outside the emergency department, representing the culmination of this progressive negotiation process; role definitions and accountability structures were formalised in parallel, with this broader governance redesign becoming most explicit during the final three months of the study. The creation of a preoperative unit, operational from around the fourth month of the study, represented a strategy for synchronising bed supply and demand, expanding the hospital's operational capacity without a physical increase in the number of inpatient beds. Before the intervention, patients scheduled for elective surgery were frequently admitted to the inpatient unit the day before the procedure, occupying hospital beds before there was a clinical need for admission, which reduced bed availability for patients

coming from the emergency department and worsened boarding periods. With the new unit, patients scheduled for elective surgery began to be admitted only a few hours before the procedure, where reception, assessment, and preoperative preparation were carried out; the inpatient bed was then occupied only during the postoperative period. This additional interval allowed the Bed Management Team to coordinate discharges, prepare new beds, and continuously balance demand from the emergency department and elective surgeries. These changes aimed to institutionalise bed management as a strategic organisational function embedded within hospital organisational structures.

2.5 Data sources and indicators

The evaluation was based on institutional operational data extracted monthly from hospital information systems and management reports. All patients treated in the emergency department during the study period were included, as well as data related to inpatient bed occupancy across all units. No exclusion criteria were applied, as the aim was to evaluate system-level patient flow performance across the entire hospital.

Primary indicators were selected to capture the key dimensions of the intervention: (1) time spent in the emergency department until admission to an inpatient bed (total ED LOS to admission); (2) boarding time (from the clinical decision to admit to actual bed allocation); (3) bed turnover interval (average time a bed remains unoccupied between successive patients); and (4) proportion of discharges completed by 12:00 (a measure of discharge flow predictability). An expanded indicator set covering all monitored dimensions is presented in the supplementary material, including operational definitions and measurement formulae.

Additionally, balancing measures were monitored, namely mortality within the first 24 hours after hospital admission and overall average length of stay, with the aim of identifying possible unintended effects of the intervention on patient safety.

2.6 Data analysis

Data were analysed using aggregated monthly indicators across the eight consecutive months of the study period (March–October 2025). The primary analytical approach was the construction of run charts for each indicator, using the median of the eight monthly observations as the centreline. Standard run chart rules were applied to distinguish signals of non-random variation from expected month-to-month fluctuation: a shift (six or more consecutive points on the same side of the median), a trend (five or more consecutive points continuously increasing or decreasing), and a non-random number of runs relative to the number expected by chance, following established quality improvement methodology.^{21,22} Medians and ranges (minimum–maximum) were additionally calculated for the pre-intervention (March–April 2025), implementation (May–August 2025), and post-intervention (September–October 2025) periods, reported alongside the previously used mean-based point comparison, to better convey the variation underlying each estimate.

Given the small size of the pre- and post-intervention comparison windows (two months each) and the limited number of overall time points (eight monthly observations), no formal hypothesis test between periods (e.g., Mann-Whitney U) was performed: with only two observations per group, such a test cannot reach conventional statistical significance regardless of the underlying effect size (minimum achievable two-sided p-value ≈ 0.33), meaning a non-significant result would be uninformative rather than a

genuine test of the null hypothesis.²³ Interrupted time series analysis would have provided a more robust causal framework, but the minimum data requirements for this method, typically 12–24 observations per segment, were not met.²⁴ Findings are therefore interpreted in terms of the magnitude, direction, and consistency of changes over time and the presence or absence of run chart signals, consistent with the analytical framework recommended for quality improvement and action research studies of this nature.²⁵

As an exploratory complement, a simple linear regression was additionally fitted for each indicator, using study month as the independent variable, to estimate the magnitude and direction of the monthly trend. Given the small number of observations, p-values are reported with Bonferroni correction for the four tests (adjusted $\alpha=0.0125$) and should not be interpreted as statistical confirmation, but as a quantitative complement to the run charts.

2.7 Ethical considerations

Ethical approval for this study was granted by the Ethics Committee for Health of Unidade Local de Saúde do Alto Ave (ULSAAVE), Guimarães, Portugal on 23 May 2025 (Approval no. 51/2025–CAF). The study used anonymised operational data routinely collected during hospital management activities. As no direct patient contact or individual-level identifiable data were involved, the requirement for individual informed consent was waived by the Ethics Committee. Healthcare professionals and managers who participated in the action research process did so voluntarily in their professional capacity as part of an organisational improvement initiative. No individual-level data were collected from participants, and no formal consent procedure was required by the Ethics Committee.

3. Results

3.1 Intervention structure and implementation

Figure 1 illustrates the four-domain organisational framework of the governance-oriented Lean bed management intervention implemented during the study period. The model illustrates the cyclical and reinforcing relationships between the four domains, each contributing distinct but interdependent elements to the overall system redesign and organisational coordination of patient flow. The detailed structure and timeline of implementation activities across each domain and visit are presented in Supplementary Figure 1.

Implementation progressed across all four domains between May and August 2025. Domain 1 activities were concentrated in May–June 2025, providing the diagnostic evidence base for subsequent domains. Domains 2 and 3 were implemented in parallel from June to August 2025, reflecting the interdependence between pathway standardisation and active bed management. Domain 4 began with board-level alignment during the first month of the study, with the preoperative unit becoming operational around month four; the Bed Management Team's formal institutional restructuring and the broader formalisation of roles and governance were consolidated progressively, becoming most explicit during the final three months and culminating in September 2025.

3.2 Primary outcomes

Table 1 presents the main operational indicators for the pre- and post-intervention periods, reported as medians with ranges. A directionally consistent pattern of change was observed across the four primary indicators, spanning distinct but interdependent

dimensions of hospital flow; as detailed below and in Section 2.6, none of the eight monitored indicators met the formal run chart criteria for a statistically distinguishable signal, a limitation of the short observation window rather than evidence against the direction of change.

Time elapsed in the emergency department until admission to an inpatient bed had a median of 808.5 minutes (range 753–864) in the pre-intervention period, decreasing to 652 minutes (range 642–662) post-intervention (–156.5 minutes; –19.4%). A more pronounced reduction was observed in boarding time, from a median of 348 minutes (range 301–395) to 188 minutes (range 170–206) (–160 minutes; –46.0%). Bed turnover interval decreased from a median of 515 minutes (range 465–564) to 429 minutes (range 406–451) (–86 minutes; –16.7%). The proportion of discharges completed by 12:00 increased from a median of 10% (range 9–11) to 15% (unchanged in both post-intervention months) (+5 percentage points; +50.0%).

Table 1. Comparison of key operational indicators before and after the intervention.

Indicator	Pre-intervention (Mar–Apr 2025) Median (range)	Post-intervention (Sep–Oct 2025) Median (range)	Absolute difference	Relative difference
ED average LOS until admission to an inpatient bed (min)	808.5 (753–864)	652 (642–662)	–156.5	–19.4%

Indicator	Pre-intervention (Mar–Apr 2025) Median (range)	Post-intervention (Sep–Oct 2025) Median (range)	Absolute difference	Relative difference
Average Boarding time (min) ¹	348 (301–395)	188 (170–206)	–160	–46.0%
Average Bed Turnover Interval – overall (min) ²	515 (465–564)	429 (406–451)	–86	–16.7%
Average Discharges completed by 12:00 (%)	10 (9–11)	15 (15–15)	+5 pp ³	+50.0%

¹ Boarding time: time from the clinical decision to admit to actual allocation to an inpatient bed. ² Overall bed turnover interval includes all inpatient units (wards and ICUs). ³ pp: percentage points. Values are presented as medians for each period, with the range (minimum–maximum) of the two months of each period in parentheses; absolute and relative differences are calculated from the median values. Discharges completed by 12:00 had the same value (15%) in both post-intervention months.

3.2.1 Complementary linear trend analysis

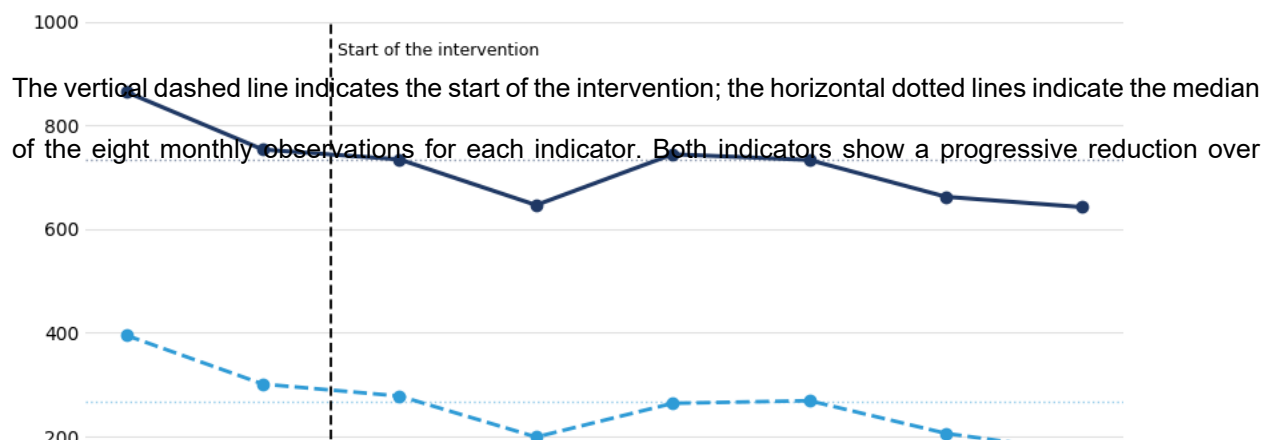
As a complement to the run charts, monthly linear regression estimated mean reductions of 22.8 min/month in time to admission (95% CI: –42.2 to –3.4; $p=0.028$), 24.0 min/month in boarding time (95% CI: –40.1 to –7.8; $p=0.011$), and 13.7 min/month in bed turnover interval (95% CI: –27.2 to –0.3; $p=0.047$), and an increase of 0.77 percentage points/month in discharges by 12:00 (95% CI: 0.48 to 1.07; $p<0.001$). After Bonferroni

correction (adjusted $\alpha=0.0125$), only boarding time and the proportion of discharges by 12:00 retained statistical significance. A transient oscillation was observed between July and August 2025 in three of the four indicators, coinciding with the parallel implementation of Domains 2 and 3, reported here transparently. Full values, including confidence intervals and p-values with and without Bonferroni correction, are presented in Supplementary Table 2.

3.3 Flow indicators: time to admission and boarding time

The monthly evolution of these indicators is illustrated in Figure 2 as run charts, with the median of the eight monthly observations shown as a horizontal reference line for each series. Both time to inpatient admission and boarding time show a progressive reduction after the start of the intervention in May 2025, with sustained improvements throughout the post-intervention period in September–October 2025; neither indicator, however, meets the formal run chart criteria for a non-random signal (Methods, Section 2.6), reflecting the limited number of monthly observations rather than an absence of directional change. It should be noted that these changes occurred in parallel with increasing emergency department activity, from a median of 8,502 visits/month (range 8,306–8,698) pre-intervention to 8,867 (range 8,651–9,082) post-intervention (+4.3%).

Figure 2. Monthly trends in time to admission to an inpatient bed and boarding time, March–October 2025.



time, with a greater magnitude observed for boarding time, although neither meets the formal run chart signal criteria given the limited number of monthly observations.

Decomposition of the total ED LOS until admission into its constituent components reveals that the decision-to-admit time remained relatively stable throughout the study period, while boarding time accounted for most of the observed reduction. This pattern is consistent with an intervention that preserved clinical decision-making autonomy while targeting operational inefficiencies in the post-decision phase, specifically, the processes governing bed identification, cleaning, preparation, and patient transfer.

3.4 Bed utilisation efficiency

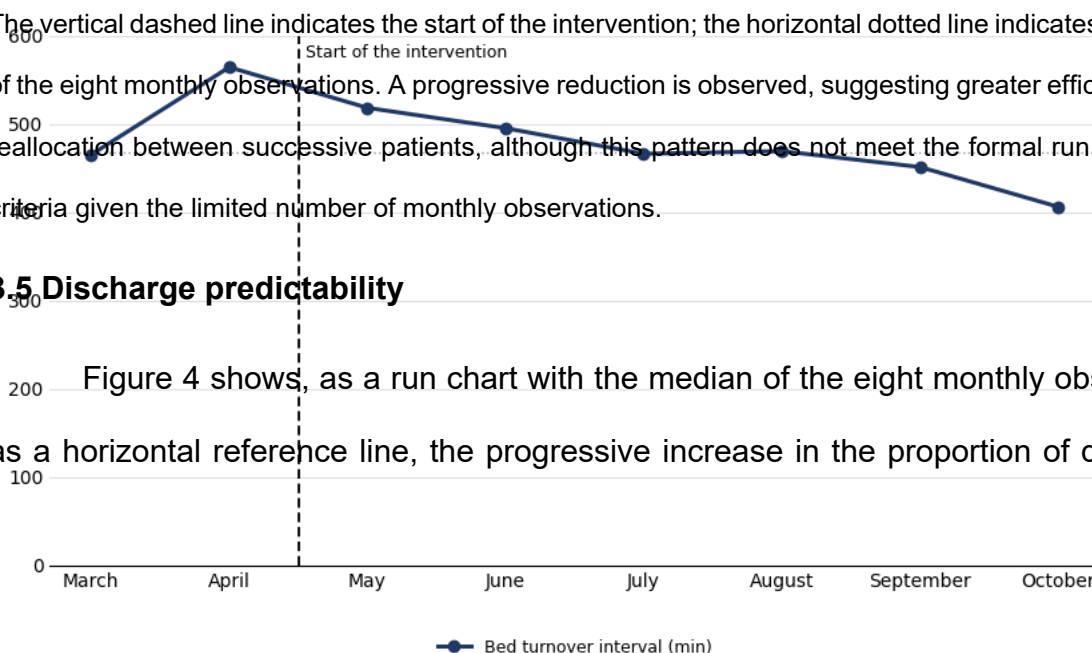
Figure 3 illustrates the monthly evolution of the bed turnover interval as a run chart, with the median of the eight monthly observations shown as a horizontal reference line. After an increase in April 2025, which coincided with the diagnostic phase and the identification of existing inefficiencies, a progressive reduction was observed from May onward; this pattern does not meet the formal run chart criteria for a non-random signal (Methods, Section 2.6), a limitation of the short observation window.

Figure 3. Monthly trends in bed turnover interval, March–October 2025.

The vertical dashed line indicates the start of the intervention; the horizontal dotted line indicates the median of the eight monthly observations. A progressive reduction is observed, suggesting greater efficiency in bed reallocation between successive patients, although this pattern does not meet the formal run chart signal criteria given the limited number of monthly observations.

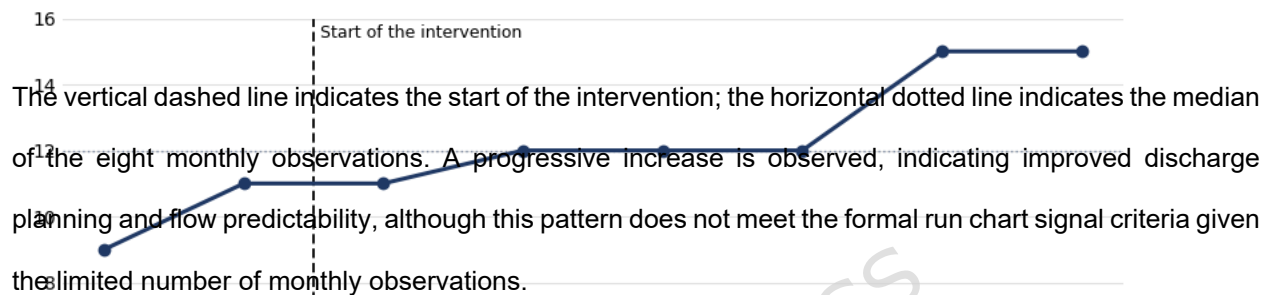
3.5 Discharge predictability

Figure 4 shows, as a run chart with the median of the eight monthly observations as a horizontal reference line, the progressive increase in the proportion of discharges



completed by 12:00, from 9% in March 2025 to 15% in October 2025. This change was gradual and directionally consistent throughout the intervention period, although it does not meet the formal run chart criteria for a non-random signal (Methods, Section 2.6).

Figure 4. Monthly trends in the proportion of hospital discharges completed by 12:00, March–October 2025.



3.6 Secondary indicators

The broader set of monitored indicators, presented in Supplementary Table 3, provides additional context for interpreting the primary outcomes. Emergency department length of stay for non-admitted patients remained broadly stable throughout the study period (306 minutes pre-intervention vs. 305 minutes post-intervention). The same-day surgery cancellation rate declined from 7.2% to 5.3%. Overall average length of stay remained stable (6.3 days pre-intervention vs. 6.4 days post-intervention).

Overall, the observed changes were consistent across multiple dimensions of hospital flow, reflecting coordinated improvements across interdependent operational processes.

3.7 Balancing measures

Mortality within the first 24 hours after admission remained low throughout the study period (ranging between 0% and 0.16% across the eight months). Overall average length of stay likewise remained stable, with a median of 6.3 days (range 6.2–6.4) in the pre-intervention period (March–April 2025) and 6.4 days (range 6.3–6.5) in the post-intervention period (September–October 2025). These results are presented descriptively, without formal statistical inference (Section 2.6).

4. Discussion

4.1 Summary of main findings

This study demonstrates that the implementation of a structured Lean Healthcare-based intervention, operationalised through action research cycles and grounded in a governance-centred organisational framework, was associated with consistent and substantial improvements in indicators related to patient flow and hospital bed management. The observed improvements, reductions of 46% in boarding time, 19% in time to inpatient admission, and 17% in bed turnover interval, alongside a 50% relative increase in morning discharge rates, occurred without expansion of physical bed capacity and in a context of increasing emergency department demand.

These findings indicate that the intervention acted on underlying organisational mechanisms of hospital flow, rather than merely redistributing existing capacity. Taken together, they point to a coherent pattern of systemic improvement across interconnected dimensions of bed management and patient flow, consistent with the theoretical premises of the intervention design.

4.2 Theoretical contributions

This study makes several contributions to the organisational and management literature on health systems. First, it provides empirical grounding for the theoretical proposition that bed management dysfunction is primarily a governance failure, rather than a physical capacity problem. The diagnostic phase revealed that despite adequate physical resources, the hospital's BMT operated within a fragmented governance structure, embedded within the ED, with limited system-wide visibility and accountability, that systematically produced reactive rather than proactive responses to occupancy pressures. This configuration reflects patterns described in the literature as siloed governance: the persistence of departmental decision-making in contexts that require cross-functional coordination.^{6,7}

Second, the study describes and empirically examines a four-domain intervention structure for bed management governance redesign, which emerged from the action research process. This framework, integrating structured diagnosis, pathway standardisation, active bed management, and structural reorganisation, extends existing conceptualisations of bed management beyond their predominantly operational focus^{5,6} towards a more comprehensive governance model. Each domain addresses a distinct organisational layer: Domain 1 targets diagnostic knowledge and capacity assessment; Domain 2 addresses process standardisation and role clarity; Domain 3 introduces real-time information tools and coordination mechanisms; and Domain 4 restructures the formal organisational architecture within which all other interventions operate. The cyclical and reinforcing relationships between these domains, illustrated in Figure 1, reflect the premise that sustainable organisational improvement requires the alignment of technical tools, process redesign, and coordination structures.

Third, the study illustrates how action research, as a methodology, enables the adaptation of governance interventions to the specific institutional context without sacrificing theoretical rigour. The iterative cycles of the intervention allowed the research team to detect, respond to, and learn from implementation challenges in real time, including the non-adoption of daily huddles discussed below, generating context-specific knowledge that complements the generalisable findings reported through quantitative indicators.

4.3 Interpretation in the context of existing literature

The apparent divergence between the absence of a formal signal in the run charts and the presence of nominally significant linear trends for two of the four indicators reflects methodological differences between the two approaches: run chart rules are deliberately conservative, whereas linear regression is more sensitive to an underlying trend, albeit dependent on independence assumptions that cannot be fully verified. Considered together, they suggest a genuine trend of improvement, but of variable magnitude and statistical certainty across indicators.

The observed reductions in boarding time and time to inpatient admission are consistent with existing literature on Lean and governance-oriented bed management interventions.^{26,27} However, the magnitude of the boarding time reduction (−46%) is notable by comparison with published studies, which typically report reductions in the range of 20–35%.^{26,27} This likely reflects the governance-centred design of the intervention: by targeting the structural determinants of boarding (fragmented accountability, lack of system-wide visibility, absence of proactive discharge

management) rather than individual process steps, the intervention addressed the root causes of delay rather than their symptomatic manifestations.

Even accounting for the statistical limitations inherent to the study design, the magnitude of the observed reductions is also relevant from a clinical and operational standpoint. Previous studies have associated prolonged boarding and delays in transfer to inpatient beds with higher mortality, a higher incidence of adverse events, and worse clinical outcomes, particularly among critically ill patients.⁸⁻¹¹ The 160-minute (46%) reduction in mean boarding time and the 156-minute (19.4%) reduction in total time to admission observed in this study are consistent with magnitudes previously associated in the literature with clinically relevant differences in risk. The study design does not allow the effect on clinical outcomes such as mortality to be directly quantified; nevertheless, the convergence between the direction of the effect, its magnitude, and the existing literature reinforces the practical, and not merely statistical, relevance of the observed changes.

The decomposition of the total ED LOS into decision-to-admit time and boarding time is an analytically relevant contribution of this study. The stability of the decision-to-admit component throughout the study period indicates that the intervention successfully targeted operational inefficiencies while preserving clinical autonomy, a balance that is frequently cited as a prerequisite for sustainable Lean implementation in healthcare.¹⁵ The use of disaggregated indicators to identify system bottlenecks and track the mechanistic pathways through which improvements occur represents a methodological advance over studies that report only composite outcome measures.

The reduction in bed turnover interval reflects coordinated operational changes implemented across Domains 2 and 3: standardisation of discharge communication routines, Kanban-based visual management of bed status, and the establishment of a preoperative unit reducing early elective admissions. These changes compressed the “interbedding interval”, the time a bed spends unoccupied between successive patients, a metric that has received relatively limited attention in the literature despite its direct operational significance.^{28,29} By increasing the proportion of the day during which each bed is occupied by a patient whose admission is clinically appropriate, the intervention effectively increased operational capacity without adding physical resources.

The increase in the proportion of discharges completed by 12:00 is consistent with the literature on the flow benefits of discharge timing advancement.^{28,29} Earlier discharges create downstream capacity for ED admissions, reducing the period during which boarding occurs. The progressive nature of this improvement across the study period indicates sustained organisational learning and behavioural adaptation, rather than a short-term Hawthorne effect.

A noteworthy finding is that these improvements were achieved despite the non-adoption of routine daily huddles. Although daily huddles were planned, developed, and trained as part of the intervention, their systematic implementation was not achieved during the study period, reflecting a contextually-specific organisational decision shaped by cultural and operational constraints. This finding is particularly relevant for implementation science: it suggests that meaningful and sustained improvements in patient flow can be achieved through structural reorganisation and process standardisation, even in the absence of full intervention fidelity. It also highlights that

different components of complex interventions may contribute differently to outcomes, and that contextual adaptation, including selective non-adoption, is an inherent feature of real-world implementation rather than a failure of the intervention.³⁰

The secondary indicators provide additional interpretive context for the primary findings. The stability of ED length of stay for non-admitted patients (306 vs. 305 minutes) suggests that the observed improvements were specific to the admitted patient pathway, rather than reflecting a generalised change in ED processing efficiency. The decline in same-day surgery cancellation rate from 7.2% to 5.3% indicates collateral benefits in surgical pathway organisation, consistent with the pathway standardisation and preoperative unit activities implemented under Domains 2 and 4. The stability of overall average length of stay (6.3 vs. 6.4 days) is particularly relevant for interpreting the reductions in boarding time and bed turnover interval: it confirms that these gains were not achieved through premature discharge practices, but through improvements consistent with enhanced flow coordination.

4.4 Mechanisms of organisational change and learning

Implementation experience suggests four interconnected organisational mechanisms underlying the observed changes, operating not in isolation but as a system that reinforced itself throughout the action research cycles. Although these four mechanisms emerged as the main explanatory elements during implementation, their relative contribution likely varied over time and across different hospital sectors.

The first concerns the impartial coordination of competing demand for beds. Before the intervention, it was found that, in the absence of a truly independent bed management function, bed allocation was carried out informally by a nurse based in the emergency

department and hierarchically linked to that department's leadership, which tended to favour patients coming from the emergency department to the detriment of elective patients and inter-unit transfers, leaving effective allocation responsibility with the nurses on each shift in the inpatient units. The creation of an independent Bed Management Team, together with the joint development, with the heads of each service, of standardised discharge and bed-reoccupation pathways, may have helped reduce this structural conflict in bed allocation priorities.

The second mechanism concerns team behaviour in managing the bed turnover interval: the observed reduction did not result solely from faster cleaning or physical bed availability, but from a broader shift in visibility and accountability. Before the intervention, it was found that information on bed status depended mainly on telephone communication and records that were not updated in real time, which occasionally kept beds marked as occupied long after the patient's actual discharge; the introduction of active information-seeking, regular unit visits, and a Kanban board with expected discharge dates appears to have made these delays more, not less, visible to the Bed Management Team, reducing the extent to which bed release depended solely on unverified manual records.

The third mechanism is the synchronisation of bed supply and demand introduced by the preoperative unit, which, by separating the moment of hospital admission from the moment of actual occupation of the inpatient bed, seems to have functioned as one of the most tangible mechanisms of functional capacity gain without physical bed expansion, although, because it was implemented as part of an integrated package of structural changes, its specific contribution cannot be statistically isolated.

The fourth mechanism, and perhaps the one most transversal to the other three, was the progressive development of organisational learning. One of the most relevant products of the action research process was apparently not limited to the implementation of specific Lean tools: throughout the successive cycles of diagnosis, action, observation, and reflection, including the joint meetings with the heads of each service to design the new pathways, the building of a local organisational capacity to identify flow problems, discuss indicators as a team, and adapt solutions to the institutional context was also observed, a capacity that has the potential to persist beyond the specific tools implemented in this study. This organisational learning should not be interpreted as an outcome independent of the other interventions, but as a transversal process that sustained the implementation, adaptation, and progressive integration of the programme's different components.

Taken together, these four mechanisms suggest that the observed results stemmed from the combination of governance redesign, active bed management, interdepartmental collaboration, and continuous organisational learning, rather than from any single isolated component of the intervention. Although the study design does not allow definitive causal relationships to be established between specific components and the observed results, the action research approach made it possible to understand how progressive organisational changes can favour sustainable improvements in patient flow coordination.

Beyond these four mechanisms, during the action research process both researchers and hospital staff perceived an improvement in the working relationship between the emergency department and the inpatient and surgical services. In several post-implementation meetings and discussion groups, staff from different departments spontaneously and repeatedly praised the Bed Management Team for the results

achieved, suggesting a shift toward a more collaborative and communicative interdepartmental climate. This observation is consistent with the collaborative process through which the new discharge and bed-allocation pathways were jointly developed (Section 2.4), although it was not systematically measured and is reported here as a qualitative impression from the action research process rather than a documented outcome.

The description of these mechanisms is not intended to establish independent causal relationships between specific intervention components and the observed results. On the contrary, one of the main methodological findings of the action research process was precisely to demonstrate that complex organisational changes tend to emerge from the interaction between multiple interventions implemented in a coordinated manner, making it difficult to attribute the observed effects to any single component in isolation. This impossibility of causal decomposition should be understood not so much as a limitation of the study, but as a characteristic inherent to complex organisational interventions developed in real-world contexts.

The accumulated experience during implementation highlights some lessons that may be relevant to other organisations seeking to develop similar interventions. First, visible commitment from hospital leadership proved essential to sustaining changes that extended beyond the boundaries of a single service. Second, the collaborative construction of solutions, involving professionals from different sectors and their respective managers, favoured greater adherence to the proposed changes. In addition, short feedback cycles between researchers and clinical teams allowed the interventions to be continuously adapted to the local context, including the reformulation or

abandonment of less viable components, such as the daily huddles. Finally, the continuous use of operational indicators as a tool for dialogue and collective learning, rather than merely as a performance measure, contributed to consolidating organisational capabilities that may persist beyond the intervention.

4.5 Strengths and limitations

Among the strengths of this study is the rigorous application of action research methodology, with strong stakeholder engagement across all phases of the intervention and longitudinal follow-up over eight months. The use of institutional operational indicators, directly extracted from hospital information systems, ensures ecological validity and reduces the risk of observer bias. The decomposition of composite indicators into their constituent components provides mechanistic insight that supports theoretical interpretation. The reporting in accordance with SQUIRE 2.0 guidelines enhances transparency and reproducibility.²⁵

This study has several limitations that should inform the interpretation of the findings. It was conducted in a single hospital, limiting the generalisability of the results. The before-and-after design, without a control group, limits causal attribution: external factors, temporal trends, and unobserved confounders may have contributed to the observed improvements. Seasonal variation is an additional consideration; although the pre- and post-intervention periods were selected to correspond to comparable, typical periods of hospital activity in the Portuguese context, residual seasonal differences cannot be fully excluded. The use of aggregated monthly data and the limited number of time points (eight observations) precluded interrupted time series analysis and constrain the inferential power of the findings. Relatedly, the pre- and post-intervention comparison

windows (two months each) were too small for a formal hypothesis test to reach conventional statistical significance regardless of effect size, and none of the eight monitored indicators met the standard run chart criteria for a non-random signal; these limitations mean that the observed changes, although directionally consistent, should be interpreted as suggestive rather than statistically confirmed. The complementary linear regression analysis also assumes independence between consecutive monthly observations, an assumption that may not fully hold in hospital operational data; the reported p-values should be interpreted with caution, particularly for the two indicators whose significance does not survive Bonferroni correction. Finally, the study did not examine in depth the team's experience, organisational culture, or process fidelity, which limits understanding of the mechanisms of change beyond the indicator-level evidence presented.

The stability of early mortality and overall length of stay throughout the implementation period suggests that the observed gains in hospital flow and boarding time reduction were not achieved at the expense of prematurely accelerated discharges or compromised patient safety.

4.6 Implications for policy, practice, and research

The findings of this study have direct implications for health system organisation and management. From a practice perspective, they support the repositioning of bed management as a strategic governance function within hospital organisations. The four-domain intervention structure described in this study may serve as a starting point for hospitals seeking to redesign their bed management structures without capacity expansion. The experience of the study hospital suggests that meaningful gains in system

performance are achievable through organisational redesign within relatively short timeframes, provided that senior leadership commitment, interdepartmental engagement, and adequate implementation support are in place.

From a policy perspective, the findings reinforce the case for recognising bed management governance as a strategic institutional function within hospital accreditation frameworks, performance management systems, and healthcare reform agendas, particularly in Southern European public health systems under significant demand pressure. Policy instruments that prioritise structural reform in bed management, rather than simply requiring additional physical capacity, may represent a more cost-effective and sustainable approach to addressing hospital flow dysfunction.

From a research perspective, the four-domain intervention structure described in this study warrants further theoretical development and empirical testing in multicentre settings. Multicentre studies with more robust designs, including controlled before-and-after studies, stepped-wedge designs, or longer time series allowing interrupted time series analysis, are needed to assess the generalisability and sustainability of this organisational model across different health system contexts. Future research should also examine the role of health system-level factors, including hospital ownership, financing models, workforce composition, and regulatory environments, in shaping the transferability of governance-oriented interventions. Mixed-methods and implementation science frameworks would enrich understanding of the mechanisms of change, the organisational conditions that enable or inhibit organisational redesign, and the long-term sustainability of improvements beyond the intervention period.

Overall, this study reinforces that improving patient flow requires more than operational optimisation. It requires organisational alignment, coordination structures, and coordinated decision-making processes across hospital units. By positioning bed management as a central organisational function, this work contributes to bridging the gap between operational improvement and organisational design in healthcare systems, offering a framework for more integrated and effective hospital management.

5. Conclusion

This study provides evidence that Lean-based interventions, when structured around the redesign of bed management governance and operationalised through iterative action research cycles, may be associated with substantial and consistent improvements in hospital flow performance, without expansion of physical bed capacity, although the short observation window precludes firm causal attribution. The four-domain intervention structure, comprising structured diagnosis, pathway standardisation, active bed management, and structural reorganisation, illustrates a theoretically grounded and practically applicable approach to addressing the systemic organisational failures underlying hospital flow dysfunction.

The findings reinforce that boarding and emergency department overcrowding are not primarily problems of physical capacity, but of organisational coordination and accountability: how hospitals structure accountability, coordinate across departments, and manage real-time information on occupancy and patient status. Repositioning bed management as a strategic institutional function, supported by formal accountability structures and continuous indicator monitoring, represents a critical and underutilised lever for improving hospital performance and patient safety.

Future research should build on and test this intervention structure in multicentre settings and with more robust evaluation designs to strengthen the evidence base for policy and management decisions. Ultimately, sustainable improvements in hospital flow may depend not only on the availability of beds, but also on the quality of the organisational structures and accountability mechanisms through which those beds are managed, highlighting the central role of organisational design in health system performance.

6. List of abbreviations

BMT: Bed Management Team

ED: Emergency department

ICU: Intensive care unit

ITS: Interrupted time series

LOS: Length of stay

OECD: Organisation for Economic Co-operation and Development

SNS: Serviço Nacional de Saúde (Portuguese National Health Service)

SQUIRE: Standards for Quality Improvement Reporting Excellence

VSM: Value stream mapping

7. Declarations

7.1 Ethics approval and consent to participate

This study was reviewed and approved by the Ethics Committee for Health of Unidade Local de Saúde do Alto Ave (ULSAAVE), Guimarães, Portugal (Approval no. 51/2025–CAF), approved on 23 May 2025. The study was conducted in accordance with the principles of the Declaration of Helsinki. As the study used routinely collected, anonymised operational data and did not involve direct patient contact or identifiable patient-level data, the requirement for individual informed consent was waived by the Ethics Committee for Health of ULSAAVE. Healthcare professionals and managers who participated in the action research process did so voluntarily in their professional capacity as part of an organisational improvement initiative. No individual-level data were collected from participants, and no formal consent procedure was required by the Ethics Committee.

7.2 Consent for publication

Not applicable.

7.3 Availability of data and materials

The datasets used and/or analysed during the current study are not publicly available due to institutional confidentiality and data governance restrictions, but aggregated data may be made available from the corresponding author upon reasonable request and subject to institutional approval.

7.4 Competing interests

The authors declare that they have no competing interests.

7.5 Funding

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7.6 Authors' contributions

BDDO: Conceptualisation, study design, intervention planning and implementation, data collection, data analysis, manuscript writing, and overall project coordination. PMF: Contribution to intervention execution, data collection support, and critical revision of the manuscript. SCML: Contribution to local project coordination, intervention implementation, and critical revision of the manuscript. LADR: Contribution to data generation, operational indicators management, and critical revision of the manuscript. AMPS: Contribution to institutional facilitation, project governance support, and critical revision of the manuscript. PGC: Contribution to institutional facilitation, project governance support, and critical revision of the manuscript. RML: Contribution to study design, methodological supervision, critical revision of the manuscript, and overall project supervision. All authors read and approved the final manuscript.

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7.8 AI use disclosure

The authors used AI-assisted tools (Claude, Anthropic) for language refinement, structural editing, and writing support. All intellectual content, interpretations, and conclusions are the responsibility of the authors. AI tools were not used to generate original data, analysis, or conclusions.

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