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Lean–Visual Management Integration in Hospital Information Systems to Sustain Pharmacy Performance Under High Workload

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ABSTRACT

Introduction: Hospital pharmacy services face increasing operational complexity, requiring efficient, adaptive, and data-driven systems. Integrating Lean Thinking (LT) and Visual Management (VM) into Hospital Information Systems (HIS) offers strategic potential to enhance workflow transparency, reduce waste, and improve service quality. This study aimed to evaluate the impact of LT–VM within HIS on service effectiveness, measured through prescription response times, and process efficiency, measured using the Value Added Ratio (VAR) derived from Value Stream Mapping (VSM).

Methods: A quantitative case study was conducted in the outpatient pharmacy unit of PKU Muhammadiyah Wonosobo Hospital, Central Java, Indonesia. Secondary data of 55,767 outpatient prescriptions were analyzed (17,373 pre-implementation and 38,394 post-implementation), while primary data were collected through direct workflow observation using VSM. Statistical analysis used the Mann–Whitney U test to assess pre-post differences, while process efficiency was examined through VAR calculations for compounded and non-compounded prescriptions.

Results: Non-compounded prescriptions showed a significant improvement in response time ($p = 0.005$), despite a 2.5-fold increase in prescription volume, indicating sustained system performance. Notably, unlike most Lean studies that emphasize waiting-time reduction, the present findings demonstrate that LT–VM–HIS integration primarily contributed to maintaining workflow stability under increased workload. Compounded prescriptions exhibited no significant change ($p = 0.424$), although reduced variability suggested improved consistency. VSM results showed VAR of 40.08% for non-compounded and 51% for compounded prescriptions, highlighting persistent bottlenecks during workflow transitions and the limited influence of digital interventions on labor-intensive manual tasks.

Conclusion: The integration of LT–VM within HIS enhanced process consistency, reduced variability, and maintained operational performance under increased workload. However, manual compounding tasks limited efficiency gains, underscoring the need for hospital-wide Lean digitalization and synchronized scheduling to balance demand and capacity. These findings support the broader application of Lean-based digital transformation to achieve resilient and patient-centered healthcare systems.

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INTRODUCTION

Globally, the healthcare sector faces significant challenges in delivering efficient and high-quality services. These challenges include financial constraints due to escalating operational costs that are not matched by reimbursement rates (1), as well as an increasing demand for technology-driven efficiency (2). Hospitals, as core healthcare institutions, are encountering growing complexities driven by rising patient demands and continuously evolving operational dynamics (3). To address these challenges, there is a growing need for systems that are efficient, adaptive, and integrated to ensure timely, accurate, and high-quality healthcare delivery (4). One strategic approach increasingly adopted to enhance operational efficiency is Lean Thinking (LT), which focuses on the elimination of waste and the optimization of value-added activities in every process (5). Rooted in the Toyota production management philosophy, this approach emphasizes the identification and elimination of non-value-added activities (waste) while promoting process optimization to create more efficient workflows (6). With its emphasis on continuous improvement and the involvement of all organizational levels, LT has been recognized for its potential to improve service quality, reduce waiting times, and enhance satisfaction among both patients and healthcare staff (7,8).

The essence of VM lies in its capacity to enhance transparency of workflows and facilitate a shared understanding of system dynamics among healthcare staff, thereby contributing to improved overview, collaboration, and engagement across professional groups (9). Through the visualization of key performance indicators and the standardization of work environments, VM reinforces communication, operational consistency, and staff accountability. When both LT and VM are systematically integrated into the Hospital Information System (HIS), the synergy between process efficiency and visual control significantly enhances the potential for service quality improvements, as evidenced by recent studies showing that the combined application of LT–VM principles improved workflow standardization, staff satisfaction, and overall care efficiency in clinical settings (10). This is particularly relevant in the outpatient pharmacy setting, which serves as a critical juncture within the continuum of patient care. As a key service point, outpatient pharmacy units often experience high patient volumes and are frequently identified as bottlenecks in service delivery due to extended waiting times, one of the most common sources of dissatisfaction among patients. Recent evidence shows that implementing electronic prescription systems can significantly reduce dispensing time and optimize pharmacy workflows, highlighting the importance of digital integration to enhance service efficiency (11). Therefore, applying LT–VM in this context presents a strategic opportunity to streamline processes, reduce delays, and ultimately improve patient experience and outcomes.

Building on these conceptual and practical insights, broader evidence indicates that improving the efficiency and reliability of hospital workflows requires management approaches reinforced by digital infrastructures. Prior studies have demonstrated that Lean-oriented digital management practices can strengthen operational performance by enhancing process standardization and real-time visibility of work activities (12). Evidence from the Indonesian healthcare system further shows that digital tools such as electronic medical records improve coordination and consistency across clinical processes, underscoring the enabling role of information systems in supporting structured managerial interventions (13). Collectively, these findings suggest a theoretical convergence in which LT contributes to waste reduction and flow stability, VM enhances situational awareness and team coordination, and HIS provide the technological platform necessary to embed these principles into daily operations. Despite this conceptual alignment, empirical research specifically examining the integration of LT–VM within HIS environments, particularly in outpatient pharmacy services, remains limited. This gap highlights the need to investigate LT–VM integration in digitally supported workflows. The present study addresses this need by assessing its impact on service effectiveness, measured through prescription response times, and process efficiency, evaluated using the Value Added Ratio (VAR) derived from Value Stream Mapping (VSM).

METHOD

Study Design

This study utilized a quantitative case study methodology, incorporating two complementary techniques to provide a comprehensive analysis of outpatient pharmacy service performance. First, a secondary data analysis was conducted using historical service records extracted from the HIS, which enabled the assessment of temporal changes and trends in prescription response times over a defined period. This approach allowed for an objective evaluation of how service delivery speed evolved following specific interventions (pre and post-intervention). Second, a direct observational study was carried out (post only), employing the VSM technique to systematically analyze and visualize the detailed workflow processes within the outpatient pharmacy. A structured VSM-based observation sheet was used to document and categorize each activity in the dispensing workflow. The data were collected by the researcher, who has a professional background in pharmacy, managerial experience in hospital operations, and formal training in health services research. Observations were conducted across multiple service periods covering both peak and non-peak hours to capture representative workflow variations. Consistency was maintained through the use of a standardized VSM checklist, and the resulting process map was validated with pharmacy staff to ensure accuracy. Potential observer effects were minimized by positioning the observer outside primary workflow pathways and avoiding interaction with staff during data collection. VSM has been widely applied in healthcare to identify process bottlenecks, visualize workflows, and quantify value-added time as a basis for calculating process efficiency metrics such as the VAR (14).

Study Setting and Context

The study was conducted at the outpatient pharmacy unit of PKU Muhammadiyah Wonosobo Hospital, a private non-teaching Islamic hospital in Central Java, Indonesia. The hospital has adopted a HIS to support digital-based service delivery. Within this context, LT and VM principles were integrated into the HIS to optimize prescription workflows. One of the key Lean interventions was the elimination of the manual pharmacy check-in system, which previously required patients to obtain a queue number before their prescriptions could be processed. This change reduced over-processing waste and unnecessary waiting time. In parallel, VM was implemented through several digital tools, including: (1) dashboards displaying each stage of prescription processing, (2) an automated queue-calling system based on waiting times, and (3) a countdown timer visualizing prescription turnaround time according to the hospital's service level agreement (30 minutes for non-compounded and 60 minutes for compounded prescriptions). The countdown timer and SLA indicators, represented through color-coded signals (green, yellow, and red), were displayed on the pharmacy staff dashboard to support real-time performance monitoring and timely workflow adjustments. These interventions streamlined operations, improved transparency, and enhanced patient experience.

Data Collection and Analysis

Response Time Analysis

Secondary data of all outpatient prescriptions were analyzed to assess the mean dispensing time before and after the implementation of LT–VM approaches in the HIS. Total population sampling was used to include all outpatient prescriptions processed between October 2023–March 2024 (pre-implementation, n = 17,373; consisting of 14,071 non-compounded and 3,302 compounded prescriptions) and May 2024–October 2024 (post-implementation, n = 38,394; consisting of 35,778 non-compounded and 2,616 compounded prescriptions).

Prescriptions were excluded from the analysis if they were pre-filled, uncollected by patients, delivered to patients' homes, or affected by system downtime. In the pre-implementation period, a total of 2,184 prescriptions (11.17%) out of 19,557 were excluded, consisting of 1,263 pre-filled prescriptions, 144 uncollected prescriptions, 777 home-delivered prescriptions, and none affected by system downtime. In the post-implementation period, 1,594 prescriptions (3.98%) out of 39,988 were excluded, comprising 520 pre-filled prescriptions, 104 uncollected prescriptions, 907 home-delivered prescriptions, and 63 prescriptions affected by system downtime.

Value Stream Mapping and Value Added Ratio (VAR)

Direct observations were conducted in the outpatient pharmacy to assess prescription service workflows using VSM. A total of 60 cases were selected through convenience sampling, consisting of 30 compounded and 30 non-compounded prescriptions. Each process was observed in real time, from prescription entry to medication dispensing.

Activities were categorized as value-added or non-value-added based on Lean Healthcare principles. The VAR was calculated by dividing the total value-added time by the total cycle time for each prescription type, serving as a quantitative indicator of process efficiency.

Validity and Reliability

The study's validity was ensured through the use of authentic operational data from the HIS and VSM process mapping verified with pharmacy staff. Reliability was reinforced by the extensive dataset (n = 55,767 prescriptions), the consistency of system-generated reports, and the application of non-parametric statistical tests to minimize potential bias.

Ethics approval

This study received ethical approval from the Health Research Ethics Committee of Universitas Muhammadiyah Yogyakarta, with approval number 088/EC-KEPK FKIK UMY/III/2025, approved on March 12, 2025.

RESULT

Response Time Analysis Before and After LT–VM Implementation

Table 1. Kolgomorov-Smirnov, Mann-Whitney U Test, and effect size on the waiting time for non-compounded prescription services

	Kolgomorov-Smirnov			median	mean	SD	IQR	95% CI	Mann-Whitney U test			r
	Statistics	Df	p						p	W	Z	
Pre–implementation	0.16	14071	0.000	10	12.98	10.83	9.00	[12.79, 13.15]	0.05	346709143.5	-2.78	–0.0124
Post–implementation	0.13	35778	0.000	11	12.96	9.38	10.00	[12.86, 13.06]				

Secondary Data, Outpatient Pharmacy Hospital Information System (SIMRS), PKU Muhammadiyah Wonosobo, 2025; df=degree of freedom, SD= standard deviation, IQR= Interquartile Range

Table 1 presents a comparison of waiting times for non-compounded prescriptions before and after the implementation of LT–VM. Despite a 2.5-fold increase in prescription volume (from 14,071 to 35,778), average waiting time remained stable (12.98 to 12.96 minutes), indicating stable system performance under substantially higher demand. The Mann–Whitney U test identified a statistically significant difference between the two periods (Z = –2.78, p = 0.005). However, the effect size was extremely small (r = –0.0124), demonstrating that the observed difference is not practically meaningful. This negligible effect reinforces the conclusion that the LT–VM–enhanced digital workflow maintained service stability and operational resilience despite the increased workload.

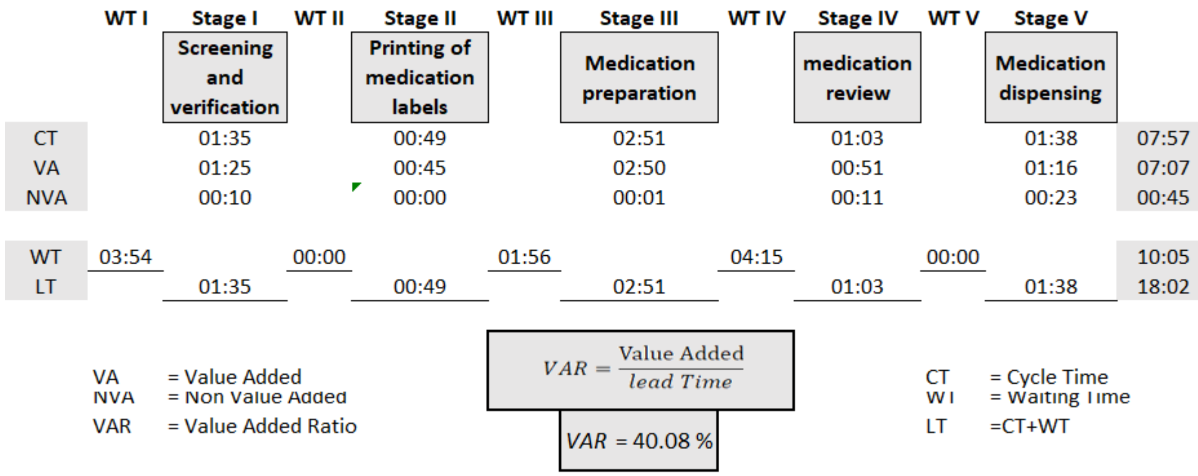
Table 2. Kolgomorov-Smirnov, Mann-Whitney U Test, and effect size on the waiting time for compounded prescription services

	Kolgomorov-Smirnov			median	mean	SD	IQR	95% CI	Mann-Whitney U test		
	Statistics	Df	p						p	W	Z
Pre–implementation	0.15	3302	<0.001	14	17.24	14.20	12	[16.75, 17.72]	0.424	7689931	-0.79
Post–implementation	0.13	2616	<0.001	14	16.23	10.79	12	[15.81, 16.64]			

Source: Secondary Data, Outpatient Pharmacy HIS, PKU Muhammadiyah Wonosobo, 2025; df=degree of freedom, SD= standard deviation, IQR= Interquartile Range

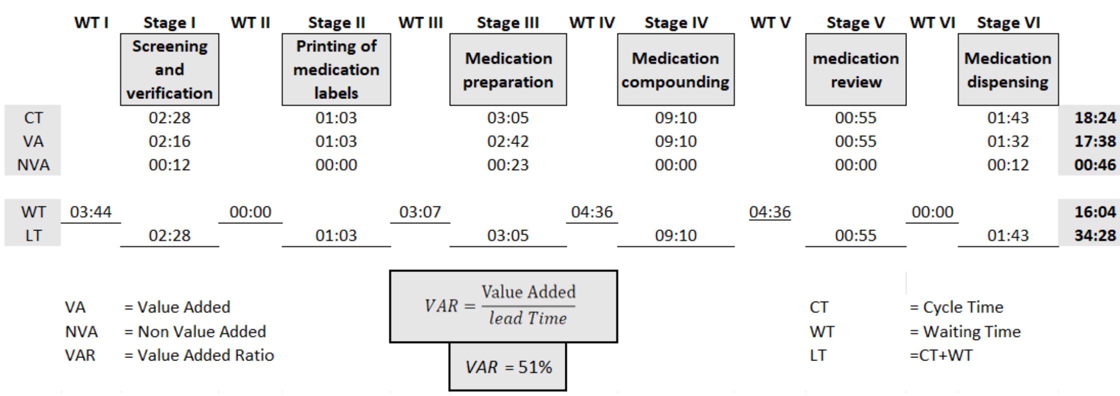
Table 2 shows that mean waiting time for compounded prescriptions slightly decreased from 17.24 to 16.23 minutes after LT–VM integration. The Mann–Whitney U test indicated no significant difference (Z = -0.79, p = 0.424), but the reduced standard deviation (14.20 to 10.79 minutes) suggests improved process consistency.

Value Stream Mapping (VSM) Analysis of Outpatient Pharmacy Workflow



Source: Primary Data, Outpatient Pharmacy Process Observation, 2025
Figure 1. Value stream mapping of non-compounded prescription services

Figure 1 illustrates the workflow analysis of non-compounded prescription services following the implementation of LT–VM through HIS integration. The total lead time was 18 min 2 sec, consisting of 7 min 7 sec of value-added time and 45 sec of non–value-added time. The VAR was calculated at 40.08%, reflecting the proportion of value-adding activities within the total process duration.



Source: Primary Data, Outpatient Pharmacy Process Observation, 2025
Figure 2. Value stream mapping of compounded prescription services

Figure 2 presents the process mapping for compounded prescription services following the implementation of LT–VM. The total lead time was recorded at 34 min 28 sec, with a total value-added time of 17 min 38 sec and a non value added time of 46 sec. The resulting process efficiency ratio (*VAR*) reached 51%, indicating that more than half of the total process duration consisted of value-adding activities related to compounding, preparation, and dispensing.

DISCUSSION

System Efficiency and Response Time under Operational Pressure

The results in Table 1 demonstrate a statistically significant change in response time for non-compounded prescriptions ($p = 0.005$), yet the mean service time remained stable despite a 2.5-fold increase in prescription volume. Despite the statistical significance, the effect size was extremely small ($r = –0.0124$), indicating that the magnitude of change was practically negligible. This suggests that the intervention's primary value did not lie in accelerating service time, but in maintaining workflow stability amid a substantial increase in workload. This indicates the system's ability to handle higher workloads without efficiency loss, reflecting the impact of Lean-based workflow modifications and digital integration in the HIS, which streamlined tasks and reduced administrative waste. This study provides a novel contribution by showing that LT–VM–HIS integration primarily enhances workflow stability rather than accelerating service time. Despite a 2.5-fold increase in prescription volume, the system maintained consistent performance, indicating that Lean-enabled digital integration can function as a resilience mechanism, an effect not widely reported in previous Lean healthcare studies.

In contrast to previous studies that primarily report improvements in waiting time following the application of Lean methods in combination with VM tools and information system enhancements (15,16), the present study highlights a different and underexplored effect of LT–VM integration. The findings show that the central contribution of this intervention lies in its ability to maintain system stability even when prescription volume increased by 2.5-fold. This offers a novel perspective: Lean-driven digital integration may serve not only to streamline workflows but also to function as a resilience mechanism, enabling healthcare systems to absorb substantial fluctuations in workload without compromising performance. This insight advances current theoretical understanding of Lean in HIS-supported environments and addresses a notable gap in the literature, particularly within high-volume outpatient pharmacy settings in resource-limited hospitals.

Although the statistical analysis indicated a significant change, the magnitude of time reduction was minimal, suggesting that the intervention's primary contribution lay in process stabilization rather than acceleration. This interpretation is consistent with Chadha, Singh, and Kalra (2012), who demonstrated that integrating Lean with queuing and VM principles enhances process stability and system flexibility, enabling healthcare organizations to maintain service quality even under high-pressure conditions (17). While lean does not always directly reduce waiting times, it contributes to building a resilient and adaptive system capable of preserving service quality, thereby ensuring consistent performance across various situations and operational challenges (18).

These findings differ from evidence reported at the King Hussein Cancer Center in Jordan, where Lean implementation in the outpatient pharmacy successfully reduced waiting times for prescriptions containing fewer than three medications—from 22 minutes 3 seconds to 8 minutes 1 second (7). Additional evidence from an Emergency Department action research project demonstrated a similar pattern, showing that Lean interventions reduced waste and shortened physician response time by an average of 1 minute and 29 seconds (19). Together, these studies illustrate Lean's capacity to accelerate service times in time-critical clinical environments. In contrast, the present study observed relatively stable, or slightly increased, response times, although performance remained within acceptable operational thresholds. This outcome is likely associated with the substantial increase in prescription volume, which heightened workflow complexity and introduced additional challenges in maintaining service performance under elevated demand conditions.

Limited Impact on Manual Compounding Processes

In contrast to non-compounded prescriptions, no statistically significant change was observed in the response time for compounded prescriptions at table 2 ($p = 0.424$). This persistently long turnaround is likely attributable to the inherently manual and variable nature of compounding processes, which remain largely unaffected by digital enhancements. A deeper analysis is warranted by considering the distinct operational characteristics of compounded medications, which involve time-intensive steps such as weighing raw materials, manual mixing, labeling, and final validation. These physical and manual tasks limit the extent to which digital interventions alone can accelerate the process. Similar observations were documented in a recent Lean action research study in an Indonesian outpatient pharmacy, where manual compounding and material preparation activities were identified as the dominant contributors to extended lead times (20). Despite reductions in non–value-added steps and a marked increase in the value-added ratio following Lean implementation, the study found that production-stage tasks continued to constrain overall process efficiency. These findings suggest that while digital enhancements can streamline administrative tasks and improve workflow visibility, efficiency gains in labor-intensive compounding processes require deeper process redesign, skill standardization, and, where feasible, partial automation. This aligns with the present study's conclusion that Lean–VM–HIS integration has limited influence on time-bound manual procedures, even when showing improvements in consistency and variability reduction.

The absence of significant improvement response time in compounded prescription services should not be interpreted as a failure of intervention, but rather as evidence that the digitalization implemented thus far, such as electronic prescribing, countdown timers, and queue display systems, primarily optimizes administrative workflows and patient communication, without directly impacting the core production time of compounded drugs. Sunarko and Koeswo (2020) reported similar delays in Indonesian hospital settings, highlighting task complexity and workforce shortages as key constraints (21).

Nevertheless, the observed reduction in standard deviation (SD: from 14.2 to 10.8 minutes) post-intervention indicates an increase in process consistency, even in the absence of significant speed gains. This finding aligns with Peralta's (2022) description of early-stage Lean maturity, wherein variability reduction often precedes time reduction, laying the groundwork for future efficiency improvements through deeper process redesign or automation (22**)**.

Identifying Systemic Bottlenecks through Value Stream Mapping

The most critical finding in Figure 1 is the relatively low VAR of only 40.08% in outpatient pharmacy services following the implementation of LT-VM through enhanced SIMRS integration. Although the actual lead time (17 min 46 sec) remained well within the operational service standard of 30 minutes, this relatively low VAR indicates that a substantial portion of patients' time was spent waiting rather than receiving value-adding services. The VSM results further demonstrate the presence of bottlenecks within the service flow. The total lead time for non-compounded prescriptions was 18 min 02 sec, consisting of 07 min 07 sec of value-added (VA) activities, 45 sec of non-value-added (NVA) processing, and 10 min 05 sec of waiting. The longest delays occurred before prescription processing (3 min 54 sec) and before medication handover (3 min 28 sec), confirming that the low VAR (40.08%) is driven primarily by waiting at transition points rather than inefficiencies within the pharmacy's core processing stages.

Importantly, the low VAR should not be interpreted as a failure of the LT–VM intervention but rather as a diagnostic signal revealing systemic bottlenecks, particularly at transition points where service flow becomes constrained. In Lean systems, excessive waiting between active processing steps typically reflects imbalances between workload inflow and processing capacity, signaling opportunities for further redesign and demand leveling. This pattern illustrates a classic bottleneck at service transition points rather than inefficiencies in core pharmacy operations.

The simultaneous operation of multiple outpatient clinics amplifies this challenge, leading to workload surges that periodically exceed available pharmacy staffing capacity. These findings are consistent with Yulia et al, who identified pharm acist workload, particularly during peak hours,as a primary driver of prolonged waiting times in Indonesian hospitals (23).

Addressing these systemic bottlenecks requires aligning service demand with processing capacity, an increasingly complex challenge in healthcare systems characterized by variable patient inflow and fragmented scheduling across departments. Effective demand–capacity balancing and patient-flow coordination are central to Lean healthcare implementation, recent reviews show that applying Lean principles to hospital flow management can substantially reduce bottlenecks and delays. Van Bussel et al. (2018) emphasize that effective bottleneck resolution relies on strategic alignment between patient demand and available service capacity, as imbalances between inflow and processing ability often lead to queues and access delays within outpatient systems (24). In this context, the uneven scheduling of outpatient clinics emerges as a major contributor to concentrated demand surges that disrupt pharmacy workflows. Redistributing outpatient clinic schedules to ensure a more even patient flow throughout the day represents a critical step toward demand leveling.

Improving flow efficiency under Lean principles therefore calls for interventions that transcend unit boundaries. Beyond technical adjustments within pharmacy operations, coordinated scheduling and shared visibility across clinical and pharmacy units are essential. Recent findings from an Integrated Practice Unit (IPU) model at the Dell Medical School highlight that coordinated scheduling across heterogeneous patient types (Virtual Medicine and In-Clinic patients) can significantly enhance system performance and patient access without additional resources25.

These insights reinforce the argument that synchronized planning across outpatient clinics and pharmacy departments is critical to reducing transition delays and achieving a resilient, patient-centered workflow.

The increased VAR in the compounded medication process at figure 2 (51%) compared to the non-compounded stream (40%) is structurally driven by the inclusion of the compounding step, a labor-intensive activity that significantly extends value-added time. However, this higher VAR does not reflect improved system efficiency, as core bottlenecks, particularly in medication retrieval and preparation, persist across both streams. Despite process differences, both streams exhibit similar flow disruptions during peak hours, pointing to unresolved issues in demand leveling and cross-departmental coordination. As highlighted by Yu (2022), lean can be extended to coordinate schedules across different departments, ensuring a smoother patient flow and better resource allocation (26). Overall, these findings reinforce that improving pharmacy service flow demands a shift from isolated digital interventions toward holistic system redesign, encompassing synchronized scheduling, real-time capacity visibility, and cross-unit accountability. Recent reviews have emphasized that combining Lean methodologies with digital tools such as VSM dashboards enables hospital-wide demand–capacity alignment and enhances organizational resilience (27).

This study's primary strength lies in its utilization of a large dataset combined with a comprehensive quantitative assessment that extends beyond mere measurement of prescription response times. The incorporation of VSM enabled a detailed examination of process flows, facilitating the identification of systemic bottlenecks and providing a robust framework for evaluating service efficiency. This multifaceted approach offers a nuanced understanding of workflow dynamics in outpatient pharmacy settings, thereby contributing valuable insights to LT–VM implementations in healthcare.

Limitations and Cautions

This study is limited by its exclusion of key factors such as staff workload and patient satisfaction, both of which are critical to comprehensively assessing the impact of LT–VM interventions. Readers should also exercise caution when interpreting these findings, as contextual factors such as workflow complexity, staffing ratios, and hospital digital maturity may influence the outcomes. The absence of these variables constrains the ability to evaluate the interventions' effects on human resource capacity and patient-centered outcomes.

Recommendations for Future Research

This study underscores the importance of expanding LT–VM integration beyond the pharmacy unit toward a hospital-wide redesign of service processes. Hospitals should reinforce cross-unit coordination and implement demand–capacity balancing mechanisms, such as synchronized outpatient scheduling, to reduce bottlenecks at transition points. Future Lean-based digital interventions should integrate HIS with automated workforce planning tools and real-time workload dashboards to improve system adaptability and patient flow stability.

Furthermore, future evaluations should incorporate staff workload and patient satisfaction measures as essential indicators to further optimize efficiency and service quality. Continuous monitoring using VSM is also recommended as an iterative evaluation tool to identify inefficiencies and guide ongoing process improvement.

CONCLUSION

Non-compounded prescriptions demonstrated a significant improvement in response time despite a more than twofold increase in prescription volume, whereas compounded prescriptions did not show a comparable enhancement. The VSM analysis revealed a VAR of 40.08% for non-compounded and 51% for compounded prescriptions. These findings indicate that the integration of LT–VM maintained service performance and enhanced process consistency, yet had limited impact on labor-intensive manual tasks. The persistently low VAR highlights systemic bottlenecks at process transition points, underscoring the need for stronger inter-unit coordination, demand and capacity balancing, and organizational alignment to strengthen overall system efficiency.

A key contribution of this study is the identification of workflow stability as the primary impact of LT–VM–HIS integration, rather than acceleration of service time. This finding highlights the role of Lean-based digital transformation as a resilience mechanism that enables outpatient pharmacy services in resource-limited settings to sustain performance under substantial workload fluctuations. These insights extend current Lean healthcare theory by emphasizing stability and adaptability as critical outcomes of digital–Lean integration.

AUTHOR'S CONTRIBUTION STATEMENT

CP: Conceptualization, Methodology, Formal analysis, Data curation, writing – original draft, Visualization, Project administration.

MA: Conceptualization, Methodology, Validation, Supervision, Writing – Review & Editing.

All authors reviewed the final manuscript and approved it.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors declare that ChatGPT, an AI-assisted tool, was used solely to improve the language clarity and structure of the manuscript. The use of this tool did not affect the study's conceptualization, data collection, analysis, interpretation, or conclusions. The authors take full responsibility for the content and integrity of this manuscript.

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