PROCEEDINGS OF ASIA DESIGN AND INNOVATION CONFERENCE
5–6 DECEMBER, 2024, SHANGHAI, CHINA

A STUDY ON SERVICE DESIGN OF PHYSICAL THERAPY CENTERS FOR DIGITAL TRANSFORMATION

Yu-Hsiu HUNG[1] and Jia-Bao LIANG[1]
[1]Department of Industrial Design, National Cheng Kung University

ABSTRACT
As healthcare demands grow, public expectations for affordable, high-quality services have increased. Traditional service models rely on manual scheduling and paper records, leading to inefficient information flow, frequent interruptions, long patient waiting times, and subpar experiences. Digital technology offers potential solutions to these challenges. This study focuses on the transformation of service models in Physical Therapy Centers (PTCs) through digital advancements, aiming to enhance scheduling systems, improve operational efficiency, and increase patient satisfaction. Using field research, contextual inquiry, and participatory design, we observed appointment processes and used Value Stream Mapping (VSM) to identify bottlenecks. Additionally, interviews with staff and therapists provided insights into scheduling logic. In a participatory workshop with 8 PTC staff members, we explored strategies for a digital scheduling system, addressing workflow inefficiencies and proposing targeted improvements. The new model integrates real-time information sharing and intelligent task allocation, reducing wait times and optimizing resource usage. Results show that the new model addresses information flow issues and identifies process improvements from a lean perspective, achieving enhanced outcomes for patients, staff, and departments while avoiding extra costs during digital transformation.

Keywords: Digital transformation, Physical Therapy Center, Service Design, Lean Management, Digital Technology

1 INTRODUCTION

Physical Therapy Centers (PTCs) are vital in the healthcare system, with their service quality directly influencing patient recovery and experience. Traditional service models rely on manual scheduling and paper records, leading to inefficient information flow, longer patient wait times, and suboptimal treatment experiences. Digital transformation offers new opportunities for optimizing service models and improving efficiency in response to these challenges.

Although digital service models have become more prevalent in healthcare, tensions persist between patient needs and service providers' maintenance requirements in physical therapy. Balancing patient experience with service management needs has emerged as a critical research focus. Recent studies explore the role of digital technologies in enhancing physical therapy, such as using the Internet of Things (IoT) for data collection [1] and applying smart algorithms for scheduling [2]Additionally, machine learning has been used to predict patient outcomes [3, 4]. These studies underscore the potential of digital technology to improve efficiency and patient experiences, but they also highlight the need for innovative service models.

However, gaps remain in integrating lean management with digital tools. Most studies emphasize technical advancements but often overlook the coordination between patient experience and service optimization [2, 5, 6]. Additionally, some focus on specific digital tools without a holistic approach [1, 7, 8]. Many prioritize efficiency or patient experience improvements in isolated stages rather than balancing patient needs with service provider requirements during digital transformation.

To address these gaps, future research could analyze bottlenecks in traditional scheduling models, integrate lean management with digital technologies for overall process optimization, and explore the relationship between stakeholder satisfaction and digital transformation outcomes. Some studies have begun addressing these aspects, such as examining digital lean's role in reducing waste and enhancing

efficiency [9]and using Value Stream Mapping (VSM) in lean healthcare [10]. However, these efforts lack depth in their application to PTCs and in designing models that balance patient experience with resource optimization.

This study aims to design a lean and digitally transformed service model for PTCs to enhance patient experience, streamline service management, and support the digitalization of PTCs. The research questions are: 1. How can lean management principles be integrated with digital tools to optimize PTC service processes? 2. How can a digital scheduling system adapt dynamically to patient needs and resource allocation? 3. How can the new service model balance the satisfaction of multiple stakeholders? By addressing these questions, this research contributes a novel framework that combines lean management and digital service models specifically for PTCs. This study not only seeks to improve the efficiency of PTC operations and enhance patient satisfaction but also aims to offer insights and a replicable model for other healthcare institutions pursuing digital transformation.

2 LITERATURE REVIEW

Assigning suitable doctors based on patient conditions is often inefficient and prone to errors [11]. In traditional scheduling and assignment models, gaps in service processes extend patient wait times, increase anxiety, and may delay treatment, leading to higher healthcare costs. While electronic medical records facilitate outpatient assignment communication, administrative staff and medical professionals often struggle with effective communication, resulting in delays in care despite technological support[12]. This has led many researchers to explore digital solutions for scheduling and assignment services.

Different studies propose various approaches to determining the logic of assignment systems. Keely and Liddy [13] emphasize the importance of specialists in designing eConsults and eReferrals systems, focusing on standards for specialist recruitment and maintaining service quality. Todd, Richards [14] analyze the information on referral forms and compare it with factors that influence assignment decisions, using similarity scores to understand which factors affect the judgment of physicians or administrative staff, thus providing a basis for assignment system design.

These studies suggest that digital systems can significantly improve scheduling efficiency in healthcare processes, yet many remain in the conceptual phase or use simulations for validation, with few tracking real-world system performance.

Lean Thinking originated from the Toyota Production System (TPS), with its core idea being to maximize value by eliminating waste, optimizing processes, and improving efficiency. In the late 1990s, researchers began exploring the application of lean in non-manufacturing sectors, particularly in the service industry[15]. By reducing redundant steps, shortening service time, and optimizing resource allocation, the application of lean in the service industry has achieved initial success. Gunawan, Matondang [16] addresses high logistics costs due to lengthy port service times and proposes lean technology as a solution. Using VSM at BICT port, it identified reducible activities like administration and waiting. Optimization reduced non-value-added time from 2,370 to 878 seconds, increased value-added activities from 27% to 50%, and cut import waiting time from 72 hours to 24 hours. Morales-Contreras, Suárez-Barraza [17]explores lean service application in the fast food industry, focusing on identifying Muda (waste) from the customer's perspective. An exploratory case study of three multinational companies in Madrid revealed seven types of Muda: defects, movements, process, inventory, overproduction, transport, and delay. The study provides value for practitioners by offering insights on waste identification, customer perception, and a guideline for future assessments, contributing to improving service efficiency and quality in the fast food sector.

With the successful application of Lean Thinking in the service industry, it has gradually transitioned into the healthcare sector, particularly in environments such as hospitals and clinics. When applied to healthcare, Lean can enhance system efficiency; however, the complexity and unpredictability of healthcare services require adaptive adjustments. Ankrum, Neogi [18] used VSM in a pediatric teaching hospital to reduce turnover time in isolation rooms, improving processes. As digital manufacturing and future factories emerge, Lean must also evolve, as Hamidi, Mahendran [19] found that digitalizing visual management tools and integrating them with hospital information systems (HIS) can reduce data redundancy and loss, enhancing data availability.

These studies highlight the global drive to deliver higher quality services at lower costs and shorter times, with digitalization offering great potential in improving quality, flexibility, and capacity. Most research focuses on strategic decisions, with limited studies on real-world implementations, especially

considering environmental factors that can complicate mathematical models. Additionally, studies often focus on operating rooms and emergency departments, with less attention to appointment-based systems for PTCs. Furthermore, many outpatient clinics, especially specialized care clinics, handle diverse patient needs, yet optimization studies typically assume homogeneous treatment plans for all patients. This study will address these gaps by focusing on appointment scheduling in PTCs, considering different patient types and therapists, and testing the system in real-world conditions to identify and continuously improve based on environmental impacts.

3 METHODOLOGY

This study employs a lean problem-solving framework, divided into three phases: understanding the current situation, analyzing task assignment and therapy logic, and developing strategies through participatory design (see Figure 1).

1. **Understanding the Current Situation**: The initial phase involved observing appointment and treatment processes for both new and existing patients. Using VSM, we identified bottlenecks, such as information stagnation, that hinder operational efficiency. By mapping the flow of information and patient activities, VSM provided a comprehensive overview of the processes, revealing inefficiencies like redundant steps and extended waiting times. These findings were not only data-driven but also grounded in lean principles that focus on maximizing value and reducing waste.
2. **Analyzing Task Assignment and Therapy Logic**: This phase included interviews with front-desk staff to understand their approach to task assignment and with therapists to explore their logic for assigning therapies based on patient symptoms.
3. **Participatory Design**: A workshop brought together stakeholders to discuss root causes, challenges faced by staff, process limitations, and potential digital scheduling solutions through a lean perspective.

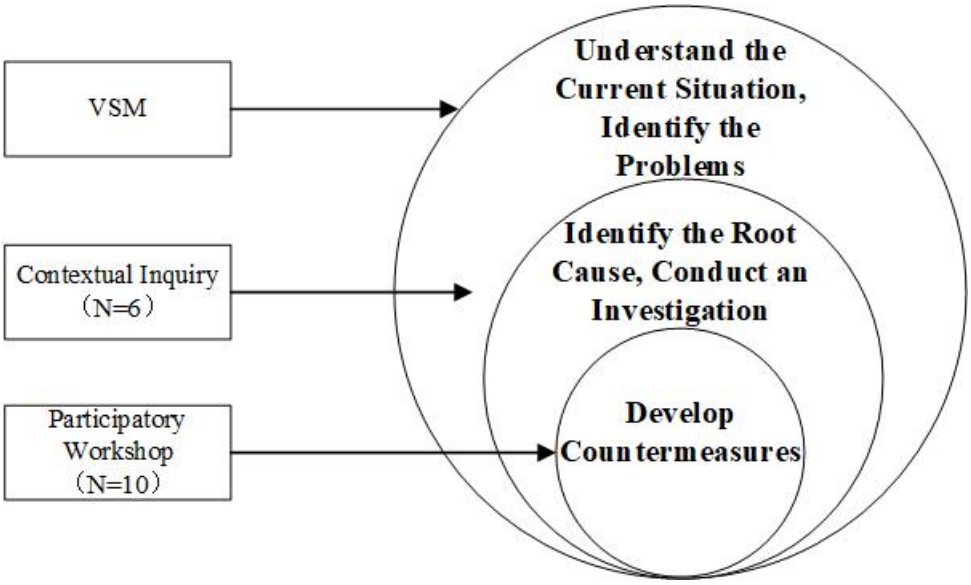

Figure 1. Research Framework Diagram

3.1 Service Value Stream Mapping

VSM analysis was used to visualize information flow, identify interruptions, and understand their impact on front-desk services, highlighting mismatches between service processes and patient needs. VSM is more than a descriptive tool; it implements core lean principles such as waste elimination, process simplification, and the enhancement of value-adding activities. In this study, its application included:

1. **Visualization of Information and Material Flows:** By mapping out the entire service process—patient scheduling, evaluation, and follow-up treatments—VSM highlighted how information bottlenecks (e.g., delays in therapist assignment) disrupted the service flow. The tool's structured nature minimized subjective bias by focusing on objective process parameters, such as time taken at each stage and resource utilization.

2. **Objective Identification of Inefficiencies:** Unlike traditional observations, VSM integrates quantitative data (e.g., process times, waiting periods) with qualitative insights from contextual inquiries. This dual-layered approach ensures that inefficiencies, such as over-allocation of patient slots or misaligned scheduling logic, are identified based on evidence rather than individual perception or intuition.
3. **Actionable Insights for Lean Improvement:** VSM outcomes were instrumental in setting the stage for participatory workshops. By pinpointing breakpoints like redundant administrative steps or unclear treatment assignments, VSM provided a clear, shared framework for discussing redesign opportunities. These findings were then validated by stakeholders, reducing the reliance on individual analytical skills.
4. **Alignment with Lean Principles:** VSM embodies the lean focus on continuous improvement. In this study, it was not used in isolation but as part of an iterative process where identified inefficiencies informed actionable strategies, such as the development of a rule-based digital scheduling system. This iterative refinement ensures that the solutions remain adaptable to real-world complexities.

By combining VSM with contextual inquiries and participatory workshops, this study demonstrated that the identification of inefficiencies is neither entirely subjective nor overly reliant on individual analytical capabilities. Instead, it is a structured, collaborative process grounded in lean principles, leveraging tools and stakeholder inputs to generate replicable and practical solutions.

3.2 Contextual Inquiry

Interviews clarified the root causes of information flow issues. Interviews with front-desk staff focused on patient assignment logic, while sessions with five therapists examined factors like fee structure, therapy types, required space, and work time allocation.

(1) Participants

This study plans to interview administrative staff, physical therapists, and patients at the PTC.

- **Administrative staff and physical therapists**: Given the current staff at the center—1 administrative staff member and 5 full-time therapists—recruitment is limited, so interviews will be conducted with all staff.
- **Patients**: The study will use purposive sampling to select patients from the center. It is expected to recruit 30 participants. All patients will be informed about the research purpose before deciding whether to participate, and the study will proceed only after obtaining "informed consent."

  Criteria for case selection include: (a) Having at least two prior appointment experiences. (b) No communication barriers. (c) Willingness to cooperate with observation and interviews. (d) Age between 20-65 years.

  The selection criteria aim to ensure that patients have enough appointment experience to fully understand the current scheduling system (first appointment confirming the therapist, second appointment obtaining scheduling information for follow-up). The age range is set to ensure minimal communication barriers, facilitating smooth interview progress.

Exclusion criteria include: (1) Severe cognitive impairment. (2) Foreign nationals.

(2) Methodology and Process Design

- **Interviewing patients about their treatment experience**: This phase will involve asking patients about their satisfaction with the current appointment process, frequency, and waiting time, and understanding the challenges they face during scheduling.
- **Interviewing administrative staff about scheduling logic**: This phase will first ask service providers about the resources, processes, and methods (people, machines, materials, methods, environment) involved in service provision, as well as the constraints in back-end execution. Observations will then be conducted to understand potential difficulties patients face during the appointment process.
- **Interviewing therapists about patient work-hour allocation logic**: This phase will ask therapists about the decision-making process when allocating work time to patients, including items such as patient billing, treatment items, required equipment space, treatment frequency, and required work time. Challenges encountered during the decision-making process will also be explored.

3.3 Participatory Workshop

Two workshops with a total of 10 participants, including physical therapists, administrative staff, a director, and lean experts, were conducted to generate service concepts. Different participants in each workshop helped ensure diverse input and reliability of the design results.

The goal of this ideation phase is to balance the needs of both providers and customers and discuss areas for redesign and how to design them. The principles for service design in this phase are as follows:

1. **Identify Breakpoints**: From the patient's service experience value stream, identify any stagnation in information or patient flow, and mark these as breakpoints.
2. **Balance Countermeasures**: Discuss the reasons for patient breakpoints and, through discussion and innovation, explore how to allocate different service resources to increase (or create) important value.
3. **Eliminate Waste**: Identify unnecessary resource inputs and eliminate them to reduce costs, balancing the cost of patient experience with minimal resources.
4. **Continuous Improvement**: Identify the next imbalance in patient satisfaction and importance, mark it as a breakpoint, and continue improving and innovating to meet maximum customer demand with minimal resources.

4 RESULTS

4.1 Value Stream Mapping: Identifying Bottlenecks and Clarifying Issues

The PTC primarily serves orthopedic patients, particularly those with shoulder conditions. The VSM (see Figure 2) highlights three key processes involved in patient treatment:

- **Scheduling the First Evaluation:** Patients schedule their initial appointment after receiving a referral. Administrative staff only enter the patient's name and assign a therapist.
- **Conducting the First Evaluation:** On the scheduled day, patients arrive at the center for assessment. The therapist evaluates the patient's pain, shoulder range of motion, muscle strength, and daily living capabilities. After the assessment, patients check out at the front desk, where follow-up treatments (2-6 sessions) are scheduled.

  Existing Patients Scheduling New Treatments: Existing patients typically schedule their next therapy sessions at the end of their current treatment. When patients arrive, they check in at the front desk and usually wait in the waiting area until the therapist completes the previous patient's treatment.

The analysis reveals two significant bottlenecks:

- **Bottleneck 1:** Patients must first schedule a therapist evaluation before actual treatment, resulting in unnecessary waiting times. After scheduling, patients often leave and return later for their evaluation.
- **Bottleneck 2:** Long wait times for patients, both during initial evaluations and follow-up treatments, suggest inefficiencies in the current scheduling system.

4.2 Contextual Inquiry: Investigating Issues

Interviews conducted with administrative staff and therapists revealed important insights regarding the identified bottlenecks:

Bottleneck 1 arises from administrative staff lacking the professional knowledge required to diagnose patients and assign appropriate therapies. This gap leads to delays, as patients are required to go through multiple scheduling steps before receiving treatment.

Bottleneck 2 is caused by the administrative staff's misunderstanding of treatment durations, leading to inefficient patient allocations. Patients are often scheduled without consideration of the time required for their specific therapies, resulting in longer wait times.

To address these issues, the research aims to:

1. **Establish expert logic for assigning therapists based on specific patient needs.**
2. **Clarify the decision-making processes therapists utilize when assigning therapies, taking into account treatment duration and patient conditions.**

These steps are intended to streamline the scheduling process, enhance operational efficiency, and improve patient satisfaction.

Interview with Front-Desk Administrative Staff: Front-desk staff schedule only one evaluation treatment for new patients and assign them to various therapists during the initial visit, as patients prefer

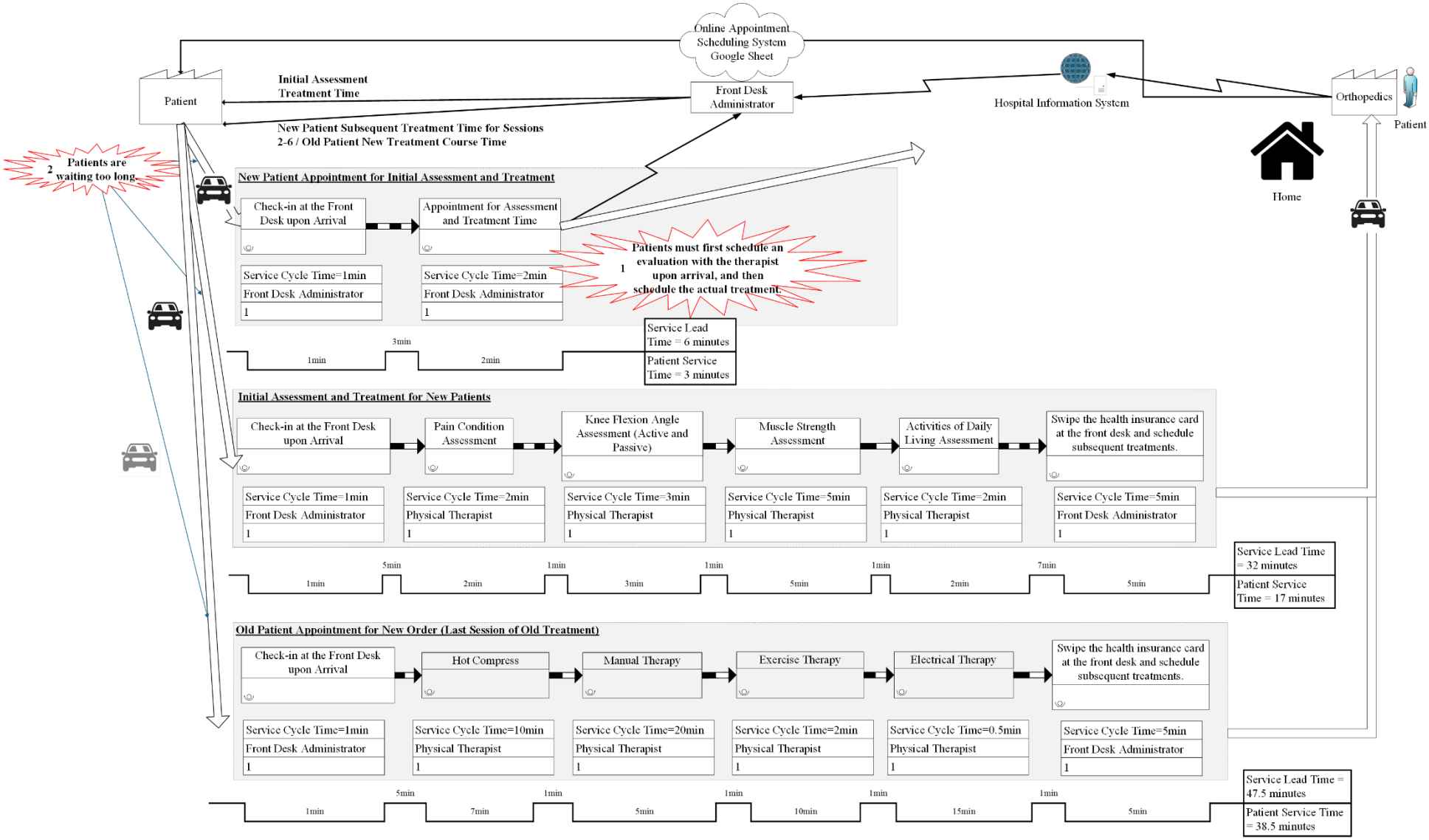

Figure 2. Value Stream of Patient Symptom Assessment and Treatment in PTCs

to continue seeing the same therapist. Staff assess patients based on the disease type listed on the referral form. For example, orthopedic patients are treated by Therapist A, while patients with urinary incontinence are assigned based on gender. If multiple therapists are available, staff coordinate appointment times and select the earliest available therapist or randomly choose one if necessary (see Figure 3 for the logic flow).

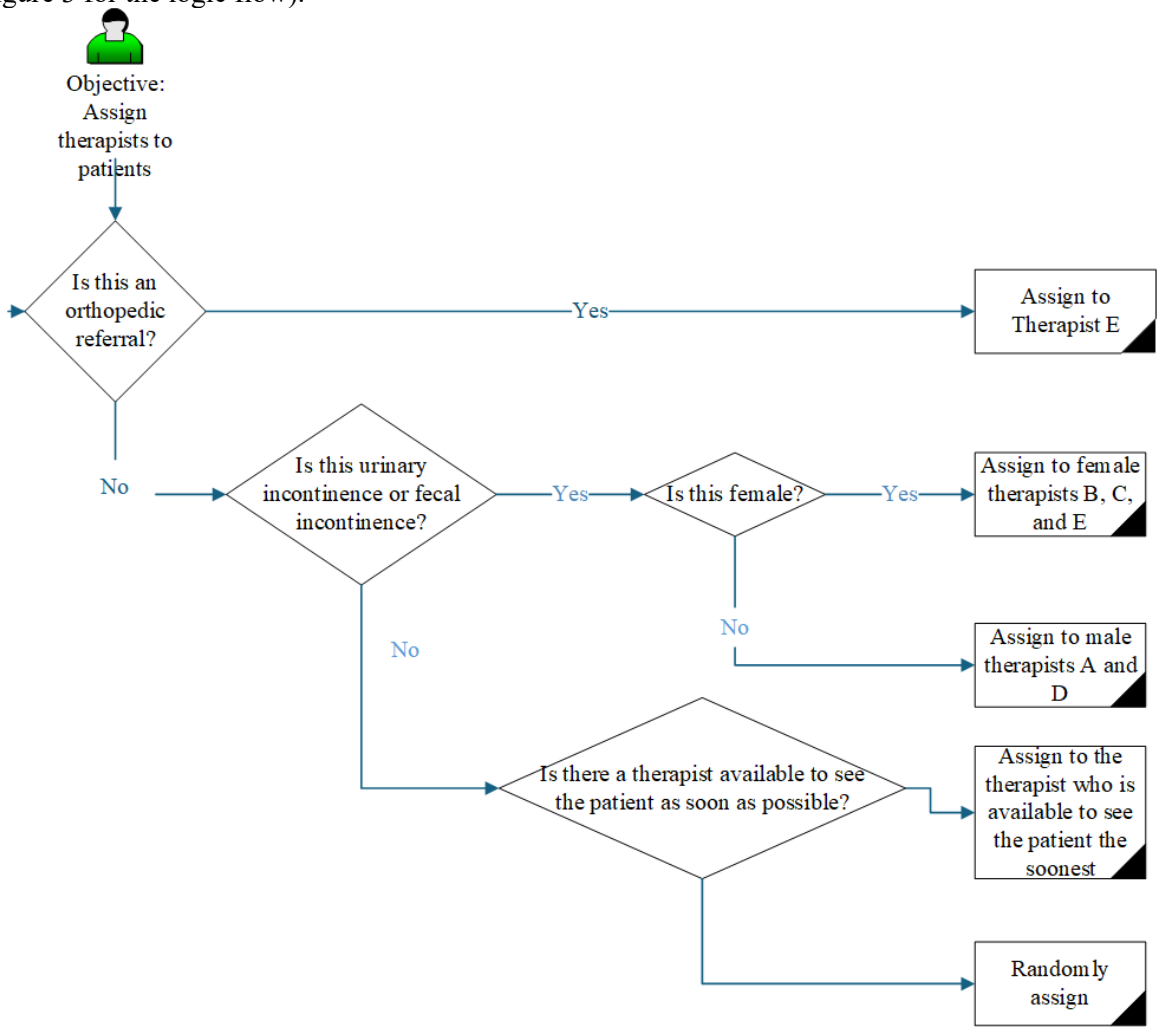

Figure 3. Logic flow for front-desk administrative staff in therapist assignment

4.3 Conducting Participatory Workshops to Develop Strategies

Participatory design workshops were organized to address root causes, staff methods, existing processes, and equipment limitations. The aim was to explore design strategies for a digital scheduling system (simple rule-based digitalization). The results are summarized in Table 1.

Table 1. Correspondence between bottlenecks, objectives, root causes, and strategies

Bottleneck	Objective	Root Cause	Strategy
1. Patients must first schedule a therapist's evaluation before actual treatment.	1. Patients will be assigned therapy automatically by the system after answering basic questions upon arrival.	Administrative staff lack professional knowledge for patient diagnosis and therapy assignment.	Develop a simple rule-based digital scheduling system that automatically assigns therapists and therapies based on inputted information.
2. Long waiting days for patients.	2. Reduce patient waiting days to a reasonable range and minimize complaints.	Administrative staff do not understand the treatment duration of therapists, leading to broad patient allocation.	Similar to above, in addition, the system can record and display patient waiting days (eKanban)

			and establish thresholds for tracking management.

5 DISCUSSION

This study explores the service design of PTCs for digital transformation by integrating lean management principles with a digital scheduling system to enhance patient satisfaction and operational efficiency. The findings indicate that lean management can effectively address inefficiencies in current service models, minimizing waste, including unnecessary waiting times and repetitive tasks, and thereby enhancing overall service efficiency. By doing so, this research provides PTCs with a more effective, streamlined process design, which ultimately improves patient experience and operational performance.

The study diverges from previous research in several key aspects. While prior studies focused primarily on applying lean management in manufacturing, this research centers on the healthcare sector and the unique, dynamic environment of PTCs. In this context, patient needs are complex and variable, adding layers of complexity to service processes not typically encountered in manufacturing settings. This research underscores the critical role of digital tools in implementing lean principles, particularly in optimizing patient scheduling and supporting real-time information transfer. Unlike prior studies, which highlighted lean management's strength in optimizing fixed processes[20, 21], the current findings suggest that adaptability is even more crucial in healthcare environments, where system flexibility is necessary to meet personalized patient demands.

Despite these differences, this study corroborates certain aspects of existing literature. For instance, the data support the notion that reducing waiting times through lean management significantly enhances both patient satisfaction and resource utilization, aligning with findings by Adeodu, Kanakana-Katumba [21]. Furthermore, the role of digital tools in facilitating lean management processes, as demonstrated here, is consistent with findings by Dossou, Torregrossa [20], providing new evidence for digital lean management in service sectors beyond manufacturing.

This study's methodological approach is distinctive. By integrating lean and digital solutions specifically within physical therapy, and by prioritizing a patient-centered perspective while considering service provider constraints, the research quickly identified process bottlenecks. This approach has been seldom addressed in previous research and establishes a new methodological framework for future studies. Moreover, the personalized scheduling model proposed here shows strong practical applicability, particularly for managing both new and returning patients. This model not only boosts service efficiency in PTCs but also provides valuable insights for potential applications in other healthcare contexts.

This research explored three main questions.

1. **RQ1: How can lean management principles be integrated with digital tools to optimize PTC service processes?** The findings demonstrate that lean management can significantly improve PTC service processes by identifying and mitigating inefficiencies within the existing model. Through VSM, key bottlenecks—such as extended waiting times and redundant tasks—were identified. The integration of a digital scheduling system introduced real-time tracking and dynamic task allocation, which reduced unnecessary steps and improved information flow. This created a more responsive, efficient service model that highlights the potential of lean management principles when applied to healthcare service design.
2. **RQ2: How can a digital scheduling system adapt dynamically to patient needs and resource allocation?** The results show that a rule-based digital scheduling system can dynamically adjust to varying patient needs and resource constraints. This system uses patient data to assign therapists and schedule treatments in real-time, effectively reducing waiting times through optimized resource allocation. Furthermore, the system monitors patient flow and wait times, allowing administrators to make timely schedule adjustments as needed. This adaptability enables personalized scheduling that meets specific treatment requirements and fluctuating demand, ensuring resources are utilized efficiently.
3. **RQ3: How can the new service model balance the satisfaction of multiple stakeholders?** This study finds that a service model integrating automated scheduling and real-time data can enhance satisfaction for both patients and staff. By involving patients and frontline staff in participatory design workshops, the model achieved a balance between operational efficiency and positive user experience. Patients benefit from reduced waiting times, while staff experience a reduced administrative load and greater job satisfaction due to streamlined operations. These

findings highlight the model's ability to meet the varied needs of stakeholders, ensuring effective resource management in PTCs.

In conclusion, the study underscores the value of lean management principles in PTC service design, highlighting the importance of digital tools in implementing flexible and responsive processes. By comparing with prior studies, this research reveals gaps in existing literature and offers new perspectives and methodologies for future studies. The findings regarding service process optimization, enhanced patient satisfaction, and effective digital tool utilization provide a strong foundation for continued exploration of lean management in healthcare service settings.

REFERENCES

[1] Postolache, O., et al., Remote monitoring of physical rehabilitation of stroke patients using IoT and virtual reality. 2020. **39**(2): p. 562-573.

[2] Valenzuela-Núñez, C., G. Latorre-Núñez, and F.T.J.I.A. Espinosa, Smart Medical Appointment Scheduling: Optimization, Machine Learning and Overbooking to Enhance Resource Utilization. 2024.

[3] Harari, Y., et al., Inpatient stroke rehabilitation: prediction of clinical outcomes using a machine-learning approach. 2020. **17**: p. 1-10.

[4] Shtar, G., et al., Using machine learning to predict rehabilitation outcomes in postacute hip fracture patients. 2021. **102**(3): p. 386-394.

[5] Li, X., H.J.S. Chen, and E. Computation, Bi-objective scheduling of physical therapy treatments with coupled operations for inpatients in rehabilitation departments. 2024. **86**: p. 101523.

[6] Kumar, S.M., et al. Cloud-Powered Healthcare Appointment Optimization with Reinforcement Learning for Efficiency. in 2024 Second International Conference on Intelligent Cyber Physical Systems and Internet of Things (ICoICI). 2024. IEEE.

[7] Haleem, A., et al., Internet of things (IoT) applications in orthopaedics. 2020. **11**: p. S105-S106.

[8] Xiao, X., et al., Machine-learning-aided self-powered assistive physical therapy devices. 2021. **15**(12): p. 18633-18646.

[9] Tlapa, D., et al., Effects of lean interventions supported by digital technologies on healthcare services: a systematic review. 2022. **19**(15): p. 9018.

[10] Tortorella, G.L., et al., Digital transformation of health services: a value stream-oriented approach. 2023. **61**(6): p. 1814-1828.

[11] Odisho, A.Y., et al., Design and development of referrals automation, a SMART on FHIR solution to improve patient access to specialty care. JAMIA open, 2020. **3**(3): p. 405-412.

[12] Esquivel, A., et al., Improving the effectiveness of electronic health record-based referral processes. BMC medical informatics and decision making, 2012. **12**(1): p. 1-8.

[13] Keely, E. and C. Liddy, Specialist Participation in e-Consult and e-Referral Services: Best Practices. Telemedicine and e-Health, 2020.

[14] Todd, J., et al., Text mining and automation for processing of patient referrals. Applied clinical informatics, 2018. **9**(1): p. 232.

[15] Gupta, S., et al., Lean services: a systematic review. 2016. **65**(8): p. 1025-1056.

[16] Gunawan, I., A. Matondang, and M. Sembiring. Lean Technology Implementation For Reducing The Dwelling Time Level. in Proceedings of the 1st International Conference of Global Education and Society Science, ICOGESS 2019, 14 March, Medan, North Sumatera, Indonesia. 2020.

[17] Morales-Contreras, M.F., et al., Identifying Muda in a fast food service process in Spain. 2020. **12**(2): p. 201-226.

[18] Ankrum, A.L., et al., Reduced isolation room turnover time using Lean methodology. Infection Control & Hospital Epidemiology, 2019. **40**(10): p. 1151-1156.

[19] Hamidi, M., P. Mahendran, and K. Denecke, Towards a Digital Lean Hospital: Concept for a Digital Patient Board and Its Integration with a Hospital Information System. Studies in health technology and informatics, 2019. **264**: p. 606-610.

[20] Dossou, P.-E., P. Torregrossa, and T.J.P.C.S. Martinez, Industry 4.0 concepts and lean manufacturing implementation for optimizing a company logistics flows. 2022. **200**: p. 358-367.

[21] Adeodu, A., et al., Implementation of Lean Six Sigma for production process optimization in a paper production company. 2021. **14**(3): p. 661-680.