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Flow Optimization and Waste Reduction: Application of Lean Healthcare and Value Stream Mapping in a Private Medical Analysis Laboratory

Optimisation des flux et réduction des gaspillages : Application du Lean Healthcare et de la cartographie des chaînes de valeur dans un laboratoire privé d'analyses médicales

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Abstract
Medical analysis laboratories (MALs) face continuous pressure to improve service quality and efficiency to meet patients' needs. Lean Management, especially Lean Healthcare, offers a practical approach to simplify operations and eliminate waste. A key tool in this process is Value Stream Mapping (VSM), which helps analyze workflows and identify inefficiencies. This study aims to map the operational processes of a newly established medical analysis laboratory, identify sources of waste, and propose actions to enhance performance.
To achieve this, a project team was formed, and three collaborative roundtable sessions were conducted. Data collection included on-site observations, semi-structured interviews with staff (biologists, technicians, clerks, couriers), and analysis of 80 patient samples to evaluate process metrics like turnaround time and value-added activity.
The results revealed that 45% of total processing time (average 54 minutes) was non-value-added. Only 30 minutes were dedicated to value-added tasks. Common inefficiencies included long waits at reception and sampling, sample transport delays, and repeated manual validations. Additionally, 32% of patients waited over 10 minutes for sampling, and LIS-related transmission errors required correction in 0.8 out of every 10 files.
A Lean strategy including digital tools, time-slot scheduling, automation, and transport optimization is expected to reduce turnaround time to 35 minutes and increase value-added activity to over 70%.
Keywords :
Value Stream Mapping, Lean Management, process improvement, waste elimination, medical laboratory, continuous improvement, process redesign.

Résumé
Les laboratoires d'analyses médicales (LAM) font face à une pression constante pour améliorer la qualité et l'efficacité de leurs services afin de répondre aux besoins des patients. Le Lean Management, et en particulier le Lean Healthcare, offre une approche pratique pour simplifier les opérations et éliminer les gaspillages. Un outil clé de cette démarche est la cartographie de la chaîne de valeur (Value Stream Mapping - VSM), qui permet d'analyser les flux de travail et d'identifier les inefficacités. Cette étude vise à cartographier les processus opérationnels d'un laboratoire d'analyses médicales récemment créé, à identifier les sources de gaspillage et à proposer des actions pour améliorer sa performance.
Pour ce faire, une équipe projet a été constituée et trois tables rondes collaboratives ont été organisées. Les données ont été recueillies par des observations sur site, des entretiens semi-directifs avec le personnel (biologistes, techniciens, agents administratifs, coursiers) et l'analyse de 80 échantillons de patients afin d'évaluer des indicateurs tels que le temps de traitement et les activités à valeur ajoutée.
Les résultats montrent que 45 % du temps total de traitement (moyenne de 54 minutes) n'apportaient aucune valeur ajoutée. Seules 30 minutes étaient consacrées aux activités à valeur ajoutée. Les principales inefficacités observées incluent les longues attentes à l'accueil et au prélèvement, les retards de transport des échantillons, ainsi que les validations manuelles répétées. En outre, 32 % des patients attendaient plus de 10 minutes pour le prélèvement, et des erreurs de transmission entre les équipements et le SIL nécessitaient des corrections dans 0,8 dossier sur 10.
Une stratégie Lean intégrant des outils numériques, la planification par créneaux horaires, l'automatisation et l'optimisation du transport devrait permettre de réduire le temps de traitement à 35 minutes et d'augmenter la part des activités à valeur ajoutée à plus de 70 %.
Mots clés :
cartographie de la chaîne de valeur, Lean Management, amélioration des processus, élimination des gaspillages, laboratoire médical, amélioration continue, refonte des processus.

Introduction

Medical laboratories play a vital role in clinical practice, providing essential diagnostic services that help detect infections, metabolic disorders, and cancers. By analyzing patient samples, they also help monitor how well treatments are working, allowing healthcare providers to adjust and improve care (Howanitz, 2005). Faced with increasing demand for healthcare services and better-informed patients, laboratories are under pressure to provide fast, accurate test results (DelliFraine et al., 2010). To meet these demands, many laboratories are adopting Lean Management, which streamlines operations, eliminates unnecessary steps and promotes continuous improvement (Antony et al., 2017; Womack & Jones, 1996). By applying Lean principles, laboratories can improve workflows, reduce delays and enhance service quality while maintaining patient safety (Mazzocato et al., 2010). Value Stream Mapping (VSM) is a key Lean tool that uses flowcharts to map out every step of a process. It's widely used by Lean practitioners to spot waste, shorten cycle times, and drive meaningful improvements in how processes run (Rother & Shook, 2008).

While Lean Management and VSM are widely used in hospitals and clinical settings, their application in medical analysis laboratories, especially private ones, is still not well-explored (Prakash et al., 2022). Most research has focused on public hospitals, missing the unique challenges faced by laboratories, such as managing the flow of biological samples, minimizing turnaround times, and ensuring quality results for accurate diagnoses (Antony et al., 2017). Moreover, while Lean is commonly used in hospital laboratories in developed countries, there is little research on how these strategies can be applied to private labs in low- and middle-income countries like Morocco, where resource limitations and organizational challenges may be different (Arabi et al., 2024; Farissi et al., 2021).

In Morocco, the government has intensified its efforts to modernize the healthcare system by adopting significant reforms to improve accessibility and service quality, and private medical laboratories are becoming increasingly important. These laboratories operate in a highly competitive environment, striving to meet the growing expectations of both patients and healthcare professionals. However, many face operational challenges such as delays in sample processing, long patient wait times, and difficulties in managing resources. Although Lean Management and Value Stream Mapping (VSM) could address these inefficiencies, their adoption in Moroccan private laboratories remains limited, creating a gap between current practices and the potential benefits of streamlined operations. While some studies have explored Lean implementation in Morocco's public hospitals (Arabi et al., 2024; Farissi et al., 2021),

little research has been done on its use in private laboratories, which face unique financial and organizational challenges.

The problematic of this study is: How can Lean Management, specifically through the use of Value Stream Mapping (VSM), improve the operational performance of private medical analysis laboratories in Morocco, considering the unique challenges they face such as resource limitations, long patient wait times, delays in sample processing, and ensuring accurate and timely diagnoses?

This study aims to fill this gap by examining how lean management, in particular Value Stream Mapping (VSM), can improve the operational performance of a newly established private medical analysis laboratory in Morocco. The aim is to assess current workflows, identify wasteful inefficiencies and propose practical solutions to improve both service quality and operational performance. To do this, we used a qualitative research approach, combining direct observation of different laboratory processes, interviews with staff and the creation of a value chain map to visualize workflows and identify sources of waste. In addition, we monitored and analyzed 80 patient samples to calculate key process parameters such as turnaround time, proportion of value-added and non-value-added activities. Our aim is not only to better understand how Lean tools can be applied in this context, but also to provide actionable recommendations that other laboratories in similar environments can use.

The article is structured as follows: After this introduction, the literature review will give an overview of Lean Management and VSM, focusing on their application in medical analysis laboratories. The methodology will explain how we responded to the study objectives including data collection, statistical analysis and the use of VSM to assess laboratory workflows. In the results section, we will present and interpret our key findings, highlighting areas of inefficiency and opportunities for improvement. The discussion and recommendations section will explore the main challenges identified and propose strategies for improving laboratory performance. Finally, the conclusion will summarize our main findings, address the study's limitations and suggest areas for future research.

Through this study, we aim to contribute to improving the operational performance of private medical laboratories in Morocco, by demonstrating the practical benefits of Lean Management tools and providing a reproducible framework for process optimization in similar contexts.

1. Literature Review

1.1.Lean Management and Lean Healthcare

The Toyota Way is a management approach that revolutionized not only the automotive industry, but also the world of business management. It originated what we know today as "Lean Management", an approach focused on continuous improvement, waste reduction and customer value creation (Womack & Jones, 1996). When applied to healthcare, this approach is called Lean Healthcare. It focuses on streamlining operational processes, cutting costs, and improving the quality of patient care (Salmond & Echevarria, 2017).

The key principles of Lean Healthcare include reducing processing times, minimizing human errors, optimizing the use of both human and material resources, and eliminating inefficiencies (Antony et al., 2018).

Numerous studies have shown the benefits of Lean Healthcare in various healthcare settings, such as hospitals and clinics. For example, (Poksinska et al., 2013) found that adopting Lean Healthcare results in shorter waiting times, greater patient satisfaction, and reduced operational costs. However, successfully implementing Lean methods often requires a cultural transformation within organizations, as well as effective change management (Bohmer, 2013).

1.2.Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is a powerful Lean Management tool that helps organizations see and understand how materials and information move through a process. It sheds light on both the steps that add value and the ones that generate waste (Rother & Shook, 2018).

VSM provides a clear overview of existing workflows, allowing teams to identify inefficiencies and develop improvement strategies. This tool has been widely adopted across various industries to reduce lead times, enhance quality, and cut costs (Melnyk et al., 2008).

While relatively new to healthcare, VSM is proving to be highly effective in optimizing complex workflows, including those in medical analysis laboratories. As (Z. J. Radnor et al., 2012) note, VSM helps healthcare organizations better understand their processes, pinpoint sources of waste (such as delays, unnecessary movements, and errors), and implement focused solutions to address these challenges.

1.3.Lean Approach in Medical Analysis Laboratories

In recent years, Lean Management has gained significant attention in medical analysis laboratories, driven by increasing demands for efficiency and quality. Lean techniques are

particularly effective in streamlining sample flows, reducing turnaround times, and optimizing the use of both equipment and staff.

For instance, (Van Der Meer et al., 2016) found that applying Lean methods, especially Value Stream Mapping (VSM), can notably reduce the time needed to process biological samples and lower error rates in test administration. Similarly, (DelliFraine et al., 2010) observed that laboratories implementing Lean practices experience fewer re-tests and improved sample handling management, thanks to simplified administrative processes and enhanced workflow coordination.

However, successfully adopting Lean principles in medical laboratories requires a supportive organizational culture. Resistance to change, particularly from staff accustomed to long-established practices, often presents a significant obstacle to Lean implementation (Amran et al., 2020).

1.4.Process Improvement in Morocco's Healthcare Sector

The healthcare sector in Morocco faces numerous challenges, especially in process management and the quality of patient care. Private medical analysis laboratories, in particular, are dealing with increasing competition and rising patient expectations. As a result, adopting effective management strategies like Lean Healthcare is becoming essential for staying competitive while meeting patient needs.

While research on Lean implementation in Moroccan healthcare is still evolving, recent studies suggest that Lean practices could effectively address critical workflow challenges in medical analysis laboratories (Arabi et al., 2021). These studies also highlight the importance of tailoring Lean methods to the specific context of Morocco, taking into account the cultural and organizational factors that shape the country's healthcare system.

1.5.Limitations and Research Perspectives

Despite evidence supporting the benefits of Lean Healthcare and Value Stream Mapping (VSM) in various healthcare settings, research on their application in private medical laboratories in Morocco remains limited. Several challenges persist, including difficulties in accurately measuring the impact of process improvements on both costs and service quality. Additionally, implementing Lean in these laboratories requires customized strategies that take into account local constraints, such as limited resources, regulatory requirements, and the unique characteristics of the private healthcare market.

Future research could focus on thoroughly evaluating the outcomes of Lean Healthcare in Moroccan private laboratories, specifically by measuring tangible improvements like reduced turnaround times, enhanced patient satisfaction, and fewer errors. It should also identify the key success factors and obstacles in implementing VSM.

This literature review highlights the essential role of Lean Management and Value Stream Mapping in optimizing processes within medical analysis laboratories, particularly in the private sector. While previous research has demonstrated the benefits of Lean in healthcare, its application in Morocco, and specifically in private laboratories, is still underexplored. Therefore, this study aims to fill that gap by providing an in-depth analysis of VSM implementation in a Moroccan private medical laboratory, with the objective of improving workflows and better meeting patient expectations.

2. Methodology

2.1.Project team setup

To ensure a comprehensive and accurate analysis of the laboratory's processes, we gathered an interdisciplinary project team that brought together various expertise and perspectives. The team included:

- The laboratory director who is
- A Project Manager (PhD in management), responsible for coordinating the project, managing timelines, and ensuring that objectives were met.
- The laboratory director and at the same time the medical biologist, who provided detailed insights into daily practices and internal processes.
- Another medical biologist to validate the technical and biological process.
- The technical and administrative staff (8 people), who shared their practical knowledge of routine laboratory activities and the challenges encountered in the field.
- Two nurses to sample patients and two receptionists with one courier.

This collaborative approach was essential to understanding both the technical and operational realities of the laboratory.

2.2.Data Collection Methods

To obtain a complete and realistic picture of the laboratory's processes, we used a multi-method data collection strategy, combining different but complementary approaches.

2.2.1. Direct Observations

We carefully observed the entire process, from patient arrival to receipt of their results. This enabled us to understand the different laboratory processes from pre-analytical to post-analytical. By observing daily operations, we were able to see how patients and samples moved through the system and understand how staff members worked together. These observations also helped us to find problems that would not be evident in formal procedures, such as delays, extra steps or tasks that slowed down the process. Real-life working conditions enabled us to understand how staff manage their tasks in relation to workload, available resources and day-to-day challenges.

2.2.2. Semi-Structured Interviews

In addition to direct observations, semi-structured interviews were conducted with laboratory staff, including biologists, nurses, receptionists, technicians, and administrative personnel. These interviews helped us gain in-depth insights into daily practices, as well as staff perceptions of workflow issues and opportunities for improvement.

The interview guide was carefully designed to:

- Explore how laboratory processes are carried out.
- Identify sources of waste (e.g., delays, redundancies, errors).
- Capture staff perceptions of challenges and opportunities for improvement.
- Collect practical suggestions for optimizing processes.

A detailed interview guide is provided in Appendix 1.

2.2.3. Tracking of 80 Analysis Samples

To better understand the actual workflow in the laboratory, we conducted detailed tracking of 80 analysis samples, starting from patient reception to the final stage of result completion. This tracking involved monitoring each step in the process to see how samples moved through different laboratory stages, how long each step took, and where potential delays occurred.

The tracking began at patient reception, where we observed how samples were collected, labeled, and registered in the system. We then followed their journey through various processing stages, including preparation, analysis, validation, and final reporting. By tracking multiple samples, we identified variations in processing times and analyzed factors influencing these differences, such as the type of test requested, the laboratory's workload at different times, and staff coordination.

This tracking also allowed us to compare the theoretical workflow with real-life operations, helping us understand how processes are actually carried out. By combining this structured tracking with direct observations and interviews, we obtained a more accurate and comprehensive view of the laboratory's operational flow.

2.2.4. Interview Construction

The semi-structured interview guide was carefully designed to ensure all relevant topics were covered, while allowing participants to freely share their experiences and thoughts. The interview aimed to understand the laboratory processes from patient reception to result delivery, identify inefficiencies like delays, unnecessary movements, and errors, capture staff perceptions about their work and challenges, and gather suggestions for improvements based on their daily experiences. The interview was structured into three main parts: first, the introduction, which set a comfortable atmosphere, explained the study's purpose, ensured confidentiality, and clarified the participant's role in the laboratory; second, the core interview, which focused on understanding the details of processes, identifying waste, and collecting ideas for improvement; and third, the conclusion, which gave participants the chance to add any extra thoughts and emphasize what they believe are the most important improvements. Open-ended questions allowed participants to speak freely, while targeted prompts ensured essential aspects of the process were discussed. A full version of the interview guide is available in Appendix 1.

2.3.Value Stream Mapping (VSM) Development

After completing the data collection phase, the project team analyzed the gathered information to create the Value Stream Map (VSM). This process involved identifying the key processes and participants at each stage of the sample processing workflow, highlighting sources of waste such as delays, errors, redundant tasks, and unnecessary movements, and developing a current-state VSM to illustrate how the laboratory operates in its present state. Based on these insights, the team then proposed a future-state VSM, designed to reflect optimized processes, shorter lead times, and increased efficiency, in line with Lean Healthcare principles. The final VSM became a strategic tool, guiding the laboratory's improvement efforts and encouraging ongoing optimization.

3. Results

3.1.General Presentation of the Observed Process

Through direct observation, tracking of 80 samples and interviews with laboratory staff, including biologists, technicians, nurses, administrative staff and couriers, we were able to reconstruct a typical patient's journey through the medical analysis laboratory. The process begins with patient reception and registration via the laboratory information system (LIS), where administrative data are rapidly entered and a sampling form is created (bench cards) with labels to be stuck on the sample tubes. Biological sampling then takes place in a dedicated room, with the analysis order automatically recorded in the LIS. The samples are then transported to the technical platform for analysis, where the results are validated technically and then biologically, and the whole process is monitored by the SIL. Finally, the results are delivered to the patient, either automatically via email or whatsap, or in person.

While the SIL has improved the accuracy of data capture and sample traceability, operational problems remain, particularly with regard to physical flows and workflow organization. These challenges continue to affect the efficiency of laboratory operations.

3.2.Current Value Stream Mapping (VSM)

The current VSM highlights the key steps, associated durations, and remaining wastes:

Table 1: *Current VSM showing process durations, waiting times, and main wastes identified.*

Process Step	Average Duration (min)	Waiting Time (min)	Observations / Remaining Wastes
Reception and registration (LIS)	3	5	Waiting during peak hours, slow LIS access when overloaded.
Biological sampling	5	3	Delays due to patient preparation, lack of appointment optimization.
Sample transport	2	4	Waiting before integration into the analysis chain, unnecessary movements.

Technical analysis	22	10	Queue before some analyzers, unplanned maintenance.
Technical and Biological validation (via LIS)	8	6	Manual review of results, excessive workload for biologists and technicians. Problems related to automatic transmission of results from equipment.
Results delivery (physical/email/WhatsApp)	2	10	Delay in final validation, patient follow-ups.

The table illustrates key bottlenecks in the laboratory's process. Notably, waiting times during peak periods and inefficiencies in the handling of samples contribute significantly to delays. These issues could be mitigated with better scheduling and automation.

3.3.Types of Waste Identified Despite LIS

Despite LIS automation, several sources of waste remain:

Table 2: *Types of Lean waste identified within the laboratory process despite LIS support.*

Type of Waste (Lean)	Examples Identified
Waiting time	Lines at reception and for sampling.
Unnecessary movements	Manual and multiple transports of samples.
Overprocessing	Repeated manual validation of borderline results.
Errors and corrections	Repeated manual recording of results due to transmission problems between devices and LIS.
Poor HR planning	Staff shortages during peak periods.

The presence of waste, such as waiting time and overprocessing, suggests that LIS, while improving accuracy, does not fully address physical workflow inefficiencies. These inefficiencies contribute to longer cycle times and resource strain.

3.4.Performance Indicators Measured (80 Samples)

On a sample of 80 laboratory tests, the following indicators were measured:

Table 3: *Key performance indicators measured on a sample of 80 patient pathways.*

Indicator	Measured Value
Total process duration (lead time)	Average: 54 minutes
Value-added time (VA)	Average: 30 minutes
Non-value-added time (NVA)	Average: 24 minutes
Percentage of value-added activities (%)	55.5 %
Rate of errors corrected via LIS	0.8 errors per 10 files
Rate of patients waiting >10 min for sampling	32 %

The results show that value-added activities account for only 55.5% of the total process time. Significant time (around 45%) is consumed by activities that do not add value, such as waiting and error correction. Reducing non-value-added time would significantly improve efficiency and overall service delivery.

3.5.Detailed Sources of Variability and Waste

Interviews with staff provided a deeper understanding of workflow disruptions:

Table 4: *Sources of variability and bottlenecks identified through staff interviews.*

Problem Identified	Main Cause
Long waiting times at reception	No scheduling for peak hours; absence of appointment system.
Delays in sampling	Managing multiple patients simultaneously without coordination.
Delays in analysis	Lack of optimized transport sequences; unplanned maintenance.
Repeated manual validation	No clear protocol for borderline results and problem of result transmission.
Delayed result delivery	Delays in technical and biological validation; no alert system for biologist.

The problems we identified show important areas that need improvement, especially in managing busy times, better coordination of patients, and clear rules for validation. These issues slow down efficiency and lead to longer processing times.

3.6.Target VSM with Lean Corrective Actions

A future VSM has been proposed, integrating Lean actions to reduce waste and improve efficiency:

Table 5: *Lean solutions proposed to address current workflow inefficiencies.*

Current Problem	Proposed Lean Solution
Waiting at reception	Online appointment booking via LIS, additional staff during peak periods and scheduling of home sampling.
Sampling management	Scheduled time slots to streamline patient flow.
Manual transport of samples	Dedicated trolleys, organized transport sequences.
Waiting at analyzers	Scheduled preventive maintenance, better peak period management.
Repeated manual validation	Standardized thresholds, staff training and fix the transmission issues.
Delayed result delivery	Full LIS automation, automatic alerts for biologists.

These Lean solutions aim to address the core inefficiencies identified in the current process. By optimizing the patient flow, automating tasks, and ensuring preventive maintenance, the laboratory can significantly reduce delays, enhance the quality of service, and improve staff satisfaction.

Table 6: *Comparison between current and target VSM, with Lean actions and expected process duration reduction.*

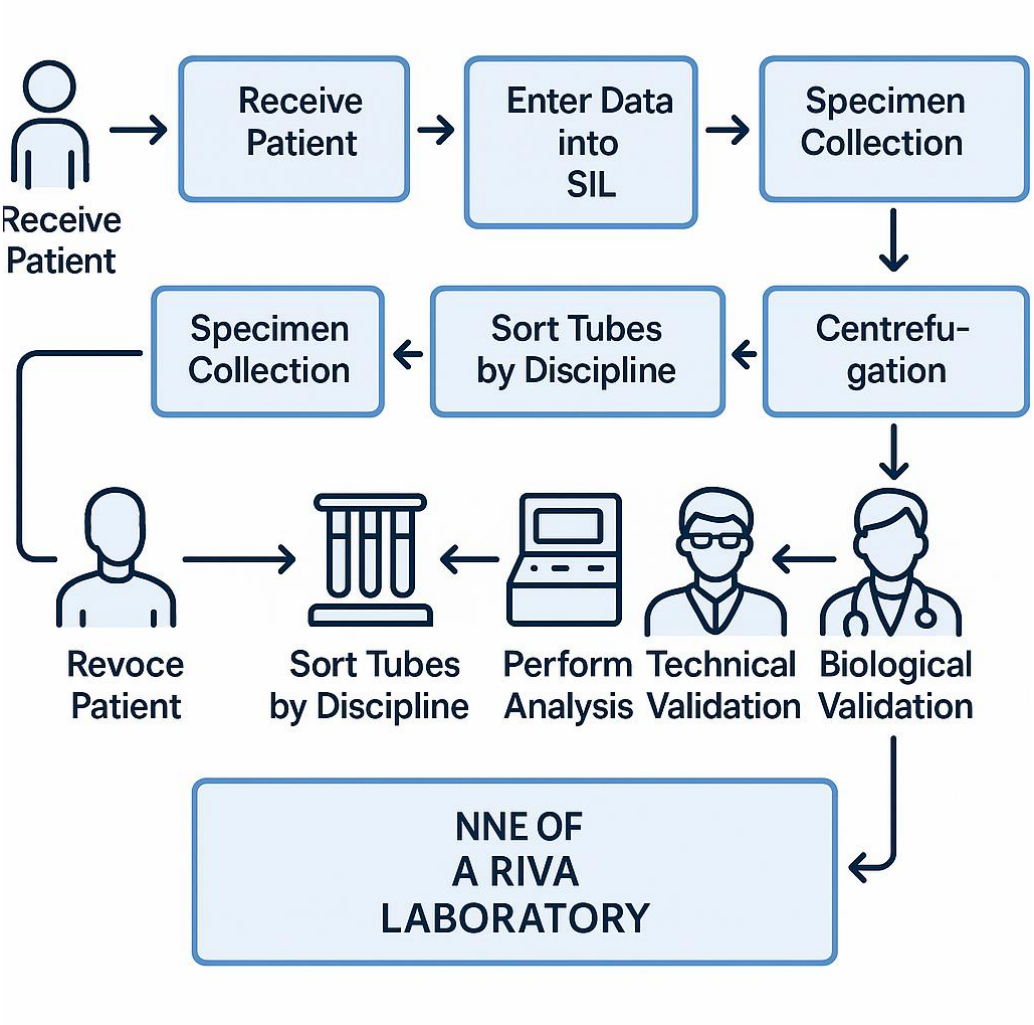
Process Step	Current Average Duration	Identified Problems (Wastes)	Proposed Lean Solutions (Target VSM)	Target Duration
Reception and registration (via LIS)	8 min (5 min wait)	Peak-hour waiting, LIS overload	Appointment scheduling via LIS, additional staff during peaks	4 min
Biological sampling	8 min (3 min wait)	Uncoordinated patient flow	Organized time slots, pre-prepared files	5 min
Sample transport	6 min (4 min wait)	Multiple, unstandardized transports	Dedicated trolleys, organized sequence	3 min
Technical analysis	32 min (10 min wait)	Analyzer queues, unplanned maintenance	Preventive maintenance, peak management	20 min
Biological validation (via LIS)	14 min (6 min wait)	Repetitive manual review, biologist overload	Standardized thresholds, delegation	8 min
Result delivery	12 min (10 min wait)	Final validation delays, patient reminders	Full LIS automation, internal alerts	4 min

The proposed Lean actions aim to reduce the average duration of each process step by eliminating wastes such as waiting and unnecessary movements. By automating certain tasks and optimizing workflows, substantial time savings are expected, benefiting both patients and staff.

Table 7: *Expected performance improvements following Lean implementation.*

Global Indicator	Current Value	Target Value
Total process duration (Lead Time)	54 minutes	35 minutes
Value-added time (VA)	30 minutes	28 minutes
Non-value-added time (NVA)	24 minutes	7 minutes
Percentage of VA activities (%)	55.5 %	80 %

The implementation of Lean practices is expected to significantly reduce non-value-added activities (NVA), improve process efficiency, and enhance patient satisfaction. The goal is to achieve a lead time of 35 minutes, with over 80% of activities contributing to value-added time.



4. Discussion

This study applied a Lean Healthcare approach using Value Stream Mapping (VSM) to identify inefficiencies in a private medical laboratory and propose improvements. The results highlighted a total lead time of 54 minutes, with 24 minutes attributed to non-value-added activities (44.5%). These inefficiencies stemmed from waiting times between stages, unnecessary sample and staff movements, and workflow bottlenecks. The target VSM proposed reducing lead time to 35 minutes while limiting non-value-added time to 7 minutes, representing a 70% reduction. This aligns with findings by (Akmal et al., 2020), who demonstrated significant process efficiency gains through Lean implementation in healthcare settings. Additionally, value-added activities were projected to increase from 55.5% to 80%, emphasizing workflow optimization.

A secondary analysis revealed that 32% of patients experienced a waiting time exceeding 10 minutes for sampling, highlighting a critical area for patient-centered improvements. Furthermore, the error correction rate via the Laboratory Information System (LIS) was measured at 0.8 per 10 files, indicating a need for enhanced automation and protocol standardization.

These findings confirm the effectiveness of Lean Healthcare, as demonstrated in prior studies. (Antony et al., 2018) emphasized that Lean optimizes workflows, reduces delays, and improves healthcare service quality. Similarly, (Z. Radnor & Osborne, 2020) reported that Lean implementation enhances operational efficiency and reduces waiting times. Furthermore, (D'Andreamatteo et al., 2019) highlighted how invisible waste, such as waiting times and unnecessary movements, burden processes and increase staff stress. The effectiveness of VSM in visualizing inefficiencies is well-documented by (Atti, 2019; Ellioua & Benamer, 2021), reinforcing the validity of our approach.

In the Moroccan context, the private laboratory sector is expanding rapidly, with increasing competition and demands for quality, speed, and safety. Lean implementation in developing countries has been shown to significantly improve service delivery when adapted to local operational challenges (Arabi et al., 2024). Our study demonstrates that process mapping enhances visibility into inefficiencies, fostering a collective improvement dynamic by involving all staff members, as supported by (Liker, 2020). Moreover, reducing waiting times optimizes resource use and enhances patient and staff satisfaction, consistent with (Langley, 2009). However, while our study confirms a reduction in patient waiting times, further research is

required to measure its direct impact on patient satisfaction, as recommended (Tlapa et al., 2020).

Despite these contributions, certain limitations must be acknowledged. The study focused on a single private laboratory, restricting the generalizability of results to other settings, such as public or larger laboratories. Although our sample size (n=80) aligns with similar pilot studies (Burgess & Radnor, 2013), larger-scale research is needed. Additionally, the impact of proposed improvements on patient satisfaction has not been directly measured, a crucial aspect for future evaluation. The study also did not assess staff perceptions of Lean changes, which could influence implementation success. Future studies should investigate staff buy-in and potential resistance to change, as explored by (Bhasin & Burcher, 2019).

To enhance Lean adoption in Moroccan private laboratories, we recommend conducting VSM before any reorganization to establish a clear process overview (Graban et al., 2021), providing targeted Lean training to staff (Z. Radnor & Osborne, 2020), and implementing regular monitoring of key performance indicators, such as lead time, patient satisfaction, and error rates (Subramanian et al., 2022). Reducing unnecessary movement by optimizing workspace layout is also crucial, as emphasized by (Arabi et al., 2021; Womack & Jones, 1996).

Future research should focus on a longitudinal evaluation of Lean interventions to assess long-term impacts (D'Andreamatteo et al., 2019; Z. Radnor & Osborne, 2020), compare Lean applications in private and public laboratories (Liker, 2004; Rother & Shook, 2018), and explore the integration of digitalization and LIS as complementary efficiency tools (Andreadis et al., 2017). Addressing these aspects will provide a more comprehensive understanding of Lean's effectiveness in laboratory settings and support its broader implementation in Moroccan healthcare.

In conclusion, this study demonstrates that the Lean approach, particularly through VSM, is a relevant tool for improving the operational efficiency of a private medical laboratory, by reducing waste and optimizing processing times. These results advocate for a wider integration of Lean methods in Moroccan laboratories to meet the growing demands for quality and speed in healthcare delivery.

Conclusion

This study aimed to analyze and improve the operational processes of a newly opened private medical laboratory by applying the Lean Healthcare method and Value Stream Mapping (VSM). This approach allowed for a precise diagnosis of the various steps in the production

flow, highlighting non-value-added activities and identifying the main sources of waste that hinder the efficiency of the service.

The results revealed that approximately 44.5% of the total time spent on processing samples was wasted on non-productive activities, mainly due to waiting times, unnecessary movements, and disorganization in the management of samples and equipment. Through the use of VSM, a reorganization proposal was developed, which significantly reduced the lead time, with an estimated improvement of 35% in total time.

This approach underscores the importance of integrating Lean tools in medical laboratories, not only to improve productivity and reduce costs but also to enhance service quality and patient satisfaction. Our study shows that even small private structures, often considered outside major reforms, can benefit from this approach. This proves that Lean methods are not only reserved for large hospital systems but can also be a transformative tool for smaller laboratories.

However, this research has some limitations. It is based on a single laboratory and does not yet measure the long-term impact of the proposed changes. Therefore, future studies should focus on generalizing this approach to other laboratories, both public and private, and assess its real effects on indicators such as quality, safety, and economic performance.

In conclusion, the implementation of Lean Healthcare, supported by rigorous process mapping, proves to be a powerful lever for continuous improvement in the medical laboratory sector. In the face of increasing challenges related to care quality and competitiveness, it is essential that Moroccan laboratories adopt these tools to better meet the expectations of both patients and healthcare professionals.

Appendix 1: Semi-Structured Interview Guide

Part 1: Introduction

1. Can you briefly describe your role within the laboratory?
2. How long have you been working in this laboratory?
3. What are your main daily responsibilities?
4. We want to assure you that all your responses will remain confidential and anonymous. Do you feel comfortable proceeding?

Part 2: Core Interview

2.1 Understanding Process Steps

5. Can you describe the complete process from the reception of samples to the delivery of test results?
6. On average, how long does each step in this process take?
7. Who is responsible for each stage of this process?
8. Are there interactions or handovers between different teams or departments during this process?

2.2 Identifying Sources of Waste

9. Are there specific steps where you often notice delays or waiting times? If so, where and why?
10. Are there any tasks or processes that seem repetitive or unnecessary to you?
11. Have you observed any frequent errors or mistakes in the process? How are these typically handled?
12. Are the laboratory's tools and equipment used efficiently, or are there periods when they are idle?

2.3 Staff's Perspective on Process Improvement

13. From your perspective, what could be done to improve the workflow and efficiency of the laboratory?
14. Do you have any suggestions for tools, technologies, or practices that could make sample management easier or faster?
15. What challenges do you regularly encounter in your work, and how do you usually deal with them?

Part 3: Conclusion

16. Is there anything else you would like to add regarding the laboratory processes or potential improvements?
17. In your opinion, what should be the top priorities for improvement in the laboratory?

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