

Lean management approach as an application tool for cost reduction

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Abstract:

This paper investigates the lean management methodology and its applications in organizations, specifically in the healthcare sector. The study focuses on analyzing three healthcare organizations, Odense University Hospital (Denmark), Virginia Mason Medical Centre (USA), and Mbeya Zonal Referral Hospital (Tanzania), seeking to reduce the cost of their daily operations via Value Stream Mapping, Kizen, Toyota Production System, and Total Quality Management. The study's research methodology was based on analyzing previously published articles, papers, and reports on the later organizations. Furthermore, we examined the cost of waiting time, the number of treated patients, the number of walked steps for nurses to reach patients, the number of problems faced by a hospital, and resources management, before and after the implementation of lean management. The results of this research demonstrated a significant impact of implementing Value Stream Mapping, Kizen, Toyota Production System, and Total Quality Management as effective cost-reduction tools for healthcare organizations.

Keywords: Lean management, Value stream mapping, Kizen, Toyota production system, Total quality management, Healthcare.

JEL Classification Codes : M110 ; I150

1. Introduction

Healthcare systems worldwide face mounting cost pressures, driven by factors such as aging populations, increasing prevalence of chronic diseases, and technological advancements in medical treatments (World Health Organization, 2018). In many countries, healthcare expenditures are growing faster than GDP, raising concerns about long-term sustainability (OECD, 2019). For instance, in the United States, healthcare spending reached 17.7% of GDP in 2019, significantly higher than other high-income nations (Papanicolas et al., 2021). Low- and middle-income countries face additional challenges, including limited resources and infrastructure (Kruk et al., 2018). These cost pressures are exacerbated by inefficiencies in healthcare delivery, with estimates suggesting that 20-40% of healthcare spending may be wasted on inefficient processes or unnecessary care (Shrank et al., 2019). Consequently, healthcare organizations are increasingly seeking innovative management approaches, such as lean methodology, to

enhance efficiency and control costs while maintaining or improving quality of care (D'Andreanmatteo et al., 2015).

Lean management, originally developed in the Toyota Production System, is a systematic approach to eliminating waste and maximizing value in organizational processes (Womack and Jones, 2003). The core principles of lean management include identifying value from the customer's perspective, mapping the value stream, creating flow, establishing pull, and continuously improving processes (Toussaint and Berry, 2013). In healthcare, these principles are adapted to focus on patient-centered care, streamlined workflows, and evidence-based decision-making (D'Andreanmatteo et al., 2015). Key lean tools applied in healthcare settings include value stream mapping, 5S (Sort, Set in order, Shine, Standardize, Sustain), and rapid improvement events or "kaizen" workshops (Mazzocato et al., 2010). The lean approach emphasizes respect for people, empowering frontline staff to identify and solve problems, and fostering a culture of continuous improvement (Drotz and Poksinska, 2014). By reducing non-value-adding activities and variability in processes, lean management aims to improve quality, reduce waiting times, and enhance resource utilization in healthcare organizations (Costa and Godinho Filho, 2016).

This study aims to investigate the effectiveness of lean management as a cost control tool in diverse healthcare settings through a comparative analysis of three case studies: Odense University Hospital (Denmark), Virginia Mason Medical Centre (USA), and Mbeya Zonal Referral Hospital (Tanzania). The primary objectives are to: (1) examine the specific lean management strategies implemented in each organization; (2) evaluate the impact of these strategies on cost control measures; and (3) identify contextual factors that influence the success or limitations of lean management in healthcare cost control. The significance of this research lies in its potential to bridge the gap between theoretical lean principles and their practical application in healthcare cost management across varied economic and cultural contexts. By analyzing organizations from high-income and low-income countries, this study offers insights into the adaptability and scalability of lean management approaches in healthcare. Furthermore, the findings may inform policy-makers and healthcare administrators on effective strategies for implementing lean management to address the pressing challenge of rising healthcare costs while maintaining or improving quality of care. This research contributes to the growing body of literature on healthcare management and provides a foundation for future studies on innovative cost control measures in healthcare organizations.

This study examines lean management implementation in three diverse healthcare settings. Odense University Hospital (OUH) in Denmark, one of the country's largest hospitals, has been at the forefront of lean adoption in European healthcare since 2006 (Dammand et al., 2014). Virginia Mason Medical Center (VMMC) in Seattle, USA, is renowned for its early and comprehensive adoption of lean principles, having developed

its own Virginia Mason Production System based on Toyota's model (Kenney, 2010). In contrast, Mbeya Zonal Referral Hospital (MZRH) in Tanzania represents a resource-constrained setting in a low-income country, where lean management has been explored as a means to improve efficiency and quality of care despite limited resources (Ishijima et al., 2016). These organizations offer a spectrum of contexts: OUH operates within a publicly funded healthcare system in a high-income European country, VMMC functions in the complex, predominantly private U.S. healthcare market, and MZRH serves as a critical healthcare provider in a developing nation with significant resource limitations. By examining lean management implementation across these diverse settings, this study aims to provide a comprehensive understanding of its applicability and effectiveness as a cost control tool in varied healthcare environments (D'Andreanmatteo et al., 2015).

2. Literature review:

2.1 Lean management in healthcare: principles and applications

Lean management in healthcare has gained significant traction over the past two decades as a methodology to improve efficiency, quality, and patient satisfaction while controlling costs. Originating from Toyota's manufacturing principles, lean healthcare focuses on eliminating waste, improving flow, and adding value from the patient's perspective (Womack and Jones, 2003).

The core principles of lean in healthcare include identifying value, mapping the value stream, creating flow, establishing pull, and pursuing perfection (Toussaint and Berry, 2013). These principles are operationalized through various tools and techniques such as value stream mapping, 5S, kaizen events, and visual management (Mazzocato et al., 2010).

Several studies have documented the application of lean principles in diverse healthcare settings. For instance, DelliFraine et al. (2010) conducted a systematic review of lean and Six Sigma applications in healthcare, finding positive impacts on process outcomes and financial performance. However, they noted inconsistencies in implementation and measurement approaches across studies.

Radnor et al. (2012) explored lean implementation in the UK National Health Service, highlighting the importance of adapting lean principles to the specific context of healthcare organizations. They emphasized the need for a holistic approach that goes beyond tool-based implementations to foster a culture of continuous improvement.

In emergency departments, lean methods have been applied to reduce wait times and improve patient flow. Holden (2011) reviewed 18 studies of lean in emergency departments, finding generally positive outcomes but also noting methodological limitations in many studies.

Lean principles have also been applied in surgical settings. Mason et al. (2015) reported on the use of lean to improve operating room efficiency, resulting in increased case volume and reduced turnover times.

However, the implementation of lean in healthcare is not without challenges. De Souza (2009) identified barriers such as professional silos, resistance to change, and the complexity of healthcare processes. Andersen et al. (2014) further noted the importance of leadership commitment and employee engagement in successful lean implementations.

Critics have also raised concerns about the appropriateness of applying manufacturing-derived principles to healthcare. Waring and Bishop (2010) argued that lean implementation in healthcare often fails to account for the complex social and political contexts of medical work.

Despite these challenges, lean continues to evolve in healthcare settings. More recent research has focused on combining lean with other improvement methodologies, such as Six Sigma (Improta et al., 2019), and on applying lean principles to specific healthcare challenges like patient safety (Hines et al., 2020).

In conclusion, while lean management has shown promise in improving healthcare processes and outcomes, its application remains complex and context dependent. Future research should focus on long-term sustainability of lean implementations, adaptation of lean principles to diverse healthcare settings, and rigorous evaluation of outcomes.

2.2 Cost control challenges in healthcare organizations

Healthcare organizations worldwide face significant challenges in controlling costs while maintaining quality of care. These challenges are multifaceted and complex, stemming from various sources within and outside the healthcare system.

One of the primary cost control challenges is the rising demand for healthcare services. Aging populations and the increasing prevalence of chronic diseases have led to higher utilization of healthcare resources (Bloom et al., 2015). This demographic shift has put pressure on healthcare systems, particularly in developed countries, to manage costs associated with long-term care and complex medical needs.

Technological advancements in medical treatments and diagnostics, while improving patient outcomes, have also contributed to rising costs. Sorenson et al. (2013) argue that the rapid pace of medical innovation often outstrips the ability of healthcare systems to assess cost-effectiveness, leading to the adoption of expensive technologies without clear evidence of their value.

The structure of healthcare financing and reimbursement models presents another significant challenge. In many countries, fee-for-service models have been criticized for incentivizing volume over value, potentially leading to unnecessary treatments and increased costs (Berwick and Hackbarth, 2012). Alternative payment models, such as value-based care, have been proposed to address this issue, but their implementation remains challenging (Porter and Kaplan, 2016).

Inefficiencies in healthcare delivery systems contribute substantially to cost control difficulties. Waste in healthcare, including unnecessary services, inefficient delivery of care, and administrative complexity, has been estimated to account for up to

30% of total healthcare spending in some countries (Shrank et al., 2019). Identifying and eliminating these sources of waste remains a significant challenge for healthcare organizations.

The fragmentation of healthcare services also poses cost control challenges. Lack of coordination between different levels of care and providers can lead to duplication of services, medical errors, and inefficient use of resources (Stange, 2009). Efforts to implement integrated care models have shown promise but face barriers in implementation (Nolte and Pitchforth, 2014).

In many countries, regulatory requirements and compliance costs add to the financial burden on healthcare organizations. While these regulations are often necessary for patient safety and quality assurance, they can also create administrative overhead and limit flexibility in cost management (Conover, 2004).

The pharmaceutical sector presents unique cost control challenges. High drug prices, particularly for specialty and orphan drugs, have become a significant concern for healthcare systems globally (Kesselheim et al., 2016). Balancing the need for innovation with affordability remains a complex issue for policymakers and healthcare organizations alike.

In low- and middle-income countries, cost control challenges are often exacerbated by limited resources, weak health systems infrastructure, and the dual burden of communicable and non-communicable diseases (Mills, 2014). These countries face the additional challenge of expanding access to healthcare while managing costs.

Lastly, the COVID-19 pandemic has highlighted and intensified many of these cost control challenges, while also introducing new ones related to surge capacity, supply chain resilience, and telehealth implementation (Blumenthal et al., 2020).

In conclusion, cost control in healthcare organizations involves navigating a complex landscape of demographic, technological, structural, and systemic challenges. Addressing these issues requires multifaceted approaches that balance cost reduction with maintaining or improving quality of care.

2.3 Lean management implementation in healthcare

Lean management implementation in healthcare has been the subject of numerous studies over the past two decades, with researchers examining its impact on various aspects of healthcare delivery and organizational performance.

A seminal systematic review by Mazzocato et al. (2010) analyzed 33 articles on lean applications in healthcare, identifying four main change mechanisms: understanding processes, organizing more effective and/or efficient processes, improving error detection, and collaborating to solve problems. This review highlighted the potential of lean to improve healthcare processes but noted that most studies focused on technical applications rather than the socio-technical aspects of lean implementation.

D'Andreamatteo et al. (2015) conducted a comprehensive literature review of lean in healthcare, analyzing 243 articles. They found that lean was applied across various

healthcare settings, from hospitals to pharmacies, and identified positive outcomes in terms of process optimization, cost reduction, and quality improvement. However, they also noted significant variability in implementation approaches and a lack of standardized measurement methods.

Focusing on specific healthcare settings, Holden (2011) reviewed 18 studies of lean implementation in emergency departments. The review found generally positive outcomes, including reduced waiting times and improved patient flow, but also highlighted methodological limitations in many studies and the need for more rigorous evaluation approaches.

In the context of surgical care, Mason et al. (2015) conducted a systematic review of lean interventions in surgical settings. They found evidence of improved efficiency, reduced costs, and enhanced patient and staff satisfaction. However, they also noted the need for more robust study designs to establish causal relationships between lean interventions and outcomes.

Moraros et al. (2016) provided a critical perspective on lean in healthcare through a systematic review of 22 articles. Their findings suggested that while lean showed some positive effects on process outcomes and patient satisfaction, there was limited evidence of its impact on health outcomes and worker satisfaction. This review highlighted the importance of considering potential negative consequences of lean implementation.

The long-term sustainability of lean in healthcare has been a concern in several studies. Andersen et al. (2014) conducted a longitudinal case study of lean implementation in a Norwegian hospital, emphasizing the importance of leadership, employee participation, and cultural factors in sustaining lean improvements over time.

In the context of low- and middle-income countries, Dickson et al. (2009) reported on lean implementation in community health clinics in Kenya, demonstrating the potential of lean principles to improve healthcare delivery in resource-constrained settings. However, they also highlighted the need to adapt lean approaches to local contexts.

More recent studies have focused on integrating lean with other improvement methodologies. For instance, Improta et al. (2019) explored the combination of lean and Six Sigma in healthcare, reporting positive outcomes in terms of process efficiency and cost reduction in an Italian hospital setting.

The impact of lean on healthcare workers has also been a subject of investigation. Hung et al. (2018) conducted a mixed-methods study on the effects of lean implementation on primary care workforce experiences, finding both positive (improved teamwork) and negative (increased workload) impacts.

In conclusion, while numerous studies have demonstrated the potential benefits of lean management in healthcare, the literature also reveals significant variability in implementation approaches, outcomes, and evaluation methods. Future research should focus on developing more standardized implementation and evaluation frameworks,

exploring the long-term sustainability of lean initiatives, and examining the broader organizational and cultural factors that influence lean success in healthcare settings.

3. Methodology:

3.1 Research design: multiple case study approach

This study employs a multiple case study approach to investigate the implementation of lean management as a cost control tool in three diverse healthcare organizations: Odense University Hospital (Denmark), Virginia Mason Medical Centre (USA), and Mbeya Zonal Referral Hospital (Tanzania).

Rationale for Case Study Approach: The case study method is particularly suitable for this research as it allows for an in-depth exploration of lean management implementation within the unique contexts of each healthcare organization (Yin, 2018). This approach enables us to examine the complex interplay of factors influencing the adoption, implementation, and outcomes of lean management practices in different healthcare settings.

Case Selection: The three cases were purposefully selected to represent diverse healthcare contexts:

- a. Odense University Hospital: A large public hospital in a high-income European country with a universal healthcare system.
- b. Virginia Mason Medical Centre: A private, non-profit hospital in the United States, known for its early adoption of lean principles.
- c. Mbeya Zonal Referral Hospital: A public hospital in a low-income country, facing significant resource constraints.

This selection allows for comparison across different economic, cultural, and healthcare system contexts, enhancing the generalizability of findings (Eisenhardt and Graebner, 2007).

3.1.1. Data Collection Methods:

- a. Document analysis: We will review published documents such as articles and papers, that includes lean implementation reports, financial statements, and performance metrics to understand the formal processes and outcomes of lean implementation.
- b. Quantitative data collection: We will gather, from published papers and reports, relevant quantitative data on cost control measures, quality indicators, and operational efficiency metrics before and after lean implementation.

3.1.2. Data Analysis: We will employ a mixed-methods approach to data analysis:

- a. Qualitative analysis: Thematic analysis of interview transcripts and observational notes to identify common themes and patterns across cases (Braun and Clarke, 2006).
- b. Quantitative analysis: analysis of cost and performance metrics to assess the impact of lean implementation on cost control and operational efficiency.
- c. Within-case analysis: Detailed examination of lean implementation processes and outcomes within each healthcare organization.

Limitations: We acknowledge potential limitations, including the generalizability of findings from three specific cases and the potential for researcher bias in qualitative data interpretation. These limitations will be explicitly addressed in the final report.

This research design provides a robust framework for exploring lean management as a cost control tool across diverse healthcare settings, allowing for rich, contextual insights while also enabling comparative analysis.

4. Case studies of lean management application:

4.1. Value stream mapping at Odense University Hospital:

Value Stream Mapping (VSM) is a fundamental lean management tool that has gained significant traction in healthcare settings. Originally developed in manufacturing, VSM is a visual representation technique that helps organizations identify and eliminate waste in complex processes (Rother and Shook, 2003). The VSM method includes the visualization of complex workflows, quantification of the resources needed and restructure of the workflows into an improved version with a focus on the patient's needs. Therefore, VSM aims to reduce unnecessary process steps. Simultaneously, the essential process steps and time, which improve the quality of the process for patients, are aimed to be increased (Nowak et al, 2017). In healthcare, VSM has been adapted to map patient journeys, information flows, and resource utilization across various care pathways (Jimmerson et al., 2005). The tool enables healthcare providers to visualize both value-adding and non-value-adding activities, thereby highlighting opportunities for process improvement and waste reduction (Henrique et al., 2016). VSM has been successfully applied in diverse healthcare contexts, from emergency departments to surgical units, often resulting in reduced wait times, improved patient flow, and enhanced resource allocation (Tortorella et al., 2017). For instance, Lummus et al. (2006) demonstrated how VSM implementation in an outpatient clinic led to a 48% reduction in patient lead time. However, researchers also caution that effective VSM implementation requires a systems thinking approach and active engagement from multidisciplinary teams to ensure that improvements are sustainable and aligned with overall organizational goals (Poksinska, 2010). As healthcare organizations continue to grapple with cost pressures and efficiency challenges, VSM remains a valuable tool for identifying and addressing systemic inefficiencies in care delivery processes.

A seminal study by Dammand et al. (2014) investigated the potential benefits of lean management implementation in healthcare settings, focusing on Odense University Hospital (OUH) in Denmark. In response to common healthcare challenges, OUH initiated a Lean Project Implementation (LPI) in 2006, with Department O, responsible for orthopedic surgeries across Southern Denmark, volunteering as the pilot site. This department, one of the largest of its kind in the Nordic countries in terms of outpatient visits and annual admissions, served as a critical test case for lean principles in healthcare (Dammand et al., 2014). The authors reported that following the lean initiative, OUH experienced gradual improvements in overall performance, particularly

in managerial and financial aspects.

Table 1. Waiting time in the emergency room at OUH

June 2009				
Time	Number	Percentage %	Accumulated %	
Under 15 min.	2228	56,40	56,40	
Under 1 hour.	514	13,00	69,40	
Under 3 hours.	698	17,70	87	
Over 3 hours.	512	13,00	100	
Total	3952	100		
January 2010				
Time	Number	Percentage %	Accumulated %	
Under 15 min.	2141	58,70	58,70	
Under 1 hour.	541	14,80	73,50	
Under 3 hours.	629	17,20	90,80	
Over 3 hours.	336	9,20	100	
Total	3647	100		

A notable application of lean principles occurred in OUH's emergency department, where traditional approaches to reducing waiting times, such as ward remodeling and increased staffing, had proven ineffective (Dammand et al., 2014). The lean team identified that a significant portion of waiting time resulted from the requirement for every patient to be seen by a physician. In response, hospital management employed value stream mapping to identify bottlenecks and propose solutions. This analysis led to a policy change in 2010, allowing nurses to treat non-complex cases, and reserving physician time for more complex patients. This intervention exemplifies the application of lean tools to optimize patient flow and resource utilization in healthcare settings (Holden, 2011; Mazzocato et al., 2010). The effectiveness of this approach was subsequently evaluated by comparing the number of patients treated before and after the implementation of the nurse intervention policy.

As illustrated in Table 1, the number of patients treated under 3 hours and over 3 hours in June 2010 fell in January 2010 by 69 and 176 respectively.

4.2. Kaizen at Virginia Mason Medical Centre

Kaizen, a Japanese term meaning "continuous improvement," is a fundamental lean management tool that has been widely adopted in healthcare settings. This approach emphasizes incremental, ongoing improvements involving all levels of an organization, from frontline staff to senior management (Imai, 1986). In healthcare, Kaizen events, also known as rapid improvement events, typically involve short, focused projects aimed at improving specific processes or addressing particular challenges (Singh et al., 2009). These events often utilize other lean tools such as value stream mapping and 5S to identify and eliminate waste, streamline workflows, and enhance patient care (Filser et al., 2017). Graban and Swartz (2012) demonstrated the effectiveness of Kaizen in healthcare through multiple case studies, showing improvements in patient safety, quality of care, and operational efficiency. For instance, Bahensky et al. (2005) reported that a Kaizen event in a radiology department led to a 60% reduction in patient wait

times. However, researchers have also noted that successfully implementing Kaizen requires a supportive organizational culture and sustained leadership commitment (Mazzocato et al., 2016). Critics argue that the focus on incremental changes may sometimes overlook larger systemic issues in healthcare delivery (McCann et al., 2015). Despite these challenges, Kaizen remains a valuable tool in the lean healthcare toolkit, offering a structured approach to continuous improvement and employee engagement to enhance patient care and operational excellence.

Virginia Mason Medical Center (VMMC), a private, non-profit healthcare organization in Seattle, Washington, has become a pioneering institution in the application of lean management principles to healthcare. Founded in 1920, VMMC undertook a significant transformation in 2002 when its board decided to implement the Toyota Production System (TPS) philosophy, adapting it to healthcare and dubbing it the Virginia Mason Production System (VMPS) (Kenney, 2010). This initiative positioned VMMC as one of the first healthcare institutions to comprehensively apply lean principles across its operations (D'Andreanmatteo et al., 2015).

The primary objectives of VMPS were to reduce costs by eliminating waste and defects while focusing on four key areas: prioritizing customer needs and quality, emphasizing safety, enhancing staff satisfaction, and ensuring economic viability (Toussaint and Berry, 2013). The implementation of VMPS yielded significant improvements in operational efficiency and patient care. For instance, nurse workflow optimization resulted in a dramatic reduction in daily steps walked from approximately 10,000 to 1,200, while time spent in direct patient care increased from 35% to 90% (Nelson-Peterson and Leppa, 2007).

Furthermore, VMMC's finance department achieved notable improvements in revenue cycle management. Cash deposits increased from \$471 million in 2003 to \$794 million in 2009, representing a \$323 million revenue increase (Blackmore et al., 2011). Over six years, VMPS reportedly saved the institution between \$12 to \$15 million (Poksinska, 2010).

These improvements contributed to VMMC's recognition as one of the Leapfrog Group's top hospitals and one of two top hospitals of the decade in 2010 (Chassin et al., 2013). The success of VMPS has made VMMC a benchmark for lean healthcare implementation, inspiring numerous case studies and research initiatives in the field of healthcare management (Mazzocato et al., 2010).

However, it is important to note that the implementation of lean principles in healthcare is not without challenges and criticisms. Some researchers have raised concerns about the potential negative impacts on staff workload and the applicability of manufacturing-derived principles to complex healthcare environments (Moraros et al., 2016). Additionally, the significant compensation of VMMC's CEO in 2016, reported at \$11.7 million, has sparked discussions about executive remuneration in non-profit healthcare systems (Young et al., 2019).

In conclusion, while VMHC's implementation of lean principles through VMPS has demonstrated significant positive outcomes in terms of efficiency and patient care, it also highlights the complex nature of adapting industrial management techniques to healthcare settings and the ongoing debates surrounding healthcare management and governance.

4.3. 5S-KAIZEN, TQM at Mbeya Zonal Referral Hospital:

5S Kaizen, a combination of two fundamental lean management tools, has gained significant traction in healthcare settings as a means to improve efficiency and quality. The 5S methodology, originating from five Japanese words (Seiri, Seiton, Seiso, Seiketsu, and Shitsuke), translates in Fig. 1 to Sort, Set in order, Shine, Standardize, and Sustain (Gapp et al., 2008). When integrated with Kaizen's continuous improvement philosophy, 5S Kaizen provides a structured approach to workplace organization and process enhancement (Bayo-Moriones et al., 2010). In healthcare, 5S Kaizen has been applied to various areas, from operating rooms to pharmacies, yielding improvements in workflow efficiency, inventory management, and patient safety (Fillingham, 2007). For instance, Trakulsunti et al. (2020) reported that implementing 5S Kaizen in a hospital pharmacy led to a 30% reduction in medication errors and a 25% increase in productivity. Similarly, Ikuma and Nahmens (2014) demonstrated how 5S Kaizen in an emergency department resulted in reduced wait times and improved staff satisfaction. However, researchers like Al-Araidah et al. (2010) caution that successful implementation requires sustained leadership commitment and cultural change within the organization. Despite challenges in adaptation and sustainability, 5S Kaizen continues to be a valuable tool in the lean healthcare arsenal, offering a systematic approach to creating and maintaining an efficient, safe, and quality-focused healthcare environment (Mazzocato et al., 2010).

Total Quality Management (TQM), while not exclusively a lean tool, is often integrated with lean methodologies in healthcare settings to create a comprehensive approach to quality improvement and waste reduction. TQM, originating from the work of quality pioneers like Deming and Juran, emphasizes organization-wide commitment to quality, continuous improvement, and customer satisfaction (Powell, 1995). In healthcare, TQM principles have been adapted to focus on patient-centered care, evidence-based practice, and systematic process improvement (Talib et al., 2011). The integration of TQM with lean management has been shown to enhance overall organizational performance in healthcare institutions. For instance, Chiarini and Baccarani (2016) demonstrated that the combined application of TQM and lean principles in Italian hospitals led to significant improvements in patient satisfaction and operational efficiency. Similarly, Mosadeghrad (2015) found that TQM implementation in healthcare organizations was associated with improved clinical outcomes, reduced costs, and enhanced employee satisfaction. However, researchers like Øvretveit (2000) caution that successful TQM implementation in healthcare requires adaptation to the

unique complexities of medical environments and sustained leadership commitment. Critics argue that the resource-intensive nature of TQM implementation can be challenging for some healthcare organizations, particularly in resource-constrained settings (Kanji and Moura e Sá, 2003). Despite these challenges, TQM remains a valuable complement to lean management in healthcare, offering a holistic framework for quality improvement and organizational excellence (Dahlgaard et al., 2011).

Kaplan showed a “Wheel of waste” which evidently states seven wastes. Figure 3 displays this wheel also known as “Wormpit”, which Kaplan derived from the Kaizen training materials originally used by Toyota (Kaplan et al., 2012). Kaplan added that if all of those parts can perform continuous improvement, the whole company will definitely be transformed to the better.

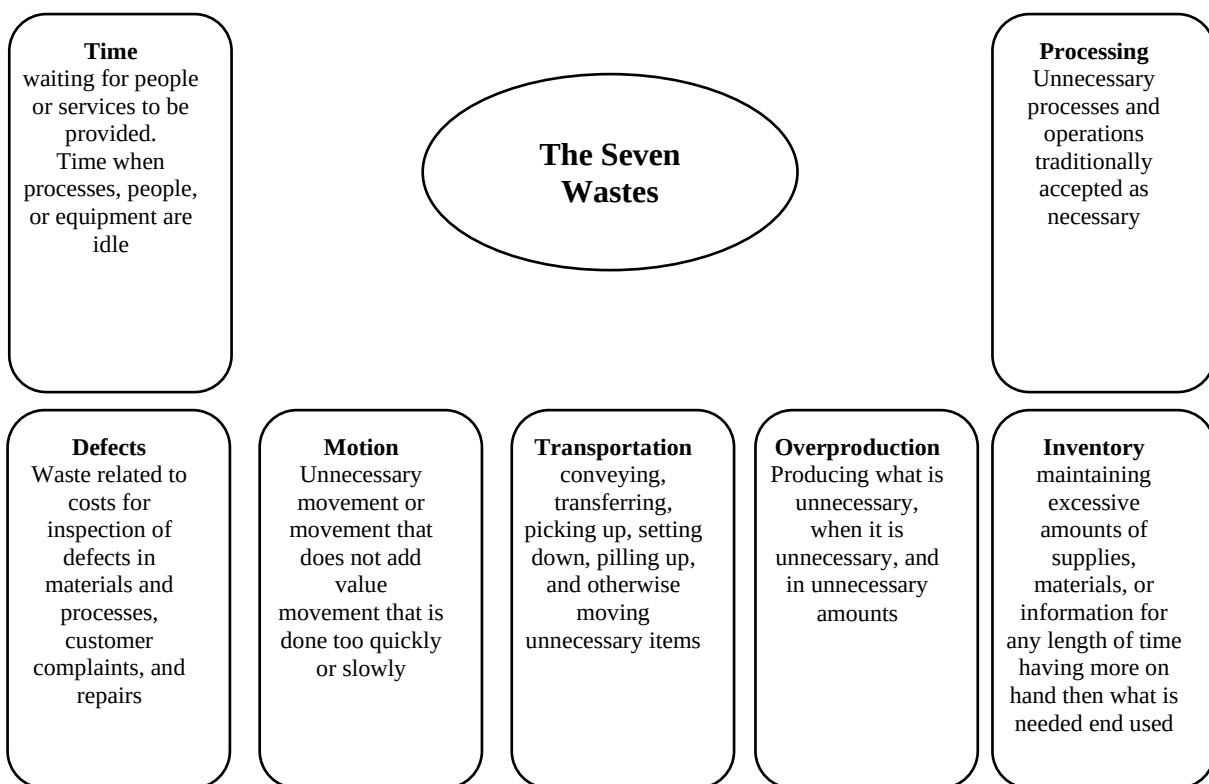


Fig.1. The seven types of waste. Source: (Kaplan, 2012, p. 162).

Mbeya Zonal Referral Hospital (MZRH), located in Tanzania, represents a significant case study in the application of lean management principles in a resource-constrained, developing country context. Originally upgraded from a regional hospital in 1984 with support from the United Kingdom government, MZRH was officially inaugurated in 1985 and has since evolved into a crucial healthcare provider serving approximately 8 million people across six regions in Tanzania (Ishijima et al., 2016).

MZRH has established itself as a center for tertiary patient care, medical education, and research, encompassing about 20 departments and sections that span a wide range of medical specialties (Mwansisya et al., 2022). The hospital's commitment to continuous improvement is evident in its collaborations with various international partners, including the Baylor International Pediatric AIDS Initiative (BIPAI), Walter

Reed Program, and Mbeya Medical Research Center (MMRC), among others (Sanga, 2022).

A pivotal moment in MZRH's quality improvement journey came in 2007 with the introduction of the 5S-KAIZEN-TQM approach, a lean management strategy adapted from the manufacturing sector (Ishijima et al., 2014). This initiative involved systematic staff training, including students and new employees, in 5S principles, with high-performing areas progressing to KAIZEN practices. The hospital's commitment to this approach was recognized in 2014 when it received the "Best Process Award" for 5S-Kaizen Practice and Infection Prevention and Control (Ishijima et al., 2016).

One of the primary objectives of implementing lean management at MZRH was to reduce patient waiting times for consultations in the Outpatient Department (OPD). Kanamori et al. (2015) reported that the application of Kaizen principles led to a significant reduction in the frequency of problems faced by the hospital, from 42 to 24, representing a 42.9% improvement as shown in Fig. 2 . This outcome demonstrates the potential of lean management tools to address efficiency challenges in resource-limited healthcare settings.

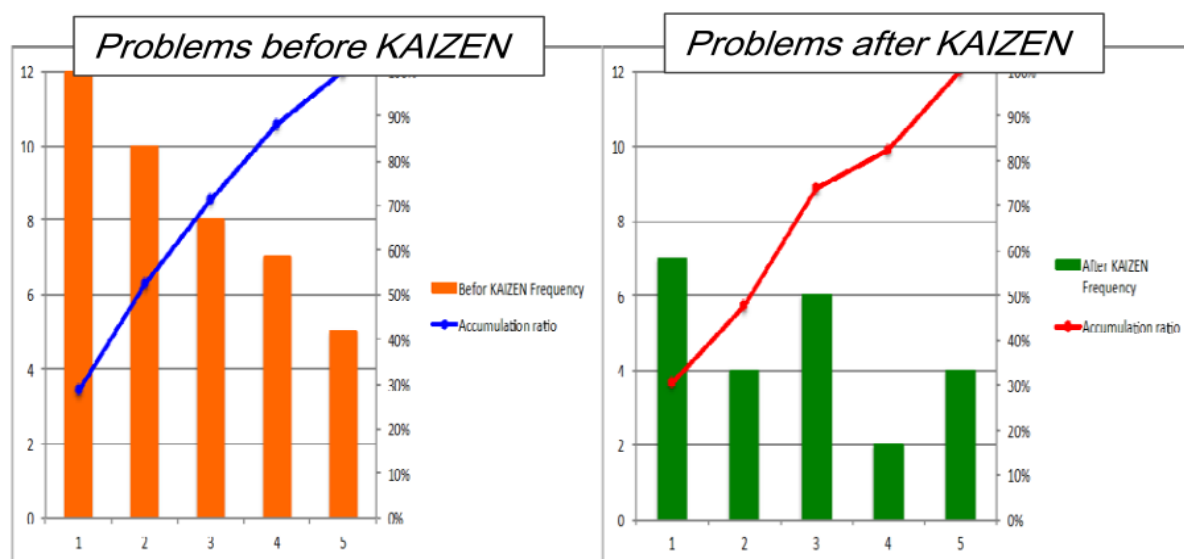


Fig. 2. Number and percentage of problems before and after Lean management

The case of MZRH illustrates the adaptability of lean management principles to diverse healthcare contexts and highlights the importance of continuous improvement initiatives in enhancing healthcare delivery in developing countries. However, researchers like Kohntopp and McCann (2023) emphasize the need for contextual adaptation and sustained leadership commitment for the long-term success of such initiatives in resource-constrained environments.

Another significant outcome was the reduction in patients' waiting time for a doctor checkup, which went notably down from 42 to just 24 minutes. Table 2

demonstrates the waiting time for consultation before and after implementing 5S Kaizen and TQM in MZRH.

Table. 2. Patients' waiting time for consultation before and after Lean management

Contributing factors	Frequency in (min)		Reduction rate %
	Before	After	
Delay in starting consultation	12	8	33,3
Long break during a consultation	10	4	60,0
Interruption by emergency cases	8	6	25,0
Bypass of staff	7	2	71,4
Long contact time	5	4	20,0
total	42	24	42,9

The application of 5S Kaizen and TQM in MZRH yielded another significant improvement in waste management practices, a critical aspect of healthcare operations with implications for both environmental sustainability and infection control. Quantitative analysis of waste management outcomes revealed a substantial reduction in instances of improper waste handling, with reported occurrences decreasing from 155 to 22, representing an 85.8% improvement (Ishijima et al., 2016). This marked enhancement in waste management efficiency aligns with findings from other studies on lean implementation in healthcare settings, such as those reported by Chiarini (2014), who observed significant reductions in healthcare waste through the application of lean tools. The magnitude of improvement at MZRH underscores the potential of lean methodologies to address operational challenges in resource-constrained healthcare environments, particularly in areas critical to patient and staff safety.

Table. 3. Waste management improvement before and after Lean implementation

Case of ...	Frequency		Reduction rate %
	Before	After	
Bin liners in the wrong containers	42	4	90,5
One type of bin liner missing (out of stock) at the point of waste collection	38	2	94,7
Mixing up of waste at a collection point (i.e. an item gets into the wrong containers)	29	14	51,7
A waste container without a bin liner	25	1	96,0
Unauthorized waste containers/bin liners found at disposal point (incinerator)	11	0	100
Container found in the wrong area (areas which do not generate waste that matches with container)	7	0	100
Mixing waste bags in the waste storage area	3	1	66,7
Total	155	22	85,8

This table presents data on waste management improvements at a healthcare facility, likely Mbeya Zonal Referral Hospital (MZRH), following the implementation of lean management principles. The data compares the frequency of various waste management issues before and after the intervention, along with the calculated reduction rates.

Key observations:

- a. Overall improvement: The total instances of waste management issues decreased from 155 to 22, representing an 85.8% reduction. This substantial improvement suggests that the lean management intervention was highly effective in addressing waste management challenges.
- b. Most significant improvements:
 - "Unauthorized waste containers/bin liners found at disposal point" and "Container found in the wrong area" both achieved 100% reduction, indicating complete elimination of these issues.
 - "A waste container without a bin liner" saw a 96% reduction (from 25 to 1 instance).
 - "One type of bin liner missing at the point of waste collection" decreased by 94.7% (from 38 to 2 instances).
- c. Moderate improvement: "Mixing up of waste at a collection point" showed a 51.7% reduction, which, while significant, indicates there may still be room for further improvement in this area.
- d. Variability in outcomes: The reduction rates range from 51.7% to 100%, suggesting that some aspects of waste management were more responsive to the intervention than others.
- e. Persistence of challenges: Despite significant reductions, some issues persist, particularly "Mixing up of waste at a collection point" (14 instances remaining) and "Bin liners in the wrong containers" (4 instances remaining).

This data demonstrates the potential of lean management principles to significantly improve waste management practices in healthcare settings. The varying degrees of improvement across different aspects of waste management suggest that targeted strategies may be necessary to address persistent challenges. Further research could explore the specific interventions that led to these improvements and investigate strategies for addressing the remaining issues.

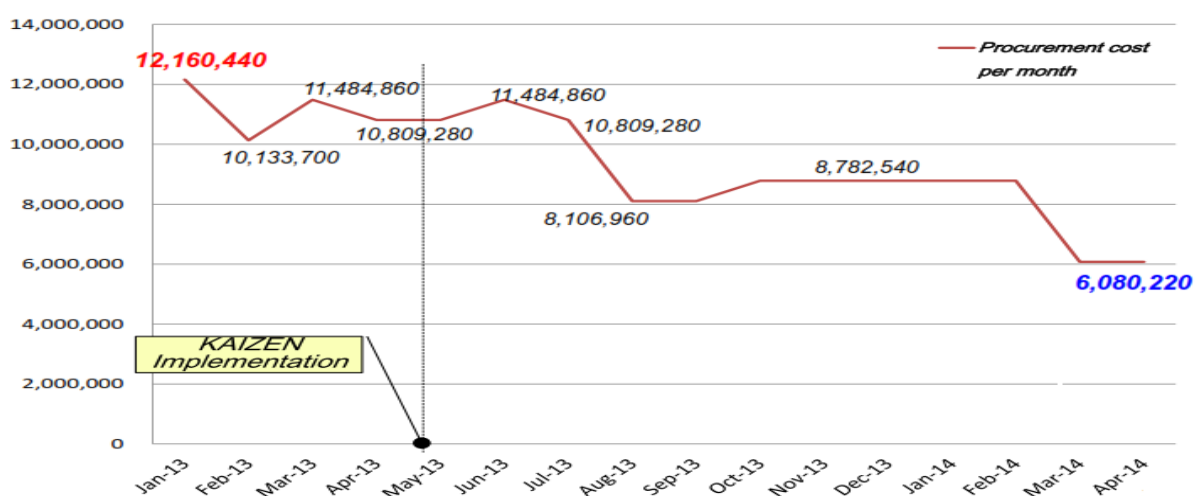


Fig. 3. Cost of waste bin liners procurement before and after Lean management implementation

These findings align with other studies on lean healthcare implementation, such as those by Chiarini (2014) and D'Andreanmatteo et al. (2015), which have reported significant improvements in operational efficiency and waste reduction following lean interventions. However, as noted by Moraros et al. (2016), it would be valuable to conduct follow-up assessments to evaluate the long-term sustainability of these improvements.

Moreover, as it appears in Fig. 3. The application of KAIZEN methodology in May 2013 at MZRH has helped to reduce the monthly cost of procurement. In April 2014, just one year after Kizen was implemented, the cost of waste bin liners went down to half.

5. Discussion:

The analysis of the previous case studies presented several key themes regarding the implementation of lean management principles in healthcare settings. The cases of Odense University Hospital (OUH), Virginia Mason Medical Center (VMMC), and Mbeya Zonal Referral Hospital (MZRH) demonstrate the versatility and potential effectiveness of lean methodologies across diverse healthcare contexts.

A common thread across all three cases is the significant improvement in operational efficiency. At OUH, the application of Value Stream Mapping (VSM) in the emergency department led to a notable reduction in patient waiting times (Dammand et al., 2014). Similarly, VMMC's implementation of the Virginia Mason Production System (VMPS) resulted in dramatic improvements in nurse workflow efficiency and direct patient care time (Nelson-Peterson and Leppa, 2007). MZRH's adoption of the 5S-KAIZEN-TQM approach yielded substantial improvements in waste management and patient waiting times (Ishijima et al., 2016).

However, the cases also highlight the importance of contextual adaptation. While VMMC, operating in a high-resource setting, was able to implement a comprehensive lean system (Kenney, 2010), MZRH's approach in a resource-constrained environment focused on specific tools like 5S and Kaizen (Ishijima et al., 2014). This underscores Rosa et al.'s (2021) assertion that contextual adaptation is crucial for the success of lean initiatives in diverse healthcare settings.

The long-term sustainability of lean implementations remains a critical question. While all three cases reported significant short-term gains, the literature suggests that maintaining these improvements can be challenging (Moraros et al., 2016). Future research should focus on longitudinal studies to assess the long-term impacts and sustainability of lean management in healthcare.

Moreover, these cases illuminate the potential of lean methodologies to address both clinical and non-clinical aspects of healthcare operations. From improving patient

flow at OUH to enhancing financial performance at VMMC (Blackmore et al., 2011) and improving waste management at MZRH, lean principles demonstrate broad applicability across various hospital functions.

To sum up, while these case studies provide compelling evidence for the potential of lean management in healthcare, they also highlight the need for careful adaptation to local contexts, sustained leadership commitment, and ongoing evaluation to ensure long-term success and avoid potential pitfalls noted by critics (Young et al., 2019; McCann et al., 2015).

6. Conclusion:

In conclusion, the implementation of lean management principles in healthcare settings demonstrates significant potential for improving operational efficiency, patient care, and cost control across diverse contexts. The cases of Odense University Hospital, Virginia Mason Medical Center, and Mbeya Zonal Referral Hospital illustrate the adaptability and effectiveness of lean methodologies in addressing various healthcare challenges, from reducing patient waiting times to enhancing waste management practices. However, these studies also underscore the critical importance of contextual adaptation, sustained leadership commitment, and ongoing evaluation to ensure the long-term success and sustainability of lean initiatives. While the short-term gains reported in these cases are promising, the literature suggests that maintaining these improvements over time remains a significant challenge (Moraros et al., 2016). Furthermore, the broad applicability of lean principles to both clinical and non-clinical aspects of healthcare operations highlight the potential for comprehensive organizational transformation. As healthcare systems globally continue to grapple with cost pressures and efficiency challenges, lean management offers a valuable framework for process improvement and waste reduction. Nevertheless, future research should focus on developing standardized implementation and evaluation frameworks, exploring the long-term sustainability of lean initiatives, and examining the broader organizational and cultural factors that influence lean success in healthcare settings. Additionally, careful consideration must be given to potential unintended consequences and criticisms raised by scholars regarding the application of manufacturing-derived principles to complex healthcare environments (Young et al., 2019; McCann et al., 2015).

7. References:

- Al-Araidah, O., Momani, A., Khasawneh, M., & Momani, M. (2010). Lead-time reduction utilizing lean tools applied to healthcare: The inpatient pharmacy at a local hospital. *Journal for Healthcare Quality*, 32(1), 59-66.
- Andersen, H., Røvik, K. A., & Ingebrigtsen, T. (2014). Lean thinking in hospitals: is there a cure for the absence of evidence? A systematic review of reviews. *BMJ open*, 4(1), e003873.
- Bahensky, J. A., Roe, J., & Bolton, R. (2005). Lean sigma—will it work for healthcare. *Journal of Healthcare Information Management*, 19(1), 39-44.
- Bayo-Moriones, A., Bello-Pintado, A., & Merino-Díaz de Cerio, J. (2010). 5S use in manufacturing plants: contextual factors and impact on operating performance. *International Journal of Quality & Reliability Management*, 27(2), 217-230.
- Berwick, D. M., & Hackbarth, A. D. (2012). Eliminating waste in US health care. *Jama*, 307(14), 1513-1516.
- Blackmore, C. C., Mecklenburg, R. S., & Kaplan, G. S. (2011). At Virginia Mason, collaboration among providers, employers, and health plans to transform care cut costs and improved quality. *Health affairs*, 30(9), 1680-1687.
- Bloom, D. E., Chatterji, S., Kowal, P., Lloyd-Sherlock, P., McKee, M., Rechel, B., ... & Smith, J. P. (2015). Macroeconomic implications of population ageing and selected policy responses. *The Lancet*, 385(9968), 649-657.
- Blumenthal, R. S., Mehta, A., & Chandiramani, R. (2024). Ignoring Mental Well-Being Is Costing Lives: Is it Time for Life's Necessary 9?. *JACC: Advances*, 3(8), 101113.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), 77-101.
- Chassin, M. R., & Loeb, J. M. (2013). High-reliability health care: getting there from here. *The Milbank Quarterly*, 91(3), 459-490.
- Chiarini, A. (2014). Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers. *Journal of Cleaner Production*, 85, 226-233.
- Chiarini, A., & Baccarani, C. (2016). TQM and lean strategy deployment in Italian hospitals: Benefits related to patient satisfaction and encountered pitfalls. *Leadership in health services*, 29(4), 377-391.
- Conover, C. J. (2004). Health care regulation: a \$169 billion hidden tax.
- Costa, L. B. M., & Godinho Filho, M. (2016). Lean healthcare: review, classification and analysis of literature. *Production Planning & Control*, 27(10), 823-836.
- D'Andre Matteo, A., Ianni, L., Lega, F., & Sargiacomo, M. (2015). Lean in healthcare: A comprehensive review. *Health policy*, 119(9), 1197-1209.
- Dahlgaard, J. J., Pettersen, J., & Dahlgaard-Park, S. M. (2011). Quality and lean health care: A system for assessing and improving the health of healthcare organisations. *Total Quality Management & Business Excellence*, 22(6), 673-689.

- Dammand, J., Hørlyck, M., Jacobsen, T., Lueg, R., & Röck, R. (2014). Lean management in hospitals: Evidence from Denmark. *Administration and Public Management Review*, 14(23), 19-35.
- De Souza, L. B. (2009). Trends and approaches in lean healthcare. *Leadership in health services*, 22(2), 121-139.
- DelliFraine, J. L., Langabeer, J. R., & Nembhard, I. M. (2010). Assessing the evidence of Six Sigma and Lean in the health care industry. *Quality Management in Healthcare*, 19(3), 211-225.
- Dickson, G. (2009). Transformations in Canadian health systems leadership: an analytical perspective. *Leadership in Health Services*, 22(4), 292-305.
- Drotz, E., & Poksinska, B. (2014). Lean in healthcare from employees' perspectives. *Journal of health organization and management*, 28(2), 177-195.
- e Sá, P. M., & Kanji, G. (2003). Leadership for excellence in the Portuguese municipalities: critical success factors, measurements and improvement strategies. *Total Quality Management & Business Excellence*, 14(2), 131-139.
- Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of management journal*, 50(1), 25-32.
- Fillingham, D. (2007). Can lean save lives?. *Leadership in health services*, 20(4), 231-241.
- Filser, L. D., da Silva, F. F., & de Oliveira, O. J. (2017). State of research and future research tendencies in lean healthcare: a bibliometric analysis. *Scientometrics*, 112, 799-816.
- Gapp, R., Fisher, R., & Kobayashi, K. (2008). Implementing 5S within a Japanese context: an integrated management system. *Management decision*, 46(4), 565-579.
- Graban, M., & Swartz, J. E. (2012). *Healthcare kaizen: engaging front-line staff in sustainable continuous improvements*. CRC Press.
- Henrique, D. B., Rentes, A. F., Godinho Filho, M., & Esposto, K. F. (2016). A new value stream mapping approach for healthcare environments. *Production Planning & Control*, 27(1), 24-48.
- Hines, P., Taylor, D., & Walsh, A. (2020). The Lean journey: have we got it wrong?. *Total quality management & business excellence*, 31(3-4), 389-406.
- Holden, R. J. (2011). Lean thinking in emergency departments: a critical review. *Annals of emergency medicine*, 57(3), 265-278.
- Hung, D. Y., Harrison, M. I., Truong, Q., & Du, X. (2018). Experiences of primary care physicians and staff following lean workflow redesign. *BMC health services research*, 18, 1-8.
- Ikuma, L. H., & Nahmens, I. (2014). Making safety an integral part of 5S in healthcare. *Work*, 47(2), 243-251.
- Imai, M. (1986). *Kaizen* (Vol. 201). New York: Random House Business Division.
- Improta, G., Romano, M., Di Cicco, M. V., Ferraro, A., Borrelli, A., Verdoliva, C., ... & Cesarelli, M. (2018). Lean thinking to improve emergency department throughput at AORN Cardarelli hospital. *BMC health services research*, 18, 1-9.
- Ishijima, H., Eliakimu, E., & Mshana, J. M. (2016). The "5S" approach to improve a working environment can reduce waiting time: Findings from hospitals in Northern Tanzania. *The TQM Journal*, 28(4), 664-680.

- Ishijima, H., Eliakimu, E., Takahashi, S., & Miyamoto, N. (2014). Factors influencing national rollout of quality improvement approaches to public hospitals in Tanzania. *Clinical Governance: An International Journal*, 19(2), 137-152.
- Jimmerson, C., Weber, D., & Sobek II, D. K. (2005). Reducing waste and errors: piloting lean principles at Intermountain Healthcare. *The Joint Commission Journal on Quality and Patient Safety*, 31(5), 249-257.
- Kanamori, S., Sow, S., Castro, M. C., Matsuno, R., Tsuru, A., & Jimba, M. (2015). Implementation of 5S management method for lean healthcare at a health center in Senegal: a qualitative study of staff perception. *Global health action*, 8(1), 27256.
- Kaplan, S., Sadler, B., Little, K., Franz, C., & Orris, P. (2012). *Can sustainable hospitals help bend the health care cost curve?*. Commonwealth Fund.
- Kenney, C. (2010). *Transforming health care: Virginia Mason Medical Center's pursuit of the perfect patient experience*. CRC Press.
- Kohntopp, T., McCann, J. (2023). Sustainability Leadership: Current Perspective and Future Adaptation. In: Poonamallee, L., Howard, A.D., Joy, S. (eds) *Managing for Social Justice*. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-031-19971-4_8
- Kruk, M. E., Gage, A. D., Arsenault, C., Jordan, K., Leslie, H. H., Roder-DeWan, S., ... & Pate, M. (2018). High-quality health systems in the Sustainable Development Goals era: time for a revolution. *The Lancet global health*, 6(11), e1196-e1252.
- Mason, S. E., Nicolay, C. R., & Darzi, A. J. T. S. (2015). The use of Lean and Six Sigma methodologies in surgery: a systematic review. *The Surgeon*, 13(2), 91-100.
- Mazzocato, P., Savage, C., Brommels, M., Aronsson, H., & Thor, J. (2010). Lean thinking in healthcare: a realist review of the literature. *BMJ Quality & Safety*, 19(5), 376-382.
- Mazzocato, P., Stenfors-Hayes, T., von Thiele Schwarz, U., Hasson, H., & Nyström, M. E. (2016). Kaizen practice in healthcare: a qualitative analysis of hospital employees' suggestions for improvement. *BMJ open*, 6(7), e012256.
- McCann, T. V., Bamberg, J., & McCann, F. (2015). Family carers' experience of caring for an older parent with severe and persistent mental illness. *International journal of mental health nursing*, 24(3), 203-212.
- Mills, A. (2014). Reflections on the development of health economics in low-and middle-income countries. *Proceedings of the Royal Society B: Biological Sciences*, 281(1789), 20140451.
- Moraros, J., Lemstra, M., & Nwankwo, C. (2016). Lean interventions in healthcare: do they actually work? A systematic literature review. *International journal for quality in health care*, 28(2), 150-165.
- Mosadeghrad, A. M. (2015). Developing and validating a total quality management model for healthcare organisations. *The TQM journal*, 27(5), 544-564.
- Mwansisya, T., Mbekenga, C., Isangula, K., Mwasha, L., Mbelwa, S., Lyimo, M., ... & Temmerman, M. (2022). The impact of training on self-reported performance in reproductive, maternal, and newborn health service delivery among healthcare

- workers in Tanzania: a baseline-and endline-survey. *Reproductive Health*, 19(1), 143.
- Nelson-Peterson, D. L., & Leppa, C. J. (2007). Creating an environment for caring using lean principles of the Virginia Mason Production System. *JONA: The Journal of Nursing Administration*, 37(6), 287-294.
- Nolte, E., & Pitchforth, E. (2014). What we know: a brief review of the evidence of approaches to chronic care. *Assessing chronic disease management in European health systems: concepts and approaches. Copenhagen: European Observatory on Health Systems and Policies*, 9-22.
- Nowak, M., Pfaff, H., & Karbach, U. (2017). Does Value Stream Mapping affect the structure, process, and outcome quality in care facilities? A systematic review. *Systematic reviews*, 6, 1-11.
- OECD. (2019). *Health at a Glance 2019: OECD Indicators*. OECD Publishing. <https://doi.org/10.1787/4dd50c09-en>
- Øvretveit, J. (2000). Total quality management in European healthcare. *International journal of health care quality assurance*, 13(2), 74-80.
- Papanicolas, I., Riley, K., Abiona, O., Arvin, M., Atsma, F., Bernal-Delgado, E., ... & Figueroa, J. F. (2021). Differences in health outcomes for high-need high-cost patients across high-income countries. *Health services research*, 56, 1347-1357.
- Poksinska, B. (2010). The current state of Lean implementation in health care: literature review. *Quality management in healthcare*, 19(4), 319-329.
- Porter, M. E., & Kaplan, R. S. (2016). How to pay for health care. *Harv Bus Rev*, 94(7-8), 88-98.
- Powell, T. C. (1995). Total quality management as competitive advantage: a review and empirical study. *Strategic management journal*, 16(1), 15-37.
- Radnor, Z. J., Holweg, M., & Waring, J. (2012). Lean in healthcare: the unfilled promise?. *Social science & medicine*, 74(3), 364-371.
- Rosa, A., Marolla, G., Lega, F., & Manfredi, F. (2021). Lean adoption in hospitals: the role of contextual factors and introduction strategy. *BMC health services research*, 21, 1-18.
- Rother, M., & Shook, J. (2003). *Learning to see: value stream mapping to add value and eliminate muda*. Lean enterprise institute.
- Sanga, E. S. (2010). *Expectations and experiences of Hiv vaccine trial participants at the Mbeya Medical Research Programme in Mbeya, Tanzania 2006-2007* (Doctoral dissertation, University of the Western Cape).
- Shrank, W. H., Rogstad, T. L., & Parekh, N. (2019). Waste in the US health care system: estimated costs and potential for savings. *Jama*, 322(15), 1501-1509.
- Singh, J., & Singh, H. (2009). Kaizen philosophy: a review of literature. *IUP journal of operations management*, 8(2), 51.
- Sorenson, C., Drummond, M., & Bhuiyan Khan, B. (2013). Medical technology as a key driver of rising health expenditure: disentangling the relationship. *ClinicoEconomics and outcomes research*, 223-234.
- Stange, K. C. (2009). The generalist approach. *The Annals of Family Medicine*, 7(3), 198-203.

- Talib, F., Rahman, Z., & Qureshi, M. N. (2011). A study of total quality management and supply chain management practices. *International Journal of Productivity and Performance Management*, 60(3), 268-288.
- Tortorella, G. L., Miorando, R., & Marodin, G. (2017). Lean supply chain management: Empirical research on practices, contexts and performance. *International Journal of Production Economics*, 193, 98-112.
- Toussaint, J. S., & Berry, L. L. (2013, January). The promise of Lean in health care. In *Mayo clinic proceedings* (Vol. 88, No. 1, pp. 74-82). Elsevier.
- Trakulsunti, Y., Antony, J., Ghadge, A., & Gupta, S. (2020). Reducing medication errors using LSS Methodology: A systematic literature review and key findings. *Total Quality Management & Business Excellence*, 31(5-6), 550-568.
- Waring, J. J., & Bishop, S. (2010). Lean healthcare: rhetoric, ritual and resistance. *Social science & medicine*, 71(7), 1332-1340.
- Womack, J. P., & Jones, D. T. (2003). Banish waste and create wealth in your corporation. *Recuperado de http://www.kvimis.co.in/sites/kvimis.co.in/files/ebook_attachments/James*, 56.
- World Health Organization. (2018). *World health statistics 2018: Monitoring health for the SDGs, sustainable development goals*. World Health Organization. <https://www.who.int/docs/default-source/gho-documents/world-health-statistic-reports/6-june-18108-world-health-statistics-2018.pdf>
- Yin, C., He, Q., Liu, Y., Chen, W., & Gao, Y. (2018). Inequality of public health and its role in spatial accessibility to medical facilities in China. *Applied Geography*, 92, 50-62.
- Young, M. F., Oaks, B. M., Tandon, S., Martorell, R., Dewey, K. G., & Wendt, A. S. (2019). Maternal hemoglobin concentrations across pregnancy and maternal and child health: a systematic review and meta-analysis. *Annals of the New York Academy of Sciences*, 1450(1), 47-68.