Expanded Value Stream Mapping in Healthcare: From Efficiency to Sustainability

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Abstract: Value Stream Mapping (VSM) is a widely used lean tool that improves efficiency by identifying and eliminating wastes across various processes, including those in healthcare. In recent years, stakeholders have increasingly pressured organisations to integrate sustainability into their operations, underscoring the need to expand lean management practices by incorporating environmental and social considerations, such as the implementation of sustainable VSM. Unlike traditional VSM, which primarily focuses on customer (i.e., patient) value, sustainable VSM addresses the needs of a broader range of stakeholders, including patients, employees (healthcare staff), labour/professional unions, insurers, local communities, and regulatory bodies. This study aims to systematically identify the metrics used in VSM within the healthcare sector and propose an expanded metrics-based VSM that integrates economic, environmental, and social dimensions. A systematic literature review on sustainable VSM was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review indicates that current VSM practices in healthcare focus on metrics related to time, efficiency, capacity, cost, patient safety, and patient satisfaction. However, the healthcare sector also has significant implications for sustainability, including environmental aspects (e.g., resource consumption and healthcare waste management) and social aspects (e.g., occupational health and safety, and stakeholder satisfaction). To address these broader considerations, this study expands the existing application of VSM in healthcare by adapting multidimensional metrics commonly used in sustainable VSM in the manufacturing sector. This approach aims to achieve comprehensive outcomes by enhancing the quality of patient-centred care, while minimising resource consumption (materials, energy, and water), ensuring effective healthcare waste management, promoting health and safety, and improving the satisfaction of patients and other stakeholders. This study establishes a theoretical foundation for future research on integrating lean practices and sustainability. Additionally, it offers actionable insights for healthcare organisations seeking to implement a comprehensive approach to VSM that improves efficiency, care quality, and sustainability.

Keywords: Metrics, Indicators, Lean management, Value stream mapping, Sustainability, Healthcare

1. Introduction

As a key lean management tool, VSM is used to improve efficiency and maximise customer value by identifying and eliminating wastes (Rother and Shook, 1999). In healthcare, VSM is applied to improve processes by identifying non-value-added activities, reducing wastes, and improving the quality of patient care (Marin-Garcia et al., 2021). Due to the growing environmental and social concerns, stakeholders have increasingly pressured organisations, including those in the healthcare sector, to integrate sustainability into their practices (Mengistu et al., 2024). In line with this, sustainable VSM expands traditional VSM by incorporating environmental and social aspects alongside economic considerations, aiming to minimise environmental impact, ensure social responsibility, and meet stakeholder requirements (Faulkner and Badurdeen, 2014). Traditional VSM primarily focuses on improving efficiency and customer value, including patient care, through waste reduction (Rother and Shook, 1999). Sustainable VSM builds on this foundation to promote sustainable operations by balancing economic, environmental, and social considerations to address the needs of various stakeholders (Lee et al., 2021).

The healthcare sector has significant social, economic, and environmental impacts. It consumes substantial resources, including materials, water, and energy, while generating considerable waste, emissions, and pollution that can negatively affect the environment. At the same time, it plays a vital role in society by providing essential care and employing a large workforce whose health and well-being should be safeguarded (Vergunst et al., 2020). The implementation of lean tools plays a crucial role in achieving sustainability in healthcare (Morell-Santandreu et al., 2020). Notably, VSM is the most widely applied lean technique in the healthcare sector, primarily aimed at improving the efficiency of care pathways (Tiso et al., 2021).

Previous studies have identified numerous economic metrics used in VSM in healthcare but have largely overlooked environmental and social metrics. The identified economic metrics focus primarily on time (Reis et al., 2023), cost (Sheehan et al., 2021), and capacity (Costa et al., 2017). In addition, a few metrics related to environmental and social aspects were identified, as shown in Table 1. Although previous studies have provided

numerous metrics, they lack a balanced consideration of the economic, environmental, and social dimensions required to address the needs of diverse stakeholders, including patients, employees, labour/professional unions, insurers, local communities, and regulatory bodies.

Therefore, the purpose of this study is to systematically identify the metrics used in VSM in healthcare, with the aim of expanding its application by incorporating widely used multidimensional metrics, primarily derived from sustainable VSM in manufacturing. This integration provides a comprehensive understanding of key metrics, enabling healthcare organisations to make informed decisions that optimize processes while promoting sustainability. Furthermore, this study can serve as a theoretical foundation for future research by offering a set of multidimensional metrics for the effective implementation of sustainable VSM in healthcare, addressing not only patient value but also the needs of other stakeholders.

The remainder of this paper is organised into four sections. Section 2 describes the methodology of this study. Section 3 presents the results with a concise overview. Section 4 discusses the findings, supplemented by additional metrics used in sustainable VSM. Finally, Section 5 presents conclusions, including directions for future research.

2. Methodology

To achieve the study's objective, a systematic review of the literature on sustainable VSM in healthcare was conducted following the PRISMA guidelines (Moher et al., 2009), as shown in Figure 1. Relevant research papers were systematically identified in Scopus and Web of Science using three keyword sets related to the study topic:

- Sustainability-related: "sustainab*" OR "green" OR "environmental" OR "cleaner production" OR "eco-efficien*" OR "carbon footprint" OR "social" OR "socially responsible" OR "corporate social responsibility" OR "stakeholder value"
- Value stream mapping-related: "value stream mapping" OR "value-stream mapping" OR "value stream map" OR "value-stream map"
- Healthcare-related: "healthcare" OR "health care" OR "health service*" OR "health center*" OR "health centre*" OR "medical service*" OR "medical center*" OR "medical centre*" OR "care service*" OR "care center*" OR "care centre*" OR "hospital*" OR "clinic*" OR "health" OR "medical" OR "care"

The keyword search specifically targeted the "Title, Abstract, Keywords" field in Scopus and the "Topic" field in Web of Science.

A total of 111 papers published up to March 2025 were identified and screened using predefined inclusion and exclusion criteria based on the study's objective. In line with the inclusion criteria, which focused on research articles and reviews written in English, two papers in other languages were excluded. Additionally, 26 book chapters, conference papers, and other types of documents were removed to focus on the most scholarly literature. Following these exclusions, 83 peer-reviewed articles and reviews were retained for further consideration. After removing 31 duplicates, 52 papers underwent title and abstract screening to evaluate their alignment with the inclusion criteria. As a result, 24 papers were excluded for being unrelated to VSM, not addressing VSM in healthcare, or not being published in high-quality journals (i.e., those ranked in quartiles 1, 2, or 3 of the SCImago Journal Rank [SJR]). Subsequently, 28 papers were considered eligible for full-text analysis. In the full-text review process, seven papers that lacked relevant metrics for VSM or primarily focused on implementation model of lean tools were excluded. Finally, 21 papers met the inclusion criteria and were selected for further analysis.

Furthermore, this study enriched the results of the systematic review by adapting widely used multidimensional metrics from sustainable VSM practices in the manufacturing sector to enhance and broaden the application of VSM in healthcare. This approach enables a comprehensive evaluation of healthcare processes, balancing economic, environmental, and social considerations to improve efficiency, care quality, and sustainability.

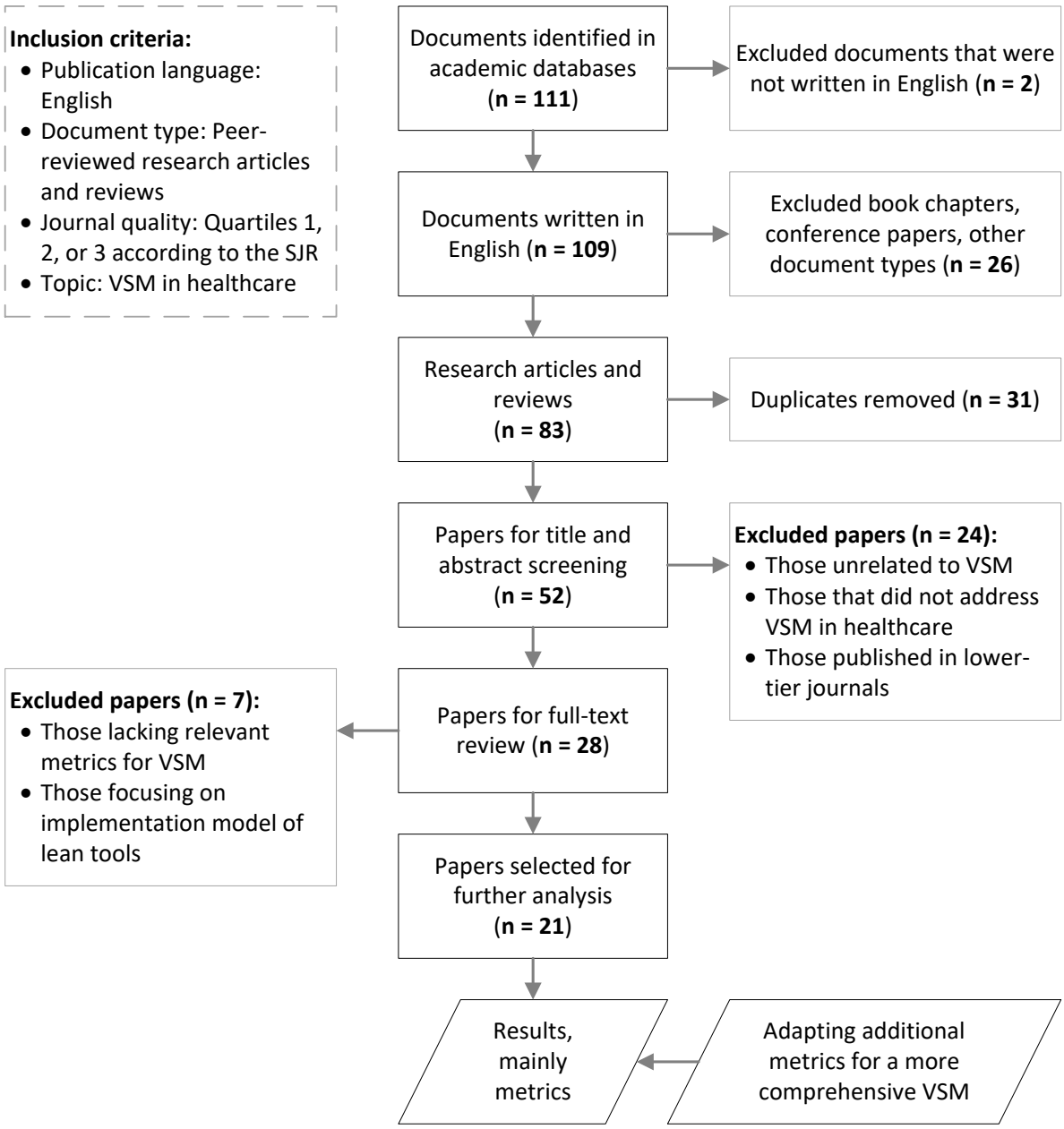

Figure 1: Systematic approach for screening and selecting relevant papers, supported by the incorporation of additional metrics

3. Results

In line with the objective of the study, the metrics used in VSM in healthcare were identified through a content analysis of the selected papers. This process involved systematically recording and coding data, including metrics mentioned in the papers. To determine the frequency of use for each metric (i.e., the number of papers that considered a specific metric), texts (words and phrases) were carefully analyzed (Hsieh and Shannon, 2005). The analysis revealed that most identified metrics were economic in nature, while environmental and social metrics were largely overlooked. Table 1 presents the frequently used metrics in VSM, highlighting the predominance of economic metrics.

Table 1: Frequently used economic metrics in the reviewed literature on VSM in healthcare

Frequently used metrics	Frequency of use
Waiting time	10
Lead time	9

Frequently used metrics	Frequency of use
Value-added time	7
Non-value-added time	6
Cost	5
Process time	4
Length of stay	3
Turnover time	3
Capacity	3
Necessary value-added-time	2
Turnaround time	2

In addition to the frequently used metrics mentioned above, numerous other economic metrics were identified, each appearing only once in the reviewed literature. Personal protective equipment (PPE) use was identified as an environmental metric (Sheehan et al., 2021). The identified social metrics include patient satisfaction (Marin-Garcia et al., 2021), staff satisfaction (Nowak et al., 2017), number of clinical trial participants (Martinez et al., 2016), infection rate (Costa et al., 2017), and patient falls (Gitlow et al., 2013).

The economic metrics focus on enhancing process efficiency, improving capacity, reducing costs, and ensuring economic viability. Among these metrics waiting time, which appeared 10 times in the reviewed literature, was the most frequently used, underscoring its significance in representing delays in the patient flow (e.g., time spent waiting for appointments, tests, or treatment). Reducing waiting time is crucial for improving patient flow and satisfaction. Lead time (9) is another key metric that represents the total duration from the start to the end of a process (e.g., from patient arrival to discharge). In VSM, reducing lead time is a primary objective to enhance the efficiency and quality of patient care delivery. Value-added time (7) and non-value-added time (6) represent the time spent on activities that directly contribute to patient care (e.g., diagnosis, treatment) and those that do not (e.g., waiting, rework), respectively. Cost (5) is a crucial economic metric, reflecting the financial impact of inefficiencies and wastes. It mostly includes labour (healthcare staff) cost, material (such as medical supplies and pharmaceuticals) cost, and stockholding cost. Process time (4) measures the duration of specific tasks within the patient care pathway (e.g., surgery, diagnostic testing). Length of stay (3) represents the total time a patient spends in a healthcare facility. In VSM, reducing length of stay by minimising delays and inefficiencies is essential for improving patient satisfaction. Additional economic metrics included turnover time (3), which is the time spent to prepare a setting (e.g., operating room, diagnostic lab) for the next patient; capacity (3), which represents the ability of resources, such as number of beds, staff, and equipment, to handle patient volume; necessary non-value-added time (2), which refers to the time spent on activities (e.g., sterilization, documentation) that do not directly contribute to patient care but are essential for compliance and continuity; and turnaround time (2), which represents the time required to complete a specific task from start to finish (e.g., time to deliver test results).

Unlike economic metrics, environmental and social metrics were largely overlooked in the reviewed literature. One example of an environmental metric is the use of personal protective equipment (PPE), which reflects the environmental impact of a process. For instance, excessive PPE use can lead to substantial end-of-life waste accumulation, potentially causing negative effects on the environment. The identified social metrics primarily focus on patients and staff. These include patient satisfaction, which reflects patients' perceptions of care quality and overall experience; staff satisfaction, an important metric for assessing well-being and engagement, helping to reduce staff turnover; the number of clinical trial participants, which indicates community engagement in research-oriented healthcare processes; infection rate, a critical metric in healthcare VSM for identifying the causes of infections, thereby improving patient safety and minimising rework; and patient falls, another essential metric aimed at enhancing safety by addressing fall-related risks.

4. Discussion

The results of the systematic review indicate that VSM practices in healthcare have primarily focused on economic metrics, largely overlooking environmental and social metrics. The identified economic metrics were retained for further consideration. Additionally, key environmental and social metrics, adapted from sustainable VSM practices in manufacturing, were incorporated to provide a comprehensive approach to VSM in healthcare. Specifically, the research team engaged in a detailed discussion on how the environmental and social metrics,

initially identified through a systematic review of the literature on VSM in the manufacturing sector, could be effectively adapted to the healthcare context. This involved assessing the relevance, applicability, and necessary modifications of the metrics to ensure alignment with the distinct characteristics of healthcare operations. Table 2 presents the recommended multidimensional metrics for expanding and enhancing VSM in healthcare.

Table 2: Economic, environmental, and social metrics for sustainable (expanded) VSM in healthcare

Economic metrics	**A concise description from a healthcare perspective**
Waiting time	Time lapse between when patients are referred or request a health service and when they receive it
Lead time	Time interval from the initiation of a patient care process to its completion
Value-added time	Duration of activities that directly contribute to patient health, such as direct care, tests, treatments, or consultations
Non-value-added time	Duration of activities that do not directly contribute to patient care or improve health outcomes, such as waiting, rework, and unnecessary administrative procedures
Process time	Duration for completing specific activities in the healthcare pathways
Length of stay	Time interval between a patient's admission to a healthcare facility and their discharge
Turnover time	Time lapse between a patient exiting the operating room and the next patient entering
Necessary non-value-added time	Duration of activities that do not directly contribute to patient care or outcomes, but are essential for the functioning of healthcare services
Turnaround time	Duration from the initiation of a specific task to its completion
Capacity	Best possible performance in terms of productivity, number of beds, or number of patients treated
Labour cost	Expenses incurred by healthcare organisations for compensating their workforce
Material cost	Expenses associated with acquiring and using physical items and supplies necessary for patient care and hospital operations
Stockholding cost	Expenses incurred by healthcare organisations for storing, managing and maintaining inventory of medical supplies, medications, and equipment
Environmental metrics	A concise description from a healthcare perspective
Energy consumption	Amount of energy used by healthcare facilities to support their operations, patient care, and infrastructure needs
Water consumption	Volume of water used by healthcare facilities for all operational, clinical, and support activities (patient care, facility maintenance, food preparation, heating and cooling systems, and sanitation)
Material consumption	Amount of physical goods used (i.e., medical devices, single-use items, pharmaceuticals, personal protective equipment, and administrative supplies) to deliver medical services and maintain healthcare facilities
Chemical consumption	Amount of chemical substances (i.e., cleaning agents, disinfectants, sterilants, laboratory reagents, pharmaceuticals, and anesthetic gases) used within medical facilities to support patient care, sanitation, diagnostics, and treatment processes
Waste recycling	Amount of collected, sorted, disinfected, and reprocessed materials by medical facilities so they can be reused or transformed into new products
Carbon footprint	Amount of emissions produced directly and indirectly by healthcare activities, facilities, and supply chains
Social metrics	A concise description from a healthcare perspective
Occupational hazards	Impact and frequency of risks faced by healthcare workers in their work environment, which can negatively affect their health, safety, and well-being (i.e., biological, chemical, physical, ergonomic, and psychosocial hazards)
Physical load index	Evaluation of the risk level of musculoskeletal strain or injury and physical demands placed on healthcare workers during their tasks, particularly those involving patient handling and transfers (e.g., measured using rapid entire body assessment method)
Mental load index	Evaluation of the cognitive and emotional effort required for healthcare professionals to perform their duties effectively, encompassing the mental

Economic metrics	A concise description from a healthcare perspective
	demands related to their work tasks, patient care, and interactions with colleagues and families (e.g., measured using NASA task load index)
Patient accident rate	Frequency of unintended injuries or harmful incidents affecting patients' safety within a specific healthcare setting
Staff accident rate	Frequency of unintended injuries or harmful incidents affecting healthcare staff's safety within a specific healthcare setting
Patient safety	Extent to which a healthcare service or practice minimises the risk of harm to patients
Safety level	Extent to which a healthcare service or practice minimises the risk of harm to staff and visitors
Absenteeism	Failure to attend to work due to personal issues or illness for one or more expected workdays
Salary level	Amount of monetary compensation paid to healthcare staff for their professional services
Patient satisfaction	Degree to which patients feel their expectations and needs have been met by the healthcare services they receive
Staff satisfaction	Degree to which healthcare workers are content and fulfilled with their jobs, encompassing their overall happiness, motivation, and sense of well-being at work
Employee/Staff turnover	Proportion of staff who leave a healthcare organisation within a certain period

*References available upon request

The use of the multidimensional metrics in VSM enables healthcare organisations to deliver stakeholder-driven outcomes. This aligns with the core principle of stakeholder theory, which emphasises the importance of addressing the interests of all stakeholders (Freeman, 1984). In the context of healthcare, this includes not only patients as a primary stakeholder group but also other stakeholders such as employees, suppliers, labour/professional unions, insurers, local communities, and regulatory bodies (Hirsch, 2019).

Applying the economic metrics in VSM plays a crucial role in identifying, analysing, and minimising inefficiencies and wastes across healthcare processes. Specifically, these metrics are used to reduce time such as waiting time and lead time, enhance capacity planning, and lower operational costs. In doing so, they help improve the quality of care through time reduction, capacity optimisation, and cost efficiency. Previous studies, such as Costa et al. (2017) and Lummus et al. (2006), demonstrated the effectiveness of VSM in healthcare to reduce time (including waiting time) and costs, thereby promoting more efficient and timely patient care delivery. Effectiveness in healthcare is achieved by delivering high-quality care that meets patients' needs. In this context, each step in the value stream should meaningfully contribute to the overall effectiveness of healthcare processes by identifying and eliminating non-value-added activities (wastes). For example, visualising and eliminating such activities can reduce the time required to initiate life-saving treatment, thereby improving effectiveness (Costa et al., 2017). Similarly, reducing the resources allocated to non-value-added activities enhances cost-effectiveness (Ersson et al., 2018). Additionally, by identifying and eliminating inefficiencies, VSM can streamline the process to provided faster access to prevention services and early diagnosis. This enables healthcare organisations to utilise their capacity more effectively by increasing number of prevention activities and new diagnosis.

Traditional VSM practices in healthcare focus on economic metrics to improve operational efficiency. However, the sector's significant sustainability impacts necessitate an expanded approach that incorporates environmental and social metrics. Integrating environmental metrics enables healthcare organisations to identify opportunities to optimise use of resources (energy, water, and materials), prevent unsafe chemical use, support effective resource recycling, and minimise the carbon footprint of healthcare activities. Aligned with this perspective, (Zhu et al., 2020) emphasised the importance of assessing energy consumption, material consumption, and carbon emissions through their green-modified VSM framework, originally proposed for manufacturing but adaptable to the healthcare sector. Similarly, Cruz et al. (2024) underscored the need to reduce the ecological impact of healthcare activities through effective waste management, efficient resource utilisation, and minimising emissions and pollution, thereby enhancing patient and public safety. Social metrics also play a critical role in sustainable healthcare, as their integration helps healthcare organisations promote the health and safety of both staff and patients, thereby improving their overall satisfaction. In this regard, Nowak

et al. (2017) highlighted the importance of using VSM to assess staff and patient satisfaction as part of healthcare quality improvement efforts, while Morell-Santandreu et al. (2020) underscored the role of lean tools in promoting sustainability in healthcare, including the social dimension.

5. Conclusions

The multidimensional metrics presented in this study provide a balanced approach that goes beyond the focus on efficiency, enabling healthcare organisations to align their processes with social and environmental sustainability goals. Specifically, the study enhances traditional VSM approach by (1) integrating environmental and social considerations alongside economic performance and (2) emphasising the importance of addressing the needs of patients and other stakeholders. This expanded VSM approach can support the achievement of healthcare sustainability goals while meeting the requirements of patients and other stakeholders. These include reducing time, increasing capacity, and reducing costs within the economic dimension; reducing resource consumption, promoting resource recycling, and minimising emissions and pollution within the environmental dimension; and enhancing health and safety and improving stakeholder satisfaction within the social dimension. Collectively, these efforts enable healthcare organisations to achieve effectiveness by delivering high-quality care that meets patients' needs.

The findings of this study impact both academic and practical domains. Academically, the study provides valuable insights for future research on integrating lean tools and sustainability principles in healthcare. It provides a conceptual foundation for empirical studies by presenting multidimensional metrics for implementing sustainable VSM in healthcare settings. From a practical perspective, the study advances the existing traditional VSM practices of healthcare by integrating economic, environmental, and social dimensions. This integration allows healthcare organisations to align their lean practices not only with the needs of patients but also with those of other stakeholders. Furthermore, it supports reputation building by enabling healthcare organisations to improve their processes through sustainable operations and effective stakeholder engagement.

This study contributes to healthcare lean management practices by expanding the existing traditional VSM approach from a primary focus on efficiency to a broader emphasis on sustainability. However, the proposed expanded approach remains at the conceptual stage and has not yet been empirically tested in healthcare settings. Future research should therefore focus on empirically testing and validating the multidimensional metrics presented in this study through real-world case studies in the healthcare sector. Specifically, these metrics could be applied in selected healthcare organisations with lean management programs to assess their effectiveness in achieving economic, environmental, and social sustainability. Additionally, integrating digital technologies with sustainable VSM to enhance data collection, sharing, utilisation, and other capabilities represents a promising research avenue for advancing both lean management and sustainability in healthcare.

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