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# VALUE STREAM MAPPING IN HEALTHCARE AND SUSTAINABLE DEVELOPMENT: A SYSTEMATIC REVIEW

# MAPEAMENTO DO FLUXO DE VALOR EM CUIDADOS DE SAÚDE E DESENVOLVIMENTO SUSTENTÁVEL: UMA REVISÃO SISTEMÁTICA

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**Resumo:** O conceito de lean manufacturing proporciona produtividade, qualidade e redução de desperdícios às organizações e adoção de suas ferramentas promove a melhoria dos processos produtivos e redução de desperdícios. O Mapeamento do Fluxo de Valor (MFV) proporciona uma análise dos processos da empresa, evidenciando eventos onde são necessárias ações objetivando a melhoria continua dos processos internos da organização. Este estudo procurou evidenciar colaborações do MFV nos âmbitos dos cuidados de saúde e desenvolvimento sustentável. Os resultados da revisão sistemática destacaram 47 artigos que abrangem a ferramenta MFV fora do ambiente de manufatura, bem como a sua participação em diferentes contextos nos cuidados com o bem-estar das pessoas e na busca pelo desenvolvimento sustentável..

**Palavras-Chave:** Lean manufacturing. Value stream mapping. Cuidados de saúde. Desenvolvimento sustentável.

**Abstract:** The concept of lean manufacturing provides productivity, quality, and waste reduction to organizations and the adoption of its tools promotes the improvement of production processes and waste reduction. Value Stream Mapping (VSM) provides an analysis of the company's processes, highlighting events where actions are necessary to continuously improve the organization's internal processes. This study sought to highlight VSM collaborations in the fields of healthcare and sustainable development. The results of the systematic review highlighted 47 articles covering the VSM tool outside the manufacturing environment, as well as its participation in different contexts in caring for the well-being of people and in the search for sustainable development.

**Keywords:** Lean manufacturing. Value stream mapping. Healthcare. Sustainable development.

## 1 INTRODUCTION

The current industry is marked by the manufacture of items so that they are passed on to the consumer at low prices and guided by their specifications to guarantee the competitiveness of the organization in the market that it proposes to serve. Lean Manufacturing seeks to make this competitive advantage feasible, addressing the entire production system of the company, acting on its main starting points so that production costs are reduced, and reflecting on the relationship with

the customer in terms of reliability, price, and quality (DADASHNEJAD; VALMOHAMMADI, 2019; DINIS-CARVALHO *et al.,* 2015).

The origins of the Toyota Production System (TPS) are related to Japanese cultural, geographical, and economic aspects. From the 1990s onwards, the term JIT was gradually replaced by lean manufacturing. Thus, in a retrospective view, lean production provided a better set than several JIT techniques, the focus was on flow, the value chain, and the elimination of Muda (waste), through Kaizen events (HOPP; SPEARMAN, 2013).

The basic idea of the TPS is to maintain a continuous flow of the products that are being produced to obtain flexibility to the changes in demand. The implementation of this flow is called production at the exact moment and it means producing only the necessary items in the necessary quantity and in the necessary time (MONDEN, 2011). Among the main general concepts related to lean production, the following stand out: (1) development of simple techniques for changing molds; (2) production in small batches; (3) company as a community; and (4) workers who are more flexible in their tasks and active in promoting the company's interests (WOMACK; JONES; ROSS, 1992).

The TPS is formed by a set of fundamental concepts that can be represented through the diagram "TPS House". It starts with the goals of better quality, lower cost, less lead time, greater safety, and high morale on the roof. It has two external columns, one representing just-in-time (right piece, right quantity, and right time) and in the other column autonomation (automation with a human touch guaranteeing quality in the sector). At the center of the system are people (organizational culture) and at its base are various processes, visual management, the Toyota Model philosophy, and level production (heijunka), both in volume and variety (LIKER; MEIER, 2007).

Value Stream Mapping (VSM) is a tool that helps you visualize and understand the flow of materials and information for a given product through the value stream. The value flow is all the actions (with added value or without added value) necessary to deliver products through the main flow of each product, that is, through VSM it is possible to visualize not only the process flow but observe the sources of waste, making possible the connection between the flow of information and material (ROTHER; SHOOK, 1998).

Therefore, it became essential to include in the study of the VSM parameters that differ beyond the organizational values, seeking to denote how the organization meets these perspectives that are internalized by the company. And environmental responsibility comprises an effort commonly observed in the routine of organizations. Therefore, the socio-ecological footprint combined with VSM can provide analysis of production metrics, such as the consumption of electricity in a sector (IKATRINASARI, HASIBUAN; KOSASIH, 2018); the percentage of reuse of water (or any reagent) from a machine or of gases expelled into the environment (SIMONS; MASON, 2010); the influence of work on employees (ergonomics) (GHOLAMI *et al.*, 2019); measuring the effects of certain processes on food (WESANA *et al.*, 2019); or even to show the company's performance in meeting international standards regarding its environmental impact (VINODH; BEM RUBEN; ASKAN, 2016), which makes sustainable development an essential element in more recent research using VSM.

Another important aspect to support this work deals mainly with the application of VSM beyond the scope of manufacturing in recent years. Mention can be made of work aimed at gaining efficiency in the movement of patients in hospital departments (BAL; CEYLAN; TAÇOĞLU, 2017); in the stages of surgical procedures (CERFOLIO *et al.*, 2016); or even have measures to effectively assist patients in regions that are difficult to access or that have difficulties in terms of medical infrastructure (RAMASWAMY *et al.*, 2017). In conclusion, evidence of the applicability of VSM in the healthcare theme makes it possible to assess the versatility of the tool in environments that start to list the human resource, or better, the care with human health as a central factor in the analysis of the processes to act in points of waste and potential points for improvement.

Therefore, this systematic review aims to research the contributions of the Value Stream Mapping tool in two environments (sustainable development and healthcare) that are gaining prominence in recent years in the area of operations management.

The following guiding questions are presented for this research:

*Main issue:*

What research methods and approaches have been used about Value Stream Mapping in the areas of lean healthcare and sustainable development?

*Secondary issues:*

a) What is the level of development and detailing of works published on Value Stream Mapping applied to lean healthcare and sustainable development?
b) Which fields or research disciplines are publishing on this topic?
c) Which sectors or market segments were studied and used as a unit of application in these works?
d) Are there similarities in the use of VSM in the areas of lean healthcare and sustainable development?

This work is structured in sections, the next (section 2) referring to the theoretical basis used for the discussions imposed in this article. It also explains the methodology of the study (section 3), results (section 4), discussion (section 5), the conclusion (section 6), and references.

## 2 METHODOLOGY

The systematic review activity took place in four stages. In the first stage (identification of keywords), the following research bases were selected: Scopus and Web of Science. The choice of such bases is justified by their wide use in the search for scientific articles. In addition, the databases offer search engines that enable filtering in the search for terms focused on certain topics in the scientific document (Abstract, Keywords, References, etc.).

Initially, “Value Stream Mapping” was searched for in both research bases, filtering the results only for articles that contained the search term in the title, so that the searches denoted works in which the Value Stream Mapping tool was present, not as an analogous subject, but that such theme was preponderant in the scientific article. The searches returned a total of 1,648 articles.

During the study, the Keywords were noted according to the number of occurrences of the same. In this way, the Keywords that were most present in each database were registered for later combination with the main search term. The keywords were filtered to prevent equivalent terms from being used as a string (Table 1) and thus causing redundancy in article searches. Thus, in the end, he chose to use two combinations for the next stage.

**Table 1 - Research strings**

| Main Term | Combine keywords |
|---|---|
| Value Stream Mapping | Healthcare<br>Sustainable Development |

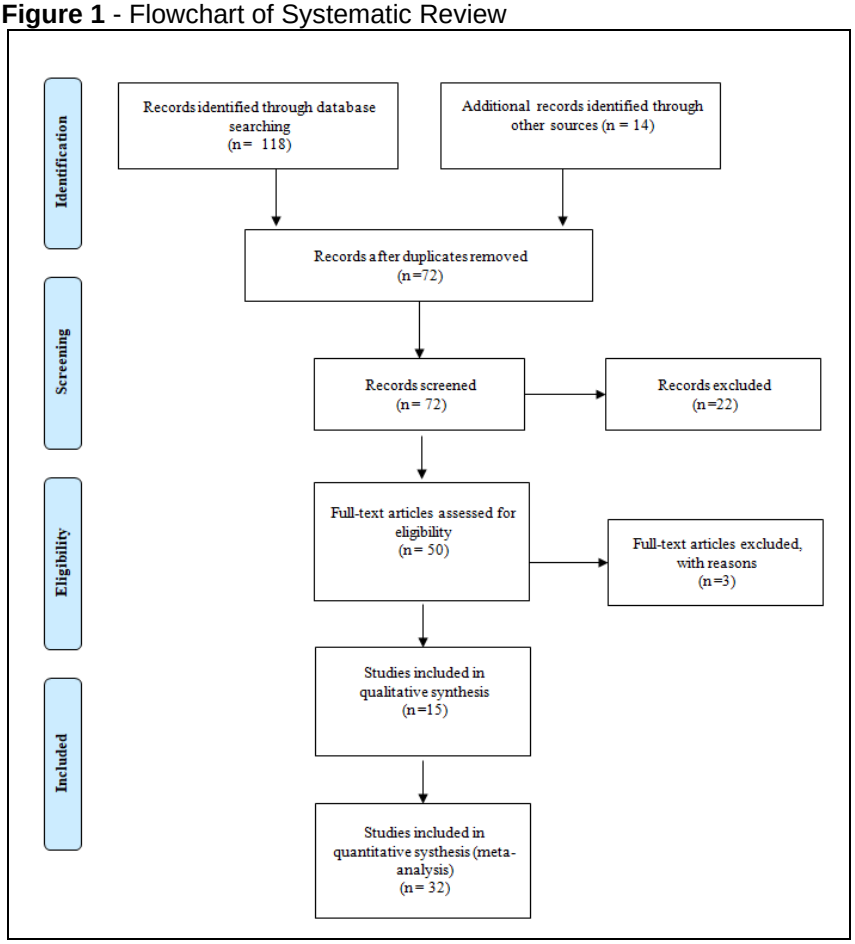
**Source**: Authors.

The next step consisted of searching for scientific articles using strings in all databases. The surveys returned a total of 118 papers. Reading the search for relevant references made it possible to identify 14 articles that were relevant to the research, making it imperative to add them in this initial phase of identification. At the same time, it was possible to remove duplicate jobs (60) between the databases, leaving 72 articles at the end of this step. Then, there was the beginning of article filtration with a reading focused on the abstract and methodologies to show collaborations in which the Value Stream Mapping was not aligned with the objectives or methods of the articles.

Thus, 22 publications were discarded, leaving 50 articles. To standardize the information in the publications, three articles were discarded that did not denote or were not consistent about the journal information, date of publication, and authorship. At the end of the stage, 47 articles were admitted to the analysis portfolio (Figure 1).

With the reading of the articles, verified in the inclusion stage, it was possible to identify them as to the characteristics of the methods used. Thus, of the 47 works, 15 fall into the qualitative perspective, while 32 collaborations cover a quantitative structure in their analysis. Table 2 reflects the analysis portfolio of this systematic review, identifying the titles of the articles, their authors, and the associated journals.

**Figure 1** - Flowchart of Systematic Review




**Source**: Authors.

**Table 2 –** Select studies (continue)

| Author (s)/year | Title | Journal |
|---|---|---|
| Alvandi*et al.* (2016) | Economic and environmental value stream map (E2VSM) simulation for multi-product manufacturing systems | International Journal of Sustainable Engineering |
| Bal, Ceylan e Taçoğlu (2017) | Using value stream mapping and discrete event simulation to improve efficiency of emergency departments | International Journal of Healthcare Management |
| Bertholey *et al.* (2009) | Méthodesd'amélioration organisationnelle appliquées aux activités des établissements de transfusion sanguine (ETS): Lean manufacturing, VSM, 5S | Transfusion Clinique et Biologique |
| Brown, Amundson e Badurdeen (2014) | Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations: Application case studies | Journal of Cleaner Production |
| Cerfolio et al. (2016) | Decreasing the precision time for pulmonary lobectomy: The process of lean and value stream mapping | Annals of Thoracic Surgery |

**Table 2 –** Select studies (continue)

| Author (s)/year | Title | Journal |
|---|---|---|
| Cookson *et al.* (2011) | Improving the quality of Emergency Department care by removing waste using Lean Value Stream mapping | International Journal of Clinical Leadership |
| Dadashzadeh e Wharton (2012) | A Value Stream Approach For Greening The IT Department | International Journal of Management & Information Systems (IJMIS) |
| Doğan e Unutulmaz (2016) | Lean production in healthcare: a simulation-based value stream mapping in the physical therapy and rehabilitation department of a public hospital | Total Quality Management and Business Excellence |
| Edtmayr, Sunk e Sihn (2016) | An Approach to Integrate Parameters and Indicators of Sustainability Management into Value Stream Mapping | Procedia CIRP |
| Eller (2009) | Rapid assessment and disposition: applying LEAN in the emergency department. | Journal for healthcare quality: official publication of the National Association for Healthcare Quality |
| Faulkner e Badurdeen (2014) | Sustainable Value Stream Mapping (Sus-VSM): Methodology to visualize and assess manufacturing sustainability performance | Journal of Cleaner Production |
| Faulkner *et al.* (2012) | Visualizing sustainability performance of manufacturing systems using sustainable value stream mapping (Sus-VSM) | Proceedings of the 2012 international conference on industrial engineering and operations management. Istanbul, Turkey |
| Garza-Reyes *et al.* (2018) | A PDCA-based approach to Environmental Value Stream Mapping (E-VSM) | Journal of Cleaner Production |
| Gholami *et al.* (2019) | Social Value Stream Mapping (Socio-VSM): Methodology to Societal Sustainability Visualization and Assessment in the Manufacturing System | IEEE Access |
| Gunduz e Naser (2017) | Cost-based Value Stream Mapping as a sustainable construction tool for underground pipeline construction projects | Sustainability (Switzerland) |
| Gunduz e Naser (2017) | Cost-based Value Stream Mapping as a sustainable construction tool for underground pipeline construction projects | Sustainability (Switzerland) |
| Hamad, Crowe e Arisha (2012) | Towards leaner healthcare facility: Application of simulation modelling and value stream mapping | 1st International Workshop on Innovative Simulation for Healthcare, IWISH 2012, Held at the International Multidisciplinary Modeling and Simulation Multiconference, I3M 2012 |

**Table 2 –** Select studies (continue)

| Author (s)/year | Title | Journal |
|---|---|---|
| Hartini et al. (2018) | Sustainable-value stream mapping to evaluate sustainability performance: case study in an Indonesian furniture company | MATEC Web of Conferences |
| Henrique *et al.* (2016) | A new value stream mapping approach for healthcare environments | Production Planning and Control |
| Hicks *et al.* (2015) | Applying lean principles to the design of healthcare facilities | International Journal of Production Economics |
| Hoffmann *et al.* (2018) | Value stream mapping to characterize value and waste associated with accessing HIV care in South Africa | PLoS ONE |
| Hung *et al.* (2015) | Integration of value stream map and healthcare failure mode and effect analysis into Six Sigma methodology to improve process of surgical specimen handling | Journal of Healthcare Engineering |
| Ikatrinasari, Hasibuan e Kosasih (2018) | The Implementation Lean and Green Manufacturing through Sustainable Value Stream Mapping | IOP Conference Series: Materials Science and Engineering |
| Jarebrant *et al.* (2016) | ErgoVSM: A Tool for Integrating Value Stream Mapping and Ergonomics in Manufacturing | Human Factors e Ergonomics in Manufacturing and Service Industries |
| Jia *et al.* (2017) | Therblig-embedded value stream mapping method for lean energy machining | Energy |
| Kasava*et al.* (2015) | Sustainable domain value stream mapping (SdVSM) framework application in aircraft maintenance: A case study | Procedia CIRP |
| Kurdve*et al.* (2011) | Use of environmental value stream mapping and environmental loss analysis in lean manufacturing work at Volvo | Sps 11 |
| Lee et al. (2014) | Six easy steps on how to create a lean sigma value stream map for a multidisciplinary clinical operation | Journal of the American College of Radiology |
| Lummus, Vokurka & Rodeghiero (2006) | Improving quality through value stream mapping: A case study of a physician's clinic | Total Quality Management and Business Excellence |
| Martínez *et al.* (2016) | Mejoraeneltiempo de atención al paciente en una Unidad de urgencias | Revista Electronica |
| Mazur e Chen (2008) | Understanding and reducing the medication delivery waste via systems mapping and analysis | Healthcare Management Science |
| Michael, Naik e Mcvicker (2013) | Value stream mapping of the pap test processing procedure a lean approach to improve quality and efficiency | American Journal of Clinical Pathology |

**Table 2 –** Select studies (continue)

| Author (s)/year | Title | Journal |
|---|---|---|
| Muñoz-Villamizaret al. (2019) | Green value stream mapping approach to improving productivity and environmental performance | International Journal of Productivity and Performance Management |
| Ng et al. (2010) | Applying the Lean principles of the Toyota Production System to reduce wait times in the emergency department | Canadian Journal of Emergency Medicine |
| Ramaswamy *et al.* (2017) | Using Value Stream Mapping to improve quality of care in low-resource facility settings | International Journal for Quality in Healthcare |
| Roosen e Pons (2013) | Environmentally Lean Production: The Development and Incorporation of an Environmental Impact Index into Value Stream Mapping | Journal of Industrial Engineering |
| Rosenbaum, Toledo e González (2014) | Improving environmental and production performance in construction projects using value-stream mapping: case study | Journal of Construction Engineering and Management |
| Sampalli *et al.* (2015) | Improving wait times to care for individuals with multimorbidities and complex conditions using value stream mapping | International Journal of Health Policy and Management |
| Schwarz *et al.* (2011) | Lean processes for optimizing or capacity utilization: Prospective analysis before and after implementation of value stream mapping (VSM) | Langenbeck's Archives of Surgery |
| Shou *et al.* (2017) | A cross-sector review on the use of value stream mapping | International Journal of Production Research |
| Simons e Mason (2010) | Environmental and Transport Supply Chain Evaluation With Sustainable Value Stream Mapping | System |
| Teichgräber e De Bucourt (2012) | Applying value stream mapping techniques to eliminate non-value-added waste for the procurement of endovascular stents | European Journal of Radiology |
| Torres e Gati (2009) | Environmental value stream mapping (EVSM) as sustainability management tool | PICMET: Portland International Center for Management of Engineering and Technology, Proceedings |
| Tortorella *et al.* (2017) | Making the value flow: application of value stream mapping in a Brazilian public healthcare organisation | Total Quality Management and Business Excellence |
| Verma e Sharma (2016) | Energy value stream mapping a tool to develop green manufacturing | Procedia Engineering |
| Vinodh, Ben Ruben e Asokan (2016) | Life cycle assessment integrated value stream mapping framework to ensure sustainable manufacturing: A case study | Clean Technologies and Environmental Policy |

**Table 2** – Select studies (conclusion)

| Author (s)/year | Title | Journal |
|---|---|---|
| Wesana*et al.* (2019) | Measuring food and nutritional losses through value stream mapping along the dairy value chain in Uganda | Resources, Conservation and Recycling |
| Wojtys *et al.* (2009) | Applying lean techniques to improve the patient scheduling process. | Journal for healthcare quality: official publication of the National Association for Healthcare Quality |

**Source**: Authors.

The search for articles using the strings defined at the beginning served as a basis for grouping collaborations according to the theme healthcare and sustainable development, which will be addressed in their delimitations in the results of the systematic review.

## 4 RESULTS

The articles were synthesized highlighting the objective and methods used in the research, the location of the study (when applicable), the defined samples, and the main contributions related to its theme (healthcare and sustainable development).

### 4.1 Heacthcare

Table 3 shows the portfolio of articles that were grouped according to the healthcare theme. Then, the works will be approached briefly, emphasizing the VSM's contribution to the aforementioned theme.

**Table 3** - Analysis portfolio (Healthcare) (continue)

| Authors | Methodology | Local | Sample |
|---|---|---|---|
| Bal, Ceylan e Taçoğlu (2017) | Lean VSM and discrete event simulation models patient screening processes | Istanbul, Turkey | Hospital Emergency Department (ED) |
| Bertholey *et al.* (2009) | Lean VSM and Method 5S applied to a blood processing | Pays de la Loire, France | Two Blood Transfusion Establishments (BTE) |

**Table 3** - Analysis portfolio (Healthcare) (continue)

| Authors | Methodology | Local | Sample |
|---|---|---|---|
| Cerfolio *et al.* (2016) | Lean VSM applied to stages before pulmonary lobectomy operation | Birmingham, Alabama, USA | Patients with a minimum age of 19 years who underwent a pulmonary lobectomy |
| Cookson *et al.* (2011) | Lean employee training and VSM application | Leicester, England | Emergency Department (ED) |
| Doğan e Unutulmaz (2016) | Arena Simulation software for modeling patient flow (current and future states) | Turkey | Department of Physiotherapy and Rehabilitation of Public Hospital |
| Eller (2009) | VSM of patient flow and implementation of a rapid assessment process | USA | Emergency Department (ED) |
| Hamad, Crowe e Arisha (2012) | VSM analysis based on simulation of healthcare processes | Dublin | Hospital ward |
| Henrique *et al.* (2016) | Bibliographic review, the adaptation of a VSM, and action research in its implementation | São Paulo | Cancer treatment hospital |
| Hicks et al. (2015) | Participating in research with 3P Lean Planning, VSM, and CAD layout design | Gateshead, England | Endoscopy unit of a hospital |
| Hoffmann *et al.* (2018) | Interview, VSM to describe clinical service arrival, waiting, and process times | Northwest Province, South Africa | Consultations in 15 clinical visits with HIV positive patients |
| Hung *et al.* (2015) | VSM and HFMEA in sample processes along the DMAIC (Six Sigma) method | Taipei, Taiwan | Procedures for collecting and transporting surgical samples from a hospital |
| Lee *et al.* (2014) | SIPOC and VSM tool- information flow involving Magnetic Resonance (MRI), Benchmarking in health units with best practices, Brainstorming of interventions | Baltimore, Maryland, USA | Radiology department magnetic resonance imaging (MRI) processes |
| Lummus, Vokurka e Rodeghiero (2006) | VSM of patient flow | USA Midwest | Medical clinic |
| Martínez *et al.* (2016) | Semi-structured interview, Spaghetti Diagram, VSM of patient flow, and applicability assessment via software simulation | Bogotá | Emergency Unit (Average of 3,592 patients / month) |
| Mazur e Chen (2008) | VSM and analysis of information on medication administration via IV | Bozeman, Montana, USA | Intravenous (IV) medication administration unit |
| Michael, Naik e Mcvicker (2013) | Filming and data collection (waste points) in sample processing and flow VSM | An Arbor, Michigan, USA | Cytopathology laboratory with the processing time of 1140 samples in 54 hours |

**Table 3** - Analysis portfolio (Healthcare) (conclusion)

| Authors | Methodology | Local | Sample |
|---|---|---|---|
| Ng *et al.* (2010) | Time collection (total lead time), VSM of information, just-in-time delivery | Windsor, Ontário, Canada | Emergency Department (ED) |
| Ramaswamy *et al.* (2017) | Workshop for employees to prioritize improvement activities, preparation, and evaluation of VSM | Nairobi, Kenya | Maternal and neonatal medical care clinic |
| Sampalli *et al.* (2015) | Survey interviews with patients and doctors, elaboration of VSM, and satisfaction survey | Nova Scotia, Canada | Polyclinic specializing in chronic diseases |
| Schwarz *et al.* (2011) | VSM analysis and design (patient flow and transfer information) | Luxembourg | Hospital |
| Shou *et al.* (2017) | Intersectoral bibliographic review about VSM | Not applicable | 131 articles on the subject of VSM |
| Teichgräber e De Bucourt (2012) | VSM of information in the administration of vascular endo stents | Berlin | Department of radiology of a university |
| Tortorella *et al.* (2017) | Semi-structured interview with managers and employees, VSM of materials sterilization processes, yokoten (learning sharing) | Southern Brazil | University hospital sterilization unit |
| Wojtys *et al.* (2009) | Initial satisfaction survey, VSM of the patient scheduling steps | An Arbor, Michigan, USA | Outpatient sports medicine clinic |

**Source**: Authors.

The work Bal, Ceylan, and Taçoğlu (2017) makes evident a problem that is present in the emergency departments (ED) and aims to increase the efficiency in the patient screening processes about overcrowding and waiting time in a hospital located in Istanbul. It was evident that the VSM associated with simulation software can reveal imperative questions to increase the future VSM. The contribution of Bertholey *et al.* (2009) part of the idea of applying lean tools in the processes inherent to the environment of two blood transfusion establishments, using the 5S methodology, as well as the mapping of blood processing activities.

Cerfolio *et al.* (2016), the main question was to analyze the situation after the implementation of the lean philosophy in the preoperative processes of pulmonary lobectomy. Cookson *et al.* (2011), applies the VSM in the processes that relate to the activities of an emergency department (ED) in Leicester, England. The article proposes to show how the VSM can be used as a source of ideas for a more efficient service for the patient. Doğan and Unutulmaz (2016) map the flow of patients in a physiotherapy and rehabilitation unit in Turkey. Allied to simulation software, the

current and future state maps were continuously modeled until the most ideal one was determined. The work of Eller (2009), reiterates the problem of waiting time in emergency departments (ED), in addition to the fact that they show constant queues, a situation that, as the authors emphasize, is quite common in the USA, the place of the research. VSM had points where they could concentrate their efforts on the analysis.

Hamad, Crowe and Arisha (2012) used VSM in a hospital ward located in Dublin. Among the motivations for carrying out the work, there is, according to the authors, the lack of scientific evidence that can subsidize the decision-making by the directors. The study by Henrique *et al.* (2016) sought a new perception of VSM so that it can be used specifically in the health sectors. The ideal VSM identified sources of waste that directly influence the treatment of patients. The research conducted by Hicks *et al.* (2015) concerns the scopes of the various projects that are carried out for the construction or renovation of facilities that are used for medical assistance. Among the results, it is possible to infer a wider range of stakeholders in the project, and coupled with the VSM, it was noted that the patient flow is a preponderant issue in the building projects that have the aforementioned purpose. Hoffmann *et al.* (2018) used the VSM to highlight waiting and service times in 15 clinical visits in South Africa with HIV-positive patients.

In the work by Hung *et al.* (2015), the authors adopted a Six Sigma methodology, which covers the Effects and Failure Modes Analysis (FMEA) aimed at healthcare, and VSM in the processing of surgical samples from a hospital located in Taipei, Taiwan. The VSM presented in Lee *et al.* (2014) demonstrates losses due to delay in the steps from the referral via fax to the moment of patient registration for Magnetic Resonance Imaging (MRI) in a radiology department located in the USA. Lummus, Vokurka, and Rodeghiero (2006) report the application of VSM in a clinic located in the midwest of the USA and that was overburdened by attending some patients that contrasted with the small size of the unit. Martínez *et al.* (2016) address the flow map along with the spaghetti diagram in an emergency room in Bogotá to determine points to concentrate improvement efforts and, thus, make the service more efficient, from triage patients to consult with the doctor.

Mazur and Chen (2008) used an intravenous (IV) medication administration unit, located in Montana, USA, as the basis for the VSM elaboration. Michael, Naik

and Mcvicker (2013) adopted the VSM tool in a laboratory to show the processing of samples in Pap tests and identify sources of waste that can be points for improvement actions. Ng *et al.* (2010) implemented the lean philosophy in an emergency unit located in Windsor, Canada. The methodology encompassed the elaboration of the VSM of the current situation and, through its analysis, it was possible to adopt measures that led to a decrease in the patient's length of stay in the unit.

In Ramaswamy *et al.* (2017), the application of the VSM is noted taking into account the patient flow, the administration of supplies, and data on the number of patients in process at a certain time and the number of employees per stage. The study took place at a maternal and neonatal healthcare facility, located in Nairobi, Kenya. The work of Sampalli *et al.* (2015) aims to minimize the waiting time for care in a polyclinic specialized in chronic diseases and located in Nova Scotia, Canada. Thus, the VSM was focused on highlighting the added value to the patient. The article by Schwarz *et al.* (2011) aimed to optimize the use of an operating room in a hospital located in Luxembourg. The VSM tool was approached to describe the information relevant to the transfer of patients.

Teichgräber and De Bucourt (2012) aim to eliminate waste in services performed in a radiology department of a university hospital in Berlin. The focus of the research was from the acquisition of vascular endo stents to their arrival in patients, using VSM in the processes. The research conducted by Tortorella *et al.* (2017) took place at a university hospital located in southern Brazil. The VSM tool was adopted in a sterilization unit (US) of materials that are used from laboratory environments to surgical procedures. Wojtys *et al.* (2009) showed, through a survey of patient satisfaction, the need for improvement about the scheduling processes of a clinic focused on sports medicine.

### 4.2 Sustainable development

Table 4 shows the articles that follow the sustainable development theme. For a better understanding, the collaborations will be approached highlighting the VSM approach on the theme.

**Table 4** - Analysis portfolio (Sustainable Development) (continue)

| Authors | Methodology | Local | Sample |
|---|---|---|---|
| Alvandi*et al*. (2016) | Data collection in ERP system, machine status in supervisory software (SCADA), construction of E2VSM | Uninformed | Railway market company (6 products with the most demand) |
| Brown, Amundson e Badurdeen (2014) | Case study review, information gathering from companies | Uninformed | One manufacturer of satellite dishes, one cathode manufacturer, and one company working under contract |
| Dadashzadeh e Wharton (2012) | Analysis of the Green VSM methodology (GVSM) | Not applicable | IT departments as the focus of discussion |
| Edtmayr, Sunk e Sihn (2016) | VSM and Methods-Time Measurement (MTM) | Not applicable | Not applicable |
| Faulkner e Badurdeen (2014) | A questionnaire with employees, Sus-VSM | Lexington, Kentucky, USA | TV antennas manufacturer |
| Faulkner *et al*. (2012) | Sus-VSM, a study of times (monitoring of processes), collection of stock data | Lexington, Kentucky, USA | TV antennas manufacturer |
| Garza-Reyes *et al*. (2018) | Action research, Environmental VSM (E-VSM), and PDCA cycle in the helical lamination process | Uninformed | Manufacturer of mining grinding media |
| Gholami*et al*. (2019) | Action research, Socio-VSM, Ergonomic analysis | Malaysia | Manufacturer of hard disk components |
| Gunduz e Naser (2017) | Workflow diagram, VSM of construction steps | Uninformed | Underground pipeline construction project |
| Hartini *et al*. (2018) | A questionnaire with employees, VSM with economic-environmental-social metrics | Semarang, Java Island, Indonesia | Furniture company |
| Ikatrinasari, Hasibuan e Kosasih (2018) | Current and future VSM, power consumption graphs, SMED method | Bekasi, West Java, Indonesia | Stamping department of an electronic components industry |
| Jarebrant*et al*. (2016) | ErgoVSM, video recording of discussions in VSM application groups | Sweden | Three manufacturing companies and one from the auto industry |
| Jia *et al*. (2017) | VSM incorporated into Therblig (TVSM) and calculation of energy efficiency in the machining process | China | Machining lathe |

**Table 4** - Analysis portfolio (Sustainable Development) (conclusion)

| Authors | Methodology | Local | Sample |
|---|---|---|---|
| Kasava*et al*. (2015) | Direct observation, SMMIAI Methodology, SdVSM, Method 6R | Uninformed | The maintenance process of Boeing 737 aircraft |
| Kurdve*et al*. (2011) | Two case studies, Interviews with production coordinators, Environmental-VSM | Sweden | One assembly station and five welding stations |
| Muñoz-Villamizar*et al*. (2019) | OGP-VSM in the manufacturing sector | Spain | Bumper manufacturing company |
| Roosen e Pons (2013) | Use of Standard Operating Procedure (POP) in the application of EW-VSM, survey with users, radar graphics | Christchurch, New Zealand | Remanufacturing company |
| Rosenbaum, Toledo e González (2014) | Direct observation, construction of the VSM in an ecological dimension, feedback survey with participants, validation with experts | Santiago, Chile | Medical center project |
| Simons e Mason (2010) | Theoretical study of VSM with CO2 metrics that add value to the process | Not applicable | Not applicable |
| Torres e Gati (2009) | Survey with employees and supervisors of the production line, VSM with EPA recommendations, Graph Tree of losses | São Paulo | Alcohol and sugar manufacturing industry |
| Verma e Sharma (2016) | Energy Value Stream Mapping (EVSM) in the process of a product component | Uninformed | Small factory |
| Vinodh, Ben Ruben e Asokan (2016) | Software for measuring environmental impact based on ISO 14044, Sus-VSM for the production of an automotive component | Tamil Nadu, India | Automotive component manufacturing company |
| Wesana*et al*. (2019) | Interview with employees, VSM in the processing of UHT yogurt and milk, Food loss report | Western Uganda | Dairy manufacturing company |

**Source**: Authors.

Alvandi *et al.* (2016) propose a method to structure the VSM to the environmental footprint, so that the VSM shows a dynamic flow of information, taking into account energy consumption to manufacture a range of products. The Economic and Environmental Value Stream Mapping (E2VSM), in addition to describing the data as the conventional VSM, demonstrates the energy consumption that adds or does not add value to the process, as well as the calculations related to CO2 emissions for the production sectors. Brown, Amundson, and Badurdeen (2014) proposed to evaluate Sus-VSM (Sustainable VSM) for its versatility. The

methodology consisted of using the VSM referenced from the work of Faulkner and Badurdeen (2014), which integrates data related to the company's sustainability.

Dadashzadeh and Wharton (2012) aimed to analyze the applicability of Green Value Stream Mapping (GVSM) in IT departments, reiterating that it is necessary to adopt a strategic positioning towards ecological and sustainability for these sectors. The work of Edtmayr, Sunk, and Sihn (2016) survey the characteristics that dominated the VSM while showing sustainability management. The article by Faulkner and Badurdeen (2014) proposes, through the so-called Sus-VSM, the performance evaluation focused on the sustainability of a company, increasing metrics of a sustainable nature of works that dealt with the same issue.

Garza-Reyes *et al.* (2018) aimed to present a mixed approach with Environmental VSM (E-VSM) and the PDCA cycle. Gholami *et al.* (2019) propose to address the gap that exists in the studies of the application of sustainable VSM with emphasis on the social aspect. The study was applied to a hard disk substrate manufacturing company in Malaysia. In Gunduz and Naser (2017) the objective was to apply the idea of VSM related to costs in the construction industry. The concept was approached in the stages of a project to build underground pipelines to provide information that would make it possible to model a sustainable cost estimate for the realization of the project.

Hartini *et al.* (2018) highlighted in their work the need to adapt the VSM tool so that it would show the socio-environmental performance of the analyzed organization with its application. Ikatrinasari, Hasibuan and Kosasih (2018) proposed to apply the lean and green manufacturing approach to sustainable VSM (SVSM), which quantifies the energy used as well as the waste generated in a production process. Jarebrant *et al.* (2016) sought to integrate ergonomics with the VSM tool, as well as examine its applicability. ErgoVSM was developed at 3 manufacturing companies located in Sweden.

Jia *et al.* (2017) incorporate the VSM tool into the concept of a simple work unit in industrial processes (Therblig) in the machining industry. The TVSM presents the demand for energy in carrying out tasks in the workplace. Kasava *et al.* (2015) highlight the VSM tool of the sustainable domain, the SdVSM, which is similar to the standard VSM in the identification of activities that add and do not add value, but in addition, they seek to reduce the social, economic and environmental burden. Kurdve

*et al.* (2011) consisted of bringing together the perspectives of environmental management, which seek to minimize the use of materials and the lean tool VSM. For the use of Environmental VSM, an assembly sector (first case study) and five welding stations (second case study) were admitted, both located in Sweden.

Muñoz-Villamizar *et al.* (2019) present the Overall Greenness Performance (OGP) integrated into VSM, aiming to increase productivity and increase sustainability management. Roosen and Pons (2013) proposed integrating environmental waste in the development and application of the lean VSM tool so that it provides action plans that cover the environmental perspective. Rosenbaum, Toledo and González (2014) adopted the lean-green concept in the VSM tool in the construction stages of a hospital, to manage not only productivity but ecological waste.

Simons and Mason (2010) incorporated sustainability indexes into the VSM methodology and seek to demonstrate that the lean feature of the tool already covers the aspect of environmental responsibility. In their work, Torres and Gati (2009) set out to align the objectives of mapping the value of a process line through a tool that links VSM to the flow of environmental values. Verma and Sharma (2016) focused their article on the application of VSM to increase efficiency in energy consumption. The VSM of the current and future state was elaborated by adding the energy consumption data in KWhr per part in each of the stages, following the power of each engine in the process of calculating consumption.

Finally, Vinodh, Ben Ruben and Asokan (2016) present an integration between VSM and Product Life Cycle Assessment (LCA) to show the sustainable performance of the organization. Wesana *et al.* (2019) adopted VSM in their study as a way to identify the magnitude of food losses in the dairy industry in the production lines of yogurt and UHT milk which also end up reflecting on the nutritional value.

## 5 DISCUSSION

The articles selected for analysis, understood the use of Value Stream Mapping, either as the main discussion in the study or for complementary analysis to the other tool. The following observations are addressed to the main and secondary questions presented at the beginning of this research.

*Main question: What research methods and approaches have been used about Value Stream Mapping in the areas of lean healthcare and sustainable development?*

The research approaches present in the 47 articles of the portfolio highlight techniques that allow discussions in quantitative and qualitative terms, from specific manufacturing processes to gauge their environmental impact (VINODH, BEM RUBEN; ASOKAN, 2016), to dimensioning the flow of patients in medical clinics (LUMMUS, VOKURKA; RODEGHIERO, 2006). The qualitative aspects range from discussions with groups participating in the research about the feasibility of adopting ergonomic measures in production lines (JAREBRANT *et al.* (2016) to workshops with an employee for maternal and neonatal health care (RAMASWAMY *et al*., 2017).

*Secondary question a: What is the level of development and detailing of works published on Value Stream Mapping applied to lean healthcare and sustainable development?*

The VSM in its original application comes as a way to show the details of the processing that results in serving customers so that the tool elucidates issues that are not within the reach of managers or are not perceptible to employees. Along these lines, Tortorella *et al.* (2017) address points of an administrative scope that end up determining different positions of managers when in public and private institutions, which influences the development of best practices in their organizations. The development of VSM in Sampalli *et al.* (2015), for example, covered the dimension of the effects that occurred with the implementation of actions that took place behind the entire structure of a medical center, which shows that patient satisfaction is a reflection of what happens “behind the scenes ", that is, the client as a patient is the value that must be continuously shaped when analyzing the procedures inherent to the Healthcare service.

The development of VSM also needed to be linked to environmental factors, such as the carbon dioxide metric explained in Simons and Mason (2010). The data normally considered in the processes are characterized, for example, in lead time or cycle time, but in the ecological footprint, water consumption, energy use (Verma & Sharma, 2016), and carbon emission (SIMONS; MASON, 2010). It is evident that the articles on the theme of sustainable development sought to preserve the original structure of the VSM, but that its development requires adaptation to the context of

the organization to align the socio-economic-environmental aspect in lean manufacturing practices.

*Secondary question b: What research fields or disciplines are you publishing on this topic?*

About healthcare, countless studies concentrate efforts to serve patients more efficiently and streamline the care process. Among the focuses of research, there is the search for reducing scheduling times and keeping patients in queues or implementing improvements in the steps of procedures in health units (BAL; CEYLAN; TAÇOĞLU, 2017; DOĞAN; UNUTULMAZ, 2016; ELLER, 2009; HOFFMANN *et al.*, 2018, SCHWARZ *et al.*, 2011; WOJTYS *et al.* 2009). Articles with similar objectives to this showed starting points in the problem of patient care, from the time he entered a health unit until the time of medical discharge.

In addition, it is observed in sustainable development the application of VSM in civil construction (GUNDUZ; NASER, 2017), to support sustainable cost estimates for carrying out the project is also noted. VSM can expand the analysis in project scope disciplines, as well as highlight points of improvement for its continuous remodeling. The effort to make the VSM explain data about the environmental impact that an organization cause is evident. Many approaches identified in the portfolio can be understood as fields of extension to VSM research, although they include a term or another to refer to sustainability in the use of resources such as Green VSM (GVSM) (DADASHZADEH; WHARTON, 2012) and Sus-VSM (FAULKNER; BADURDEEN, 2014).

A mixed approach can be seen in Garza-Reyes *et al.* (2018) that included the PDCA Cycle together with the so-called Environmental VSM (EVSM), and also linked to ergonomic-social criteria such as Socio-VSM (GHOLAMI *et al.*, 2019) and ErgoVSM (JAREBRANT *et al.*, 2016). The articles sought to show that the lean tool in question, in addition to enabling the analysis of a company's productive capacity, can also be modeled to have instruments for assessing the sustainability of an organization, a potential field of research in the manufacturing area.

*Secondary question c: Which sectors or market segments were studied and used as a unit of application in these works?*

As for the places where the studies were carried out, in Healthcare, most of the publications used environments as emergency units (MARTINEZ *et al.*, 2016;

BAL, CEYLAN; TAÇOĞLU, 2017; COOKSON *et al.*, 2011; ELLER, 2009; NG *et al.*, 2010), departments of specialties such as physiotherapy (DOĞAN; UNUTULMAZ, 2016), endoscopy (HICKS *et al.*, 2015), radiology (LEE *et al.*, 2014; TEICHGRÄBER; DE BUCOURT, 2012) and sterilization units (TORTORELLA *et al.*, 2017), which belong to universities, hospitals, and medical clinics.

As for sustainable development, it can be emphasized from IT departments (DADASHZADEH; WHARTON, 2012), aircraft maintenance projects between landings and takeoffs (KASAVA *et al.*, 2015), and a series of manufacturing sectors, such as the hard drive components (GHOLAMI *et al.*, 2019), bumpers (MUÑOZ-VILLAMIZAR *et al.*, 2019), stamping sectors (IKATRINASARI, HASIBUAN; KOSASIH, 2018), grinding (GARZA-REYES *et al.*, 2018) and machining (JIA *et al.*, 2017), as well as a production chain plant, as seen in Wesana *et al.* (2019) which covers a dairy farm.

*Secondary question d: Are there any similarities in the use of VSM in the areas of lean healthcare and sustainable development?*

Regarding the similarities between the VSM applications in the themes admitted in this work, the first similarity can be pointed out as the use of auxiliary software in the application of the lean tool. In healthcare, one can notice works that used modeling and simulation software to study the flow of patients and thus be able to prepare maps of the current and future states, as seen in Doğan and Unutulmaz (2016) and Martínez *et al.* (2016). In sustainable development, supervisory systems are highlighted, normally used in contexts that require data acquisition and management of possible variables as noted in Alvandi *et al.* (2016) and software to measure the environmental impact of the organization according to international standards as provided by Vinodh, Ben Ruben and Asokan (2016).

It is important to highlight that the activities developed to start from the questioning about the entire framework of the sample, a point that is inherent at the beginning of the research. For the VSM study, information is collected from machines, ERP systems, monitors with monitoring software, among others, and the human resource (employee, client-patient) is a preponderant issue in these terms, which can be pointed out as another similarity between research on both themes. In this sense, the role of related people in activities that define the stages in the development of VSM maps stands out.

As for practices, in sustainable development, the use of questionnaires and survey interviews can be highlighted (FAULKNER; BADURDEEN, 2014; HARTINI *et al.*, 2018; KURDVE *et al.*, 2011; TORRES; GATI, 2009; WESANA *et al.*, 2019), video recordings with groups applying the VSM (JAREBRANT *et al.*, 2016) and feedback surveys with participants as done in Rosenbaum, Toledo and Gonzaléz (2014). In healthcare, demonstrates the training focused on the lean methodology (Cookson *et al.*, 2011), benchmarking consultations (LEE *et al.*, 2014), Workshops with employees to improve neonatal medical care (RAMASWAMY *et al.*, 2017), in addition to, of course, satisfaction surveys (SAMPALLI *et al.*, 2015; WOJTYS *et al.*, 2009) and the sharing of ideas for “yokoten” improvement (TORTORELLA *et al.*, 2017).

## 6 CONCLUSION

This study contributes to the debate on the application of concepts and tools related to lean manufacturing (Value Stream Mapping) outside the industrial context in two important areas: healthcare and sustainable development. First, the article explains the current evolution of research regarding the application of VSM in the areas of healthcare and sustainable development based on the articles, enabling key elements for scholars and professionals to consider using this lean manufacturing tool. This first contribution may help the lean manufacturing area to reflect on the expansion of other concepts of industrial emphasis to the area of services and environment.

According to the current review, it enriches knowledge in the area of lean manufacturing, especially related to the application of VSM, by highlighting the benefits and impacts that the tool causes in organizational environments focused on healthcare and sustainable development. Third, the main question and the secondary questions elaborated in the introduction of this study were answered appropriately through the methodology adopted to carry out this systematic review.

Fourth, the focus on the two areas of research showed collaborations in different locations and in a way little similar to the manufacturing environment. The requirements presented in each context have characterized publications in which lean thinking can be increased to change a problematic situation or that require actions for improvement. Fifth, the use of the VSM tool provided additional methods

for analyzing certain realities, as well as presenting suggestions based on more judicious analyzes. In this way, it was possible to show information inherent to the researched environment, making it possible to structure measures aimed at holistic performance and covering all processes in the environments used.

In conclusion, the main contribution of this systematic review was to highlight some of the problems faced in critical environments in healthcare, such as the application of VSM in surgical procedures that can pose risks to the patient, expanding the visualization of these processes so that ways can be determined to guarantee the satisfaction of people. The efforts based on the socio-economic-environmental perspective, in turn, highlighted that the VSM has characteristics that can serve as a basis for the analysis of data related to sustainability, making it an indispensable tool for companies that value the minimum human interference in nature.

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