Surgical flow improvement based on lean healthcare: a Brazilian case study using the VSM

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Abstract. Hospitals have adopted lean healthcare implementations with the aim of increasing value creation for their patients, reducing lead time and costs, in addition to supporting hospital quality accreditations. An important sector in this process is the operating room, which usually has a high cost and revenue potential for hospitals. In this context, this study analyzed the value stream map of two large hospitals in Brazil, through a case study, to evaluate their lead time, their waste, and general problems and propose a framework to improve the surgical flow. The average lead time found in the surgical flow of the study hospitals was around 6.8 hours, with 50% of non-value-added activities, such as waiting, rework, and low quality in some processes, indicating great possibilities for improvement in the hospitals, such as improvements in physical space through 5S and visual management, end-to-end flow optimization with reduced waits, improved setup, and patient flow planning; and, performance management with the implementation of efficiency, quality and cost indicators such as the ORE.

Keywords: Lean Healthcare, Operating Room, Value Stream Mapping.

1 Introduction

The need for process improvements in hospital services increases every year [1] [2] with evident challenges to increase efficiency, improve care quality and deal with high demand rates and low patient care capacity [2] [3]. Insufficient resources and high flow of patients contribute to the formation of waiting lines and overcrowding, which can affect the patient's health and the general quality of care [2] [3].

Surgical centres are essential in hospital units and have a strong contribution to the restoration of patient health [3] [4] [5]. It refers to a unit that presents a linear flow basically involving preparation, operation, and post-operation [4]. However, surgical centres face challenges such as limited capacity, the number of operating rooms, necessary equipment, and available trained professionals, among other factors [6]. Such challenges can generate a high rate of demand for surgeries, queues and waits, dissatisfaction with care and worsen the clinical condition of the patient's health [4]. A

study carried out in Brazil analysed the application of the Operating Room Effectiveness (ORE) indicator in a hospital operating room, to measure performance and identify losses. Using the indicator, it was possible to classify the losses and develop improvement actions, which resulted in operational efficiency gains of 12% and annual savings of approximately US$400,000 [7].

An alternative used to address the management strategies of operations in hospital units is through initiatives such as Lean Healthcare, which aims to reduce or eliminate waste and activities that do not add value to the patient, contributing to improving efficiency, increasing quality, and reducing costs [2] [4] [7] [8].

Although Lean Healthcare has relatively recent evidence in the literature, authors point out that it is being increasingly studied, with the operating room being an effective performance of philosophy. In Brazil, a study was carried out with the application of the ORE indicator in a hospital general surgical centre. The results showed improvements in the efficiency of the flow of elective and urgent surgeries, with evidence from the indicator of an availability of 78.4% and performance of 77.1%, resulting in an average annual ORE of 60.4% [7]. Another study, carried out in a Brazilian university hospital, proposed a conceptual model of Planning, Scheduling and Control of Patient Flow (PSCPF), with the objective of integrating the planning and programming of consultations, surgeries, preoperative and materials. The results showed an average reduction of queues for consultations by 50%, and savings of R$700,000.00 with preoperative exam schedules [4].

Given this context, the objectives of this article are: i) to analyse two different surgical flows through the VSM tool and identify the main waste and flow problems; ii) propose a general framework to improve the surgical flow based on Lean Healthcare, using the analyses collected and the main insights of the study.

2 Theoretical background

2.1 Surgical Flow Management

Surgical flow management comprises the care capacity, organization of procedures based on available teams and resources, purchasing management, and especially the patient's clinical health condition [4]. The flow of patients in a hospital environment generally includes the patient's waiting time to be seen, the length of stay and their exit [3] [4].

The ORE indicator proposed by Souza (2022) [5] was adapted from the OEE (Overall Equipment Effectiveness) and is focused on measuring the efficiency of flows in surgical centres and their specificities. The ORE can be found through the product of the Availability, Performance and Quality indicators [5]. The equations to obtain the ORE are presented below:

Availability = Total Time Scheduled (TTS) / Total Time Available (TTA)
Performance = Total Time Used (TTU) / Total Time Scheduled (TTS)

Quality = Total Value-Added Time (TVAT) / Total Time Used (TTU)
ORE = Availability x Performance x Quality

Production Planning, Scheduling and Control (PPCP) systems aim to contribute to decisions about “what”, “how much”, “when” and “where” to produce and about “what”, “how much” and “when” to buy. [11]. In surgical centres of a hospital, the concepts of PPCP can also be applied for good management in reducing the waiting time for surgeries [12]. PSCPF performs well in reducing surgery waiting lines, better operational efficiency, better scheduling of agendas and materials, among others, as proposed and presented by Souza et al. (2021) [4].

2.2 Lean Healthcare

The term Lean can be defined as a management system that promotes a culture of continuous improvement and aims to reduce or eliminate waste [2] [8] [13] [14]. The implementation of the Lean philosophy has been carried out by several organizations to improve and monitor work processes [5] [13] [15].
Many organizations in the healthcare industry are implementing Lean management tools, primarily to balance capacity and demand, and improve the quality of patient care [3] [8] [15]. In the 2000s, the Lean concept entered the healthcare area, well known as Lean Healthcare [2] [10].

Healthcare organizations, such as hospitals, are implementing Lean Healthcare to train frontline professionals such as doctors, nurses, administrative and support staff so that they can solve problems and reduce waste, identifying and prioritizing activities that add value to the health of the patient [2] [8].

There are some wastes inherent to any production flow, whether in health or other industries, which can be categorized as: losses from overproduction, waiting time, transport, processing, stock, defect and movement, and these wastes can be summarized as activities that do not add value to a service or product [3] [16].

Waste in the Healthcare context refers to activities that do not add value to the patient's health, such as the inappropriate use of space, time, or unnecessary resources, causing patient dissatisfaction and being harmful to their health [2] [3] [13].

To reduce waste and improve the quality of patient care, it is essential to implement Lean Healthcare, which contributes to the identification of activities that do not add value to the patient, and thus they can be reduced or eliminated [2] [3]. With the reduction of activities that do not add value, it is possible to increase service capacity, reduce waiting lines, reduce non-essential costs for patient care, improve the number of resources, among others [3] and an important tool for mapping these activities is called Value Stream Mapping.

2.3 VSM: Value Stream Mapping

Value Stream Mapping (VSM) refers to the mapping of activities, identification, and elaboration of action plans to eliminate waste, that is, it seeks to identify and reduce or eliminate activities that do not add value to the process [17] [18].

Sales and Castro (2021) carried out a study at the Vall d'Hebron hospital in Barcelona, where the lean projects of a surgical centre team were analysed. The hospital is one of the largest in Spain and approximately 38,000 surgeries are performed each year, with more than 900 professionals working in the hospital's surgical sector. To improve the surgical processes, Lean tools were used, mainly the VSM. The results of the VSM implementation showed that the hospital's surgical productivity increased by an average of 8.4%, in the three years analysed, which means that the waiting time of patients for surgery reduced significantly, and this occurred without increasing resources or hiring. of additional staff. And the number of operations between July 2017 and July 2018 increased by 11.4% in just one year [18].

Ruohoaho et al. (2020) used the VSM in their study to map the surgical processes of urology, plastic surgery, and neurosurgery patients at a university hospital in Finland. Approximately 550 elective urology surgeries, 1,000 plastic surgeries and 1,200 neurosurgeries are performed annually. The results show that in the 23h process, patients started to stay in one place, which improved treatment efficiency and reduced unnecessary displacement between employees during the work shift. The allocation of patients in a single place favoured rehabilitation, due to frequent monitoring by nurses and doctors, and reduced the time the patient spent in the hospital. About 90% of patients in urology, 89% in neurosurgery, and 86% in plastic surgery were discharged within 24 hours of surgery, and only 4% of patients required slightly longer hospital care, regardless of the type of procedure [17]. The findings show that the application of the VSM is useful in identifying activities that do not add value and contributes to meeting the needs of patients.

3 Research Method

The method chosen to conduct the article was the case study. The case study can be defined as empirical research that aims to analyse and increase knowledge about a given phenomenon in its real and contemporary context through the in-depth analysis of one or more objects of analysis, commonly called "cases" [19] [20].

The present case study was carried out in two large, philanthropic hospitals in the southeaster region of Brazil. The procedures used to conduct the cases was based on the proposal of Yin (2017). The cases were based on the essential concepts of Lean and data collection occurred through on-site observations and document analysis of the VSMs of hospitals A and B.

The data collection of case A was conducted in 2018 while case B was conducted in 2019. Two VSMs of surgical centres prepared by hospitals teams were analysed and based on this analysis and the Lean concepts and practices, a generic framework was proposed to improve the efficiency of the surgical flow through Lean Healthcare.

4 Results

4.1 Value Stream Mapping - Hospital A

Hospital A has more than 300 beds, sixty years of history, located in the south-easter region of Brazil, has high complexity care, from urgency and emergency, surgery, hospitalization, oncology, among others. Implements lean projects since 2018 focusing on areas such as pharmacy, supplies and surgery centre. Figure 1 presents the Value Stream Mapping of the flow of surgical patients at hospital A.

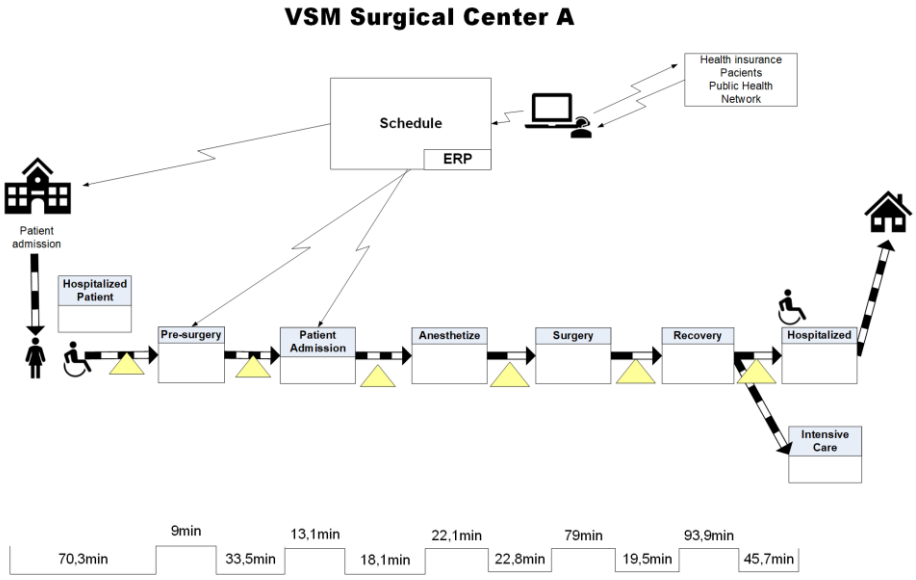

Fig. 1. Value Stream Mapping – Hospital A

Data from this VSM were collected from a sample of 279 patients with a margin of error of 5%. The lead time of the process from the time the patient enters the operating room to the release to the inpatient ward corresponds to approximately 427 minutes, and of these, only 51% of the activities performed add value to the patient. Activities that do not add value are characterized as waste in the flow, which are detailed in the following topic. Table 1 shows the detailed VA and NVA times.

Table 1. Main metrics collected VSM – Hospital A

	Minutes	Hours
Lead Time	427	07:06

NVA	209,9	03:30
VA	217,1	03:36
%VA	**51%**	

It was possible to observe that there are three waiting times that significantly impact the lead time, the time for the patient to enter the admission to the operating room, the wait to enter the operating room, followed by the waiting time for discharge to the hospital bed, being that these times total 35% of the lead time.

To identify the waste in this value stream, on-site observations (Gemba) and brainstorming with the project team were carried out. After surveying the waste, they were categorized among the seven Lean wastes and it was possible to identify large losses in the Value A stream: waiting, defect/quality and processing/rework, which represented about 80% of the waste. Table 2 presents the main identified offenders.

Table 2. Main waste in the flow of surgical patients – Hospital A

Wastes – Hospital A	
Waiting	- Delay in patient care, release, and transport - Delay of surgeons and anaesthesiologists - Delay for cleaning the rooms (setup) - Delay in releasing documents and processing information
Defect/Quality	- Wrong information in the agenda - Communication failure between sectors - Non-conforming material - Delay in the planned team
Overprocessing	- Rework due to the process of doctors in training (students) - Inappropriate use of trousseau

4.2 Value Stream Mapping – Hospital B

Hospital B has more than 100 years of history in the southeaster region of Brazil and has a total capacity of 300 beds, 1,400 employees and serves patients from different regions of the country in highly complex services. Figure 2 presents the Value Stream Mapping of the flow of surgical patients at hospital B.

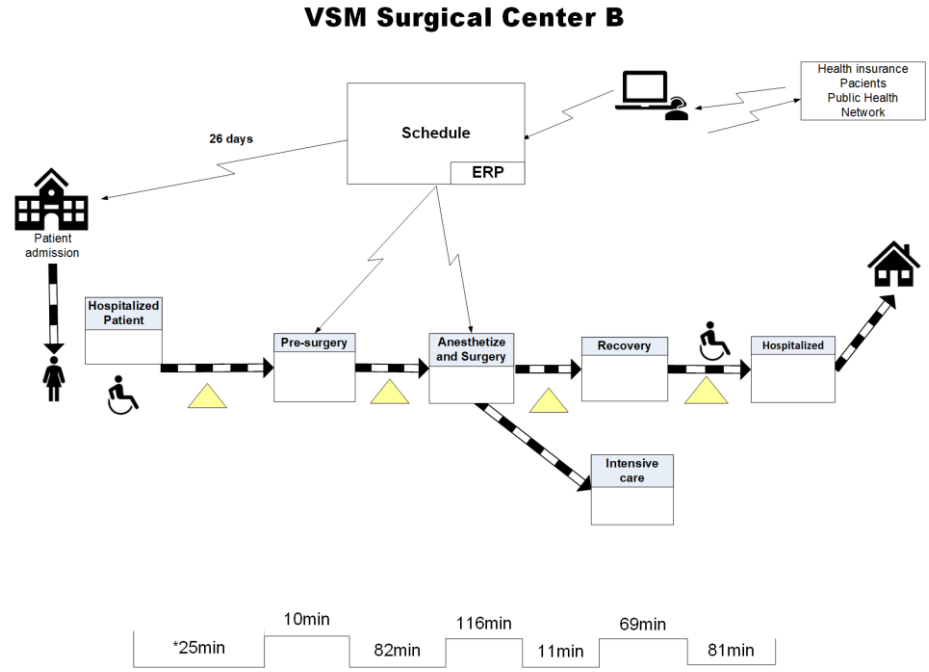

Fig. 2. Value Stream Mapping – Hospital B

Data from this VSM were collected from a sample of 98 patients in the system, with a margin of error of 5%. The Lead Time of the process from the time the patient enters the operating room to the release to the inpatient ward corresponds to approximately 394 minutes, and of these 49% of the activities performed add value to the patient. Activities that do not add value are characterized as waste in the flow, the main ones being detailed in the next topic. Table 3 shows the VA times and rates and NVA under the lead time.

Table 3. Main metrics collected VSM – Hospital B

	Minutes	Hours
Lead Time	394min	06:33
NVA	199min	03:18
VA	195min	03:15
%VA	**49%**	

Based on the times collected, it is noted that the wait between the anaesthesia and surgery process, and the wait for release to the hospital bed represent 41% of the lead time of this study.

As in Value Stream A for the identification of waste in value stream B, workshops were conducted with the project team to validate the current value stream as well as a brainstorming session to identify the main wastes, Table 4 below shows the main wastes found, which were like the first case: waiting, rework and inadequate processing representing almost 70% of all waste listed.

Table 4. Main waste in the flow of surgical patients – Hospital B

Wastes – Hospital B	
Waiting	- Delay in releasing the patient to bed - High setup time - Delay in delivery of materials
Defect/Quality	- Lack of patient identification - Wrong information in the system - Communication faille
Overprocessing	- Disorganization of documents - Lack of programming for the request of medicines and materials

4.3 Discussion and Framework Proposition

Based on the results found, it was possible to identify that in both cases the activities that do not add value correspond to approximately 50% of the time of a surgical flow with an average lead time of 6.8 hours and that the waste is mainly concentrated in waiting for the patient. patient and materials, low quality in processes and rework in routine activities. Another common point identified in the two flows is related to the waiting times to admit the patient for surgery as well as the time for release to the hospital bed, with great representation in the lead time.

In addition, it was identified that the gap of good scheduling of the agenda, delays of people and materials and errors in the flow of information can be the main causes of waiting and non-conformities in the studied process, in addition to a good organization of the space. physical for a good dynamism of the flow of people and materials. Thus, actions based on a well-defined agenda, alignment and communication between sectors and standardization of processes can collaborate to reduce waste and increase the efficiency of surgical centres. Thus, in the following table, a generic framework is proposed to guide lean actions in surgical flows according to the hospitals studied and based on the literature about Lean Healthcare implementation [13] [14] [15], presenting general objectives, actions for each category, main tools such as VSM and waste survey and average times raised in the project to guide future measurements and thus compare the value added of the surgical flow.

FRAMEWORK FOR LEAN SURGICAL FLOW IMPROVEMENTS		
Objective: reduce lead time and increase patient value addition		
Work Space	**End-to-end flow**	**Performance Management**
- Implement the 5s *- Develop Visual Management* *- Ensure necessary maintenance and infrastructure* *- Analyse work ergonomics and environment improvements for employees*	*- Reduce waits and delays* *- Standardize and balance times and operations* *- Standardize setup* *- Scaling the ideal number of employees* *- Structuring global patient flow planning* *- Develop the materials management process*	*- Parameterize efficiency, quality, and cost KPIs* *- Develop the ORE indicator as the main guide for efficiency* *- Establish continuous search for waste* *- Implement routine management and daily meetings*
Value Stream Mapping (VSM) **Lean waste survey** **ORE (Operating Room Effectiveness)**		
Key metrics for surgical VSM [average of cases studied] Lead time: 410,5 minutes [6,8 hours] NVA: 204,4 minutes [3,4 hours] VA: 206,1 minutes [3,4 hours] %VA: 50%		

Fig. 3. Framework proposed by the study.

The framework has three main pillars for the lean improvement of a surgical flow: physical space, end-to-end flow, and management by indicators. These pillars guide researchers and managers in the organization of the physical arrangement, visual management, maintenance, and ergonomics. In addition to guiding the visualization of the global flow (and not local) with the application of planning tools, balancing operations, setup, personnel sizing, materials management, as well as reducing waits in the process. And so, such implementations must be measured and analysed with a focus on efficiency and quality indicators and the establishment of routine management processes. These pillars are based on three main work tools: i) the VSM for mapping the flow and main metrics, ii) the survey of waste to visualize the main losses in the process and, iii) the ORE indicator as the main measurement and analytical basis to manage the surgical flow and support decision making.

Also, it is important to emphasize, as shown by the study's literature review [21], that hospitals should be culturally reshaped through structural changes, following new visions and strategic goals, supported by real models of structural and sustained continuous improvement. Thus, the proposal is that this framework is a structured model

of continuous improvement in surgical centres aligned with the strategic objectives of hospitals.

5 Conclusion

The pressure on hospital services has been increasing annually due to the aging of the population, inflation of costs related to the operation, among others, driving the search for operational efficiency, quality of care and value-based healthcare. Thus, a strategic area to leverage the operation would be the surgical centre, as it is a high-cost, high-demand unit, with great revenue opportunities and its relationship with other hospital flows. This study contributes to this issue by evaluating the surgical flow under the lean healthcare optimality, mainly using the tool called VSM for mapping the value stream. Besides that, there is a theoretical implication regarding to presenting empirical case of Lean Healthcare implementation.

From the case study in two Brazilian hospitals, it can be concluded that, on average, the patient's lead time from entering the hospital to undergo surgery until his discharge to the hospital bed is 6.8 hours. Since in this flow, only 50% of the activities add value to patients, raising several opportunities for improvement and evident losses such as waiting, delays, high setup, communication failures, physical disorganization, etc. Thus, studying such problems, main metrics and initiatives of the cases studied, a framework with the objective of reducing the patient's lead time and increasing its value addition was developed, proposing pillars of organization of the workspace, end-to-end vision flow and management of performance indicators.

As a suggestion for future research, it is proposed to increase the replication and comparative analysis of VSMs in other Brazilian and foreign hospitals to integrate and share more evidence of the flow, making the framework optimized. Another research suggestion would be to apply the framework in an exploratory project in a surgical centre of a philanthropic hospital with similar contexts to the case study to refine and evaluate the model.

References

1. Al-Zuheri, A., Vlachos, I., Amer, Y.: Application of lean six sigma to reduce patient waiting time: literature review. International Journal for Quality Research 15(1), 241–258 (2020).
2. Zepeda-Lugo, C. A., Tlapa, D., Baez-Lopez, Y. A., Limon-Romero, J., Ontiveros, S., Perez-Sanchez, A., Tortorella, G.L.: Assessing the Impact of Lean Healthcare on Inpatient Care: A Systematic Review 17 (15), 1-23 (2020).
3. Tlapa, D., Zepeda-Lugo, C. A., Tortorella, G.L., Baez-Lopez, Y. A., Limon-Romero, J., Alvarado-Iniesta, A., Rodriguez-Burbon, M. I.: Effects of Lean Healthcare on Patient Flow: A Systematic Review. Value in Health 23 (2), 260-273 (2020).
4. Souza T.A, Vaccaro, G.L.R, Lima, R.M. PSCPF: planning, scheduling and control of patient flow. Production. 2021;31(2009):1–14.).

5. Souza, T.A., Vaccaro, G.L.R., Lima, R.M.: Operating Room effectiveness: a lean healthcare performance indicator. International Journal of Lean Six Sigma 11(5), 973-988 (2020).
6. Cima, R.R., Brown, M.J., Hebl, J.R., Moore, R., Rogers, J.C., Kollengode, A., Team, S.P.I.: Use of lean and six sigma methodology to improve Operating Room efficiency in a high-volume zertiary-care academic medical center". Journal of the American College of Surgeons 213(1), 83-92 (2011).
7. Souza, T. A., Queiroz, G. A., Lima, R.M., Pimenta, L. V.: Application of the Operating Room Effectiveness indicator (ORE) in a Brazilian hospital. XXVI International Joint Conference on Industrial Engineering and Operations Management (IJCIEOM), (2020).
8. Reponen, E., Jokela, R., Blodgett, J. C., Rundall, T. G., Shortell, S. M., Nuutien, M., Skants, N., Makijarvi, M., Torkki, P.: Validation of the Lean Healthcare Implementation Self-Assessment Instrument (LHISI) in the fnnish healthcare contexto. BMC Health Services Research 21(1289), 1-9 (2021).
9. Souza, L. B.: Trends and approaches in lean healthcare. Leadership in Health Services 22(2), 121-139 (2009).
10. Costa, L. B. M., Godinho Filho, M. Lean healthcare: review, classification and analysis of literature, Production Planning & Control. (2016).
11. Pedroso, M. C., Corrêa, H. L.: Sistemas de Programação da Produção com capacidade finita: uma decisão estratégica? Revista de Administração de Empresas 36(4), 60-73 (1996).
12. Conill, E. M., Giovanella, L., Almeida, P. F.: Listas de espera em sistemas públicos: da expansão da oferta para um senso oportuno? Considerações a partir do Sistema Nacional de Saúde espanhol. Ciência e Saúde Coletiva 16(6), 2783-2794 (2011).
13. Marsilio, M., Pisarra, M., Rubio, K., Shortell, S.: Lean adoption, implementation, and outcomes in public hospitals: benchmarking the US and Italy health systems. BMC Health Services Research 22(122), 1-10 (2022).
14. Beers, J. C. V., Dun, D. H. V., Wilderon, C. P. M.: Effective hospital-wide lean implementation: top-down, bottom-up or through co-creative role modeling?. International Journal of Lean Six Sigma 13(1), 46-66 (2022).
15. Reponen, E., Rundall, T. G., Shortell, S. M., Blodgett, J. C., Juarez, A., Jokela, R., Makijarvi, M., Torkki, P.: Benchmarking outcomes on multiple contextual levels in lean healthcare: a systematic review, development of a conceptual framework, and a research agenda. BMC Health Services Research 21(161), 1-18 (2021).
16. Womack, J. P., Jones, D. T.: Lean thinking: banish waste and create wealth in your Corporation. Simon and Schuster, (2010).
17. Ruohoaho, U., Kokki, M., Hirvonen, J., Joukainen, S., Aaltomaa, S., Fraunberg, M., Leinonen, V., Reijula, J.: Value stream map assessment of the extended day: 23h surgery model. Intelligent Buildings International 12(1), 17-31 (2020).
18. Sales, M., Castro, R.: Value-based lean implementation in a surgical unit: the impact of the methodology. The TQM Journal 33(6), 1484-1501 (2021).
19. Yin, R. K.Case Study Research and Applications: Design and Methods. 6th ed. Vol. 1. Sage Publications; 2017. 108–110 p.
20. Cauchick-Miguel, P. A., Sousa, R.: O método do Estudo de Caso na Engenharia de Produção. In: Cauchick-Miguel, P. A. (coord.). Metodologia de pesquisa em engenharia de produção e gestão de operações. 3nd edn. Rio de Janeiro: Elsevier, Cap. 6, pp.131-147 (2018).
21. Lima, R.M., Dinis-Carvalho, J., Souza, T.A, Vieira E, Gonçalves B. Implementation of lean in health care environments: an update of systematic reviews. Int J Lean Six Sigma [Internet]. 2021 Mar 20;12(2):399–431. Available from: https://www.emerald.com/insight/content/doi/10.1108/IJLSS-07-2019-0074/full/html.