Simulation-based analysis of lean implementation in healthcare

Gabriela Aline Borges
Universidade Federal de Santa Catarina – Brazil

Guilherme Luz Tortorella
Universidade Federal de Santa Catarina – Brazil

Enzo Frazzon
Universidade Federal de Santa Catarina – Brazil

Felipe Martínez (felipe.martinez@vse.cz)
University of Economics, Prague – Czech Republic

Abstract

This paper aims to analyze the impact of lean practices implementation in the context of healthcare supply chain in Brazil. The paper develops a case study of a public school hospital. The research determines current value stream mapping and it proposes the future state after implementing lean practices. The simulation model uses these data to understand variability of lean practices adoption. Findings indicate that the simulation model provides a framework to support the decision-making process and it allows the verification of inventory policies. The simulation is primarily a decision support tool and does not directly seek optimum solutions.

Keywords: Lean practices, healthcare, simulation model.

Introduction

Healthcare is an important service industry given not only the criticality of quality and safety in delivering patient care, but also the associated cost involved (Dobrzykowski et al., 2014). Due to the large volumes of resources consumed, healthcare are under constant pressure to reduce costs, waiting times, errors, while improving services and patient safety (Aherne and Whelton, 2010; Waring and Bishop, 2010). An aggravating factor for the difficulty of management in healthcare is the fact that hospitals are among the most complex modern institutions (Plsek and Greenhalgh, 2001). In addition, Dooner (2014) also comments that the failure to use standardized processes implies wastage in health services.

Regarding the inherent processes to healthcare, those activities related to logistics are the most expensive ones, corresponding from 30 to 40% of the total expenditures (Aronsson et al., 2011). According to Schwarting et al. (2011), supply chain usually presents great opportunities for improvement within healthcare systems, both in term of costs reduction and quality of care increase. Among the existing improvement approaches in healthcare, the adaptation of concepts from manufacturing has been widely accepted, such as the implementation of practices and principles of Lean Production Systems (Womack et al., 2005; Brandao de Souza, 2009). However, Hasle et al. (2016) conclude that lean is useful for hospitals, but the lean concept as well as its implementation methods need to be fitted do the organizational complexity and diverging values in hospitals in order to bring about a larger impact. Moreover, studies show that most implementations fall far short from their goals because their fragmented development and lack of system-wide perspective (Radnor et al., 2012; Burgess and Radnor, 2013). McKone-Sweet et al. (2005) also reveal several barriers that inhibit the adoption of management practices, including lack of executive support and limited knowledge.

In this sense, before effectively implement changes, it is important to evaluate their impacts to ensure none alteration of the service level. According to Chung (2003), testing new concepts or systems before implementation and gaining information without disturbing the actual system are some of the purposes of simulation modelling and analysis. Moreover, simulation modelling has specific benefits. These include: experimentation in compressed time, reduced analytic requirements and easily demonstrated models. According to Hollocks (1992), as for manufacturing simulation has many benefits for healthcare applications such as reduction for changes to processes, cost and lead-time reduction, increased customer satisfaction and greater understanding of healthcare processes among their stakeholders.

In this context, this paper aims to analyse the impact of lean practices implementation in the context of healthcare supply chain using simulation models, within a developing economy, such as the Brazil. To achieve that, the research develops a case study at a Brazilian public school hospital. Specifically, it focuses on the consigned materials sector. First, the research develops the value stream mapping of the current state and then it proposes the future state implementing lean practices. After that, the research collects data during two months. The data relates with the main uncertainties sources within the value stream. The simulation model utilises these uncertainties. It aims to understand variability on the adoption of lean practices. Performance improvement of delivery service level and lead-time determine the assessment of analysis outcomes.

Literature review

Lean Healthcare Supply Chain

Lean practices implementation in healthcare context promotes a new way of thinking and a different organizational culture, requiring change and participation from everybody at all levels (Graban, 2016). Lean healthcare implies prioritizing patients, specifying what creates value from their perspective, removing wastes, and reducing processing times. (Womack et al., 2005). In addition, lean methods and practices lead to better performance in areas such as patient safety, quality, waiting times, cost, improved work environment, increased employee motivation, and improved inter-departmental communication (Waring and Bishop, 2010; Radnor et al. 2012).

In supply chain context, Tortorella et al. (2017) reviewed the literature to find the most common lean practices. Their study identified 27 lean practices implemented in supply chain context in manufacturing companies. However, when implementing in healthcare practices originating from manufacturing, adaptations might be needed (Fillingham, 2007). In this sense, Adebanjo et al. (2016) identified through previous studies 18 initiatives of lean practices in healthcare supply chain management. The reasons behind the different practices found in the literature can be due both to the novelty of lean in the sector or the complexity of these organizations. The lean philosophy is a more recent approach in the healthcare sector. However, process improvement in healthcare organizations possesses an inherent complexity given from environments with high dynamicity and specificity of professionals and patients (Shah et al., 2008).

Among the lean practices frequently implemented in healthcare, standardized work procedures is the most common ones, since it is considered simple and precursory to others (Shah et al., 2008; Kimsey, 2010; Farrokhi et al., 2013; Liu et al., 2015; Hasle et al., 2016; Costa et al., 2017). Furthermore, kanban (pull system) is another lean practice frequently implemented, as seen in Teichgräber e De Bucourt (2012), Papalexi et al. (2016) e Lim et al. (2017). Other initiatives such as visual management (Liu et al., 2016), RFID - Radio-Frequency Identification (Nabelsi and Gagnon, 2017), value chain analysis or value stream mapping (Kumar et al., 2008; Kimsey, 2010; Chiarini, 2013), inventory management system (Aguilar-Escobar and Garrido-Vega, 2013), among others, are less frequent.

A successful implementation of any specific management practice depends upon a set of organizational characteristics, therefore implying that not all organizations should implement the same set of tools (Pettersen, 2009). In this sense, there is not a fixed approach for success since organizations present different contextual variables and constraints (Bhasin, 2011). However, there is still a gap to be explored about lean practices in healthcare supply chain, since existing studies address few practices and focus on particular sectors (without addressing the whole chain).

Simulation approaches

Simulation-based techniques develops or evaluates complex systems (Frazzon et al., 2017b). Their applications have grown in all areas, supporting managers in the decision-making process and enabling a better understanding of processes in complex systems (Sakurada and Miyake, 2009). In addition, the simulated model is also a tool to analyze the response of systems under various scenarios (Sharma et al., 2007). Events-based simulation is a powerful tool to analyze the alternative system configuration (Sharma et al., 2007), and within the literature there are some examples of this tool being applied across a wide range of healthcare activities and issues (Doğan and Unutulmaz, 2016). Moreover, supply chain simulations are generally built as events-based simulation. Although there is only limited evidence of simulation and lean being used together within the healthcare literature (Robinson et al., 2012), Young et al., (2004) see simulation modelling as a means for determining the benefits of lean before implementation, in a healthcare context.

Simulation modelling can be used both as an analysis tool for predicting the effect of changes to existing systems and as a design tool to predict and evaluate the performance of new systems under varying sets of circumstances (Frazzon et al., 2017a). One of the main steps of a simulation study is the system modelling, and according to Robinsons (2004), conceptual modelling consists of the following subprocesses: (*i*) develop an understanding of the problem situation; (*ii*) determine the modelling objectives; (*iii*) design the conceptual model; (*iv*) collect and analyze the required data.

It is important to notice that this step consist of a process of creation and description of the problem with a certain degree of abstraction. Kelton et al. (2010), defines a model as an external and explicit representation of the reality. The difficulty in this step may lead to the need for a number of simplifications regarding the organization and operation of the real system (Frazzon et al., 2017b). Among the advantages of using simulation models, one can point out that it allows testing new concepts or systems before implementation and gaining information without disturbing the actual system (Chung, 2003).

Research method

The proposed methodological approach consists of a case study based on qualitative and quantitative data provided by the department leadership. In addition, further data are gathered from local visits and semi-structured interviews with leadership and employees from the sector in study. The following steps describes the research method for this paper,.

In step 1, we propose a literature review on lean healthcare supply chain and simulation approaches. Such review enables the identification of existing research gaps and opportunities, and cites how simulation modelling can be useful in the decision-making process of lean implementation.

Step 2 consists of selecting an appropriate healthcare organization for carrying out the implementation study. The area or sector is also determined in this step. This step also includes the creation of an improvement team. This team includes employees' knowledgeable and a team leader with experience in lean and its tools. This step contributes with the understanding of the sector's processes.

Step 3 consists of the value stream mapping, which is composed of four steps: (*i*) the selection of a product/service family; (*ii*) current state map is drawn; (*iii*) future state map is drawn; and (*iv*) an implementation plan for reaching the desired future state is prepared. The current state map enables the assessment of process operations with respect to the waste, and it is important to search for performance improvement opportunities in the future state. Designing the future state allows the clear definition of improvement opportunities that lead to waste elimination, iterative improvement, and sustained benefits.

Step 4 involves the simulation modelling, problem definition, project planning, system definition, conceptual model formulation, and data collection. Then follows to experiments designing, experiments running, results analysis and interpretation, and finally realization and documentation of the results (Kelton et al., 2010; Doğan and Unutulmaz, 2016).

Case Study

To understand the many layers of complexity frequently associated with supply chains, the approach requires problem definition by understanding the flows across organizational interfaces; which can include materials, cash, information, and patients (in the case of healthcare) (Böhme et al., 2014). Problem definition is also based on the degree of control afforded by the organizations' value-added process as it places orders on its suppliers and responds to demands (patient/clinician needs). In practice, supplies management within a hospital setting may be concerned with managing the entire internal/external supply chain (including manufacturers, vendors, and distributors) or it may be confined to one or more value streams (supplies in wards, operating theatres, and medical supplies stores) (Shih et al., 2009; Bhakoo and Chan, 2011; Böhme et al., 2014).

In this study, the internal chain will be investigated and the focus will be especially on the stock policies implementation, in order to analyze the impact of this implementation mainly on delivery service level and lead-time. Specifically, the paper analyzes the consigned materials sector of a public University hospital in the south of Brazil. In order to better understand the sector's processes, an improvement team, including employees' knowledgeable and a team leader with experience in lean and its tools, was put together to draw the current state map. The current state map enables the assessment of process and the identification of waste (either in material of information flows), which is very important on searching for performance improvement opportunities in the future state. After assessing the current state and the improvement opportunities, it was possible to draw the future state map. According to Womack and Jones (1997), designing the future state allows the clear definition of improvement opportunities that lead to waste elimination, iterative improvement, and sustained benefits. To complete the drawing of both maps, three 3-hour meetings were carried out. It is important to notice that data collected to draw the value stream map are based on samples available at the time of the mapping and therefore do not reflect the variations over time in this flow.

Figure 1 depicts the current state map, displaying materials and information flow; some information emerged from its analysis, as follows.

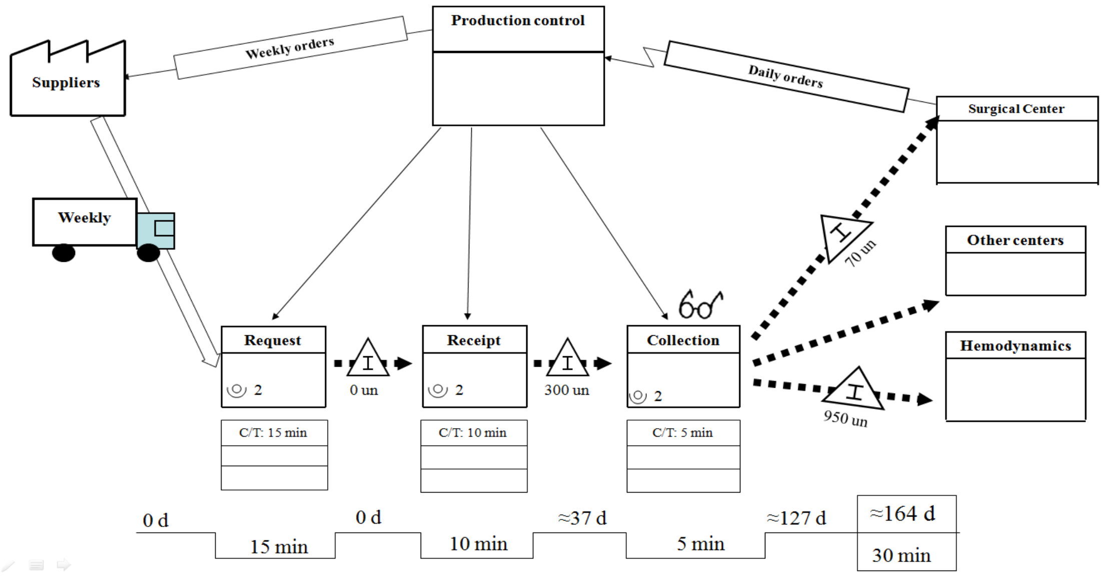

Figure 1-Current state map

The consigned materials sector manages approximately 300 different materials. Currently, the sector does not have a systematic stock policy. The material replacement task is done on employees' experience basis, and so there is no standardized work procedure. The consigned materials sector provides materials to other sectors, such as hemodynamics and surgical center, and the customers' demand are received in different ways, such as e-mail, random telephone calls and physically (information flow from customers is not standardized). In addition, there are materials stocked in some of the customers and both do not have a systematic stock policy. Three programming points exist throughout the value stream: on request, on receipt and on collection. The average lead-time is approximately 164 days. After assessing the improvement opportunities, the future state map presented in Figure 2 was drew.

Some assumptions were set before drawing the future state map. First, a six-month implementation horizon was targeted for the future state map, so the team members could work on the proposed improvements without losing focus of daily activities. Second, improvement ideas that demanded capital expenditure should be limited, since the study was carried out in a public hospital with a limited budget. Thus, future state analysis focused on improving management and delivery through simplification of internal processes and standardization of procedures. In this sense, some improvement opportunities were elicited towards the desired future state; they are displayed as kaizen bursts in Figure 2.

Among the opportunities, adoption of visual systems for material and inventory control, standardization of demand information flow from customers, and simplification/elimination of some tasks and bureaucracies (non-value added activities) can be immediately implemented, since these do not affect the sector's delivery service level. However, implementation of kanban, inventory policies and inventory sizing along the value stream based on historical data and processing times require more attention, since this may affect both delivery service level and lead-time. In this sense, the performance level of this scenario will be measured using simulation modeling and the simulation will provide evidence to support decision process.

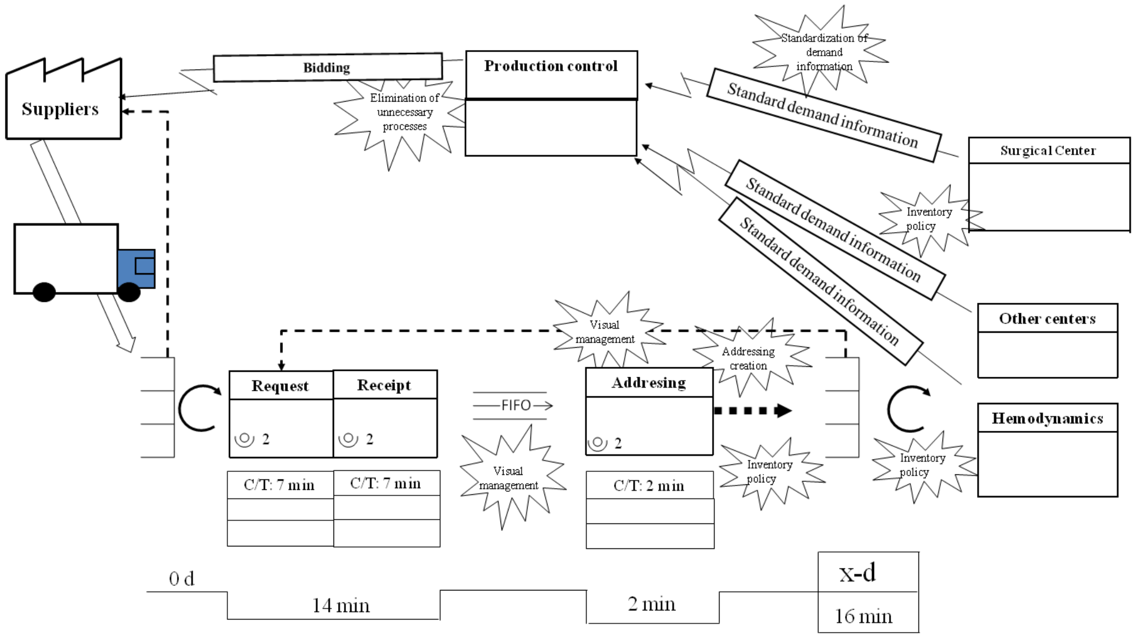

Figure 2 - Future state map

Test case

Test case presentation

We have implemented our simulation model using AnyLogic by AnyLogic Company. The model is based on the proposed by Ivanov (2016), which consists on the evaluation of the continuous review inventory control policies and performance measurement of the policies. The model consists of events-based simulation, with stochastic demand, supplier lead-time variation, fixed re-order points, and fixed order quantity. The ABC materials classification was applied, and the most important reason for this is that in most practical situations the number of inventory items is too large to implement a specific inventory control system for each item (Ernst and Cohen, 1990).

Two-months of data collection were performed to obtain the demand probability distributions. The demand probability distributions for 'A' and 'B' materials were obtained from Easyfit® software, and for 'C' materials it was obtained from Custom Distribution with the help of AnyLogic. The supplier lead-time variation was obtained on employees' experience basis. Other parameters were established based on historical data, standard deviations and on employees' experience. Table 1 summarizes the data inserted in the simulation model.

As the proposed inventory management strategy considers the ABC classification of materials (based on demand historical data), the management strategy was applied for each material classification. Initially, the stock is full. When the model starts running, materials start being collected from stock (according to ABC materials demand). In the moment the inventory level reaches the re-order point, a replenishment order is generated and a new order arrives in x-days, defined in supplier lead-time parameter.

Table 1 - Data inserted in the simulation model

	Probability distributions	Re-order point	Order Quantity	Initial Inventory Level
A-type materials	geometric (0.14497)	455	327	864
B-type materials	poisson (0.95724)	129	82	249
C-type materials	-	10	84	94
Supplier lead-time	triangular (3, 7, 5)	-	-	-

Results and analysis

Regarding the simulation results, our analysis comprised 365 days of simulation. For the inventory policy proposed, delivery service level was 100 per cent. A conservative policy was considered, with 99 per cent of confidence. Nevertheless, the average lead-time after improvement implementations was 142 days (a reduction of 13 per cent). Figures 3, 4 and 5 show the simulation results.

Even with a conservative policy, A-type materials have to be controlled tightly and monitored closely due to higher demand. However, it is noteworthy that a fixed lot size creates some stability in the process, since at least the quantity remains the same between orderings, even though the time between orders may vary (Olhager and Persson, 2006). Moreover, the results indicate that a less conservative inventory policy might be possible, especially for C-type materials, due to low demand presented. However, it is important to notice that the ABC materials classification is a significant simplification, and may not be able to provide a good classification of inventory items. To create a higher fidelity model would require a greater level of detail and more accurate data.

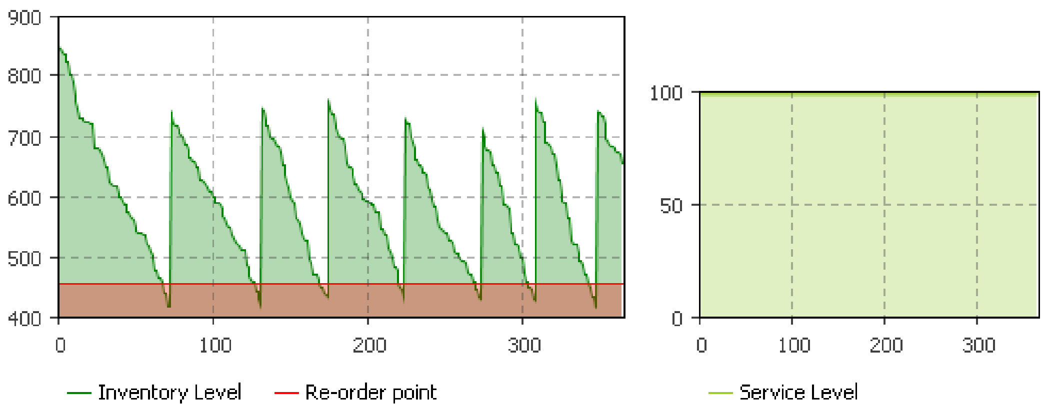

Figure 1 - Simulation results for A-type materials

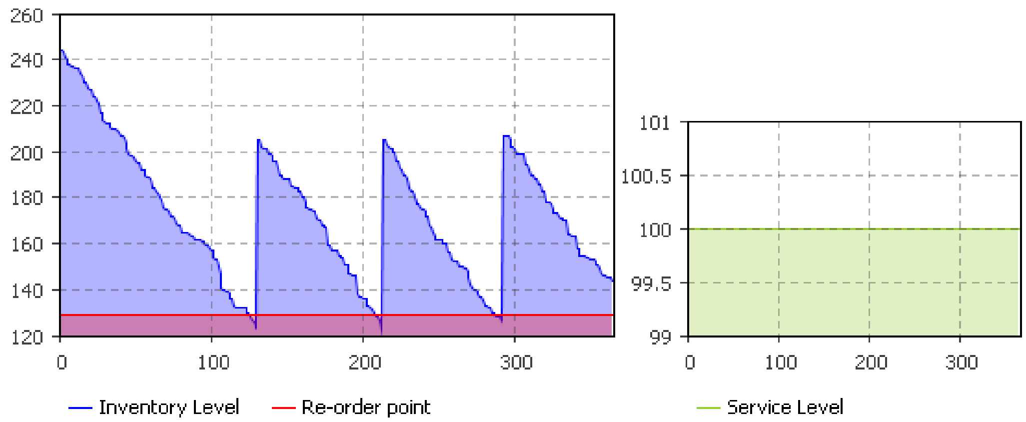

Figure 4 - Simulation results for B-type materials

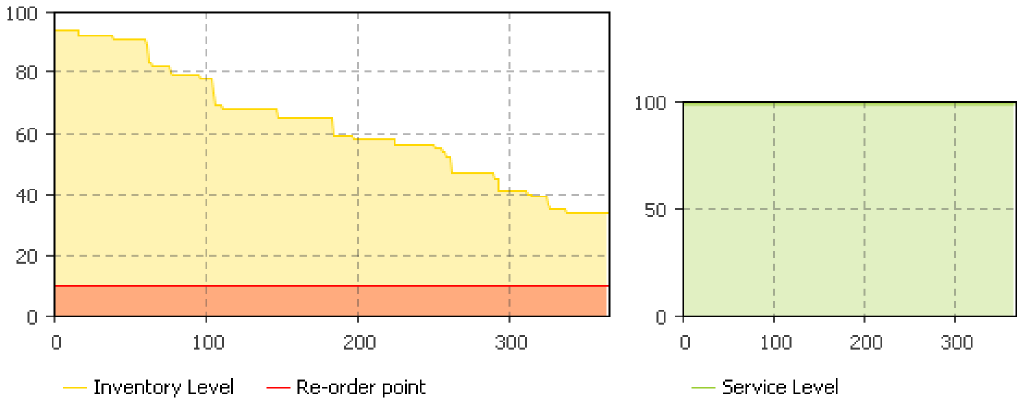

Figure 5 - Simulation results for C-type materials

Conclusions

This study contributes to the body of literature on lean healthcare supply chain by proposing a simulation-based model that analyzes the impact of lean practices implementation mainly on delivery service level and lead-time. The proposed research method refers to the steps to be applied and conducted during lean implementation taking into account key uncertainties sources within the value stream of the assessed system. In addition, the adoption of traditional manufacturing production management practices in a public healthcare organization may characterize an important contribution to the area.

Our study has shown how a healthcare organization can benefit from lean practices by evaluating its current state and understanding its potential for improvement. During the improvement process, insights grow, paradigms are shifted, and consensus is built. In addition, the research method and the proposed improvement opportunities have practical contributions, as it may help practitioners to solve real life problems related to the implementation of lean in public healthcare organizations. The findings of this study provide guidance to decision/policy-makers of healthcare sector for improving the quality and efficiency of the health service delivery. For the healthcare organization under study, delivery service level and lead-time were used as performance indicators and both indicated that the improvements proposed contribute to increase healthcare efficiency. For other organizations, especially those sharing a similar context, the approach here proposed is a source of lean initiatives implementation. However, it is worth to notice that, depending on the target value stream to be improved, further adaptations might be needed.

References

Adebanjo, D., Laosirihongthong, T., & Samaranayake, P. (2016). Prioritizing lean supply chain management initiatives in healthcare service operations: a fuzzy AHP approach. Production Planning & Control, 27(12), 953-966.

Aguilar-Escobar, V. G., & Garrido-Vega, P. (2013). Lean logistics management in healthcare: a case study. Revista de calidad asistencial: organo de la Sociedad Espanola de Calidad Asistencial, 28(1), 42-49.

Aherne, J., & Whelton, J. (Eds.). (2010). Applying lean in healthcare: a collection of international case studies. CRC Press.

Aronsson, H., Abrahamsson, M., & Spens, K. (2011). Developing lean and agile health care supply chains. Supply chain management: An international journal, 16(3), 176-183.

Bhakoo, V., & Chan, C. (2011). Collaborative implementation of e-business processes within the health-care supply chain: the Monash Pharmacy Project. Supply Chain Management: An International Journal, 16(3), 184-193.

Bhasin, S. (2011). Performance of organisations treating lean as an ideology. Business Process Management Journal, 17(6), 986-1011.

Böhme, T., Williams, S., Childerhouse, P., Deakins, E., & Towill, D. (2014). Squaring the circle of healthcare supplies. Journal of health organization and management, 28(2), 247-265.
Brandao de Souza, L. (2009). Trends and approaches in lean healthcare. Leadership in health services, 22(2), 121-139.
Burgess, N., & Radnor, Z. (2013). Evaluating Lean in healthcare. International journal of health care quality assurance, 26(3), 220-235.
Chiarini, A. (2013). Waste savings in patient transportation inside large hospitals using lean thinking tools and logistic solutions. Leadership in Health Services, 26(4), 356-367.
Chung, C. A. (Ed.). (2003). Simulation modeling handbook: a practical approach. CRC press.
Costa, L. B. M., Rentes, A. F., Bertani, T. M., & Mardegan, R. (2017). Lean healthcare in developing countries: evidence from Brazilian hospitals. The International journal of health planning and management, 32(1).
Dobrzykowski, D., Deilami, V. S., Hong, P., & Kim, S. C. (2014). A structured analysis of operations and supply chain management research in healthcare (1982–2011). International Journal of Production Economics, 147, 514-530.
Doğan, N. Ö., & Unutulmaz, O. (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 & Business Excellence, 27(1-2), 64-80.
Dooner, R. (2014). How supply chain management can help to control health-care costs. CSCMP's Supply Chain Quarterly, 8(3).
Ernst, R., & Cohen, M. A. (1990). Operations related groups (ORGs): a clustering procedure for production/inventory systems. Journal of Operations Management, 9(4), 574-598.
Farrokhi, F. R., Gunther, M., Williams, B., & Blackmore, C. C. (2013). Application of lean methodology for improved quality and efficiency in operating room instrument availability. Journal for Healthcare Quality.
Fillingham, D. (2007). Can lean save lives?. Leadership in health services, 20(4), 231-241.
Graban, M. (2016). Lean hospitals: improving quality, patient safety, and employee engagement. CRC press.
Frazzon, E., Holtz, T., Silva, L., et al. (2017a). Simulation-Based Analysis of Intelligent Maintenance Systems and Spare Parts Supply Chains Integration. Journal of Intelligent Systems, 0(0), pp. -. Retrieved 5 Feb. 2018.
Frazzon E., Tortorella G.L., Dávalos R., Holtz T., Coelho L., (2017b) "Simulation-based analysis of a supplier-manufacturer relationship in lean supply chains", International Journal of Lean Six Sigma, Vol. 8 Issue: 3, pp.262-274.
Hasle, P., Nielsen, A. P., & Edwards, K. (2016). Application of lean manufacturing in hospitals—The need to consider maturity, complexity, and the value concept. Human Factors and Ergonomics in Manufacturing & Service Industries, 26(4), 430-442.
Hollocks, B. (1992). A well-kept secret? Simulation in manufacturing industry reviewed. OR Insight 5 (4), 12–17.
Ivanov, D. (2016). Operations and supply chain simulation with AnyLogic 7.2. D Ivanov.–2016.–97 p.
Kelton, D., Sadowski, D. and Sadowski, R. (2010), Simulation With ARENA, McGraw-Hill, New York, NY.
Kimsey, D. B. (2010). Lean methodology in health care. AORN journal, 92(1), 53-60.
Kumar, A., Ozdamar, L., & Ning Zhang, C. (2008). Supply chain redesign in the healthcare industry of Singapore. Supply Chain Management: An International Journal, 13(2), 95-103.
Lim, J., Norman, B. A., & Rajgopal, J. (2017). Process Redesign and Simplified Policies for More Effective Vaccine Inventory Management. Engineering Management Journal, 29(1), 17-25.
Liu, M. (2015). Optimal scheduling of logistical support for medical resources order and shipment in community health service centers. Journal of Industrial Engineering and Management, 8(5), 1362.
Liu, T., Shen, A., Hu, X., Tong, G., Gu, W., & Yang, S. (2016). SPD-based Logistics Management Model of Medical Consumables in Hospitals. Iranian Journal of Public Health, 45(10), 1288–1299.
McKone-Sweet, K. E., Hamilton, P., & Willis, S. B. (2005). The ailing healthcare supply chain: a prescription for change. Journal of Supply Chain Management, 41(1), 4-17.
Nabelsi, V., & Gagnon, S. (2017). Information technology strategy for a patient-oriented, lean, and agile integration of hospital pharmacy and medical equipment supply chains. International Journal of Production Research, 55(14), 3929-3945.
Olhager, J., & Persson, F. (2006). Simulating production and inventory control systems: a learning approach to operational excellence. Production Planning & Control, 17(2), 113-127.

Papalexi, M., Bamford, D., & Dehe, B. (2016). A case study of kanban implementation within the pharmaceutical supply chain. International Journal of Logistics Research and Applications, 19(4), 239-255.
Pettersen, J. (2009). Defining lean production: some conceptual and practical issues. The TQM Journal, 21(2), 127-142.
Plsek, P., & Greenhalgh, T. (2001). The challenge of complexity in health care: an introduction. BMJ, 323(7314), 625-628.
Radnor, Z. J., Holweg, M., & Waring, J. (2012). Lean in healthcare: the unfilled promise?. Social science & medicine, 74(3), 364-371.
Rivard-Royer, H., Landry, S., & Beaulieu, M. (2002). Hybrid stockless: A case study: Lessons for health-care supply chain integration. International Journal of Operations & Production Management, 22(4), 412-424.
Robinson, S., Radnor, Z. J., Burgess, N., & Worthington, C. (2012). SimLean: Utilising simulation in the implementation of lean in healthcare. European Journal of Operational Research, 219(1), 188-197.
Robinson, S. (2004). Simulation: the practice of model development and use (p. 336). Chichester: Wiley.
Sakurada, N. and Miyake, D. (2009), "Aplicação de simuladores de eventos discretos no processo de modelagem de sistemas de operações de serviços", Gestão & Produção, Vol. 16 No. 1, pp. 25-43.
Schwarting, D., Bitar, J., Arya, Y., & Pfeiffer, T. (2011). The transformative hospital supply chain: Balancing costs with quality. Booz & Company.
Shah, R., Goldstein, S. M., Unger, B. T., & Henry, T. D. (2008). Explaining anomalous high performance in a health care supply chain. Decision Sciences, 39(4), 759-789.
Sharma V., Abel J., Al-Hussein M., Lennerts K., Pfründer U., (2007) "Simulation application for resource allocation in facility management processes in hospitals", Facilities, Vol. 25 Issue: 13/14, pp.493-506.
Shih, S. C., Rivers, P. A., & Hsu, H. S. (2009). Strategic information technology alliances for effective health-care supply chain management. Health services management research, 22(3), 140-150.
Teichgräber, U. K., & de Bucourt, M. (2012). Applying value stream mapping techniques to eliminate non-value-added waste for the procurement of endovascular stents. European journal of radiology, 81(1), e47-e52.
Tortorella, G. L., Miorando, R., & Tlapa, D. (2017). Implementation of lean supply chain: an empirical research on the effect of context. The TQM Journal, 29(4), 610-623.
Waring, J. J., & Bishop, S. (2010). Lean healthcare: rhetoric, ritual and resistance. Social science & medicine, 71(7), 1332-1340.
Womack, J. P., Byrne, A. P., Fiume, O. J., Kaplan, G. S., & Toussaint, J. (2005). Going lean in health care. Cambridge, MA: Institute for Healthcare Improvement.
Womack, J. P., & Jones, D. T. (1997). Lean thinking—banish waste and create wealth in your corporation. Journal of the Operational Research Society, 48(11), 1148-1148.
Young, T., Brailsford, S., Connell, C., Davies, R., Harper, P., & Klein, J. H. (2004). Using industrial processes to improve patient care. BMJ: British Medical Journal, 328(7432), 162.