LEAN HEALTHCARE: AN APPROACH TO OPTIMIZING PHARMACEUTICAL STOCKS IN A PUBLIC HOSPITAL

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Abstract

Background: Lean healthcare methodology has been applied in healthcare institutions to process management and waste reduction, focusing on reviewing processes based on three organizational principles: patient, time and value. The current research sought to explore optimization opportunities in the management of pharmaceutical stocks in a Brazilian public hospital through the utilisation of a lean healthcare approach. Methodology: Firstly, the sector as well as the dynamics that compose the processes within the organization were studied, which led to the elaboration of a set of value flow mappings to identify the main sources of system waste and the respective improvements demanded. Once the main sources of waste were identified, a multi-criteria decision model was developed to prioritize action plans for their elimination or reduction. Results: As a result, improvements were proposed to address the main system needs, directing the organization towards a more assertive and efficient optimization process. The multi-criteria model supported the decision maker with the ordering of action plans to be implemented according to the sector conditions and needs. The action of setting specific units for the sourcing of each type of supply was classified as a priority, as the value stream map (VSM) carried out identified several units supplying the same stock items, bringing inconsistency in the stock value. Conclusion: It was possible to detect the singularities involved in the processes of lean approach implementations in hospital systems, displaying its optimization potential for complex systems, at the same time that it presents alternatives to eliminate waste and reduce supply disruptions and storage costs. Ethic statement: Not applicable
• **Results:** As a result, improvements were proposed to address the main system needs, directing the organization towards a more assertive and efficient optimization process. The multi-criteria model supported the decision maker with the ordering of action plans to be implemented according to the sector conditions and needs. The action of setting specific units for the sourcing of each type of supply was classified as a priority, as the value stream map (VSM) carried out identified several units supplying the same stock items, bringing inconsistency in the stock value.

• **Conclusion:** It was possible to detect the singularities involved in the processes of lean approach implementations in hospital systems, displaying its optimization potential for complex systems, at the same time that it presents alternatives to eliminate waste and reduce supply disruptions and storage costs.

• **Ethic statement:** Not applicable

**KEYWORDS**
Supplies distribution; Hospital; Logistics; Multi-criteria Decision Analysis; Lean Healthcare.

**HIGHLIGHTS**
- The relevancy of applying Lean principles can be seen in view of complexity of hospital context.
- The process mapping was verified as crucial to better understand the supplies distribution system.
- The Multi-criteria decision analysis proved to be an efficient tool to support decision-making in management of projects.
- The FITradeoff method for multi-criteria decision analysis improved the decision-making process, making it more structured and assertive.

**ACKNOWLEDGEMENTS**
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**BACKGROUND**
When studying the Toyota Production System-TPS, origin of the Lean philosophy, Womack and Jones (1992) observed five principles that can represent it: (i) Value - defined by the end customer; (ii) Value chain - the processes necessary to add value to the product; (iii) Flow - continuous sequence of steps to create value; (iv) Pull production - production on demand only; and (v) Perfection - seeking constant improvement. It is considered that these principles should be applied as a strategy for any type of organization, aimed at improving the system’s processes.

Shingo (1996) observes that the TPS has the ability to track waste that is normally not identified because it is already considered intrinsic to daily work. Thus, the author considers that waste is any activity that does not contribute to the production process, constituting operations that do not add value. On the other hand, operations that add value are capable of actually transforming raw materials into components or products, in order to demonstrate their efficiency.

There are seven types of waste presented by Ohno (1997) that can interfere and reduce the productive capacity in any industry, namely: (i) overproduction; (ii) waiting; (iii) overprocessing; (iv) inventory; (v) transport; (vi) motion; and (vii) defects. The complete elimination of waste, according to Shingo (1996), represents the basic TPS cost minimization principle, which enables production on demand due to high variability.

According to Dombrowsky and Malorny (2018), the implementation of Lean Manufacturing enables organizations to be dedicated to activities that increase the added value of their product to the customer whilst avoiding waste in their processes. Thus, a successful implementation also enables processes to be carried out in a more reliable, agile manner, in line with customer demand and with more transparency in the market, thus improving performance indicators related to quality, time and costs.
Lean thinking has been tried and developed in several segments, especially on healthcare, known as lean healthcare (REGATTIERI et al., 2018; LINDHOLM et al., 2018; CROMWELL et al., 2018; MAZUR et al., 2019; GAO E GURD, 2019; CASTRO et al., 2020; ROSA et al., 2021). However, it is clear that there is still room for further investigation, especially for studies that seek a holistic perspective on the integration of agents and sectors involved in the health system (MAHMOUD et al., 2021).

Costa et al. (2017) argues that the application of lean techniques in healthcare evolves quality of service, patient safety, cost reduction, waiting time reduction, and period of hospital stay. In order to understand the relationship between patient safety, financial performance and the application of lean healthcare, Dobrzykowski et al. (2016) argued that the complexity of hospital systems highlights the role of integration between different sectors, as well as between professionals, leaving room for positive interferences of the lean approach to organizational performance.

In healthcare systems, supplies delivery to the point of use is submitted to a series of steps in highly complex flows, in which there are usually fragmented flows that are conducive of waste. Given that each medical item can be considered critical and indispensable at the time it is requested, the hospital inventory and supply management system is one of the most important of health systems. Its efficiency not only helps to reduce system costs, but also ensures service quality and safety (XU et al., 2011).

According to Bharsakade et al. (2021), health care systems must be improved not only in the quality of service, but also in multiple objectives, such as costs, time, use of resources and efficiency of methods. Thus, it is common to come across different alternatives of tools, procedures or improvements to be used, which may require prioritization for an implementation aligned with the different demands and conditions in which they will be inserted.

Such situations, in which there is a need to choose between two or more alternatives due to goals that are often in conflict with one another, can be understood as multicriteria decision problems (DE ALMEIDA, 2016). Thus, decision models based on multicriteria decision analysis can be understood as relevant alternatives to support the decision-making process within healthcare (FRAZÃO et al. 2018; FRAZÃO et al. 2021).

Therefore, the current study seeks to explore, based on a lean healthcare approach, opportunities to optimize the supply management process in the pharmaceutical sector of a public hospital in Brazil.

### METHODOLOGY

The current research methodology focused on the knowledge of the distribution flows of pharmaceutical stocks, being preceded by the study of storage and stock management systems. The following points were observed and recorded: (i) The sequential steps that supplies go through until they reach their points of use; (ii) The professionals involved; (iii) the procedures performed; and (iv) the temporal variables. Furthermore, conducting unstructured interviews made it possible to collect the necessary data to support the understanding of the pharmaceutical units and construction of flow mappings.

The value stream mapping – VSM was utilised as a lean approach, to identify the stages of distribution of pharmaceutical supplies from the hospital’s central supply unit to the satellite units, allowing for a better view of inventory management, enabling the identification of problems in the supply flow before their last storage points.

The VSM model utilised for this work was based on the studies by Rother and Shook (2003) and Henrique et al. (2016), adjusting their propositions to better fit the current context. Thus, the VSM was carried out as a way of studying the sequencing of activities involved in the distribution of supplies from the central warehouse, through which it was possible to identify sources of waste and opportunities for improvement.

A model based on multicriteria decision analysis was developed, based on the framework proposed by de Almeida et al. (2015), in order to support the prioritization of improvements to be implemented in the system. Thus, the development of the model was carried out through an approach of successive refinements in three stages: (i) preliminary phase; (ii) preference modelling and method choice; and (iii) completion.
The preliminary phase sought an adequate understanding of the problem in order to correctly structure the decision model; whilst in the preference modelling and method choice stage, the factors directly related to the setting of the multicriteria method to be used in the model were structured.

Given the specificities of the studied problem, the application of the FITradeoff method presented by Frej et al. (2019) was deemed adequate due to the compensatory rationality of the decision problem, the need to adopt an approach based on partial information, and the decision maker’s preference relations, which could incorporate relations of preference as well as indifference when relating two consequences associated with the problem.

Lastly, during the finalization stage of the proposed model, the steps that enabled the resolution of the problem in question and the presentation of the recommended actions were developed.

CASE STUDY

The Hospital in which the current research was carried out is a university hospital in Brazil, with a total area of 31,000 m² and 242 beds, with 19 destined for ICU, 84 outpatient clinics; 12 operating rooms, 7 of which are allocated in the surgery centre, 2 in ophthalmology and 3 for minor surgeries. The pharmaceutical supply sector manages approximately 1500 different items, of which 1000 are considered hospital medical supplies and 500 are medicines. On these items, there was a monthly average of approximately R$7,000,000.00 in stock of materials and medicines from the year 2018 to the month of June 2020, in which a monetary value of approximately R$9,000,000.00 was recorded in stock.

On analysing the internal distribution system, it was possible to distinguish two types of storage units: the ones whose main purpose is to mediate the transfer of stocks, and the sectorial service units, which focus on the supplies needed for the specialties of the sector in which they operate.

RESULTS

The internal supply distribution flow occurs as a function of the supply categories from the Pharmaceutical Supply Unit - PSU, being then directed to one of the other three stock transfer units or directly to sectorial service units. It is important to note that the Central Pharmacy is mainly dedicated to the distribution of medications; the Pharmacotechnical Unit, dedicated to the distribution of antiseptics and sanitizers; and the satellite unit of the Hospitalization Centre - HC is dedicated to the distribution of materials in small volumes. Sectoral care units refer to the Surgical Centre, Ophthalmic Surgical Centre, Diagnostic Imaging Centre and Intensive Care Unit - ICU. Figure 1 summarizes the system flows.

Figure 1: The system flow of supply distribution
According to their demands, the sectorial service units can carry out their supply requisitions for one or more of the stock transfer units. Thus, the pharmaceutical units use the ”AGHU System” as the standard electronic system for supplies requisition and control, except when liaising with the Pharmacotechnical Unit, which uses the ”MV System”, due to their fractionation needs.

As for the procedures for requisitioning, controlling and distributing supplies, each unit’s functioning differs in several aspects, corresponding to their respective objectives and demands. Hence, a more detailed investigation about the characteristics and functioning of each unit is considered ideal in order to map the internal supply distribution flow and identify opportunities for improvement.

* Sanitizing and antiseptic mapping

The pharmacotechnical unit is the main intermediary for the distribution of antiseptics and sanitizers, due to the fact that the volumes need to be fractionated. The unite performs the distribution of sanitizers and antiseptics in a distinct routine compared the other supplies’ flows, focusing on the daily demands of the pharmaceutical units and the various hospital sectors, so that it does not carry out stock transfers through electronic systems. The flow of sanitizers and antiseptics is described in Figure 2.

Figure 2 : Mapping of the distribution flow of sanitizers and antiseptics
It is possible to note on Figure 2 that the flow comprises a cycle time of 44.8 days and a processing time of 3.94 hours, including the procedures performed by the PSU as well as the pharmacotechnician for the materials formulation, which is a specific procedure of this unit.

Regarding the possibility of waste along the flow, it was found that although the use of the MV electronic system allows a more adequate recording and control of the fractioned volumes of supplies; its utilization makes necessary for the pharmacotechnical unit to manage two electronic systems concurrently, given that the requisition of supplies to the PSU is still made by the AGHU system.

Furthermore, it is perceived that the order printing operation to separate the requested items can represent a waste by processing, as it could be supplied by the use of electronic equipment, also avoiding the generation of physical documents to be later stored.

**Drug flow mapping**

The drug distribution flow has ramifications that determines the unique nature of pharmaceutical units, demonstrating that the flow tends to follow alternative paths according to the drug classifications. Although the current research adopted the representation of only one general category for drugs, it should be emphasized that the units mainly distinguish drugs as being of low and high cost. High-cost medications are distributed mainly by the PSU, directly to the sector service units. Low-cost medications are distributed by the central pharmacy, in terms of nominal prescriptions to patients or in stock transfers. For the mapping process, only distributions in stock transfer were taken into account. Although the supplies related to sodium chloride are considered medicines, they were not considered in the current flow, being considered alongside materials. This is due to the volume characteristics of serums, which make their flow more similar to that of materials than medicines. The more detailed mapping containing the procedures involved in drug distribution is shown in Figure 3.

**Figure 3 : Mapping of the drug distribution flow**

The drug flow from the PSU to the requesting units comprised a cycle time of 9.1 days and a processing time of 2.42 hours. Although the units serve units in common, it is clear that the flow is distinctly divided between the supply of high and low-cost medications, without crossovers.

With regards to the procedures adopted by the central pharmacy unit in preparing stock transfer orders, as well as in pharmaceuticals, printing the list of orders to be sorted is seen as a step that does not add value to the supply distribution process. Moreover,
Moreover, it seems that the unit does not rigorously check the drugs received and does not adopt a signed document return system after the delivery of supplies, so that it becomes more susceptible to failures, not practicing a more consistent record of deliveries, which could strengthen control of the distribution of supplies.

Also, the unit adopts, as a first procedure for placing orders, only a visual check of the shelves, in order to establish an estimate of what is in stock and what should be ordered. It is possible to affirm that requesting by visual inspection does not reliably establish the quantity of supply in inventory, nor the ideal order quantity, which can hide excess stock or make a standard procedure in the ordering routine more difficult and imprecise.

**Material Flow Mapping**

Material distribution encompasses three of the four stock transfer units, the PSU, the HC’s pharmacy and the central pharmacy. The PSU is mainly intended for the distribution of high-volume or high-cost materials. On the other hand, low cost materials and low volume materials can be distributed either by the central pharmacy or by the HC pharmacy.

Throughout the interviews, it was reported that the central pharmacy was built in order to meet the demand for materials from the different hospital sectors, mainly due to the lack of storage space in the central pharmacy. However, it is observed that all sector service units still receive materials from the central pharmacy, with the exception of the HC unit. Figure 4 demonstrates the procedures involved in this specific flow.

Figure 4: Mapping of the distribution flow of materials and serums

Source: Elaborated by the authors (2021)

The mapping shown in Figure 4 describes the flow of materials and serums from the PSU exit to their arrival at the requesting units, passing through the central pharmacy and the HC pharmacy. This stream comprises a cycle time of 27.5 days and a processing time of 2.42 hours. Regarding processing times, there is the possibility of extending it due to rework, generated by the lack of supplies in the intermediary units, given that some materials are supplied by both units and that there is incompatibility between the inventory numbers in the electronic system and in the physical inventory, which makes it difficult for the requesting units to visualize the supplies available.

Thus, it was reported the occurrence of situations in which a requesting unit places the order for one of the other units, which only upon receiving the order realizes the unavailability of the requested supplies
and therefore needs to notify the requesting unit so that the order is placed again towards the other unit, generating a rework stream.

Furthermore, different units store the same type of item, which causes cross-flows of these supplies between the units, resulting in transport and processing waste. These movements occur mainly due to requests from the central pharmacy to the HC, as the central pharmacy is open 24 hours a day but does not have the capacity to store the items.

**Analysis**

Upon understanding the system under study – through the investigation of its stages, agents, and focusing on the mapping of the supply distribution flows – it became possible to identify waste sources that relate to five types of waste, amongst the seven presented by Ohno (1997). Given the context under analysis, related to a service production system, Table 1 presents the identified waste sources, linking them to the types of waste presented by Ohno (1997) and their possible counterparts according to Andrés-lópez et al. (2015), who suggest an adaptation of the terms for service systems.

Table 1: Identification of waste in distribution flows

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous use of two systems (AGHU and MV)</td>
<td>Sanitizing</td>
<td>Processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Printing orders for item separation only</td>
<td></td>
<td>All streams</td>
<td>Defects</td>
<td></td>
</tr>
<tr>
<td>Receipt without checking</td>
<td></td>
<td>All streams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shipment of supplies without requesting proof of correct delivery</td>
<td>Medicines and Materials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incompatibility between virtual and physical inventory</td>
<td>Medicines and Materials</td>
<td></td>
<td>Waiting</td>
<td>Stock</td>
</tr>
<tr>
<td>Supplies requisition based on quick visual checking</td>
<td>Medicines and Materials</td>
<td></td>
<td>Waiting</td>
<td></td>
</tr>
<tr>
<td>Lack of space on drives</td>
<td>Materials</td>
<td></td>
<td>Waiting</td>
<td>Stock</td>
</tr>
<tr>
<td>Prevention against possible shortages</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplies transport between units</td>
<td>Materials</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Elaborated by the authors (2021)

The sources of waste were identified based on the interviews and mappings as procedures or elements that do not add value to the supply distribution service. Although the lack of space in the units is not a procedure, it is considered relevant as a source of waste, as the inadequacy of physical storage spaces can indicate a failure in the arrangement of spaces, a high variability in the delivery routine or even a failure to schedule requests (Shah and Ward, 2007).

As seen in Table 1, from the identified waste sources, it is possible to observe the occasion of processing waste, defects, waiting, transport/movement, and these wastes are characteristic of the TPS concepts according to Ohno (1997). The adaptation of these wastes to the terms presented by Andrés-Lopez et al. (2015) allows for a better understanding of service production.

The waste due to excessive quality demonstrates the existence of unnecessary procedures, which mainly represent the cost of labour, time and availability of employees for other necessary activities. On the other hand, failures in service can lead to situations of rework, which also reflect labour costs, or in more critical situations, the inadequate registration of items in stock.

During the dynamics of the supply distribution system, waste occurs mainly due to waiting or delay, especially due to the lack of reliable information about supplies availability. This type of waste is quite grave, as it can lead to delays in emergency medical procedures.

Although the system under study refers to the distribution of supplies as well as the composition of stocks, the
observation of waste helps to understand the problems with the procedures of the distribution service. Thus, the excessive variation demonstrates the inexistence of standards in the internal distribution procedures, reflecting in terms of required quantities, requisition periods or even supplying units.

Variations in ordering procedures become even more relevant as they can cover-up several problems in the system, such as unfamiliarity of true demands or accumulation of supplies. Furthermore, the variation in suppliers to which requisitions are directed can also contribute to the fourth identified waste, of transport/movements, due to the need to shift supplies between different units.

The perception of different waste sources associated with different types of waste alerts to the need to adopt an action plan to address the needs for improvement of the analysed system. Thus, it was found that there are several improvement alternatives that could optimize the distribution flows of the pharmaceutical sector, despite the fact that, due to sector limitations, could not be implemented simultaneously.

Hence, aiming at the prioritization of improvements under a structured implementation proposal, a multi-criteria decision support model based on the framework based on De Almeida (2013) was applied.

At first, the head of the pharmaceutical dispensing unit was perceived as the sole decision maker, especially due to his role in the dynamics of distribution involving the other units and the knowledge gathered about the sector and its operations.

Based on the context and its peculiarities, the objectives of the decision problem were identified, which made it possible to list the criteria capable of reflecting the degree of performance of the alternatives in relation to each one of them. Thus, Table 2 demonstrates the established criteria and their respective classification in minimizing or maximizing different alternatives performance.

Table 2: Criteria associated with decision objectives

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Criteria Classification</th>
<th>Type of criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_A. Implementation cost</td>
<td>Minimization</td>
<td>Natural</td>
</tr>
<tr>
<td>C_B. Implementation time</td>
<td>Minimization</td>
<td>Natural</td>
</tr>
<tr>
<td>C_C. Results operational impact level</td>
<td>Maximization</td>
<td>Built</td>
</tr>
<tr>
<td>C_D. Implementation complexity</td>
<td>Minimization</td>
<td>Built</td>
</tr>
<tr>
<td>C_E. Required labour</td>
<td>Minimization</td>
<td>Natural</td>
</tr>
<tr>
<td>C_F. Training needs</td>
<td>Minimization</td>
<td>Natural</td>
</tr>
<tr>
<td>C_G. Need for technological resources</td>
<td>Minimization</td>
<td>Natural</td>
</tr>
<tr>
<td>C_H. Amount of waste eliminated</td>
<td>Maximization</td>
<td>Natural</td>
</tr>
<tr>
<td>C_I. Number of flows benefited</td>
<td>Maximization</td>
<td>Natural</td>
</tr>
<tr>
<td>C_J. Number of units benefited</td>
<td>Maximization</td>
<td>Natural</td>
</tr>
</tbody>
</table>

Source: Elaborated by the authors (2021)

Based on Keeney’s (1992), it was decided that only two of the criteria should be constructed, namely: (i) Operational impact level of the results; and (ii) Implementation complexity; given the subjectivity in the evaluation of these factors as well as the necessary contextualization of the relevant problem. Therefore, a five-level assessment scale was adopted.

The scope of problem under study is composed of six alternatives for improvement, proposed for the reduction of waste along the supply distribution flows:

- A1 - Unification of electronic inventory control systems
- A2 - Utilization of portable electronic equipment
- A3 - Adoption of a standard protocol for supplies delivery and receipt
- A4 - Application of barcode reader for movement registration
- A5 - Implementation of the two-drawer inventory control system
• A6 – Determination of specific units for each type of supply

Given the presented alternatives, it is possible to consider that the decision space corresponds to a set of discrete variables. Moreover, taking into account the interest in prioritizing improvements, the problem under study is perceived as an ordering problem.

Furthermore, given that all the alternatives were validated by the decision maker and that the nature of the problem is of ordering, it stands to reason that the poor performance of an improvement in one criterion can be compensated by its good performance in another. Hence, the compensation between the criteria can integrate better investment viability for a given improvement, making this a decision problem of compensatory rationality.

The intra-criteria assessment, as to establish the consequences matrix, was carried out mainly by the decision maker, supported by specialists from the hospital’s inventory sector, who assisted in the evaluation of the CA-Cost of implementation criterion, and by a pharmaceutical specialist, who supported it in the evaluation of the CB, CC, CD and CE criteria, for which the simple average evaluation from both decision-makers and specialist was adopted as the alternative performance values.

It is valid to note that, although the current work offers a prior perspective on the waste that could be addressed by each alternative, the decision maker was given the possibility of evaluating this criterion according to their own perspectives, receiving information about what each waste represents. Table 3 presents the matrix of consequences built for the decision problem.

Table 3: Consequence Matrix

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>CA</th>
<th>CB</th>
<th>CC</th>
<th>CD</th>
<th>CE</th>
<th>CF</th>
<th>CG</th>
<th>CH</th>
<th>CI</th>
<th>CJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 - Unification of electronic inventory control systems</td>
<td>0</td>
<td>17.5</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>A2 - Utilization of portable electronic equipment</td>
<td>3360</td>
<td>30</td>
<td>4</td>
<td>3</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>A3 - Adoption of protocol for supplies delivery and receipt</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>A4 - Application of barcode reader for movement registration</td>
<td>1450</td>
<td>30</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>A5 - Implementation of the two-drawer inventory control system</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>14</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>A6 - Determination of specific units for each type of supply</td>
<td>0</td>
<td>12.5</td>
<td>5</td>
<td>5</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>

Source: Elaborated by the authors (2021)

Upon using the FITradeoff method, the inter-criteria evaluation stage occurred simultaneously with alternatives evaluation, in order to establish the scale constant values for each criterion. At first, an initial ordering of the criteria based on a systematic evaluation was established with the decision maker. This was made possible by successive questions that were made in relation to their preference if it was possible to improve the performance of an alternative, improving its assessment in only one of the criteria presented. Thus, it became possible to order the criteria according to their scale constant, establishing the following relation about them:

\[ k_{C_1} \neq k_{C_2} \neq k_{C_3} \neq k_{C_4} \neq k_{C_5} \neq k_{C_6} \]

The evaluation of the alternatives took place through the FITradeoff SAD, with which the decision-maker’s preference elicitation procedure was carried out, developed from a sequence of questions about hypothetical consequences. At each cycle of questions, the decision maker was prompted to answer which, amongst two consequences, would be preferable depending on the conditions presented for the problem criteria.

The elicitation procedure was carried out in thirty-five cycles of interactions, at which time the decision maker affirmed the adequacy of the ranking already obtained in five levels, especially considering the set of actions composed of six alternatives, so that the result already obtained was considered satisfactory and capable of solving its decision problem, enabling the completion of the interaction procedure. The result obtained is shown in Figure 5 in a Hasse diagram.
The dashed lines in Figure 5 indicate the obtained ranking levels separation; moreover, it is also observed that each improvement is allocated in a position that represents the domain in relation to the improvements allocated in lower positions. Thus, alternative A6, "Determination of specific units for each type of supply", dominates all others, whilst alternative A1, "Unification of electronic inventory control systems", is subject to all others. It is also observed that between alternatives A2 and A5 (Utilization of portable electronic equipment and Adoption of the two-drawer system) no dominance relationships were identified, so they were placed at the same level in the ranking.

Further to the partial ranking of alternatives, the elicitation procedure also allowed the identification of value intervals associated with the scale constants of each criterion. Figure 6 demonstrates the identified intervals whilst Table 4 presents the maximum and minimum values assigned to the criteria C1, C2, C3 and C4.

### Table 4: Values of scale constants

<table>
<thead>
<tr>
<th></th>
<th>C1 - Number of flows that benefit</th>
<th>C2 - Results operational impact level</th>
<th>C3 - Amount of waste that you eliminate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.</td>
<td>0.32</td>
<td>0.32</td>
<td>0.29</td>
</tr>
<tr>
<td>Min.</td>
<td>0.28</td>
<td>0.28</td>
<td>0.24</td>
</tr>
</tbody>
</table>
Based on the responses provided by the decision maker along the sequence of interactions, Graph 1 and Table 4 display that the two most impactful criteria have equal intervals, whilst the two following criteria demonstrate a gradual reduction in intervals.

Regarding the criteria from C5 to C10, the scale constant intervals equal to zero can be justified due to the high number of interaction cycles with the decision maker, which by providing a large volume of preferential information generated a reduction in the weight space of these criteria. From the information obtained from the decision maker, the identified preferences directed significantly higher values to the criteria presented in Table 2, causing the space for the weights of the other criteria to be significantly reduced until their upper and lower limits were equal to zero, as the sum of the scale constants must equal 1.

In order to verify how well the proposed model responds to changes in its component aspects, with the support of the FITradeoff SAD, a sensitivity analysis was carried out. Thus, after checking the results obtained and observing the criteria of higher values in scale constants, the analysis took place in three scenarios of variations in the space of consequences as a function of the criteria with higher scale constants. From an initial scenario, the space of consequences was varied by 10% more or less in relation to criteria C1 and C2. Subsequently, the space of consequences was varied by 10%, more or less, in relation to the four criteria of greatest scale constant in the result originally obtained, C1, C2, C3 and C4. Finally, a variation of 20% more or less in the consequences space was applied in relation to criteria C1 and C2, and a variation of 10% for criteria C3 and C4. The results obtained are described in Tables 5A, 5B and 5C:

Table 5A: Sensitivity Analysis First Scenario Results

<table>
<thead>
<tr>
<th>Alternatives / Position</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>100.00%</td>
</tr>
<tr>
<td>2</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.60%</td>
<td>99.90%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>3</td>
<td>0.00%</td>
<td>8.00%</td>
<td>99.40%</td>
<td>0.10%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>4</td>
<td>0.00%</td>
<td>92.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>8.10%</td>
<td>0.00%</td>
</tr>
<tr>
<td>5</td>
<td>8.10%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>91.90%</td>
<td>0.00%</td>
</tr>
<tr>
<td>6</td>
<td>91.90%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Table 5B: Ranking variations in the second sensitivity analysis scenario

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>A6</th>
<th>A4</th>
<th>A3</th>
<th>A2</th>
<th>A5</th>
<th>A1</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Original Position</td>
<td>100.00%</td>
<td>97.80%</td>
<td>92.40%</td>
<td>88.80%</td>
<td>11.10%</td>
<td>11.10%</td>
</tr>
<tr>
<td>% Changes</td>
<td>0.00%</td>
<td>2.20%</td>
<td>7.60%</td>
<td>11.20%</td>
<td>88.90%</td>
<td>88.90%</td>
</tr>
</tbody>
</table>

Table 5C: Results of the third scenario of the sensitivity analysis

<table>
<thead>
<tr>
<th>Alternatives / Position</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>2.10%</td>
<td>0.00%</td>
<td>99.80%</td>
</tr>
<tr>
<td>2</td>
<td>0.00%</td>
<td>7.20%</td>
<td>19.70%</td>
<td>85.70%</td>
<td>0.20%</td>
<td>0.20%</td>
</tr>
<tr>
<td>3</td>
<td>0.00%</td>
<td>31.70%</td>
<td>66.40%</td>
<td>11.40%</td>
<td>9.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>4</td>
<td>4.20%</td>
<td>56.10%</td>
<td>9.40%</td>
<td>0.80%</td>
<td>37.30%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>
Alternatives / Position | A1 | A2 | A3 | A4 | A5 | A6 |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>32.80%</td>
<td>5.00%</td>
<td>4.50%</td>
<td>0.00%</td>
<td>53.50%</td>
<td>0.00%</td>
</tr>
<tr>
<td>6</td>
<td><strong>63.00%</strong></td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

As presented in Table 5A, in a set of simulated situations considering the required variations, the ranking obtained tends to remain with strong similarities in relation to the original ranking, so that the main changes would be on the positioning of alternative A5, fifth place in 91.9% of the situations, and on the placement of alternative A1, in sixth place also in 91.9% of the cases.

As in the first simulated scenario, in the second scenario there is a tendency for the positioning of the alternatives to remain in place, even though variations are made in the space of consequences in relation to four of the criteria. Regarding the first simulated scenario, Table 5B shows that alternatives A5 and A1 tend to have less changes in their positions, whilst alternatives A4, A3 and A2 proved to be a little more sensitive to the variations submitted.

As displayed in Table 5C, even when subjected to a more intense variation in the space of consequences in relation to the criteria of greater scale constant, the alternatives tend to remain in the positions they were allocated in the original result. Even though they show greater variations, the main divergences observed between the third scenario and the original results reflect the positioning of alternative A5 in the fifth place, so that alternative A1 is still allocated as an alternative to be dominated by all others, but now in sixth place.

**PROPOSITIONS**

Given the results obtained with the application of the proposed method, the alternative with the best performance is alternative A6, “Determination of specific units for each type of supply”. Observing the matrix of consequences built for the problem in question, the result obtained can be supported by verifying that alternative A6 achieved maximum performance in the four criteria of the largest scale constant of the problem, except for criterion C3, in which, however, obtained the highest rating compared to the other alternatives.

The alternative A6 ranking, as a matter of fact, converges with the decision maker’s objectives, given that it is evaluated as an alternative capable of benefiting the maximum number of flows and units possible, with a high operational impact on the results and solving most of the waste identified in the system. However, the same alternative was also evaluated with the worst possible performance in relation to criterion C7, “CD - Implementation complexity”, which indicates that the result obtained was interfered by the compensation between criteria, especially considering that criterion C7 was not associated to significant scale constant values.

The positioning of alternatives A2 and A5 in fourth place indicates that these alternatives are dominated by all others, with the exception of alternative A1. Although they are equally ranked, it is not yet possible to indicate a relationship of indifference between the alternatives. By the time the procedure was completed, there was not enough information to establish relationships of dominance between the alternatives, but this relationship could be identified if the decision maker chose to continue the procedure.

By simulating different scenarios through sensitivity analysis, it was possible to observe that the result of non-dominance between alternatives A2 and A5 proved to be sensitive to small variations in the consequences space in relation to the criteria of greater scale constant. Thus, in the three simulated scenarios, there is a trend towards the dominance of alternative A2 over alternative A5.

From the preferential information provided by the decision maker, the intervals of scale constants identified indicated a greater interest of the decision maker in promoting improvements that could reach the sector in...
the most comprehensive and efficient way possible, as seen in the results of criteria C1 and C4, in relation to scope, and C2 and C3 in relation to the impact resulting from the implementation of the improvements.

In view of the observed results, it seems that the decision maker already has a clear direction to elucidate his decision problem. Thus, it is recommended that the results obtained be considered as a relevant foundation for the implementation of the alternatives in question, in order to offer an ordering based on the sector real objectives.

With the results obtained from the decision support model developed, it is possible to elaborate and propose a future value stream map that considers the implementation of at least two of the ranked improvements, the fixation of specific units for the sourcing of each type of supply and implementation of the barcode reader for movements registration. Figure 7 presents the proposed future state VSM.

Figure 7: Future state VSM of material flow

As seen in Figure 6, the implementation of the proposed improvements allows the reduction of the flow processing time of 8.4 minutes, besides removing one of the waiting stages of 12 minutes between processing. The greatest gain demonstrated in the future state VSM is due especially to two impacts generated by the improvements:

Firstly, the establishment of specific units to source the types of supplies leads the requesting units into having a more assertive knowledge of where to look for the supplies they need, whilst supplying units could control their inventories more efficiently.

Source: Elaborated by the authors (2021)
Secondly, in a similar manner, the implementation of the barcode reader for movement registration improves the procedures for recording movements, which generates better inventory control and allows for a significant reduction in delivery failures. When observing the impacts of the proposed improvements, there is a focus mainly on reducing delivery failures, which, in its turn, reduces rework procedures as well as waste for processing, waiting or even transport.

CONCLUSION

This present work endeavoured to explore, through a lean healthcare-based approach, opportunities for optimizing the distribution of supplies in the pharmaceutical sector at Hospital Universitário Onofre Lopes (HUOL), enabling the identification of the sources of recurrent waste in the system, as well as the adequate improvements to address the problems.

The research considered the singularities and complexity of the dynamics that involve work in a hospital environment. Thus, the study of the entities that make up the studied flows allowed a more assertive identification of their needs, gaps and opportunities for improvement.

Upon identifying the waste along the supply flows and the necessary process improvements, the application of a model based on MCDA proved to be an efficient tool to support decision-making for the implementation of improvements in lean healthcare; given that a better planning for necessary implementations can offer a more structured and efficient optimization process, ensuring the continuity of improvement projects.

Despite the satisfactory results, the authors also faced some limitations in the current research. For instance, the research was developed in the context of the global pandemic generated by the SARS-CoV2 virus, which interfered not only in the development of the necessary activities, but also in the restriction of access to the hospital under study and the availability of support to be offered by the hospital staff.

However, the work presents relevant contributions to academia, to the object of study and also to the improvement of services provided to society. Throughout the research, it was possible to explore scientifically based applications of the lean philosophy in the hospital pharmaceutical sector, which is still little discussed in Brazilian hospital institutions.

The proposed alternatives offered the institution a guideline adjusted to its needs by indicating procedures that generate waste and alternatives for process optimization, reducing costs which may result in more efficient services for society.

Further research should explore the implementation of the proposed model as to consider its applicability as well as its financial impact. Furthermore, the current study could be expanded, in relation to the application of the lean healthcare approach in other hospital sectors or even in other contexts of distribution of pharmaceutical supplies.

REFERENCES


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