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ARTICLES

WASTE REDUCTION USING THE THOR 2 HYBRID METHOD: DECISION MAKING IN THE CONTEXT OF LEAN HEALTHCARE

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ABSTRACT. The purpose of this paper is to prioritize which waste should be treated by Lean Healthcare in a medical clinic of a middle-sized Brazilian hospital, using the multicriteria decision support method THOR 2. It focusses on structuring the problem, establishing alternatives through the study hospital and Lean interventions already made in it, and determining the criteria and parameters of THOR 2 with the help of Value Focus Thinking (VFT) and the hospital directors. THOR 2 was able to identify, taking into account its preference relationships in S2, that establishing a Kanban within the hospital's medical clinic is the preferred and the main contribution and novelty to the literature is the way that multicriteria methods can help in Lean Healthcare decision making. As conclusions, it was possible to establish a prioritization order, maintaining the concept of continuous improvement, arising from Lean Healthcare, while respecting the limits and restrictions of the hospital.

Keywords: THOR 2, Value Focus Thinking (VFT), Lean Healthcare in public hospitals.

1 INTRODUCTION

Mass production is primarily characterized by the large-scale manufacture of a parameterized product aimed at a heated and broad consumer market that does not require personalized characteristics. As much as this system has been dominant in the American production trend for years, adapting it to the Japanese market was not viable due to the market and economic differences that the countries presented (Arantes, 2008).

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Much has been said about the importance of the application of information management and bringing knowledge to business to make better decisions on a day-by-day basis (Ishikiriyama et al, 2015). Innovation is seen as a complex, uncertain and risky phenomenon. Economic development is driven by innovation through a dynamic process in which new technologies replace the old ones, (Pereira et al, 2015).

With the reality described in mind, Ohno (1997), one of the main names related to the development of the Toyota Production System (TPS), stated that the production of small quantities with a variety of products was appropriate for the reality of Japan. Toyota had visibility for the first time in the mid-1980s, when it became evident that there was a differential in Japanese quality and efficiency (Womack et al., 1990).

Over time, Lean Production was inserted into other realities, such as the service sector, creating the philosophy known as Lean Management (LM) (Simões, 2009). For Womack & Jones (2004), LM obtained more results from fewer resources, approaching customer requirements. Soon, the same was reflected in the health field, with the designation of Lean Healthcare. Managers and politicians have struggled to limit rising costs while still providing good health care (Colldén et al., 2017).

The hospital environment is very conducive to incorporating the Lean philosophy, given that such health organizations are complex places of great social importance that must provide quality services with a comprehensive restriction of resources (Raimundo et al., 2015). For Graban (2016), hospital employees need to standardize their processes and imperative tasks to ensure the improvement of their patients' safety, prevent time delays, facilitate their own responsibilities, and reduce costs.

However, achieving these goals can be challenging, as the decision-making process to implement Lean Healthcare (LH) is not always intuitive, as there is a gap between professionals who work with LH and the hospital environment regarding their processes (Soliman & Saurin, 2017). Considering the nature of health environments, their criteria, and the decision-making involved in each alternative to be performed, the Multicriteria Decision Aid (MCDA) becomes more appropriate since it represents a term that describes a collection of formal approaches that seek to explicitly consider various criteria to help individuals or groups explore important decisions (Belton & Stewart, 2002).

Some authors have already proposed to work with systematic ways of applying LH (Régis et al., 2019); however, the focus of these studies was on the application and control of LH without focusing on the decision-making that arises with such an application.

1.1 Purpose

Complex environments, conflicting criteria, uncertainties, and inaccurate information are characteristic of many decision problems that are present in the real world. In this context, the MCDA is used to describe a set of formal approaches that seek to take explicit account of multiple criteria

in helping stakeholders and groups explore decisions that matter (Costa et al., 2022) (Gomes et al, 1997).

Therefore, the purpose of this paper is to prioritize which waste should be treated by LH in a medical clinic of a middle-sized Brazilian hospital using the MCDA method THOR 2 (Hybrid Multicriteria Decision Support Algorithm for Decision Processes with Discrete Alternatives). The method has been applied in several problem situations (Santos et al., 2022; Esteves et al., 2022; Gomes et al., 2021; Tenorio et al., 2021).

Therefore, the paper focuses on a study hospital that has undergone previous interventions of systemic application of LH (Drei et al., 2021; Martins Drei & Sérgio de Arruda Ignácio, 2022), while it is necessary to apply a multicriteria method to help those responsible to continue the proposed systematic Consequently, the alternatives were raised from the previous interaction. The criteria were established using the Value Focus Thinking (VFT) structuring method (Keeney, 1992).

Thus, this paper is divided into six sections: Introduction; Theoretical framework; Research methodology (including Problem structure); THOR 2 Application; Results and Conclusions.

2 THEORETICAL FRAMEWORK

The maturity of the area of interest and, in some cases, also describes the processes that the organization will need to develop to reach a desired future. Improvements in maturity depend on a concentrated effort to develop, improve, and foster communication between executives and professionals in project management (Souza and Gomes, .2015).

2.1 Multicriteria assistance in Lean Manufacturing (LM) decision making.

The concept of LM emerged in the 1950s in Japan and can now be defined as a management philosophy. It has been inspired by TPS practices and results (Barud et al., 2021).

The objective of LM is to produce the products according to the customers' requests, resulting in minimal waste (Shah & Ward, 2003). Its concept was investigated in several areas, including Supply Chain Management (SCM), Manufacturing, Management of Construction and Services Industry (Seyedhosseini & Ebrahimi-Taleghani, 2014; Abbasian-Hosseini et al., 2014; Galankashi & Helmi, 2016). The development of LM requires the analysis of the value stream, with all the constituent activities, both with added value (AV) and non-added value (NAV) (Lasa et al., 2009).

Iyengar and Bharathi (2018) conducted a bibliometric analysis of lean, agile, and loyal supply chains in the auto industry. The result reveals that most publications are related to lean strategies for these types of companies.

Many companies apply quality approaches such as Lean Manufacturing and Six Sigma to minimize defects and waste and improve production performance. Lean manufacturing is designed to reduce the costs involved in production to minimize waste (Womack et al., 1990; Meade et al.,

2010). The literature shows that companies that implement and practice Lean Manufacturing or Lean Production observe a significant improvement in operational performance (Shah & Ward, 2003).

In addition to the focus on changing the paradigm of processes within the organization, some papers began to focus on decision making in the Lean Manufacturing application. Operations Research can be viewed as a facilitator in decision making, since it is applied to problems that comprise the conduct and coordination of operations, i.e., the activities of a process (Hillier & Lieberman, 2013).

MCDA, in turn, becomes a more appropriate term, as it describes a collection of formal approaches that seek to explicitly consider various criteria to help individuals or groups explore important decisions (Belton & Stewart, 2002).

The literature presents papers aimed at the application of Lean Manufacturing, using MCDA, as is the case of Hsieh, Chen & Do (2016) who apply the Russian Theory of Inventive Problem Solving (TRIZ) and Fuzzy-AHP (Analytic Hierarchy Process) to design a new form for machine tools, developing a scientific method based on the Lean production concept to design a new product and improve the old design process.

Anvari et al. (2014) propose a new modified multicriteria method to solve Lean tool selection problems in manufacturing systems. They developed a model to help practitioners improve their problem-solving abilities; when possible, solutions have their own individual criteria. Kpamma et al. (2018) focus on defining an agenda for research on the application of the Lean decision tool to increase user involvement in the design process.

Alsyouf et al. (2011) develop a framework for evaluating the cost-effectiveness of Lean tools. The structure consists of eight phases within the PDCA (PLAN–DO–CHECK–ACT) cycle of problem solving and continuous improvement (Kaizen). Finally, Lu et al. (2011) uses a MCDA, through a combination of Taguchi (cite) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) (cite), which considers the uncertainty of customer demand as a noise factor, to identify the most robust production control strategy for identifying an ideal scenario from alternative designs.

2.2 Multicriteria support in Lean Healthcare decision making.

As in manufacturing, healthcare services are also opportune to implement MCDA linked, in this case, to Lean Healthcare, since, as in manufacturing, healthcare management consists of eliminating errors, inappropriate procedures, and delays, and Lean philosophy tends to create a continuous flow to solve such problems and create value for the patient (Simões, 2009). This requires the implementation of quality procedures in the health field as a mandatory requirement, which consists of a detailed analysis of the processes involved in carrying out a procedure, including all aspects (Oliveira et al., 2017).

The research methodology of this survey is illustrated in Figure 1 and outlined with PRISMA in Figure 2. The search parameters were established using the keywords entered in PRISMA, and then the databases – Web of Science (WoS) and Scopus – were chosen and analysed so that others could be included if necessary. Next, the selection itself was made and proposed using the PRISMA method, unifying the bases.

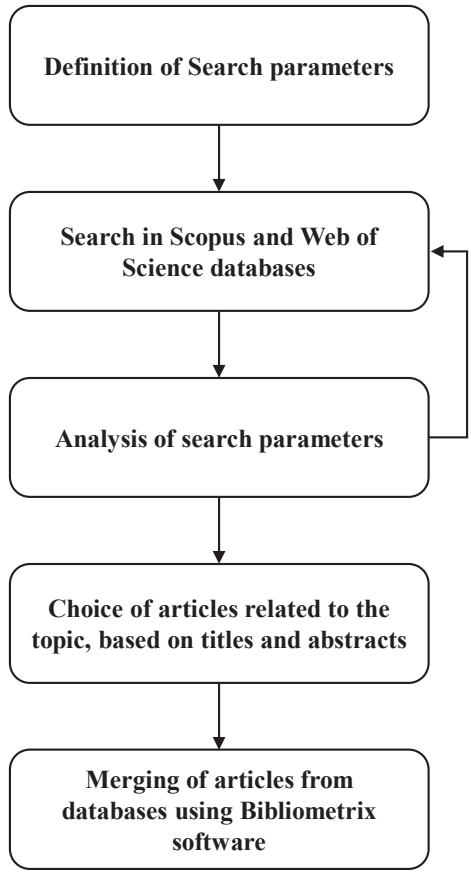

Figure 1 – Steps of the methodology.

With the aid of the proposed PRISMA step-by-step, which aims to assist in reporting systematic reviews of other types of research (Page et al., 2020), the survey was carried out in Scopus and WoS databases, using the terms ”Multicriteria” - and variations, and ”Lean Healthcare” - and variations, such as ”Lean” AND ”Health”, without applying filters. Thus, only 2 works were found in Scopus and 1 work in WoS, totalling threeg works in the identification phase.

Then, the elimination of duplicated paper between the bases was carried out, identifying one equal. From this survey, the two papers in the selection phase were analysed, and it was found that none of them escaped the theme of Lean Healthcare with MCDA, resulting in no elimination.

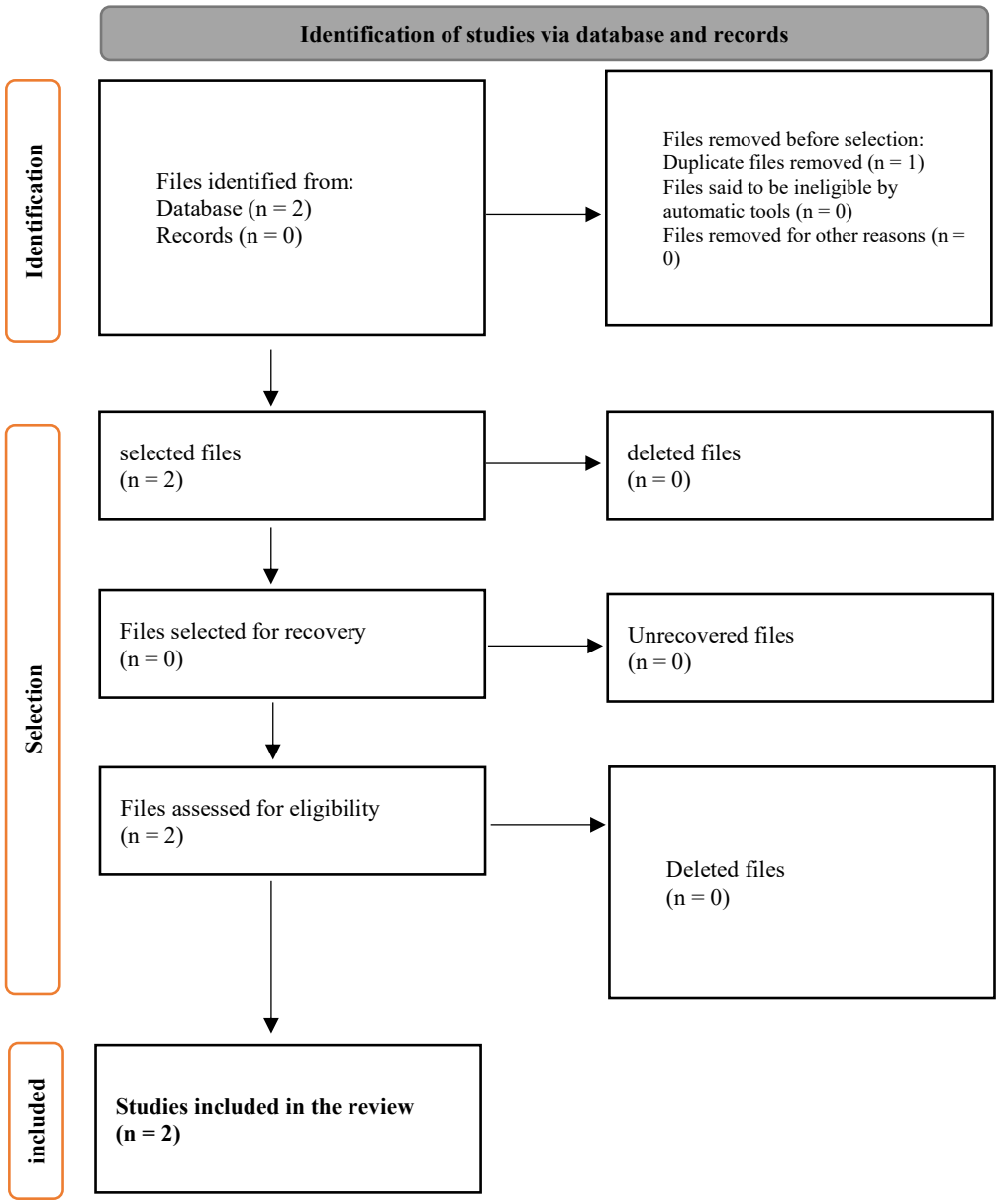

Figure 2 – PRISMA Review for Lean Healthcare and Multicriteria Decision Aid.

Source: Adapted from Page et al. (2020).

As can be seen, only two papers were identified in the databases used, and Hohmeier et al. (2020) address the complex workload, pharmaceutical practices, and numerous possible preventive interventions for a given patient as they provide a review of the theory and science of prioritization in patient care service delivery, including MCDA, Lean Six Sigma, and the Competitive Demands framework.

Akdag et al. (2014) applied the AHP and TOPSIS methods to evaluate the service quality of some Turkish hospitals. The study found the importance and weights of performance criteria with AHP, while TOPSIS was applied to find and rank efficient performance values.

Amaral and Costa (2014) applied the PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) II method to support decision-making and resource management in an Emergency Department (ED). The PROMETHEE was chosen for this study because its outranking approach is considered appropriate for the decision-making context of hospital services. The ranking showed the best alternatives to be implemented to improve the throughput of patients in the "Blue Room".

Bilsel et al. (2006) applied the AHP and PROMETHEE methods to measure the performance of the websites of Turkish hospitals. Karagiannidis et al. (2010) discussed treatment practices for infectious hospital wastes in Central Macedonia through the AHP method. The analysis demonstrated that a centralized autoclave or hydro-clave plant near Thessaloniki was the best performing option, depending on the selection and weighing of criteria of the multi-criteria process.

Liao et al. (2017) proposed a linear programming method to solve MCDA problems. The framework was applied in the evaluation of hospitals. Liu et al. (2013) present an evaluation of hospital waste disposal alternatives that can be considered a complicated MCDA problem that requires the consideration of several alternative solutions and conflicting tangible and intangible criteria; in the research in question, a new MCDA technique based on fuzzy set theory is presented and the VIKOR method is used to evaluate disposal methods.

Nilashi et al. (2016) developed a model to determine the most important factors among the four categories for HIS (Hospital Information System) adoption in the context of Malaysian public hospitals. The elements were identified and compared by 20 hospital experts and decision-makers. The authors applied the fuzzy ANP (Analytic Network Process) method to compute the weights of incorporated factors in the HIS adoption. The results revealed that hospitals with compatibility, complexity, mimetic pressure, and vendor support were more likely to adopt HIS. Hence, the decision to adopt HIS was mainly determined by technological and environmental context.

Pereira et al (2022) make an application of THOR in a health problem in the military sector. Vahidnia et al. (2009) considered the specific problem of creating a well-distributed network of hospitals that delivers its services to the target population with minimal time, pollution, and cost. The authors developed an MCDA process combining Geographical Information System (GIS)

analysis with the Fuzzy Analytical Hierarchy Process (FAHP) to determine the optimum site for a new hospital in the Tehran urban area.

Furthermore, in the paper by Fogliatto et al. (2019), a method is proposed that integrates Systematic Layout Planning techniques for Lean Healthcare practices, aided by multicriteria decision analysis, with AHP which can be applied to redesign the layout of healthcare facilities through the analysis of a high-variety sterilization unit of a large public hospital located in Brazil.

Even though both present satisfactory results from integrating LH into MCDA, neither focuses on decision-making in the application of LH or on supporting this decision for employees working in the hospital. Accordingly, this paper seeks to fill this identified gap using the THOR 2 method, since in the health sector there are uncertainties regarding the determination of certain parameters and the method has already been proven to be appropriate for this environment (Barud et al., 2020; Cardoso et al., 2009).

2.3 THOR 2

First, it is necessary to highlight that THOR 2 comes from the Hybrid multicriteria support algorithm, or THOR - currently characterized as THOR 1, based on three algorithms for simultaneous use: Preference Modelling, Utility Theory and Multi-attribute Theory (Gomes, 1999) (Gomes et al, 2010). Given the lack of security and imprecision in the value judgment used in the MCDA, decision makers must express levels of uncertainty using relevance indices, referring to the weights of the criteria and in the alternative's classification (Gomes, 1999).

The following elements may be necessary to apply THOR: (i) a weight for each criterion, representing the relative importance between them; (ii) a preference threshold (p) and an indifference threshold (q) for each criterion; (iii) a definition of the domain of disagreement; (iv) characterization of the relevance of the values of the weights assigned to the criterion; (v) the relevance of the classification (Gomes, 1999), and the alternatives are constructed through the consideration expressed by equations (1)-(3). Like its predecessor, the THOR 2 algorithm allows for three sorting operations (S1, S2 and S3), which are explained in equations (1) to (3) (Souza et al, 2023).

$$S1: \sum_{j=1}^{n}(w_j|aP_jb) > \sum_{j=1}^{n}(w_j|aQ_jb + aI_jb + aR_jb + bQ_ja + bP_ja) \tag{1}$$

$$S2: \sum_{j=1}^{n}(w_j|aP_jb + aQ_jb) > \sum_{j=1}^{n}(w_j|aI_jb + aR_jb + bQ_ja + bP_ja) \tag{2}$$

$$S3: \sum_{j=1}^{n}(w_j|aP_jb + aQ_jb + aI_jb) > \sum_{j=1}^{n}(w_j|aR_jb + bQ_ja + bP_ja) \tag{3}$$

*R_j = incomparability.

$$aPjb \leftrightarrow gj(a) - gj(b) > p \tag{4}$$

$$aIjb \leftrightarrow -qj \leq |gj(a) - gj(b)| \leq +qj \tag{5}$$

$$aQjb \leftrightarrow qj < |\, gj(a) - gj(b)| \leq pj \tag{6}$$

Observation: The parameters outlined in equations (1) to (3) are explained by equations (4) to (6). Within this framework, equations (4) to (6) consider preference relations denoted as P (strict preference), I (indifference), and Q (weak preference), taking into consideration the delineated thresholds for preference and indifference.

THOR 2 differs from the original THOR by introducing formula (7), which weights the value to be assigned to the winning alternative (aQjb) as a function of the parameters p and q. This innovative approach marks a significant evolution, as it allows for a more nuanced and adaptive decision-making process, reflecting a heightened level of sophistication and responsiveness in comparison to its predecessor.

$$w_j * \left[\frac{a_j - q_j}{p_j - q_j}\right] * 0.5 + 0.5 \tag{7}$$

THOR 2 inherited some of the characteristics from its predecessor (THOR) – remaining as a hybrid method; however, it differentiates with a distinction in the attribution of weights in situations of indifference and weak preference for S1, S2, and S3. (Tenório, 2020; Tenório et al., 2020; Tenório et al., 2021).

In addition, THOR 2 provides that the value of the weight of the criterion is multiplied by the fuzzy-approximate index (Hamming Distance, considering fuzzy number associate criterion weight, and fuzzy number associate alternative **a** associate a classification this alternative in a criterion, and fuzzy number associate the alternative **b** classification at the same criterion), deteriorating the comparison depending on the degree and security of the data, so all the uncertainty present in the attribution of the classifications of the alternatives and the weight of each criterion is quantified (Tenório, 2020; Tenório et al., 2021).

THOR 2 can be used for solving problems due to its capacity to facilitate a realistic and comprehensive approach to decision-making within intricate and multifaceted scenarios. It is a hybrid method, like its predecessor. In addition, preferential characteristics differentiate it. It furnishes potent tools for OR practitioners to grapple with real-world predicaments involving a wide spectrum of criteria and conflicting objectives (Tenório et al., 2021).

3 RESEARCH METHODOLOGY

According to Turrioni & Mello (2012), in nature, this research is applied since it is characterized by its practical interest, that is, that the results are immediately applied or used to solve problems that occur. Furthermore, its objective is explanatory, identifying the factors that determine or contribute to the occurrence of phenomena. Finally, it has a combined approach, as it considers that the researcher can combine aspects of qualitative and quantitative research in all or some of the stages of the research process.

3.1 Problem structuring

Santos (2018) presents the spiral of the decision process, conceived as a mental abstraction, since the decision process about a problem unfolds in eight stages, starting from a problematic situation until the decision to implement or not implement the model. From there, the perception of the problematic situation takes on a new dimension, incorporating new facts from the underlying reality that had not been considered before. This will lead to a new understanding of the problem and perhaps a new goal, making the whole process repeat itself.

Thus, the decision-making aid focused on their use in Lean Healthcare was chosen since, as presented in Section 2, it is still an area little explored in the literature, presenting only basic concepts of health research without exploring the benefits that multicriteria analysis can bring to decision making, through the proposal of alternatives and appropriate criteria, as shown in the map in Figure 3, made by VOSViewer, taking into account the Scopus and WoS bases.

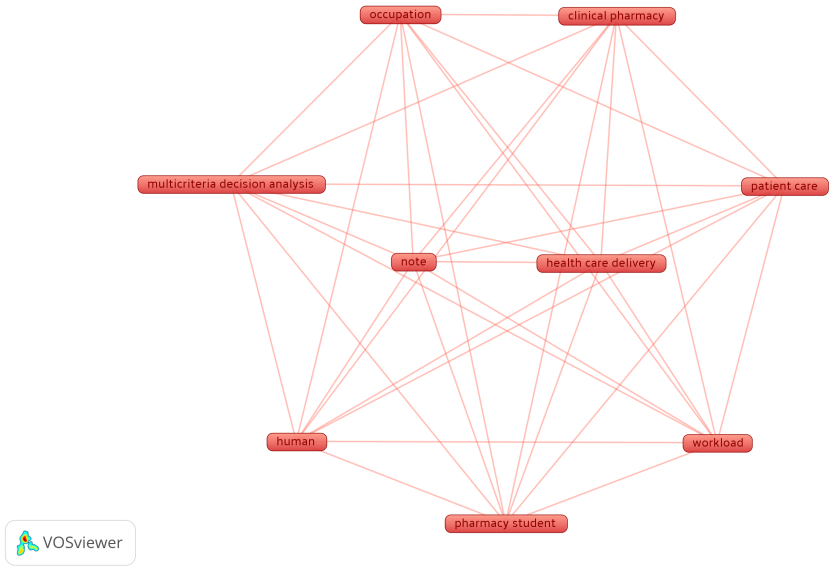

Figure 3 – Keywords of Lean Healthcare and multicriteria papers.

These points were used in this research to structure the problem. The present paper used the decision-making process that is defined in two phases – divergent phase and the convergent phase – to structure and scope the problematic situation (Franco & Montibeller, 2010), as shown in Figure 4. During the divergent phase, the main objective is to understand the problematic situation; therefore, the initial contact with the study hospital processes (Drei et al., 2021; Martins Drei & Sérgio de Arruda Ignácio, 2022) was essential to establish the need for a decision-making process and initiate contact with experts.

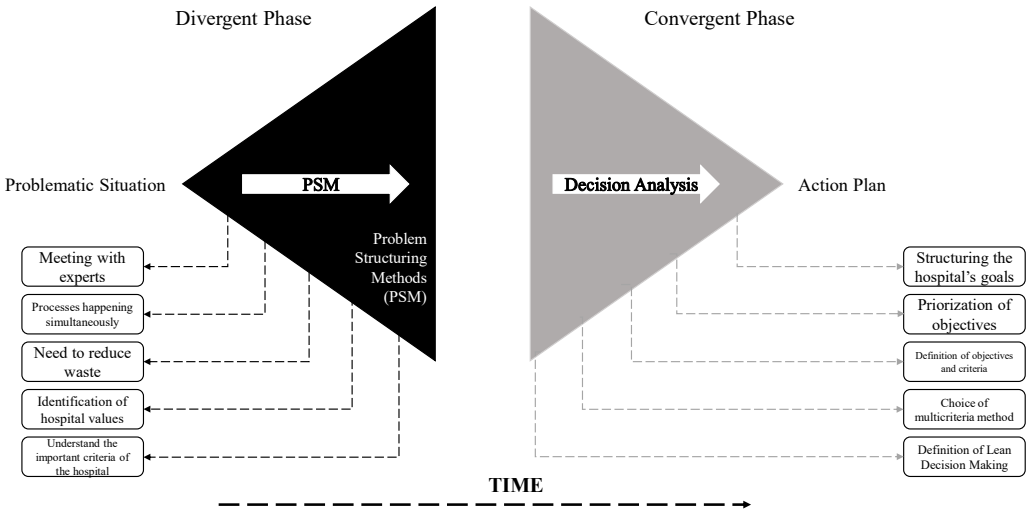

Figure 4 – Decision-making process.

Source: Adapted from Franco & Montibeller (2010).

In the convergent phase, the aim is to define the objectives, criteria, and alternatives that make up the model and to define problem-solving strategies. With the help of VFT, it was possible to propose criteria for evaluating the alternatives, directly linked to the hospital's values.

Therefore, the criteria and alternatives were determined through different metrics to be able to compose the general problem. Finally, it was decided to use the THOR 2 method for this modelling because, in the health area, there are uncertainties regarding the determination of certain parameters and the method has already proven to be appropriate for this environment (Barud et al., 2020).

Furthermore, the Rough Set Theory (RST) deals with data indiscernibility and data redundancy. RST was proposed in 1982 by Zadislaw Pawlak. As a scientific theory, it deals with the question of the granularity of the representation of a problem. This granularity causes indiscernibility, which in turn prevents the revelation of classification structures or patterns based on data that reflects an experience. In essence, it constitutes an instrument to transform a set of data into knowledge.

For this reason, it is an analysis of knowledge representation. RST is characterized by a set of elements that cannot be precisely defined regarding their attributes; the relationship of indiscernibility constitutes the mathematical basis of RST. RST is the first non-statistical methodology for data analysis (Figure 5). This methodology has the advantage, in relation to probability in statistics, that it does not require a preliminary database. (Cardoso et al., 2009) (Gomes et al., 2010) (Gomes et al., 2021) (Pawlak, 1982).

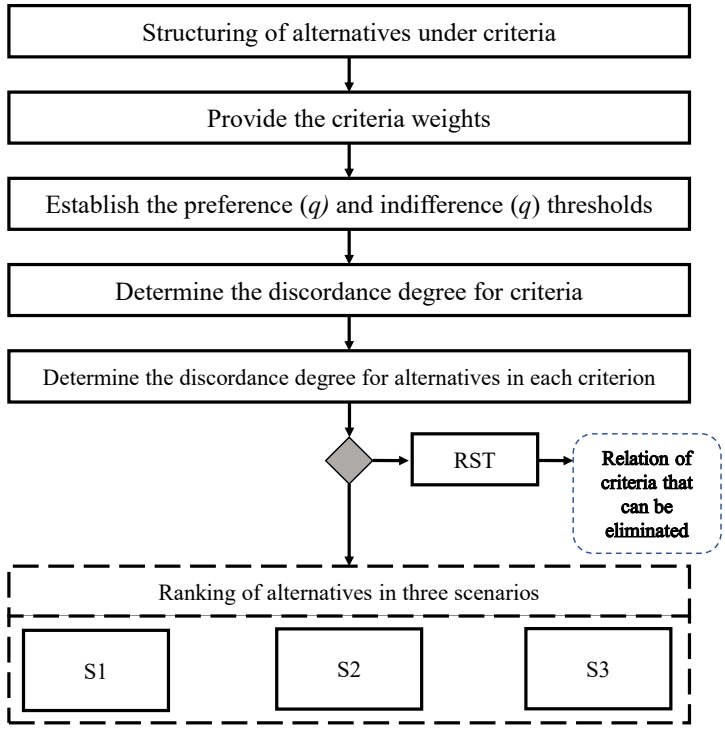

Figure 5 – Axiomatic structure of the THOR method.

3.2 Lean Healthcare application alternatives

Following the idea presented, the alternatives were raised through interventions made previously in the study hospital (Drei et al., 2021; Martins Drei & Sérgio de Arruda Ignácio, 2022), and which could not be properly treated only with direct application of Lean Healthcare.

The basic survey, carried out with observations of the daily routine of the medical clinic, considered waste present in the hospital's processes. For this paper, these wastes were translated into proposed solutions – associated with a Lean tool – so that alternatives to the problem are created.

3.3 Criteria choosing

Since not many papers are identified that focus on the intersection between Lean Healthcare and MCDA, there are no predetermined criteria to be used in Lean decision-making in healthcare, even more when it comes to the ward only of medical clinic of hospitals. Thus, to establish criteria, the VFT approach was used, separated into four stages, which are: (i) identification of objectives, (ii) structuring of objectives, (iii) construction of the relationship between types of objectives and (iv) analysis of objectives to identify criteria (Keeney, 1992).

3.4 Choice of the Decision Makers (DMs)

Regarding DMs, the studied hospital's directors were chosen, as they can have a strategic view of decision-making, and are directly linked to the processes that occur in the medical clinic.

The studied hospital has a total of four directors, three of them – technical, clinical, and administrative – reporting to the general director. However, in the current administration, the general director is simultaneously carrying out the activities of the technical director. Thus, the three management directors were selected as DM, to give increasing grades on a five-point Likert scale (Miller, 1956) for the developed criteria.

Finally, the points present in THOR 2, such as the preference limit (p), indifference (q), disagreement (D), and relevance of weights and alternatives (Tenório, 2020), will also be calculated with the help of the hospital directors. The calculations were performed on a multi-criteria platform called THOR Web, available at www.thor-web.com and developed at the Brazilian Institute of Military Engineering.

4 APPLICATION OF THOR 2 METHOD IN LEAN HEALTHCARE DECISION MAKING

As previously presented in the Research Methodology section, interviews with hospital employees involved in Lean focus activities were carried out in previous papers (Drei et al., 2021; Martins Drei & Sérgio de Arruda Ignácio, 2022)

4.1 Lean alternatives for the medical clinic

During the period of three months, it was thus established that the alternatives to the structured problem, initially, are waste identified in the flow that makes up the medical clinic of the study hospital, from its entry to the general and specific processes that occur within the wing. It is possible to identify the following waste that still occurs in the medical clinic:

1. The Stretcher bearer does not have a fixed starting place: as the hospital operates with only one stretcher bearer in the afternoon shift; he is responsible for transporting patients from various wards of the hospital. However, as there is no fixed place for him to be present, there is a wait, on the part of the patients of the medical clinic, to start a process that requires transport, since it is necessary to locate the stretcher bearer inside the hospital – D_1.

2. There is no notice of the medical clinic's capacity: there is no official communication between the departments notifying the number of spaces remaining, or if there are still vacancies, for the admission of new patients, generating a wait of patients in the hospitalization of the medical clinic - D_2.

3. Lack of signage in the medical clinic: there is no type of signage within the medical clinic that indicates the support and nurses' rooms, generating waits both on the part of patients, as well as on the part of caregivers and family members – D_3.

4. Lack of protocol for contagious diseases: when there is a suspicion that a patient has been hospitalized for a contagious disease, there is no standard hospitalization protocol, causing the patient to wait, in addition to a risk of exposure for the entire clinic medical – D_4.

5. Lack of control over the hospitalization of patients: there is no strict control, presenting the time of hospitalization of the patient in the medical clinic, only on the day he was sent there, causing them to wait for identification in exams, movements, among others – D_5.

After identifying these five wastes, the steps of the Lean Health systematic were followed, making it possible to build the five alternatives for THOR 2, through the identification and proposal of appropriate Lean Healthcare tools for each waste, as shown in Table 1.

Table 1 – Lean alternatives to THOR 2.

Waste	Lean tool	Code
D_1	**Standard Work Procedure:** Establish the stretcher bearer's Genba, that is, a place he must return to, after the end of a process; preferably a hospital room, close to the reception.	$\mathbf{A_1}$
D_2	**Standard Work Procedure:** Establish that at each new admission, the current capacity of the medical clinic is recorded for the main related wards of the hospital.	$\mathbf{A_2}$
D_3	**Kanban:** Signpost the medical clinic rooms with signs, like the ones that already exist in the rooms.	$\mathbf{A_3}$
D_4	**Checklist:** Establish a necessary checklist to be followed, every time a patient with a contagious disease is admitted to the medical clinic.	$\mathbf{A_4}$
D_5	**Standard Work Procedure:** Establish that the time of entry of the patient is recorded at each admission.	$\mathbf{A_5}$

4.2 Problem criteria from VFT

With the alternatives established, it was necessary to develop the entry criteria for analysis in THOR 2. As shown, criteria for choosing Lean Healthcare approaches are not established in the literature; therefore, the VFT was used to establish them.

Thus, first it was necessary to establish the objectives to be achieved within the vision of value in clinical medicine, so a meeting was held with the three directors of the hospital, determined as decision makers of the problem, to establish and structure these goals, building the network between fundamental objectives and means, and finally, transforming them by proposing the

criteria. This meeting took place in person, with an approximate duration of two hours, obtaining the structure of the objectives and the criteria for the problem, as shown in Figure 6.

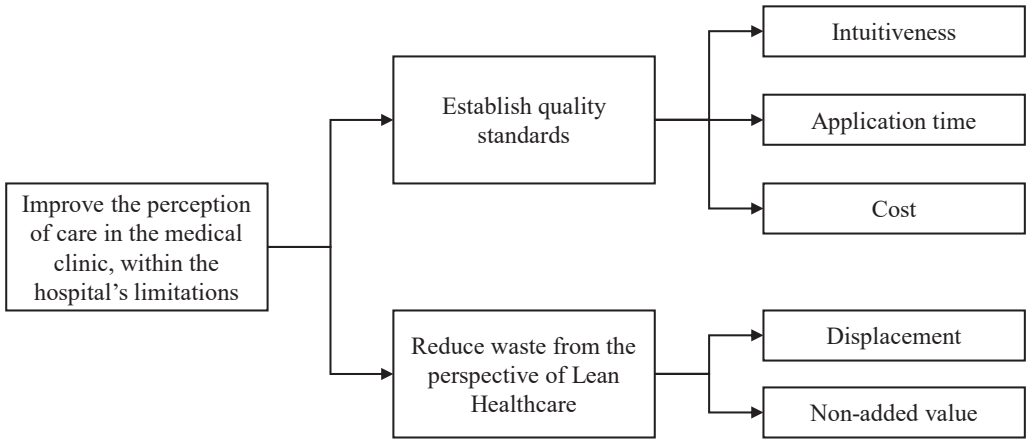

Figure 6 – Criteria generated from VFT.

During the contact, it became clear that the fundamental objective (aligned with the strategic objective of the Lean application), from the DM's point of view, was to improve the perception of care in the medical clinic. Furthermore, this objective was broken down into two middle objectives, which are to establish quality standards and reduce waste, from the perspective of Lean Healthcare. Thus, five criteria were established, based on these two middle objectives, with the help of the VFT, so that:

- (C_1) is intuitiveness, that is, the perception of ease in teaching the Lean tool proposal to employees – given by the Likert scale.
- (C_2) application time is the time needed to propose the tool until its complete insertion in the daily routine of clinical processes – given in weeks.
- (C_3) cost is the monetary value of each alternative – given in Brazilian Reais (R$).
- (C_4) is the average displacement savings made by staff at the clinic when seeking out patients and family members – taken in daily steps.
- (C_5) is the average non-added value savings on activities affected by the alternatives – given in daily minutes.

4.3 Problem data

Using the same meeting established for the criteria, it was also possible to collect data among the three directors of the study hospital. Thus, the values of each alternative under each criterion were established from the perspective of decision makers, as well as the weight of each of the criteria established by the VFT, as shown in Table 2.

Furthermore, Table 2 presents the categorization of alternatives based on criteria, along with the corresponding criteria weights assigned by each decision-maker. The determination of these weights is facilitated through the THOR 2 software, a tool designed to assist decision-makers in articulating their preferences. The criteria weights are individually elicited from each decision-maker. Additionally, the classification of alternatives within each criterion is achieved by way of thorough research on each alternative, and the results are further validated by the input and insights of decision-makers.

Decision-makers' data is aggregated by THOR 2 software. The weights of the non-standard decision-makers' criteria are summed. The elicitation of weights is done by asking questions of the decision-makers. They issue the preferences based on the criteria in a peer-to-peer comparison process. Creating a vector for each decision-maker.

Table 2 – Decision matrix for THOR 2.

Alternatives	C1	C2	C3	C4	C5
A1	5	1	0	621	30
A2	1	4	0	1008	102
A3	4	3	335	1036	96
A4	2	4	0	1067	90
A5	3	4	0	1144	88
Weights (DM1)	**0,25**	**0,15**	**0,35**	**0,15**	**0,1**
Weights (DM2)	**0,1**	**0,3**	**0,3**	**0,2**	**0,1**
Weights (DM3)	**0,25**	**0,1**	**0,25**	**0,3**	**0,1**

In intuitiveness, a five-point Likert scale was used, so that the alternative given as the most direct to be applied by decision-makers was assigned a grade of five and so on until grade one. In the application time criterion, in turn, decision makers considered the time that would be spent to train those involved in the new process.

In the case of A_3, the time taken to make the plates and adhesives, given by the supplier, was the only alternative that had a monetary cost. Furthermore, the values of savings in displacement and non-aggregated value had already been calculated previously in previous studies and were only checked for this study.

Thus, with the stipulated alternative values, the decision makers could also establish their weights for each criterion, with the total sum being equal to one. With these values, it was possible to use the THOR Web tool. It is important to emphasize that C_2 and C_3 are monotonic cost criteria, so they were entered in the tool with a negative value.

Ultimately, given the utilization of the THOR 2 methodology in this study, the decision-makers actively determined the values for preference, indifference, and disagreement, as illustrated in Table 3. The parameters listed in it were collaboratively elicited through a consensus-driven process involving the previously presented decision-makers.

The parameters presented in Table 3 are obtained as follows:

- Step 1. For each decision-maker, the smallest difference between two alternatives is presented for each criterion Cj (the initial parameter for qj).
- Step 2. The second-smallest difference for each alternative in each criterion (the initial parameter of p) was shown.
- Step 3. More difference between two alternatives for each criterion (the initial parameter of D)
- Step 4. Decision-makers are sought. In the absence of consensus, the median of the values assigned by the decision-makers is used.

Table 3 – THOR 2 parameter values.

Parameters	C1	C2	C3	C4	C5
p	1	1	500	400	30
q	0,5	0,5	300	50	10
D	4,5	4	1000	1500	50

5 RESULTS

From the decision matrix and the proposed parameters, the THOR Web was used, disregarding membership values, but considering the Approximate Set Theory for evaluation of the criteria. As shown in Table 4, from a strong preference, that is, in S1, THOR 2 could not establish a better alternative than the others: however, considering S2, that is, strong and weak preferences, he sets A_3 as being preferable to the others, keeping this preference at S3.

Table 4 – Result in S1, S2 and S3 in THOR 2.

Result S1						**Result S2**						**Result S3**					
A1	0	0,5	0,5	0,5	0,5	A1	0	0,5	0,5	0,5	0,5	A1	0	0,5	0,5	0,5	0,5
A2	0,5	0	0,5	0,5	0,5	A2	0,5	0	0	0,5	0	A2	0,5	0	0	0,507	0
A3	0,5	0,5	0	0,5	0,5	A3	0,5	0,513	0	0,513	0,5	A3	0,5	0,735	0	0,735	0,566
A4	0,5	0,5	0,5	0	0,5	A4	0,5	0,5	0	0	0	A4	0,5	0,912	0	0	0
A5	0,5	0,5	0,5	0,5	0	A5	0,5	0,509	0	0,502	0	A5	0,5	0,908	0	1,0	0
A1	2,0					A1	2,0					A1	2,0				
A2	2,0					A2	1,0					A2	1,007				
A3	2,0					A3	2,027					A3	2,536				
A4	2,0					A4	1,0					A4	1,412				
A5	2,0					A5	1,511					A5	2,408				
A1 = A2 = A3 = A4 = A5 - Original						**A3 ≥ A1 ≥ A5 ≥ A2 = A4 - Original**						**A3 ≥ A5 ≥ A1 ≥ A4 ≥ A2 - Original**					

As can be seen, based on a strong preference, that is, in S1, THOR 2 could not establish an alternative that is preferable to the others within the criteria and values established for this problem. However, by considering strong and weak preferences in S2, it was possible to determine that A_3 outperforms the other alternatives, even though this alternative has a cost, unlike the others, repeating the result even considering the indifference in S3.

Also noteworthy is the choice that THOR 2 returned, considering that A_3 is the application of a Kanban in the medical clinic of the study hospital, being the only alternative that contains a value in the cost criterion. Despite this and the fact that this criterion was penalized by all three DM in the hospital, it was still the best option among the alternatives, having a set of values that surpasses its opponents when we consider the multicriteria.

It is, therefore, important to evaluate Lean Healthcare together with the MCDA, since within the Lean philosophy, it would be recommended that changes be made within the hospital's resources to achieve improvements in the hospital environment. However, in this case, it was possible to observe that the alternative that requires monetary resources from the hospital is preferable.

It was possible to trace the criteria that alter the selection of THOR 2, according to the changes between S1, S2, and S3, as shown in Table 5.

Table 5 – Approximate Set Theory result on THOR 2.

Type	Criteria	Result	Elimination
S1	C1	A4 = A5 $\geq$ A3 $\geq$ A2 $\geq$ A1 - Without criteria	**C2 and C5**
	C2	A1 = A2 = A3 = A4 = A5 - Without criteria	
	C3	A3 $\geq$ A5 $\geq$ A4 $\geq$ A2 $\geq$ A1 - Without criteria	
	C4	A1 $\geq$ A3 $\geq$ A5 $\geq$ A4 $\geq$ A2 - Without criteria	
	C5	A1 = A2 = A3 = A4 = A5 - Without criteria	
		A1 = A2 = A3 = A4 = A5 - Original	
S2	C1	A5 $\geq$ A1 = A2 = A4 $\geq$ A3 - Without criteria	**None**
	C2	A5 $\geq$ A1 $\geq$ A4 $\geq$ A3 $\geq$ A2 - Without criteria	
	C3	A3 $\geq$ A1 $\geq$ A5 $\geq$ A4 $\geq$ A2 - Without criteria	
	C4	A3 $\geq$ A1 $\geq$ A2 = A4 = A5 - Without criteria	
	C5	A1 $\geq$ A3 $\geq$ A5 $\geq$ A4 $\geq$ A2 - Without criteria	
		A3 $\geq$ A1 $\geq$ A5 $\geq$ A2 = A4 - Original	
S3	C1	A5 $\geq$ A4 $\geq$ A2 $\geq$ A1 $\geq$ A3 - Without criteria	**C3**
	C2	A5 $\geq$ A4 $\geq$ A1 $\geq$ A3 $\geq$ A2 - Without criteria	
	C3	A3 $\geq$ A5 $\geq$ A1 $\geq$ A4 $\geq$ A2 - Without criteria	
	C4	A3 $\geq$ A5 $\geq$ A4 $\geq$ A1 $\geq$ A2 - Without criteria	
	C5	A1 $\geq$ A5 $\geq$ A3 $\geq$ A4 $\geq$ A2 - Without criteria	
		A3 $\geq$ A5 $\geq$ A1 $\geq$ A4 $\geq$ A2 - Original	

The exclusion of the criterion signifies that its removal does not alter the established ordering (as represented by RST in Figure 5 and elucidated in Section 3.1, Problem Structuring).

The Thor 2 software, starting from the criterion with the lowest weight, assigns ZERO weight to this criterion; it performs the process of sorting the alternatives. Compare the newly generated vector with the original vector. Check if the order of the alternatives has changed. If there has been no change in the order, it suggests that the criterion does not affect the order. Later the same is done for the other criteria. In this study the order was C_5; C_2; C_1; C_4 and finally C_3.

It is noted that, at first, considering S1, it is suggested that criteria C_2 - application time - and C_5 - non-added value - be removed, considering that when excluding them, the method does not suffer a change in S1, getting the exact original result.

However, when considering S2, **no criterion** becomes dispensable, with changes in the choice between the alternatives when some of them are removed, determining A_1 and A_5 as the most viable. Finally, in S3, the only criteria that can be excluded is C_3.

6 CONCLUSIONS

In this manuscript, it was possible to prioritize which waste should be treated from the perspective of Lean Healthcare in a medical clinic of a medium-sized Brazilian hospital using the THOR 2 multi-criteria decision support method, establishing that applying a Kanban, among the alternatives raised in the medical clinic, is the most advantageous, given the set of established criteria.

The approach used in this research should also be highlighted, as it benefits from the characteristics of the method since, in the health area, decisions are complex and often uncertain; thus, THOR 2 and its parameters are able to establish a viable preferential alternative within the limits established by the hospital directors.

Furthermore, the contribution and novelty to the literature are also highlighted in the way in which multi-criteria methods can aid in Lean Healthcare decision making, since it was not possible to identify the use of specific aids for decision making in the current literature. Its use was identified only as sequential, without further exploring the interaction of these two concepts.

In addition, the use of VFT also brings benefits to the proposed approach, since it was possible to determine important criteria for the hospital decision makers themselves without directing them to alternatives but rather establishing the value that one wants to achieve when applying a Lean Healthcare tool in the medical clinic.

The results obtained are also very useful for the study hospital since, since it was not possible to determine a superior alternative within S1, it was possible to establish the multi-criteria advantage in S2, that is, considering weak preferences. In addition, with the use of THOR 2 and its analysis of the Rough Set Theory, it is possible to perceive that some criteria, even if established via VFT, could be disregarded, allowing improvements to be made in the process of establishing criteria for waste from medical clinics.

Thus, for future research, it is suggested that more information be collected about waste within the medical clinic and, thus, propose more Lean Healthcare alternatives, as well as refine the

use of VFT to establish standard criteria from the perspective of lean health, systematizing the results found. Finally, it is suggested that the expansion of multi-criteria in other decisions in the application of lean health, both in the medical clinic and in other areas, make the necessary adaptations.

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