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Lean management approach in health sector: MCDM model proposal to prevention of waste

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A B S T R A C T

Lean manufacturing in the manufacturing sector corresponds to lean management in the service sector. When health services are considered, it is seen that the concepts that are important in the manufacturing sector have the same importance for health services. Because waste is the main problem of every sector. Lean management approach in the health sector enables improvements by developing solutions to many other problems of healthcare professionals, patients and hospitals, such as reducing transaction costs, ensuring patient safety, and reducing processing times. This study was carried out with the aim of establishing a lean health system by selecting the most appropriate lean management methodology in order to identify and prevent waste in health processes and to increase efficiency and service quality. In the study, the evaluation of lean methodologies that can be applied to prevent waste in health services is considered as a multi-criteria decision-making problem and a model has been proposed. In the proposed model, wastes were determined as research criteria and lean methodologies were determined as research alternatives. The solution phase of the problem was carried out in two stages with multi-criteria decision-making techniques. In the solution phase, the importance weights of 24 decision criteria were calculated with the SWARA method, while 5 alternatives were evaluated based on the decision criteria with the WASPAS method and the most suitable alternative was selected.

1. Introduction

The increasing demand for the health sector day by day causes the business processes to become more difficult and complex, as well as the difficulty of the management in maintaining the processes. In addition, the increasing costs along with the increasing demand greatly affects the hospital economy, which negatively affects the quality of service to be provided by the health sector.

Since the health sector is a sector that directly affects human life, the quality of the service provided here is of great importance. Providing a quality service to both the patient and the employee ensures a healthy, safe and happy environment. For this purpose, to increase the quality of health services, first, waste should be prevented. Prevented waste will increase productivity and performance and decrease costs. Improving business processes in health services, increasing quality and providing maximum service with minimum cost is only possible with lean thinking.

While the foundations of lean thinking were laid by Taichi Ohno as lean production in the automotive sector, lean production evolved into the concept of lean management in the service sector (Elafri et al., 2022; Perdomo-Verdecia et al., 2022). On the other hand, a lean health system is formed with the implementation of lean management according to health processes. Lean management approach in health institutions is an approach that allows hospitals to increase the quality of patient care by reducing their errors and waiting times, minimizing the obstacles in the service flow by supporting employees and management, and providing patient-oriented health care. With this approach, significant improvements are made in

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efficiency, cost and quality in health institutions and a lean health system can be created (Tiso et al., 2022; Teixeira et al., 2021). Within the scope of this study, a multi-criteria decision-making (MCDM) problem was discussed in order to determine the wastes in health services and to prevent the identified wastes and to simplify the system, and then a research was carried out on the evaluation of alternatives with SWARA (Step-wise Weight Assessment Ratio Analysis) and WASPAS (Weighted Aggregated Sum Product Assessment) techniques, which are MCDM solution methods.

In the introduction section of the study, a literature review on the subject and solution techniques is included, while in the second section, the lean management system is discussed in detail and its principles, waste types and methodologies are included. In the third section, the need for simplification in the health sector is mentioned, while in the fourth section, the wastes to be used as research criteria for the evaluation of appropriate lean methods and lean techniques to be used as research alternatives are determined in order to prevent waste in health services. In the same section, the research model is established and the established model was solved after the application steps of the solution techniques are explained and the research findings are obtained. In the last part of the study, the conclusion part and suggestions for future research are given. When the literature studies are examined, it is possible to come across examples that deal with the simplification of health systems from different perspectives. For example, Tiso et al. (2022) made a systematic literature review about health lean management implementation, Souza and Pidd (2011) and Escuder et al. (2018) explored the barriers to lean health care implementation, Dahlgaard-Park et al. (2011) and Chadha et al. (2012) investigated lean of health processes and suggested the models.

In addition, when the literature is examined in terms of studies in which SWARA and WASPAS techniques are used together, it is possible to see the studies in Table 1.

Table 1
Researches that used SWARA and WASPAS techniques together

Research	*Year*	*Author(s)*	*MCDM model*
Site selection for offshore wind farm (Fuzzy SWARA/WASPAS)	2022	Dehshiri	21 criteria 5 alternatives
Investigation of influence of using scarlet runner bean flour on the production and some properties of vegan cakes	2022	Saraç et al.	6 criteria 5 alternatives
Sustainable supplier selection in the textile dyeing industry	2022	Rahman et al.	15 criteria 5 alternatives
Site location selection for solar-powered hydrogen production plant	2022	Xuan et al.	10 criteria 13 alternatives
Optimization of pineapple drying based on energy consumption, nutrient retention, and drying time	2021	Chauhan et al.	8 criteria 6 alternatives
Investigation of issues and solutions of electronic waste urban mining	2021	Sharma et al.	24 criteria 13 alternatives
Selection of the most suitable HVAC system for an industrial building	2021	Bac et al.	27 criteria 11 alternatives
Selection of marine current energy plant location	2021	Yücenur & İpekçi	12 criteria 3 alternatives
Evaluating solutions to overcome humanitarian supply chain management barriers (Fuzzy SWARA/WASPAS)	2022	Agarwal et al.	29 criteria 20 alternatives
Prioritizing the solutions of reverse logistics implementation to mitigate its barriers	2019	Prajapati et al.	34 criteria 21 alternatives

According to the studies given in Table 1, it is clear that SWARA and WASPAS techniques are not used for the disposal of waste in the health sector. This study is aimed to contribute to the literature in terms of the sector in which it is applied and the model it proposes.

2. Lean Management System

Lean thinking increases the profitability and competitiveness of the organization by examining the system as a whole, eliminating waste and creating excellent value for the customer. At the same time, it contains basic principles that can be easily applied in all kinds of production systems, hospitals, banks, educational institutions, non-governmental organizations, institutions, organizations and companies regardless of the public and private sector, which will increase the effectiveness of the organization. Although the tools, equipment and techniques used vary according to the application area, the principles of the philosophy of lean thinking are universal. The success and rule of lean thinking has been recognized, proven and developed with practice (Çanakçıoğlu, 2019).

Womack and Jones, who enabled the full development of lean management with their book “Lean Thinking” published in 1996, define lean management as “focusing on the real needs of employees in every field along the flow to define the work of functions, divisions and firms in order to provide value-adding activities and to establish the understanding that it is in their own interest to enable the value stream" (Womack & Jones, 1996).

With the lean management system, operational quality is increased up to 80% and efficiency up to 50%, processing time is reduced by up to 90%, the amount of products waiting in stock to complete production is reduced by up to 80% and space usage is reduced by up to 75% (Kilpatrick, 2003). In addition, the system has some administrative advantages such as reduction in order processing lines, improvement in customer service functions, reduction in paperwork, documenting and streamlining business processes, hiring above-average performers, and reduction in attrition costs (Kilpatrick, 2003).

Lean management has five basic principles that can be defined as defining the value of each product, determining the value stream of the product, ensuring the continuous flow of value, ensuring that the customer pulls the value from the manufacturer, and trying to achieve excellence. Adopting these principles creates a stable workflow based on real customer demand and allows the system to continuously improve and reach a perfect structure (Awad et al., 2022).

Lean methodologies that can be used by companies in order to achieve all the targeted achievements with the lean management system can be listed as follows (Macias-Aguayo et al., 2022; Sadeghi et al., 2022; Marinelli et al., 2021): Just-in-time production, Kanban, Kaizen, Plan-Apply-Check-Act Cycle, 5S (Classification-Organization-Cleaning-Standardization-Discipline), Six Sigma, Poka-Yoke, Jidoka, AndoN, Shojinka and Value Stream Mapping.

2.1 Lean Management Approach in Health Services

The concept of leanness, which manifests itself in the production sector, has also taken its place in the health sector. Because, as in every sector, cost, efficiency and quality are important concepts in the health sector, especially in allocating public health. The increase in the demand for health services day by day also causes an increase in waste in the sector (Doğan & Yağlı, 2019). Many more problems such as the complexity in the hospital, the increasing costs, the poor quality of the service, the inefficiency of the processes or the costs of high quality have led the hospitals to lean and adopt lean management systems. Lean management approach aims to increase efficiency by eliminating wastes such as waiting, transportation, error and movement in the hospital (Bharsakade et al., 2021).

Waste, which means "all operations that do not add value but consume resources" in lean terminology, can be defined for the health sector as all the problems that hinder the work and patient care of the health sector employees. The lean management approach adopted by the healthcare industry is concerned with solving hundreds of problems that hospitals are exposed to every day, rather than just solving a big problem in hospital services. Thus, it paves the way for correction and improvement of the system in small, manageable parts.

With the value stream created in order to see the waste in the health sector more clearly, three types of activities are observed (Graban, 2019):

- Undisputed activities that create value: It covers the activities that need to be done. For example, the patient has an operation to be treated or an examination to make a diagnosis.
- Activities that create no value but cannot be destroyed: These activities, which can be exemplified such as keeping patient records or moving patients to their rooms, are called "Type-1 Muda".
- 3. Activities that do not create value but can be eliminated: These activities, which can be exemplified such as repetitive processes, errors, overproduction, waiting, are called "Type-2 Muda".

The fact that the human dynamics in a hospital is the same as in a factory increases the workload on the employees considerably. The increased workload may also cause other problems such as doing the work incorrectly, having the work done by someone else, and entering the wrong orders.

The fact that employees experience the same problems every day leads to tension on the employees and not to enjoy their work. This situation can lead to the decrease of motivation of employees to help patients, to return to their homes exhausted and even to leave the profession (Bharsakade et al., 2021; Abdallah, 2020).

Considering the fact that people in need of help come to the hospital for treatment, waiting times should be kept to a minimum. Problems such as the increase in waiting times and the inability to find an appointment are important for patients. Preventable errors that lead to injury or death are another problem that requires great attention for the patient's life. Keeping in mind that human life is at stake in all health institutions, it should be aimed to provide a safe, effective and high quality service to the patient (Tanyıldızı & Demir, 2019).

One of the main problems in terms of hospital management is the increase in the cost of providing services. Hospitals should try to reduce costs by increasing quality. The hospital management, which includes many problems such as misused storage area, confusion in the delivery of materials, unused safety equipment, not following the correct procedures, loss of personnel, not having enough equipment, should eliminate the wastes that negatively affect the employee, patient and management in business processes (Bharsakade et al., 2021).

3. Multi-Criteria Model Proposal and Its Solution to Prevention of Health Sector Waste

The health sector includes business processes with many wastes. These wastes lead to a decrease in quality, service and productivity by increasing costs. Identifying the wastes that prevent the flow of processes and eliminating them with the most appropriate lean techniques will contribute to the health economy and service by eliminating the losses.

Within the scope of this study, the problem of determining the wastage in health processes and choosing the most accurate lean methodologies to prevent the determined wastes in order to help improve the health sector business processes has been discussed and a MCDM model has been proposed. This model, consisting of 8 main criteria, 24 sub-criteria and 5 alternatives, was solved with SWARA and WASPAS techniques, which are MCDM methods.

3.1 Purpose of Research

Waste in the health sector creates negative processes for both patients, employees and hospital management. The poor service provided to the patient, the overload created on the employee leads to dissatisfaction. The resulting dissatisfaction may lead to loss of patients and personnel for the hospital, as well as cause an increase in costs.
Within the scope of the research, it is aimed to prevent the waste in health services, to ensure the smooth flow of business processes and to improve the negative processes that occur.

3.2 The main and sub research criteria

While creating a MCDM model within the scope of the research problem in which lean management techniques are evaluated to prevent wastes in the health sector, the working processes of health services were examined in detail, and the research criteria were determined with the information obtained as a result of this examination.

The main and sub-criteria of the research are as follows:

- Error Criteria: The waste of error is of great importance in the health sector. Because mistakes that occur in the hospital environment are thought to be related to human life, it may not be possible to correct them. For this reason, the medical error wastes that cause disability or death in the patient should be prevented immediately.
  - *C_1 Application of the unclaimed service to the value*: It is the criterion in which the service not requested by the patient because of the mistakes made is applied. For example, with incorrect or extra wanted tests, the patient's hospital stay may be prolonged, and the risk of infection of the patient with prolonged hospital stay increases. In addition, this waste causes an increase in costs for the hospital (Graban, 2019).
  - *C_2 Transactions that made wrongly and cause re-work and delays*: The job that is not done right in the first time causes re-work and/or delays the process. For example, if there is a problem with the blood sample taken from the patient by a bloodletting specialist, the process is repeated and there is a delay because of the procedure. This situation causes loss of time (prolongation of the treatment for the patient, the duration of the work for the employee), making extra movement and processing.
  - *C_3 Medical errors that cause disability or death of the patient*: Carelessness that may occur in the operating room, lack of knowledge of the employees, handwriting errors in patient follow-up forms or errors in the medication process of the patient are medical errors that may lead to disability or death in the patient (Bharsakade et al., 2021). This criterion, which should be paid attention to in terms of the importance of human life, causes insecurity for patients, while it creates a feeling of inadequacy, low morale and motivation in employees.
- Redundant production criteria: Every operation in hospital that is not needed but made is considered as overproduction. These unnecessary operations also lead to excessive use of materials, drugs and devices.
  - *C_4 Overproduction*: Patients discharged early by mistake and be output of the system cause unused drug returns to pharmacies and extra processes. The process should be controlled by providing fast and accurate information flow (Bharsakade et al., 2021; Graban, 2019).
  - *C_5 More than enough service*: It is the process of doing more than necessary for patient care. For example, tests performed without sufficient taken information to make a diagnosis, vascular access opened by thinking that it may be needed without need, taking more samples from the patient for extra tests that they may not be needed yet are examples of service criteria that are more than enough (Bharsakade et al., 2021).
  - *C_6 Using more materials or drugs than necessary*: The excess service applied to the patients causes the use of materials and drugs more than necessary, and this situation creates financial loss for the hospital. For example, taking extra blood causes unnecessary usage of materials such as tubes and needles (Graban, 2019).
- Unnecessary material movement criteria: These criteria, which express the excessive movement of a product in the system, cause the prolongation of work processes in the hospital.

- *C_7 Unnecessary equipment or drug transportation between processes*: If in the hospital there are insufficient numbers of devices and drugs, they have to be circulated throughout the hospital where they are needed (Bharsakade et al., 2021). Against this waste criterion, which slows down the work process and causes the employees to act unnecessarily, the hospital should review the material requirement plan and choose the most appropriate planning method.
- *C_8 Displacement of products within the hospital*: The excessive movement of the samples taken from the patient in the hospital occurs because of the wrong hospital plan, placing the patients' rooms away from the laboratories and material rooms, or the lack of a standard location for the materials. The problem can be eliminated by making changes in the hospital layout arrangement (Tanyıldızı & Demir, 2019).
- *C_9 Unnecessary patient movements*: It is the excessive movement of patients within the hospital, which usually includes walking (Bharsakade et al., 2021). Due to incorrect facility planning, patients have to walk a lot in the hospital. In addition, staff misdirecting patients also creates unnecessary movements. This causes loss of time and fatigue for patients. The constant movement of patients from one place to another within the hospital leads to service dissatisfaction. In order to provide better quality and efficient service to patients, facility layout improvements should be made and staff should be ensured to communicate with patients in a way that ensures careful and accurate information flow.

- Waiting criteria: While patients, employees or physical products should be involved in processes that add value, they may spend a large part of their time waiting without realizing the waste.
  - *C_{10} Processes pending*: It is the criterion where waiting between processes is experienced due to incorrect planning of processes or errors that occur within the processes (Bharsakade et al., 2021). This criterion also may cause employees and patients to wait along with the processes in health institutions. For example, test results that are not sent on time can cause both the patient and the doctor to wait for the next process (Graban, 2019).
  - *C_{11} Documents waiting to be approved, updated or processed*: There is a lot of paperwork involved in hospital processes. Waiting for these documents to be approved, updated or processed is a time-wasting waiting criterion. With reducing paperwork, the hospital can save time and money.
  - *C_{12} Waiting due to machine failures*: It is the criterion by which the supply process of the part is expected for the repair of the machine or the replacement of the part in order to eliminate the failure. Failure of machines causes some business processes to stop or slow down. Timely and regular maintenance of devices is important in preventing these delays (Efe & Engin, 2012).
  - *C_{13} Waiting of patients, employees, or physical products*: In healthcare facilities, patients, employees, or physical products may wait (Bharsakade et al., 2021). For example, patients wait for the next process while on the course of care, waiting for doctor's appointments due to poor flow or poor planning, waiting for procedures such as chemotherapy, radiology. Physical products (blood tubes, pharmacy orders, drugs, instruments to be sterilized, etc.) wait for reasons such as doing the work collectively, processing the products in large numbers, processes are not flowing in accordance with the first in first out rule. In addition, employees wait due to system problems, process errors, delays in previous processes, unstable workloads or low patient volumes.
- Excess stock criteria: Hospitals may have to keep stock due to possible transportation delays or possible inadequacies. However, holding more stock than needed always creates excess stock waste (Bharsakade et al., 2021).
  - *C_{14} Mandatory stock keeping due to faulty production planning*: Incorrect planning of the production process by the responsible people, ignoring the previous processes or processing the next process prematurely are result in excess drug and material stocks. This situation causes wastage of space and cash (Yılmaz et al., 2017).
  - *C_{15} Stock due to space shortage*: This ties the hospital cash to stock on the shelf. In addition, patients waiting to be discharged from the hospital are also included in this criterion.
  - *C_{16} Stock holding due to unreliable suppliers*: Transport delays or incomplete deliveries from suppliers force the hospital to keep stock. With this stock, it is tried to prevent processes from stopping or not being able to intervene in the patient due to missing materials and similar problems.
- Unnecessary human movement criteria: Unnecessary human movement, which is considered a waste, includes more walking. Excessive walking movement, which occurs due to incorrect planning of the hospital layout and similar reasons, is rarely an activity that adds value (Graban, 2019).
  - *C_{17} Unnecessary movement of employees between processes*: Situations such as the location of materials in distant places and the wrong hospital plan causes extra walking of the employees (Bharsakade et al., 2021).. This situation, which causes physical fatigue on the employees, also creates a waste of time. It should be ensured that employees devote more time to value-adding activities by preventing excessive movement waste.
  - *C_{18} Equipment search movement*: The lack of a fixed place for the materials causes each employee to put the material they use in different places, and this creates the movement of searching for materials in the employees. Having a fixed location of materials will enable employees to find the material they are looking for easily, thus eliminating unnecessary equipment search (Graban, 2019).
- Redundant transaction criteria: In these criteria, which are usually caused by the lack of communication between services or people, transactions can be performed at a higher quality level than the customer needs and be unnecessarily.
  - *C_{19} Performing a transaction out of necessity*: There are some transactions that are not needed in hospital processes due to the inaccurate flow of information. For example, taking too much medication to the clinics creates too much activity for the employees in the month-end drug counting, causing more than necessary procedures.

- C_{20} *Redundant paperwork*: Duplicating, filling out, reviewing, and classifying patients' paperwork, which contain information that they must be filled out and some of them will never be used, results in redundant paperwork for both patients and staff. Including only the necessary information in the documents will make the process easier.
- C_{21} *Redundant transaction that causes repeated action*: There are procedures that are repeated in health institutions due to habits or lack of knowledge, although they have no contribution. For example, setting the centrifugation process for more than recommended or required time does not contribute, while the process is prolonged.

- Human criteria: Lean management is not only concerned with managing processes, but also directing employees by managing them, encouraging them to develop themselves more. Because one of the main elements of lean management is respect for people.
  - C_{22} *Preventing the development of the employee and not including him/her in business processes*: Employees are only asked to fulfil their assigned tasks and they are not allowed to develop themselves and express their business ideas. This causes employees to feel worthless and like a robot. Employees should be included in business processes, their opinions should be taken and they should feel that they are important for this business.
  - C_{23} *Excessive workload and low motivation*: Sometimes employees may be given more tasks than they can do due to lack of personnel, which may result in physical fatigue, low motivation and even leaving the job. In order to reduce the overload on employees, business processes should be reviewed and a work plan should be made to optimize employee performance.
  - C_{24} *Employees' inability to use devices due to lack of knowledge*: Failure to provide employees with the necessary and sufficient training on the devices they will use causes employees to have difficulty using the devices, to feel inadequate and reduce their work motivation. This may cause errors in the processes, as well as prolonging or repetition of business processes.

3.3 Alternative lean methodologies

The huge costs and productivity decline in the health sector have revealed the necessity of applying lean production methodologies to the health sector. In this context, firstly, the situations (wastes) that prevent the process flow should be identified and made visible, and then a lean health system free from waste should be created by solving them with appropriate techniques. Alternative lean methodologies that will ensure the disposal of the research criteria, namely wastes, determined within the scope of this study, have been determined as follows:

- A_1 *Value Stream Mapping (VSM)*: With this technique, it is aimed to show the service line flow of a patient in healthcare services from arrival to hospital discharge. VSM ensures the flow of information and service without interruption. In addition, VSM takes into account many other processes such as fast and accurate examination, interested and qualified personnel, accurate diagnosis, accurate patients' information, reliable service and personnel, and compliance with hospital visiting hours.
- A_2 *5S*: Cleanliness and organized factors in health institutions are very important for both patients and employees. The 5S technique ensures that the applications that will provide a clean and spacious environment in the hospital are made permanent. Although the need to use machinery, equipment and tools in more than one different process makes the application of the 5S technique difficult, the technique also helps to make waste visible.
- A_3 *Kanban*: This methodology controls the process by providing the demand needs without any misunderstanding, at the same time, by providing the information about the number, type and delivery place and time of the product to be demanded by the next technical process. For this reason, Kanban is suitable at hospitals for use in processes where continuous flow is required such as material needs and stock management.
- A_4 *Kaizen*: With this methodology that supports continuous development and change, improvements are made in the hospital work discipline by evaluating patient complaints by ensuring integrity through the implementation of in-house coordination and planning. Kaizen philosophy can be used in the improvement of all processes in the hospital, and emphasis on employee training and employee development. The disadvantage of the methodology is that it is not easy to adopt this philosophy in all employees.
- A_5 *Six Sigma*: Methodology makes improvements with statistical calculations to ensure perfection in all processes within the hospital. For this purpose, methodology, which deals with the entire process in the hospital, covers all the wastes that occur in the hospital and focuses on eliminating these wastes.

3.4 Proposed research model

As a result of the research, the wastes and details that prevent the process flows in the health sector have been clearly identified. The multi-criteria research model established for the evaluation of lean management methodologies that can be used to prevent these identified wastes is shown in Figure 1 with its' criteria, sub-criteria and alternatives.

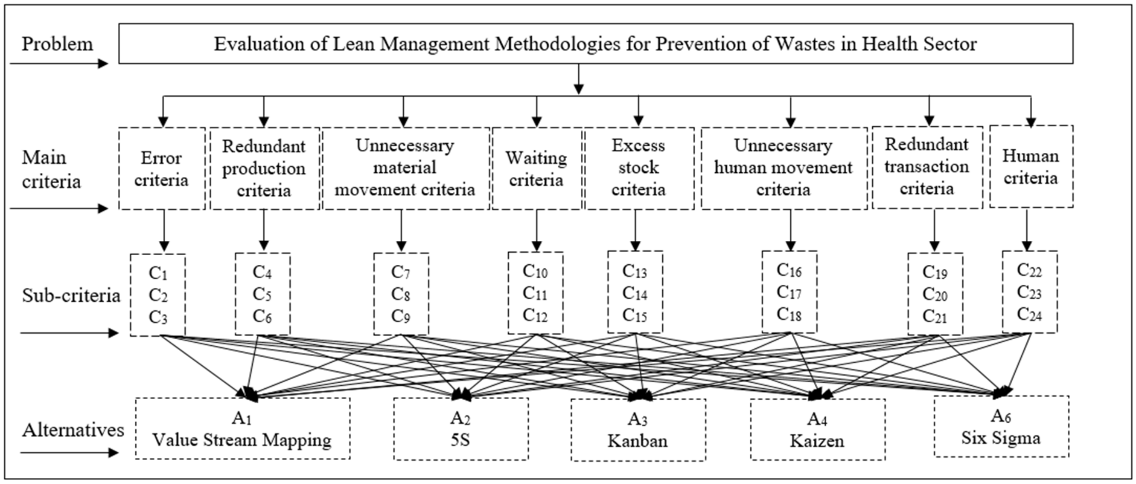

Fig. 1. Proposed research model for evaluating lean methodologies for prevention of wastes

3.5 A two-stage solution for the research problem

Today, while the development level of countries is associated with health services, it is clear that countries with high social and financial welfare have strong health services. With the health indicators formed by the measurement of the health performances of the countries, it is determined whether there is a need for change or innovation in health policies. At this point, identifying and eliminating waste are the most important indicators to ensure patient satisfaction, to carry out effective and efficient treatment processes, and to get the highest share from the existing market in global competition.

In this study, the problem of determining the wastes that negatively affect the health sector and evaluating the lean management methodologies that can eliminate these wastes are discussed. The MCDM model proposed within the scope of the problem was solved with two MCDM methods used in two stages, while the SWARA method was used to determine the importance weights of wastes in the first stage, the evaluation process of lean management methodologies was carried out with the WASPAS method. The solution stages of the research problem are shown in Fig. 2 and the application steps of SWARA/WASPAS techniques are explained in detail in the next section.

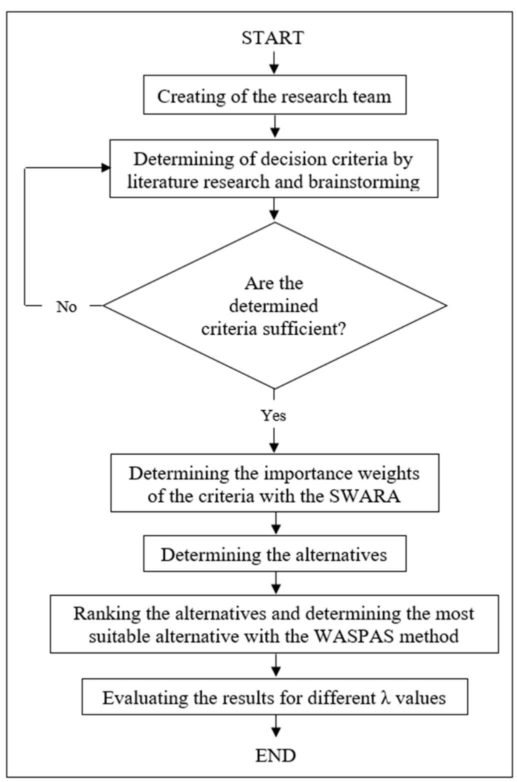

Fig. 2. The solution stages of the research problem

3.5.1 Determining of wastes importance weights with SWARA method

The SWARA method, which is used to determine the weights of the criteria that have an effect on problem solving by analyzing a large number of criteria in a way that maximizes the benefit, was proposed by Keršulienė, Zavasdkas and Turskis in 2010. Its user-friendly structure, simple application steps and adaptability to all kinds of multi-criteria problem sorts have expanded the field of use of the method in a short time.

The method, which enables the determination of criterion weights with a decision maker or group decision, encourages decision makers to make choices by paying attention to their own priorities. In this way, in order to avoid ambiguities in the calculation of criterion weights, simple comparisons are made and the knowledge and experience of experts is used (Keršulienė et al., 2010).

The application steps of the SWARA method are as follows (Keršulienė and Turskis, 2010; Debnath et al., 2023; Hassan et al., 2023).

Step 1: The criteria and the alternatives of the problem and the decision makers committee that will participate in the selection process are determined. While the criteria are indicated by C_j and alternatives by A_i, the number of decision makers is l_k.
In this study, there are 24 wastes, 5 alternative lean management methodologies and 2 decision-making groups. While the 1st decision group consists of patients, health personnel and managers working in state institutions, the 2nd decision group consists of patients, health personnel and managers working in private health institutions (*j = 1, ..., 24*; *i = 1, ..., 5*; *l = 1, 2*).
Step 2: Each decision maker involved in the selection process evaluates the criteria by utilizing their knowledge, experience and expertise and ranks the criteria from the most important one to the least important one according to their importance levels in order to create an integrated order. Then, decision makers give p_j^k values to the criteria in accordance with this ordering ($0 \leq p_j^k \leq 1$). A criterion's p_j^k value of *1.00* indicates that that criterion is the most important criterion, while other criteria take relative importance according to this criterion.
Step 3: The relative average importance score ($\overline{p_j^k}$) is calculated for all criteria with the help of Eq. (1)

$$\overline{p_j^k} = \frac{\sum_{k=1}^{l} p_j^k}{l} \tag{1}$$

In this study, the ranking of the criteria and p_j^k values of them were obtained for both decision groups, and then average $\overline{p_j^k}$ values were calculated for all criteria. The rankings and $\overline{p_j^k}$ values are shown in Table 2.

Table 2
The ranking and $\overline{p_j^k}$ values of criteria

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
DG_1	23	17	1	22	20	21	16	15	10	7	4	5
DG_2	23	11	1	17	16	24	8	9	21	10	22	3
Criteria	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}
DG_1	6	18	19	24	8	9	14	12	11	3	2	13
DG_2	12	15	13	14	7	2	20	18	19	5	4	6
Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
DG_1	0.20	0.43	1.00	0.25	0.32	0.30	0.45	0.48	0.62	0.75	0.85	0.80
DG_2	0.25	0.60	1.00	0.45	0.48	0.20	0.75	0.70	0.34	0.64	0.30	0.97
$\overline{p_j^k}$	0.225	0.515	1.000	0.350	0.400	0.250	0.600	0.590	0.480	0.695	0.575	0.885
Criteria	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}
DG_1	0.77	0.40	0.35	0.15	0.70	0.65	0.50	0.56	0.60	0.95	0.98	0.55
DG_2	0.57	0.51	0.55	0.52	0.80	0.95	0.35	0.43	0.40	0.87	0.90	0.85
$\overline{p_j^k}$	0.670	0.455	0.450	0.335	0.750	0.800	0.425	0.495	0.500	0.910	0.940	0.700

Step 4: For each criterion ranked from the largest to the smallest according to the $\overline{p_j^k}$ values, the comparative importance of the mean value (s_j) is calculated with the condition of starting from the second criterion. Each s_j value is obtained by comparing the *j* criterion with the previous one *(j-1)*.

Step 5: The coefficient value (c_j) for each criterion is calculated by Eq. (2). The c_j value of the criterion with the highest $\overline{p_j^k}$ value is *1.00*.

$$c_j = \begin{cases} 1 & if \quad j = 1 \\ s_j + 1 & if \quad j > 1 \end{cases} \tag{2}$$

Step 6: The adjusted weight value (s'_j) for each criterion is calculated by Eq. (3). The s'_j value of the criterion with the highest $\overline{p_j^k}$ value is *1.00*.

$$s'_j = \frac{s'_{j-1}}{c_j} \tag{3}$$

Step 7: The importance weight value (w_j) for each criterion is calculated by Eq. (4).

$$w_j = \frac{s'_j}{\sum_{j=1}^{n} s'_j} \tag{4}$$

For this study obtained $\overline{p_j^k}$ values and calculated s_j, c_j, s'_j and w_j values are shown in Table 3.

Table 3
For all criteria $\overline{p_j^k}$, s_j, c_j, s'_j and w_j values

Criteria	$\overline{p_j^k}$	s_j	c_j	s'_j	w_j	Criteria	$\overline{p_j^k}$	s_j	c_j	s'_j	w_j
C_3	1.000	-	1.000	1.000	0.0612	C_2	0.515	0.060	1.060	0.624	0.0382
C_{23}	0.940	0.060	1.060	0.943	0.0575	C_{21}	0.500	0.015	1.015	0.614	0.0376
C_{22}	0.910	0.030	1.030	0.916	0.0561	C_{20}	0.495	0.005	1.005	0.611	0.0374
C_{12}	0.885	0.025	1.025	0.894	0.0547	C_9	0.480	0.015	1.015	0.602	0.0369
C_{18}	0.800	0.085	1.085	0.824	0.0504	C_{14}	0.455	0.025	1.025	0.588	0.0360
C_{17}	0.750	0.050	1.050	0.784	0.0480	C_{15}	0.450	0.005	1.005	0.585	0.0358
C_{24}	0.700	0.050	1.050	0.747	0.0457	C_{19}	0.425	0.025	1.025	0.570	0.0349
C_{10}	0.695	0.005	1.005	0.743	0.0455	C_5	0.400	0.025	1.025	0.557	0.0341
C_{13}	0.670	0.025	1.025	0.725	0.0444	C_4	0.350	0.050	1.050	0.530	0.0324
C_7	0.600	0.070	1.070	0.678	0.0415	C_{16}	0.335	0.015	1.015	0.522	0.0320
C_8	0.590	0.010	1.010	0.671	0.0411	C_6	0.250	0.085	1.085	0.481	0.0295
C_{11}	0.575	0.015	1.015	0.661	0.0405	C_1	0.225	0.025	1.025	0.470	0.0287

According to Table 3, *C_3 Medical errors that cause disability or death of the patient* are at the focus of the criteria, which are given importance by the users who benefit from the health service and serve in the health sector with *0.0612* importance weight score, while this waste is followed by *C_{23} Excessive workload and low motivation* with *0.0575* importance weight score. In addition, *C_1 Application of the unclaimed service to the value* is determined as the least important waste among all criteria, with an importance weight of *0.0287*. After determining the importance weights of all criteria with the SWARA method, the second step of the solution is started with the WASPAS method. With WASPAS method, the alternatives are evaluated based on criteria.

3.5.2 Evaluating of alternative lean management methodologies with WASPAS method

The WASPAS method was developed by Zavadskas et al. in 2012. It is a MCDM method formed by the integration of the results of two different models, Weighted Sum Model and Weighted Product Model. In the solution of the problem, high consistency is the target in the method that uses the performance values and criterion weights of the alternatives based on criteria with the goal of optimality according to the results of the two models (Zavadskas et al., 2012).

The WASPAS method has been expanding its area of use in recent years, as it is user-friendly and eliminates the need for extra consistency analysis due to its structure.

The application steps of the WASPAS method are as follows (Zavadskas et al., 2012; Debnath et al., 2023):

Step 1: The criteria and the alternatives of the problem and the decision makers committee that will participate in the evaluation process of the alternatives are determined.
In this study, there are 24 wastes, 5 alternative lean management methodologies and 2 decision-making groups.
Step 2: By using one of the MCDM methods, criterion importance weights are determined by the decision makers.
In this study, the importance weights of 24 criteria were determined by SWARA method and the obtained results are shown in Table 2.
Step 3: The decision matrix (*X*) showing the performances of the alternatives based on different criteria is created as in Eq. (5).

$$X = [x_{ij}]_{m \times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}, i = 1, 2, \dots, m \text{ and } j = 1, 2, \dots, n \tag{5}$$

After the criteria weights were determined by the SWARA method, the alternatives were compared by the decision makers according to the criteria and scored between 0-100 according to their performance. The initial decision matrix created and shown in Table 4.

Table 4
Initial decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
A_1	70	95	70	85	65	65	55	75	85	65	55	50
A_2	90	80	85	40	55	55	65	85	60	50	65	100
A_3	20	20	10	100	80	85	70	65	45	90	85	75
A_4	85	65	65	75	70	70	85	95	90	80	95	95
A_5	100	100	100	60	95	95	100	50	70	100	75	85

	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}
A_1	75	75	85	80	70	90	55	60	75	50	50	50
A_2	65	55	60	60	100	100	85	85	95	85	85	100
A_3	85	100	90	100	50	40	40	40	40	35	35	35
A_4	100	95	95	85	95	85	75	75	90	100	100	95
A_5	70	85	75	75	85	70	95	95	100	95	100	75

Step 4: The decision matrix created in Step 3 is normalized and the normalized decision matrix ($\overline{x_{ij}}$) is created.
Evaluation criteria in decision processes may differ according to the nature of the problem. Some problems contain benefit-based criteria, while others include cost-based criteria. While it is aimed to maximize the values in the benefit-based criteria, it is expected to be minimized in the cost-based criteria. The benefit-based criteria are normalized with Eq. (6), and the cost-based criteria are normalized with Eq. (7).

$$\overline{x_{ij}} = \frac{x_{ij}}{max_i x_{ij}} \tag{6}$$

$$\overline{x_{ij}} = \frac{min_i x_{ij}}{x_{ij}} \tag{7}$$

Since all the criteria of the MCDM model created in this study consist of waste, all of them should be minimized. In other words, all the criteria of the model are cost-based and the normalization of the initial decision matrix is done with Eq. (7). The normalized decision matrix is shown in Table 5.

Table 5
Normalized decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
w_j	*0.0287*	*0.0382*	*0.0612*	*0.0324*	*0.0341*	*0.0295*	*0.0415*	*0.0411*	*0.0369*	*0.0455*	*0.0405*	*0.0547*
A_1	0.286	0.211	0.143	0.471	0.846	0.846	1.000	0.667	0.529	0.769	1.000	1.000
A_2	0.222	0.250	0.118	1.000	1.000	1.000	0.846	0.588	0.750	1.000	0.846	0.500
A_3	1.000	1.000	1.000	0.400	0.647	0.647	0.786	0.769	1.000	0.556	0.647	0.667
A_4	0.235	0.308	0.154	0.533	0.786	0.786	0.647	0.526	0.500	0.625	0.579	0.526
A_5	0.200	0.200	0.100	0.667	0.579	0.579	0.550	1.000	0.643	0.500	0.733	0.588

	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}
w_j	*0.0444*	*0.0360*	*0.0358*	*0.0320*	*0.0480*	*0.0504*	*0.0349*	*0.0374*	*0.0376*	*0.0561*	*0.0577*	*0.0457*
A_1	0.867	0.733	0.706	0.750	0.714	0.444	0.727	0.667	0.533	0.700	0.700	0.700
A_2	1.000	1.000	1.000	1.000	0.500	0.400	0.471	0.471	0.421	0.412	0.412	0.350
A_3	0.765	0.550	0.667	0.600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
A_4	0.650	0.579	0.632	0.706	0.526	0.471	0.533	0.533	0.444	0.350	0.350	0.368
A_5	0.929	0.647	0.800	0.800	0.588	0.571	0.421	0.421	0.400	0.368	0.350	0.467

Step 5: The total relative importance value for each alternative is first calculated by Eq. (8) according to the Weighted Sum Model. This value is called the first total relative importance value $Q_i^{(1)}$. Then, the total relative importance value for each alternative is calculated with Eq. (9) according to the Weighted Product Model. This value is called the second total relative importance value $Q_i^{(2)}$.

$$Q_i^{(1)} = \sum_{j=1}^{n} \overline{x_{ij}} w_j \tag{8}$$

$$Q_i^{(2)} = \prod_{j=1}^{n} \left(\overline{x_{ij}}\right)^{w_j} \tag{9}$$

The w_j values used in Eq. (8) and (9) are the criterion importance weights found by the SWARA method for this study.
Step 6: The combined optimality value (Q_i) for each alternative is calculated with Eq. (10) by taking into account the results of Weighted Sum Model and Weighted Product Model.

$$Q_i = \lambda {Q_i}^{(1)} + (1 - \lambda){Q_i}^{(2)} \tag{10}$$

Here, λ is the combined optimality coefficient and $\lambda \in [0,1]$. In cases where the Weighted Sum Model and Weighted Product Model approaches have equal effects on the combined optimality criterion, $\lambda = 0.5$ is taken.
In this study, the combined optimality values obtained for each alternative are shown in Table 5 by taking the optimality coefficients of *0.25*, *0.50* and *0.75*, respectively.
Step 7: Considering the combined optimality values, all alternatives are ranked. In this ranking, the alternative with the largest Q_i value is the best one.
Calculated $Q_i^{(1)}$, $Q_i^{(2)}$, Q_i values of the alternative lean methodologies and the ranking of the alternatives are shown in Table 6.

Table 6
$Q_i^{(1)}$, $Q_i^{(2)}$, Q_i values and the ranking of the alternatives

Alternatives		$Q_i^{(1)}$	$Q_i^{(2)}$	Optimality value of alternatives			Ranking of alternatives
				$\lambda = 0.25$	$\lambda = 0.5$	$\lambda = 0.75$	
A_1	Value Stream Mapping	0.6636	0.6025	0.6178	0.6330	0.6483	2
A_2	5S	0.6180	0.5345	0.5554	0.5762	0.5971	3
A_3	Kanban	0.8370	0.8131	0.8191	0.8251	0.8311	**1**
A_4	Kaizen	0.5334	0.4670	0.4748	0.4827	0.4905	5
A_5	Six Sigma	0.5349	0.4699	0.4888	0.5037	0.5186	4

The ranking of alternatives obtained according to the Q_i values shown in Table 6 is $A_3 > A_1 > A_2 > A_5 > A_4$.

3.6 Research findings

According to the results of the study, Kanban (A_1) was determined as the most suitable lean methodology alternative to prevent wastage in the health sector. Kanban alternative was followed by Value Stream Mapping, 5S, Six Sigma and Kaizen alternatives, respectively.

With the Kanban methodology, excess production in health services is prevented and negative processes arising from stocks are eliminated. Again, with the same methodology, waitings are eliminated for both employees and customers and also unnecessary equipment and employee movements are prevented.

This study is about identifying wastes and problems in health services, which issues should be paid attention to, and in which direction organizations and processes need to develop. With this study, it has become possible to clarify the issues that need to be improved by identifying the wastes that hinder development and productivity in the health sector. In particular, taking the opinions of real patients and employees in the prioritization of criteria and evaluation of alternatives contributed to the literature both theoretically and practically. While the study offers a theoretically integrated approach to the literature, it also reveals the deficiencies, risks, difficulties and errors.

4. Conclusion

Health consists of four basic components: physical, spiritual, mental and social. A healthy individual is formed by the harmony of these four basic components. The health factor is one of the most important factors in maintaining the lives of the individuals who make up the society happily. The common feature of countries with a high level of welfare and happiness is the investments they make to improve and develop the health sector, and these investments primarily affect the individual and then the society positively.

Dense population, insufficient number of healthcare providers, increasing demand, etc. sometimes may cause disruption of health services, decrease in the quality of the service provided or inefficiency of the system. It is a necessity to improve the health system and simplify it by cleaning it from wastes, especially as a result of the complexity of the hospital management, which cannot meet the demands as a result of increasing demand, increasing complaints, inefficient and poor quality processes.

This study was carried out with the aim of creating a lean health system free of waste with the most appropriate methodology by evaluating lean management methodologies in order to identify and prevent waste in health processes, to increase efficiency and service quality, in order to simplify health services and clean them from waste.

Within the scope of the study, a multi-criteria model with 24 decision criteria consisting of wastes in the health sector and 5 alternatives consisting of lean management methodologies was established and this proposed model was solved in two stages with SWARA and WASPAS methods. With this study, which draws attention to how effective and efficient MCDM techniques are in the field of health and health services, the wastes in the health sector have been identified, the importance weights of the wastes have been determined and the lean methodologies that can be applied for more efficient and effective health processes have been evaluated.

This research work carried out encourages the formation of lean health systems for the future and guides research and studies in the field of health. While not including all lean management methodologies in the evaluation is a limitation for this study, evaluations in future studies can be carried out for the purpose of lean health service by updating the criteria/alternatives, used methods and taking into account the user comments that can be added. Thus, the research interpretations made under the initial and future environmental conditions of the study can also be compared.

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