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Karakuri: A proposal to waste reduce in the Health Service

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Abstract. The objective of this study is to analyze the adherence of the Karakuri (low-cost automation) technology for eliminating Lean wastes in healthcare units. To carry out this study reports of continuous improvement practices were analyzed from three Units located in the State of São Paulo (Brazil). These practices of Lean Healthcare approach implementation were applied during the period from June to October 2020. The present literature on the term Karakuri was also analyzed in four data research bases and it was made a study around correlate cases. In conclusion, it is noted that Karakuri seems capable of eliminating the main wastes reported in the analyzed health units in question, which are: defects, motion, waiting, and not using human talent.

Keywords: Karakuri · Lean Healthcare · Lean Wastes · Low-cost automation

1 Introduction

1.1 Conceptualization

In the global pandemic scenario declared by the WHO (World Health Organization) in January 2020, worldwide attention has turned to the health area. The increase in reports and publications related to the theme is considerable, not only in the health area but also in the areas of management, technologies, and public policies. Overcrowding in health services is a problem faced worldwide that has gained a broader focus. In Brazil, SUS, the Unified Health System, stands out as the only universal public health system that serves more than 100 million people. According to IBGE (Brazilian Institute of Geography and Statistical), 7 out of 10 Brazilians depend on SUS for actions related to healthcare [8]. In the public health there is a constant political and social pressure to increase service levels and decrease costs [6].

In the context of the need to reduce waste, increase quality and productivity, Lean Manufacturing (LM), or Lean Production, stands out with the “do more

with less” approach [5] LM is an approach from the Toyota Production System (TPS - Toyota Production System) whose focus is to reduce waste, shorten times and increase the quality of production processes [21]. The term Lean Manufacturing became popularly known in the mid-90s with the book “The Machine that Changed the World” [30] segments have sought Lean approach to improve their processes.

In the current context, automation can play an important role in creating value and increasing patient satisfaction [2]. According to Granlund and Wiktorsson [6], automation proves to be a successful way of reducing the time spent on attention to activities that do not add value to the health environment.

The term *Karakuri* (which means, in Japanese, “mechanism” or “trick”) was used in the past to refer to automation dolls used as entertainment in Japan. Through the use of physic principles, the *Karakuri* devices execute intelligent movements. Today, the term is used to describe devices with similar characteristics that are being used to increase the productivity of the work environment in simple, easy-to-implement, and low-cost automation [24]. According to Bhanu and Kumar. [3], *Karakuri* is an automation technique, part of the Lean strategy that provides low-cost automation solutions, with simple maintenance and a quick return on investment capable of bringing innovation at low cost.

Considering the above, this work aims to analyze the adherence of *Karakuri* automation technique for the elimination of waste associated with 3 Emergency Care Units (UPA) located in the state of São Paulo, Brazil. This proposal is formulated to achieve the following specific objectives:

- Analysis of waste associated with the 3 UPAs under study;
- Analysis of the wastes mentioned in the *Karakuri* literature;
- Presentation of correlated *Karakuri* application in literature;
- Comparison between the need and benefits from *Karakuri* application in healthcare units.

2 Theoretical Framework

2.1 The 8 Lean Wastes

According to Bahnu and Kumar [3], lean production works with a simple but vital concept of eliminating waste and providing good quality products and services. The Lean concept, (according to the authors) keeps production costs as low as possible while guaranteeing quality. The waste or *Mura*, in Japanese, can be taken as activities that do not add value to the customer. The authors add that waste elimination results in decreased inventories, a better quality of work, products, and improved services. Leading them to build a better relationship with customers and suppliers. According to Ohno [21], real efficiency improvement is achieved when no waste is produced, that is, when only the necessary quantity is produced, with the necessary manpower capacity.

The seven wastes of lean thinking, proposed by Ohno [21] are presented in Table 1 along with the eighth waste proposed later by Liker and Meier [13]. The

waste addressed in Table 1 from Lean Manufacturing is brought to the Lean Healthcare through the examples of Costa and Godinho Filho [4].

Table 1. Lean Wastes definition and examples (Source: Adapted by the author from Ohno [21], Liker and Meier [13] and Costa and Godinho Filho [4])

Waste	Definition by Ohno [21] and Liker and Meier [13]	Example in Healthcare by Costa and Godinho Filho [4]
Overproduction	Produce earlier or in larger quantities than necessary.	Perform unnecessary treatment
Waiting	Inoperative operations, processes, or workers waiting for the end of a process, lack of tools, supplies, parts, or information.	Wait for a doctor's appointment
Transport	Parts or products moved unnecessarily.	Transfer patients between rooms
Over processing	Perform unnecessary process that does not add value to the customer.	Filling out unnecessary forms
Inventory	Raw material, finished products, or Work In Process beyond the quantity needed for a controlled system.	Medicines out of stock or in excess
Motion	Extra movement by employees that does not add value to the final customers.	Search for medicines
Defects	Need for rework or defective products.	Inspect work already done looking for errors
Defects	Waste of time, ideas, improvements, skills, and creativity	(Not covered)

2.2 Karakuri: A Lean automation technology

Karakuri dolls are the precursors of industrial robots [9]. The history of robotics in Japan began in the EDO period (1603 onwards) when several Karakuris were made with the simple intention of bringing fun to people. Despite its millenary history, Karakuri technology continues to be used today mainly in the industry. According to Murata et al. [20] the Karakuri's goal in the industry is to automate an objective operation, making it easier to perform and thus increasing productivity. Aiming this the Technology uses a simple mechanism based mainly on natural principles such as mechanical principles (levers, pulleys, gears, and cam connection mechanisms), hydromechanics, magnetism, sound, optics, and physical properties in general.

Karakuri technology consists of devices that produce work with low energy and without any motor or power unit, that is, without electricity. Weber [29] mentions, for example, that a Karakuri system of frames, can incorporate rollers, levers, pedals, and counterweights to move, by gravity, boxes of parts and components.

Currently, Karakuri is disseminated by multinational companies such as Toyota, which includes it as a global goal in their day-to-day. The company, cradle of Toyota Production System, finds in Karakuri several benefits such as energy savings, reduced emissions of carbon, ergonomic improvements, and use of human talents. The global initiative of training its employees in Karakuri Kaizen around the world can engage teams to propose solutions and implement them in their lines of work.

3 Methods and Data

3.1 Wastes Analysis in health units

For this study, the waste identified in reports from 3 UPAs located in the State of São Paulo (Brazil) was analyzed. We will call the UPAs as UPA 1, UPA 2, and UPA 3. In all, 88 reports of Lean improvement practices associated with the elimination of 8 wastes previously listed. Table 2 shows the number of times that each waste was associated with each unit analyzed.

Table 2. Wastes in analyzed ECU (UPAs).

Waste category	UPA 1	UPA 2	UPA 3	Total
Overproduction	0	1	0	1
Waiting	7	7	9	23
Transport	0	0	0	0
Over processing	0	2	2	4
Motion	2	16	13	31
Inventory	2	1	6	9
Defects	11	10	19	40
Unutilized talent	12	4	2	18
Total	34	41	51	126

Through the Pareto chart in Figure 1, it is possible to analyze that four categories are responsible for 88.9% of the waste of the analyzed UPAs, which are: defects, movement, waiting, and non-use of human talent. Therefore, by Pareto rule, we consider these to be the most important waste to be eliminated.

3.2 Karakuri – Theoretical review of eliminated Lean wastes

In this research stage, a bibliographic search for the term "Karakuri" was carried out in the following Databases: Scopus, Compendex, Web of Science, Taylor and

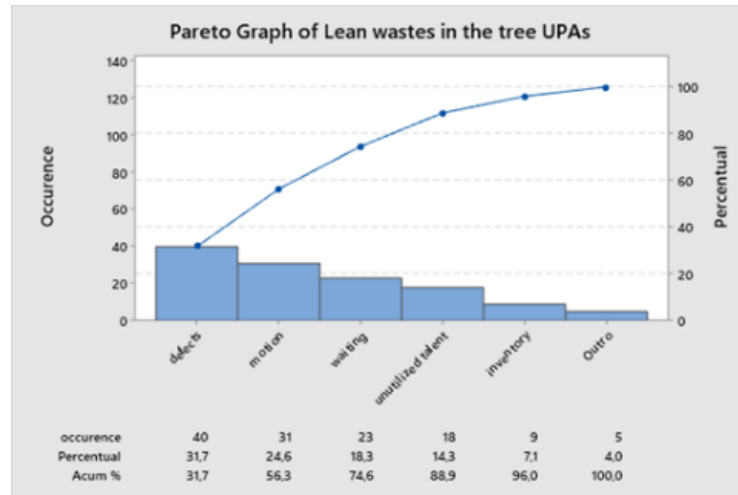


Fig. 1. Analysis of Wastes in Karakuri literature (Source: From Author)

Francis. The first search identified a total of 86 conference papers and journal articles between the years 2001 and 2020. The documents were screened by the scheme presented in Figure 2. As illustrated in the Figure, after the screening, 3 more documents were added from external fonts to enrich the analysis.

After the filtering and selection steps according to the image above, 19 articles were selected and analyzed for evidence of waste elimination. Table 3 lists the types of waste eliminated in each document analyzed. Articles 14. and 15. are purely mathematical/physical articles that do not address nor indicate the benefits of Karakuri in eliminating waste.

The Pareto chart on Figure 3 lists the waste most often cited as disposed of after the Karakuri technique implementation in the analyzed articles. From the graph, it is possible to see that, according to the authors, the most eliminated waste was respectively: excessive movement, transportation, waiting, not using human talent, being responsible to 91,7% of total wastes related.

3.3 Karakuri correlated cases from literature

From the literature review, the correlated cases was analyzed by 5 main questions as follows in Table 4.

3.4 Karakuri health examples

In the literature analyzed in previous steps, just one example was related to health use [11] however some examples of Karakuri are found in the area, despite not being popularly recognized as Karakuri. The Alcohol in Gel mechanical dispenser is a Karakuri device that allows the user to sanitize their hands with a

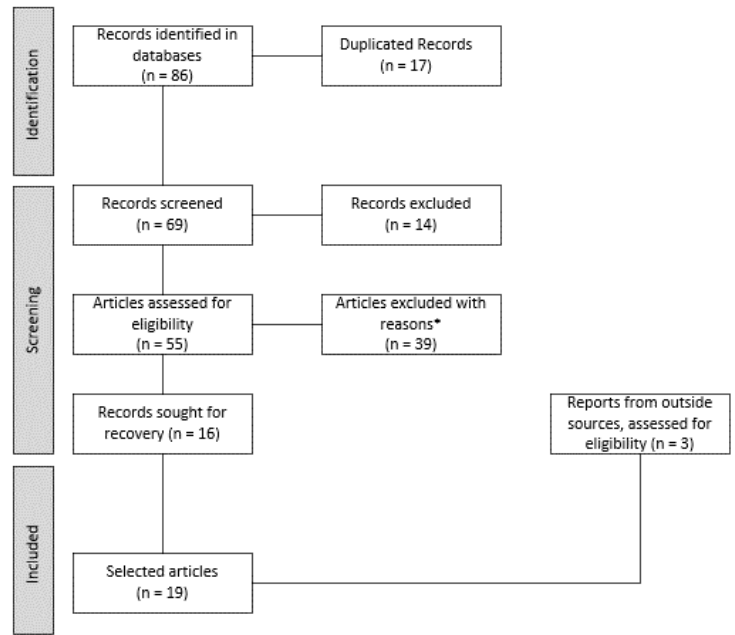


Fig. 2. Research screening process (Source: Adapted by the author from PRISMA [22].)

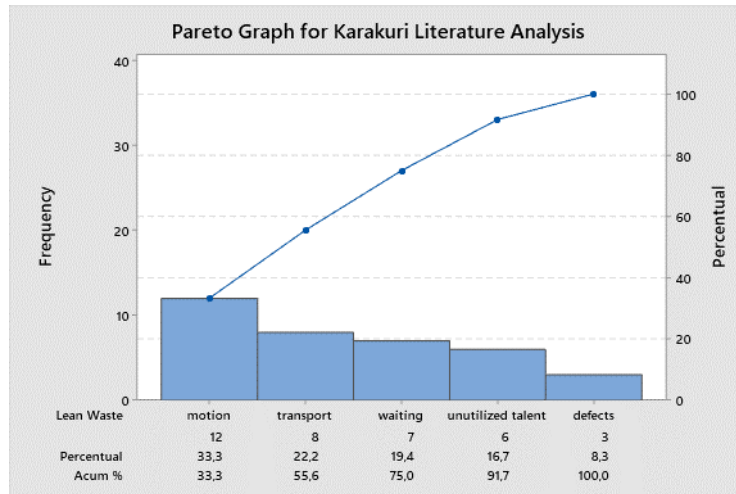


Fig. 3. Pareto Graph of Karakuri Literature Analysis (Source: From Author)

pedal input, minimizing contamination risks through a simple, ergonomic, and low-cost solution, as they can be built with easily accessible materials. In this

Table 3. Wastes in analyzed ED (UPAs).

Source	Wastes Associated
1. Prasetyawan et al.[23]	Defects, transport, motion, and unutilized talent
2. Anggrahini et al. [1]	Motion, waiting and transport
3. Riegr and Mašín [26]	Motion and transport
4. Heng et al. [7]	Motion and transport
5. Madisa et al. [14]	Waiting and motion
6. Yamamoto et al. [31]	Unutilized talent
7. Kit et al. [12]	Motion, transport, and waiting
8. Sawaguchi [27]	Unutilized talent
9. Mašín ant Riegr [15]	Unutilized talent and motion
10. Rani et al [24]	Waiting, motion, transport, and defects
11. Katayama et al. [10]	Waiting, motion, and transport
12. Weber [29]	Waiting and unutilized talent
13. Murata and Katayama [19]	Unutilized talent
14. Riegr e Mašín [25]	N/A
15. Mašín e Riegr [16]	N/A
16. Matsuidara [17]	Motion and transport
17. Kijima et al [11]	Waiting and unutilized talent
18. Shamsudin et al [28]	Motion
19. Bhanu and Kumar [3]	Motion

case, the process is facilitated, and the employee's exposure to biological risk is reduced.

Another example of this concept application in health is the device for adjusting the height of stretchers, where the principle of levers and cranks reduces the physical effort required to change the posture of bedridden patients. Thus, making the procedure more ergonomic, with less risk to the patient and the professional, in addition to allowing a smoother change in posture, ensuring the patient's well-being.

4 Conclusion

The present study aimed to compare the wastes found in the Emergency Care Units (UPAs) analyzed and what the Karakuri technique can deliver as a benefit. By comparing the wastes from literature and wastes found in UPAs we conclude that the technique seems to contribute to eliminate the three main wastes found in the studied reports from UPAs (defect/rework, movement, waiting, and non-use of human talent). Thus, by the examples in the health area and by the correlated cases, it is indicated that Karakuri could bring benefits to the humanization, environment, ergonomic improvements, savings, and risk reduction when used as a low-cost automation technique in the Lean Healthcare scenario.

As a proposal for future work, it is suggested to study more deeply the interaction between Karakuri application in Health, its limitation, and steps,

Table 4. Karakuri Correlated cases

Ref	Mechanism
[1]	The mechanism works through the gravitational potential energy (weight of the food mixture) added to the mechanical energy from a machine in the previous process, the pan with the preparation slides on the conveyor through rollers, ensuring the transfer of the mixture to the next station. The authors point out that the improvement had a low implementation cost, despite not delving into financial details.
[29]	The energy used by the Karakuri comes from the gravitational potential energy (the weight of the pan). The pan is placed on a platform that "lowers" its weight and transfers it to a conveyor, guiding it to an automated oven. After the cooking time, the oven releases the pan on the other section of the platform, taking the pan to the next production step. The Karakuri was made of aluminum, PVC tubes, bearings, and others that guarantee the low cost of the technique.
[2]	This Karakuri cart benefits from the weight transported, which releases a brake mechanism and allows movement until another brake mechanism stops the system on the opposite wheels. When the weight is removed, the cart returns to its initial position. The authors do not mention the costs for producing the solution but use low-cost materials for prototyping.
[3]	The proposed solution is an inclined plane equipped with bearings that move and provide friction as needed to the plant trays. The structure also has a mechanism for allocating pumps for irrigation of the crop. The author does not address values; however, he justifies that the choice of method is due to the low-cost relative to other automation options.
[4]	From the before/after image and the complementary text, it is possible to verify that the incorporated mechanism raised the workers' posture, acting mainly in the coil replacement system, where it is possible to verify the presence of a lever and bearings, indicating that the energy that moves the Karakuri system in question is mechanical energy. The authors point out the Karakuri as a low-cost technique, but authors do not detail them in the studied literature.
[6]	Mechanical energy reaches the Karakuri through the activation of a pedal, which transforms it into potential energy, allowing the empty input box to be replaced by a full input box to supply the workstation. For the sliding of the boxes, bearings are used in an inclined plane. A lever system is used through the foot pedal. The author does not address specific costs for implementing the technique, however, he informs that its application in transport and supply systems is justified in view of the cost of other means of automation.
[10]	The application in the manufacturing industry is justified to eliminate the need for electrical energy from the system (related to cost and supply failures). The new tipping system works through gravitational force, replacing the need for electricity. There was no substantial cost in the implementation of Karakuri, as equipment that already operated on electricity underwent adjustments to become a Karakuri solution.
[16]	The Karakuri technique is applied through a tube, which uses gravitational energy and moves a box full of parts brought by a self-guided vehicle (AGV) to a specific rail. The author ponders the savings provided by the use of Karakuri but does not effectively address its costs
[18]	The device works behind the simulated coat of a horse. The complex Karakuri mechanism receives mechanical energy through a crank and transmits it through gears, shafts, and other elements, resulting in elliptical movements in each horse's legs and other additional movements such as swinging the hips, simulating the animal trot. Despite not addressing financial aspects, the author points out that the technique had a low cost.

in order to explore the fact that there is only one article on the researched application of the method in the health area.

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