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Utilização da simulação a eventos discretos e lean production na assistência médica: análise de um centro de colonoscopia

Use of discrete event simulation and lean production in medical care: analysis of a colonoscopy center

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Resumo: A assistência médica com alta qualidade tornou-se imperativa em meio à pandemia COVID-19. Os avanços no desenvolvimento de modelos de simulação computacional para solucionar questões em serviços hospitalares ineficientes, sobretudo no que tange a utilização adequada dos recursos e redução do tempo de espera, têm propósito essencial. Neste contexto, o objetivo desta pesquisa é aplicar a Simulação a Eventos Discretos em um centro de atendimento coloproctológico, combinada às premissas do Lean Production para evidenciar as "atividades não agregadoras de valor" do fluxo processual. A metodologia empregada foi modelagem e simulação com o uso de dados reais. O objeto de estudo trata-se de centro de colonoscopia localizado no Hospital das Clínicas Samuel Libânio em Pouso Alegre, Minas Gerais, o qual realiza atendimentos em período matutino. Como resultado, evidenciou-se valor percentual médio agregador de valor de 28,24% no providing care, o qual indica operação ineficiente pela utilização insatisfatória dos profissionais médico e enfermeiro no atendimento ao paciente.

Palavras-chave: Simulação computacional; Simulação a eventos discretos; Lean Production; Análise de desperdícios; Centro de colonoscopia

Abstract: High-quality medical care has become imperative amid the COVID-19 pandemic. Advances in the development of computer simulation models to resolve issues in inefficient hospital services, especially with regard to the appropriate use of resources and reduction of waiting times, have an essential purpose. In this context, the objective of this research is to apply Discrete Event Simulation in a coloproctology care center, combined with the premises of Lean Production to highlight the "non-value-adding activities" of the procedural flow. The methodology used was modeling and simulation using real data. The object of study is a colonoscopy center located at the Hospital das Clínicas Samuel Libânio in Pouso Alegre, Minas Gerais, which provides services in the morning. As a result, an average value-adding percentage value of 28.24% in providing care was evidenced, which indicates inefficient operation due to the unsatisfactory use of medical and nursing professionals in patient care.

Keywords: Computer Simulation; Discrete Event Simulation; Lean Production; Colonoscopy Center; Waste Analysis.

1. Introdução

Because of the recent expansion of Smart Manufacturing (SM), operational systems for manufacturing and services have more technological resources available to support their management (Leite, 2023). In addition, computer simulation, which is one of the pillars of SM, had its components reinforced with the use of virtual reality in modeling and simulation projects (De Oliveira, 2023). In this context, with so many technological possibilities to help operating systems, there is, in Brazil, medical assistance with its chronic problems of management and control (De Souza, 2023). Thus, in order to mitigate these problems of inefficient management of medical care, this present project presents an application of a support and analysis tool that is discrete event simulation (DES), combined with the Lean Production philosophy.

Therefore, the objective of this research is to apply the DES in a real object of study of medical care combined with the premises of Lean Production to highlight the “non-value adding activities” (NVA).

2. Literature review

2.1. Discrete event simulation

According to Harrell, Ghosh and Bowden (2004), simulation is the imitation of a real system modeled on a computer, for later experiments to evaluate and improve its performance. On the other hand, for Banks (2005), discrete event simulation is the creation and observation of a history of a real system to generate inferences regarding it. The author Leal (2003), defines the simulation as the representation of a procedure in a shorter time than it would take in the real scenario and at a lower cost, favoring the prediction of the behavior of the system so that the necessary corrective actions can be taken, seeking the cost reduction. Second Bloomfield (2012), the fact that discrete event simulation simulates the behavior of systems without it physically existing, drastically reduces the cost of developing this system. In this same context, Ryan and Heavey (2006) point to simulation as one of the most used research techniques, mainly due to its versatility, flexibility and power of analysis.

Next, according to the definition of researchers Hillier and Lieberman (2001), DES is an extremely versatile technique, which can be used to investigate practically any type of stochastic system. This versatility has made simulation the most used operational research technique for studies dealing with stochastic systems. Also, according to these authors, due to the enormous diversity of its application, it is practically impossible to enumerate all the areas in which simulation has been used.

According to Carson (2004), the simulation is often time-consuming, the data are not available or are expensive to obtain, and the time available for decision-making is not enough for a safe study. In some situations, animations and other visual displays, combined with time pressure across all projects, can mislead decision makers into premature conclusions based on insufficient evidence. Furthermore, it is noteworthy that, according to Stansfield et al. (2014) simulation, despite having some application restrictions, if used correctly is a powerful force for organizational learning. According to Law (2009), simulation is an alternative to direct experimentation in the real system, thus avoiding costs due to real experimentation and interruption of the flow of activities in the real system. Chwif and Medina (2006) point out that, due to the great complexity of manufacturing models, due to their dynamic and random nature, a simulation model allows reproducing in a computer the same behavior that the system would have if submitted to the same boundary conditions.

Finally, regarding the advantages of DES, Banks (2005) highlight: new equipment projects, definitions of layouts and transport systems can be tested via simulation, without consuming resources or acquiring equipment; bottleneck analysis can be performed to find out where work-in-process, information and materials are in excess; and "what if " questions can be answered, which is particularly useful in designing new systems. In this context, it is worth noting that operations balancing projects can also be assertively developed through the SED (Vilela et al., 2020a).

2.2. Lean production

Lean Production (LP) had its origins in the Toyota company in the middle of the 20th century. At that time, the cost of inventories and the assembly line were significant, making it imperative to implement a new strategy focused on the analysis of waste. Taiichi Ohno, Toyota's chief executive at the time and responsible for structuring the new model, identified the seven production wastes that could be eliminated to reduce costs: defects; overproduction; unnecessary movement; unnecessary transport of material, tools or equipment; stock of final product, raw material or input; inappropriate processing; and wait. Each of the wastes is exemplified below (Ohno, 1997):

- ✓ Defects: cost of redoing, inspecting and repairing already inspected materials

✓ Overproduction: production above demand, raising manufacturing and production costs

✓ Unnecessary movement: movement of human and mechanical components unnecessary

✓ Unnecessary transport: excessive transport of materials and equipment generated, for example, by inadequate layouts

✓ Stock: Always have as little as possible in the process

The purpose of the LP is, therefore, the elimination of this waste, that is, any activity that demands resources, but does not create value for the customer (Oliveira; Afonso, 2017). The basic idea is to produce only what is needed, when needed and in the required quantity (Ohno, 1997) and according to Womack (1997), lean production is “lean” because it uses less of everything than mass production.

The LP concept, despite having already shown excellent results in its first applications with Toyota, was only popularized in the 90s with the publication of the book The Machine that Changed the World by Womack, Jones and Roos. From then on, it began to be adapted for operations management and has brought solutions to different areas, such as hospitals, education, civil construction, etc.

In this context, LP focuses on the idea of added value and consists of using best practices, tools and techniques, with the aim of reducing waste and maximizing the flow and efficiency of the production system to achieve end customer satisfaction with as little waste as possible. Therefore, LP is a manufacturing philosophy that increases the overall productivity of the system and, consequently, reduces the time between customer order and product delivery, eliminating mapped sources of waste (Rother; Shook, 1998). Finally, it is essential to highlight that one of the basic concepts of LP is the continuous improvement of the value stream or process (Kaizen). The latter is considered one of the most effective Japanese production methods since this philosophy emerged with a focus on improving processes through continuous waste reduction.

It is also worth mentioning that when carrying out temporal analyzes of a quantitative nature on the addition of value to the final product within the product flow, three different types of activities inserted in the productive environment are identified. As such, according to Hines and Taylor (2000):

✓ Value-adding activities are those for which customers are willing to pay, usually summing up to transformation activities

✓ Necessary activities that do not add value are those that are not interesting from the customer's point of view but are necessarily necessary for the production process

✓ Activities that do not add value and are unnecessary are those that are not interesting from the customer's point of view, nor necessarily necessary in the production process and, therefore, must be eliminated immediately

3. Research method

According to the classification of scientific research by Turrioni and Mello (2012) in the area of Production Engineering, this research presents an applied nature, in which the results obtained have the immediate objective of solving the problems that occur in a real system of medical care.

As for the objectives, it can be said that the research is classified as descriptive, as it tries to model and portray the particularities of the analyzed phenomenon through a systematic observation of the delimited reality in a colonoscopy clinic. It is noteworthy that one of the peculiarities of descriptive research is the use of standardized data collection techniques, such as the questionnaire and systematic observation (Gil, 2008). Regarding the approach to the problem, the research is classified as quantitative research, since the applied method was modeling and simulation (Turrioni; Mello, 2012). Thus, the stages of "conception", "implementation" and "analysis" proposed by Montevechi (2010), were adopted in conducting the research. Therefore, in the "conception" stage, the function of the computer simulation was defined, that is: to analyze the occupancy rates of human resources (HRs) and predict the average distance traveled by physicians.

In the "conception" stage, the conceptual model was also constructed and validated using the conceptual modeling technique called IDEF-SIM (Leal, 2003), input data modeling (MDE) and final documentation. It is worth mentioning that, in the MDE, the times of the following activities were timed according to the recommendations of Barnes (1977):

✓ Colonoscopy examination

- ✓ Equipment disinfection
- ✓ Patient changing clothes
- ✓ Stay in the colonoscopy room
- ✓ Patient preparation
- ✓ Stay in the recovery room
- ✓ Dress the patient and place him on another stretcher

Then, in the "implementation" stage, the Flexsim® software with the Healthcare library was selected for the construction of the computational model, and its verification and validation were applied according to the recommendations of the authors Vilela (2020b). Finally, the "analysis" is the last stage of the discrete event simulation project and in this final phase the experiments for the computational simulation were performed, the statistical analysis of the computational model outputs was carried out and an action plan as a recommendation was conceived.

4. Results

4.1. Subheadings

The object of study of this article was a colonoscopy clinic in the Hospital das Clínicas Samuel Libânio in Pouso Alegre, Minas Gerais, and as mentioned above, the stages of "conception", "implementation" and "analysis" proposed by Montevechi (2010), were adopted in conducting the research.

In the "conception" stage, the purpose was to analyze the occupancy rates of human resources (HRs) and predict the average distance traveled by physicians. Next, the conceptual modeling was applied, and the service flowchart was created as shown in Figure 1:

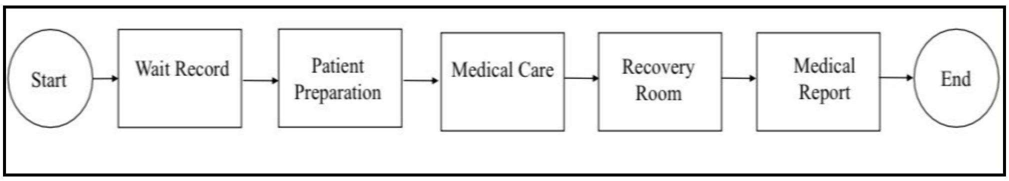

Figure 1- Service flowchart
Source: Prepared by the authors

Regarding the modeling of input data, a specific chrono analysis project that lasted one month was carried out in the endoscopy and proctology sectors of the hospital. The times were collected on site with the help of a stopwatch, and recorded in an Excel® spreadsheet, where they were divided according to the activity performed. Subsequently, the arithmetic mean of the collected times was calculated according to Table 1.

Table 1 – Summary of collected times

Type	**Average time (minutes)**	**Sample size (n)**
Colonoscopy exam	00:33:42	13
Endoscopy exam	00:03:41	16
Equipment disinfection	00:04:07	21
Change of patient's clothes	00:04:48	5
Stay in the room (Colonoscopy)	00:51:16	16
Stay in the room (Endoscopy)	00:16:23	23
Patient preparation	00:04:55	24
Stay in the recovery room	00:27:39	21
Dress patient and place on another gurney	00:06:00	5

Source: Prepared by the authors

In the "implementation" stage, the FlexSim® Healthcare module software was used to build the 3D computational model, as shown in Figure 2.

Figure 2: 3D computational model in FlexSim®

Source: Prepared by the authors

It is worth mentioning that one of the main pieces of information used was the time of appointments, obtained through chrono analysis (Table 1), and the patient arrival rate, which was obtained through the hospital's Philips Tasy® system. As the arrival of patients is scheduled, the arrival schedule function was used in this modeling.

Finally, the results of the computational model were evaluated through two parameters, defined as dashboards in this simulation project.

The first parameter defined was the "occupancy rate of human resources" which aims to measure the percentage of AV and NAV of the resources considered. Therefore, it is evident that the value-adding activity (providingCare) is very low, being 46.44% for nurses and 10.05% for physicians, (Figure 3).

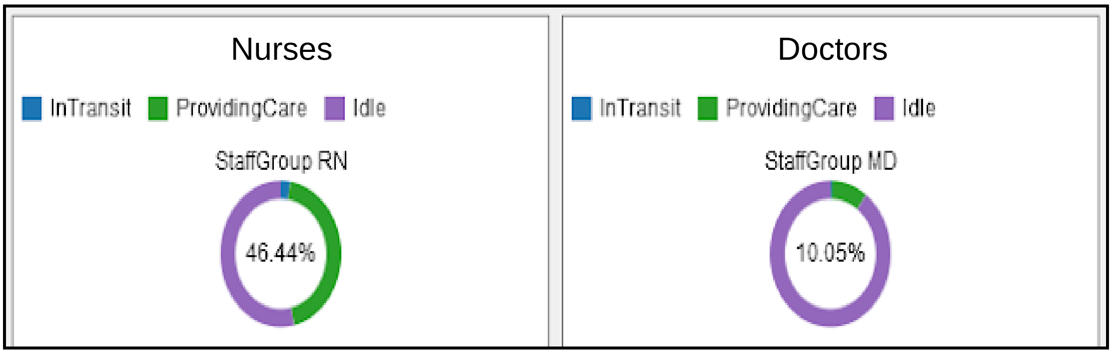

Figure 3 - Dashboard occupancy rate of human resources
Source: Prepared by the authors

The second parameter defined was the "average distance traveled by the doctors", whose function is to record how much, that is, the distance in meters that the doctor walked during the entire simulation that represents the resource's work shift. Figure 4 shows the result of this NAV activity. Therefore, the doctor travels 315.86 meters. In other words, a great waste of a resource that has a high value per hour.

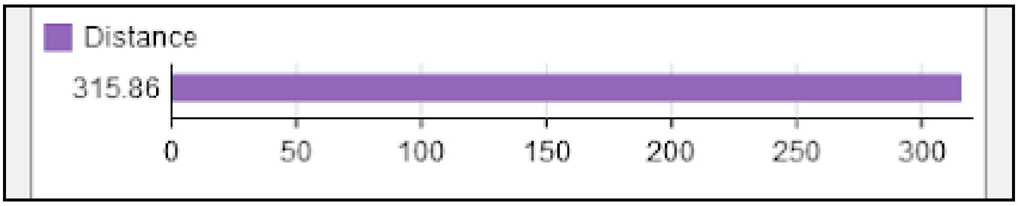

Figure 4 - Dashboard average distance traveled by physicians.
Source: Prepared by the authors

5. Conclusion

The objective of this research: to apply Discrete Event Simulation (SED) in a medical center allied to the premises of Lean Production to highlight the AV and NAV activities of the procedural flow, was successfully achieved. This way, it is evident that the average percentage value of VA of 28.24% in the provision of care indicates an inefficient operation, as it does not satisfactorily use the doctor and the nurse in patient care. Finally, the average distance covered by the physicians' NAV activity indicates a value of approximately 316 meters moved without adding value. Therefore, kaizen events and interventions must be implemented in order to increase the AV of activities and eliminate or reduce the NAV activities.

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