Implementation of Lean Six Sigma-DMAIC Methodology in Logistics. A Case Study from Romania

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Abstract

The purpose of this paper is twofold. First, the article aims to highlight the most important features of Lean Management and demonstrate how Lean paradigms can enhance the logistics segment of a business and improve the effectiveness of supply chain through the implementation of Six Sigma. Second, the paper presents a case study that provides a practical illustration of how Lean Six Sigma Logistics principles are applied in a Romanian company. The article adopts a qualitative approach. To underscore the applicability of Lean principles in logistics, the paper presents a case study outlining the application of the DMAIC (Define, Measure, Analyze, Improve, Control) methodology - a problem-solving approach integral to Lean Six Sigma - in a logistics company in Romania. Data were gathered from semi-structured interviews, internal company reports, the company website, and online studies. Thus, this article addressed a dual challenge: showcasing a specific example of how the problem-solving approach of Lean Six Sigma can be applied, while also filling certain gaps in the existing literature on its use in Romania's logistics sector. The study has demonstrated how Lean principles and the DMAIC methodology can be applied to logistics activities. This improvement process serves as a benchmark for other projects aimed at enhancing the efficiency of logistic operations.

Keywords

Logistics, Lean Logistics, Lean Management, Six Sigma, DMAIC (Define, Measure, Analyze, Improve, Control) methodology, Romanian company.

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Introduction

Nowadays, lean is one of the most successful business strategies for improving organizations' competitiveness. Lean initiatives are primarily concerned with maximizing productivity by reducing waste generation, conserving resources, and minimizing costs. Toyota System has introduced lean practices into its own production system, in order to create value for its customers using a minimum of resources (Gil-Vilda, Yagüe-Fabra and Sunyer, 2021). Value can be defined as what the customer is willing to pay for a product or service. Therefore, losses must be eliminated because the client is not interested in paying for errors, waste, or mismanagement of the resources of his suppliers. The main sources of losses are divided into seven categories (Ohno, 1988): unnecessary *transportation*, unnecessary stocks (*inventory*), unnecessary *movements* of employees, time lost due to unnecessary expectation - (*waiting* for tools, information, materials, etc.), *over - production*, *over – processing* and the existence of *defects* that bring unnecessary repairs (and therefore costs). The acronym TIMWOOD is used for these seven wastes. Because the human factor is in many situations the difference between quality services and exceptional services, a new source of losses has been identified, namely: under-use of employees (Antony, 2011).

In recent years, the *Lean methodology* is studied and applied together with Six Sigma. (Lameijer et al., 2021; Ndrecaj et al., 2023; Alsaadi, 2024). *Six Sigma* has been widely adopted since its first use at Motorola Corporation in the mid-1980s. *Six Sigma* methodology is strongly focused on defects and variability reduction in business processes and is an organized method for process improvement. The systematic method is based on the project structure, which is managed according to the Define, Measure, Analyze, Improve and Control (*DMAIC*) cycle - a five-phase algorithm for addressing existing process problems based on a scientific method (Zu, Fredendall and Douglas, 2008).

In which it concerns Lean Six Sigma's implementation in *Romani*a and especially in logistics, there are only few mentions about this topic in literature (Munteanu, 2017; Dinulescu and Dima, 2019). Thus, this article responded to a double challenge: to present a concrete case of application of the problem-solving methodology behind Lean Six Sigma, but also to cover some gaps in the literature regarding the application in the logistics sector from Romania.

In the context of such an issue, this paper, structured into six sections, presents, after this introductory part, a review of the existing literature on lean principles and practices, especially in connection with applicability in the logistics area. Then, the paper proceeds with the methodology section and the one dedicated to the case study that highlights the manner of applying DMAIC methodology in a logistics company in Romania, namely DSV Solutions. The paper proceeds with important findings of the study and ends with the conclusions section, where the implications of the case study are presented.

1. Review of the literature

Lean Management is one of the most popular techniques to improve process management and since its conception in the 1980s, it has come to be known as "the machine that changed the world" (Womack, Jones and Roos, 1990). At the core of the *Lean Management methodology* is the process of "leaning" all irrelevant activities of a company.

The method of *Lean Logistics* is a part of the *Lean Management methodology* related to production and supply and to external logistics mechanism (Baudin, 2004). The logistics sector is one where improvements can and must be made in relation to reducing unnecessary steps that do not add additional value or hinder the supply and distribution process. This methodology has identified nine areas in the logistics process that can generate losses: logistics service and customer support, forecasting demand and planning, procurement and purchasing, stock management, deliveries and communication, packaging of materials, transportation, storage, and reverse logistics (Kavota et al., 2024). The main goal of the *Lean Logistics* philosophy is to reduce waste in production and achieve maximum efficiency along the logistic chain (everything from supply, to production, to transport to the end customer and after sale services). It preoccupies itself with finding ways to add value, improve the workflow and implement a pull production system that ensures there is no extra stock, and production and storage costs are kept to a minimum.

Another important methodology for improving the process flow is *Six Sigma Logistics*. This method has as its primary objective eliminating faults and fluctuations in the business process (Pojasek, 2003). It compares the existing business process with the ideal one and, with the aid of various statistical tools, it identifies the causes for the differences between the ideal and the reality. After this analysis, it becomes easier for managers to find solutions to improve on these differences in order to achieve maximum productivity and minimum waste.

In the last couple of years, *Lean and Six Sigma* methods have been employed together with success and this hybrid approach has taken the name *Lean Six Sigma* (Alsaadi, 2024; Lameijer et al., 2021). The success comes from the fact that they tackle different issues at the core of the business and implementing both at the same time can increase the performance. The *Six Sigma Logistics* tool reflects the ever evolving and more complex methodology to improve the quality of products and operations.

DMAIC (Define, Measure, Analyse, Improve and Control*)* is the usual problem-solving methodology behind *Lean Six Sigma* (Panayiotou and Stergiou, 2022; 2020). DMAIC is the core concept of Six Sigma and is used to develop processes to ensure a stable Six Sigma performance level that guarantees a successful implementation of ICT in logistics processes (Cano et al., 2021).

2. Methodology

The purpose of this article is to present the particularities of Lean Six Sigma-DMAIC methodology in the case of a specific field (logistics), and for this, a case study based on a Romanian company was developed.

Analysis of the literature revealed a lack of case studies related to the Lean Six Sigma-DMAIC methodology in certain business areas, including the logistics industry, in particular with respect to the situation in our country. Thus, a *qualitative analysis* based on a semi-structured interview seemed to be the best method. The semi-structured preliminary interview guide was based on key themes, such as the reasoning behind the application of DMAIC in the case of DSV Solutions Romania, detailing the five stages of the process, and the views of the respondent on the implications behind Lean Six Sigma.

The interview framework was created as a list of questions that helped the interviewer keep the conversation on the research topic and obtain the most accurate information. For discussions with the company representative, namely the logistic director of the company at that time, two meetings were held, and each interview lasted approximately one hour and a half. The same interviewer managed all the discussions in a face-to-face environment. All data was recorded during interviews and immediately transcribed to ensure that all essential details mentioned by the respondent were kept on record.

Desk research was also carried out by analyzing various documents. For example, the company's website, press appearances, financial statements, and internal reports (made available to us by the company's representative, during the interview). As a result, the general data acquired by interview or through secondary sources were qualitative in nature. However, the data obtained through the company's internal reports and financial statements were quantitative.

3. Case study

3.1. Problem statement, goal, and scope

DSV is a Danish transport and logistics company offering transport services worldwide by road, air, sea, and train. Since its foundation in 1976, the company has achieved rapid expansion and international presence, predominantly through a series of strategic competitor acquisitions. With headquarters in Hedehusene (near Copenhagen), Denmark, and offices in more than 80 countries, DSV employs 47 000 people and collaborates with partners and agents worldwide (DSV, 2024). DSV is divided into three departments: DSV Air & Sea, DSV Road and DSV Solutions. Considering the continued accelerated development in recent years, both organically and through acquisitions, in Romania DSV is present through all three divisions. The branch in Romania offers services such as: warehousing, distribution, value added services, international transport of goods by road, sea and air, internal transport, oversized transport, cargo insurance and customs formalities. *DSV Solutions Romania* offers intelligent solutions for e-commerce and warehouse automation and provides planning and control operations for intelligent logistics chains, supply and delivery management, executive management and support, payment, and auditing of goods.

One of the largest *DSV Solutions Romania* customers is a producer of high-quality infant food and products for pregnant women and mothers. The analysis of the activities performed for this client in the Bucharest warehouse operated by DSV Solutions Romania revealed that the outbound operation is not cost-effective. More accurately, the outbound process is characterized by many movements of goods, people, and equipment. The goods pick-up is done directly from the upper shelf locations using man-up equipment. As a result, a traffic jam or congestion often occurs leading to extra movements, errors, and delays. The inefficiency of these processes increases by the number of unprepared orders from customers who are using the same equipment. To operate more profitable and more competitive, these processes must be reviewed and optimized. Through observation and analysis of the outbound process from the moment the order is present in WMS (Warehouse Management System) until the order is ready for shipment, it was aimed at identifying measures required to improve outbound processes by reducing the time spent and resources used for picking.

3.2. The application of DMAIC methodology

DMAIC is the problem-solving methodology behind *Lean Six Sigma* and consists of five phases (Define, Measure, Analyze, Improve and Control). Data regarding the application of this methodology in the case of DSV Romania are obtained mainly from the company's internal report and through the interview with the representative of the company.

In this process of improvement, the *DMAIC methodology* was adopted in steps that will be outlined below.

Define is the first phase of the *Lean Six Sigma* improvement process. In this phase, the project team is established. Taking into consideration the problem mentioned before (the outbound operation performed in the DSV warehouse for one of its clients is not cost-effective), it was formed a team of 7 members (including logistics director, sponsor, project owner, process owner, and project manager) that have a kick-off meeting at the beginning of the project (in order to share information, establish action list, inform member about the expected impact etc.) followed by other weekly meetings in order to monitor process, issues, and progress.

The team decided to analyze the outbound process (from the moment when the order is present in WMS to order allocation, printing picking list, picking, checking quantity and shelf life, foiling, printing delivery labels and notes and move picked pallets to delivery area) and found out the *problem*, namely: the order preparation (replenishment, picking) takes too long and thus the picking productivity is also too low. In this context, it was crucial for DSV to reduce time spent picking and increase outbound productivity by approximately 40%. The financial calculations revealed a number of 243 saved hours in case of increase outbound productivity with approximately 40% (from 786 hours in the present to 543 in the future state) and 948 euro as monthly cost savings (or 11.376-euro yearly cost savings).

Measure is the second phase and is critical throughout the life of the project. As the team begins collecting data, they focus on both the process and measuring what customers care about. The data from the process can be used to predict the future performance of the process. In this case, data were collected using the *GEMBA method.* The concept of GEMBA is a Japanese term meaning "the place where value is added" – which means the place where work is done. The team decided to analyze, in particular, the number of boxes picked and the hours dedicated for the picking/task order.

During 3 weeks, all orders were recorded in terms of date, order number, number of orderlines, number of boxes/order, start picking time and end picking time. 35 data points were recorded during this period. The sample size is large enough, and the data used as a baseline is reliable. The DSV team used the collected data to calculate the productivity as follows: sec./box = time spent picking in seconds divided by the number of boxes per order. The calculated mean is 34.57, the standard deviation is 23.26 and the p-value is 0.066. The data set is normally distributed if the p-value (probability value) is greater than 0.05. Therefore, our data follows a normal distributed pattern. Also, the set of data is normally distributed and stable, and the process is currently under control. Thus, the data from the process can be used to predict the future performance of the process. The process means and variation are stable. The process mean for productivity indicator is 34.6sec./box. Also, UCL (Upper Control Limit) and LCL (Lower Control Limit) based on the actual amount of variation of the process. The USL value (Upper Specification Limit) was set at 24 sec./box, which means that any order prepared above this productivity will not fulfil these requirements. It is important to mention that Upper Specification Limit and Lower Specification Limit are set by the customers' requirements - this is the variation that they will accept from the process. In the analyzed case 68% of the values are above the USL. This means that the process needs to be improved.

The next step is to analyze the capability of the process. From a conceptual point of view, it is a measure of the relationship between the Voice of the Process (VOC) and the Voice of the Customer (VOC). The goal of capability analysis is to ensure that a process is capable of meeting customer specifications, and we use capability statistics such as CPK (Process Capability Index) and PPK (Process Performance Index) to make that assessment. PPK and CPK are both useful measures in assessing how a parameter is performing versus specification. However, CPK is calculated using the within standard deviation, while PPK uses the overall standard deviation. CPK provides an estimate of potential process performance or capability and PPK provides the actual process performance given all the variance that is currently present in the process. PPK is generally <= CPK. Also, the values for PPK and CPK will converge to almost the same value when the process is in statistical control, as it happens in the analyzed case as well (figure no. 1).

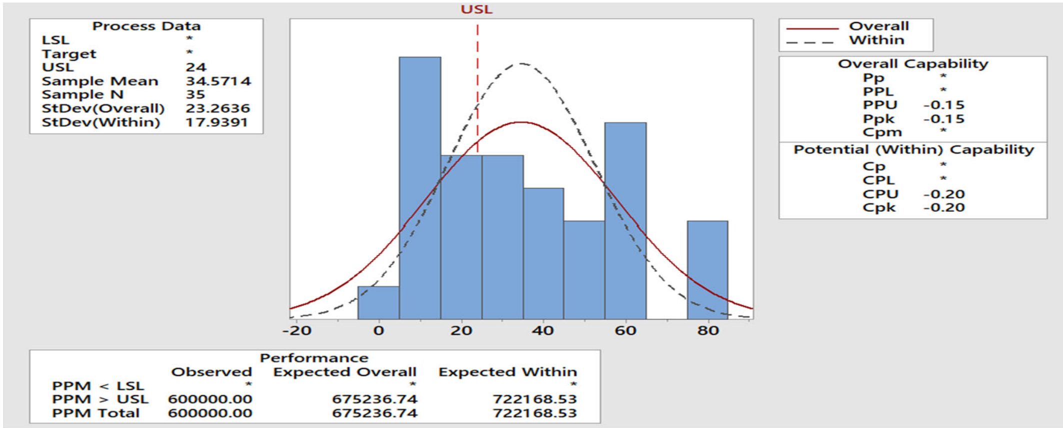

Figure no. 1. Process capability report (seconds/box) – before

Source: Authors' own contribution based on data provided by DSV Solutions Romania

Analyze is the next stage where is being sought the answer to the following question: What is causing the problem? Thus, the present study continues with the investigation of root causes. The implementation team used the Ishikawa diagram that allows to see the factors that affect or impact in the given situation of low productivity. The Ishikawa diagram (also known as the cause-effect diagram or "fish bone" diagram, given the graphical representation) was created by Kaoru Ishikawa in 1943 and graphically represents the possible causes of a given effect. The diagram shows the relationship of all factors (causes - X) that lead to a given situation (effect - Y). All possible causes were analysed, but not all of them are 100% related to the process/project and not all of them are related to Y – "picking productivity". Thus, the team decided to take them out and prioritized the main causes affecting the productivity. It can be observed that some effects have a bigger impact than others (table no. 1). The team decided not to focus on the entire list of possible causes because there are things that cannot be influenced.

Table no. 1. Causes and effects

No.	Possible causes (X)	Effect (% of the problem)	Related to output (Y or KPI)	Type of effect (TIMWOOD)
1	Picking from upper location	25%	Y	motion
2	Man-up equipment is not always available.	20%	Y	waiting
3	Picking route not defined	10%	Y	transport
4	One rack line interfered with other projects	10%	Y	transport
5	Picking using papers not RF gun ((Radio Frequency scanner)	9%	Y	defects
6	Special condition required for delivery for some customers	7%	Y	over processing
7	Lack of knowledge	5%	Y	defects
8	Man-up battery lifecycle is low due to high usage	5%	Y	waiting
9	Lack of stock traceability due to manual picking	5%	Y	defects
10	Not enough manual transpallet	4%	Y	waiting

Source: Authors' own contribution based on data provided by DSV Solutions Romania

After analyzing the picking process using the mentioned tools, the team found ten effects (X) of the problem that impact the picking productivity (Y). The main conclusion of this phase is that a clear structure is missing on the floor and the effects/results are: unclear picking route since the products are stored in different zones, lots of waiting for man-up equipment since is used by multiple customers, and pallets are picked up and put down several times.

Improve is the next part of the process that involves establishing and implementing solutions and lastly, collecting data to confirm there is measurable improvement. In the current study, is the phase when the team establishes practical solutions for the problems previously identified (table no. 2).

Table no. 2. The solutions for improvement

No.	Idea	Related to root cause no.
1	create picking zone on the ground level in order to reduce time spent using man-up for picking since the equipment is needed for other customers	1, 2 and 8
2	use scanning instead papers at picking in order to increase traceability	5 and 9
3	set picking route sequence by ABC analyze, product group, product weight (in this way articles which are picked often, and which are heavy will be moved in the locations closest to the out-bound area)	3 and 4
4	train people, set clear roles, and define work instructions.	7
5	ask client to send correct information about the final delivery address	6
6	set system allocation for special shipment shelf life required	6
7	early manual trigger for relocation in picking zone to reduce waiting time	1
8	buy or borrow EPT (Electric Pallet Truck)	10

Source: Authors' own contribution based on data provided by DSV Solutions Romania

Control is the phase when the team must ensure that the process maintains the gains, now that the problem is fixed, and improvements are in place. In this phase, to create a better flow for preparing the outbound orders, the team has set dynamic picking locations at the ground level. This results in an easy way to collect all the articles required for picking. An exception was made for full pallets that are picked from the upper location and for articles that are located at a special location for promotional purposes. All replenishment tasks are executed before picking task. After the solution is tested, more flexibility and uniformity are observed within the operation. For picking and replenishment using RF Gun (Radio Frequency scanner), the work instructions were updated with the new tasks added in the outbound flow. This was approved by the supervisors.

The p-value is now 0.114. Therefore, the data follow a normal distributed pattern (data set is normally distributed if P-Value > 0.05). Any value outside the specifications, higher than Upper Control Limit (UCL) or lower than Lower Control Limit (LCL) will show that the process is out of control. It is necessary to examine all the points outside the control limits based on the following events: an atypical order; untrained picker; an unexpected break. The test productivity results' (seconds / box) indicate that the process is under control. The mean and variation of the process are stable. There are no points out of control. The process mean for productivity indicator is now 21.65 sec/box.

This time, the USL value (Upper Specification Limit) is set at 24 sec/box, which means that any order prepared above this productivity will not fulfil our requirements. 39% of the values are above USL (figure no. 2). However, the performance is now much better than before: only 39% of the values are above USL where we used to have 68%.

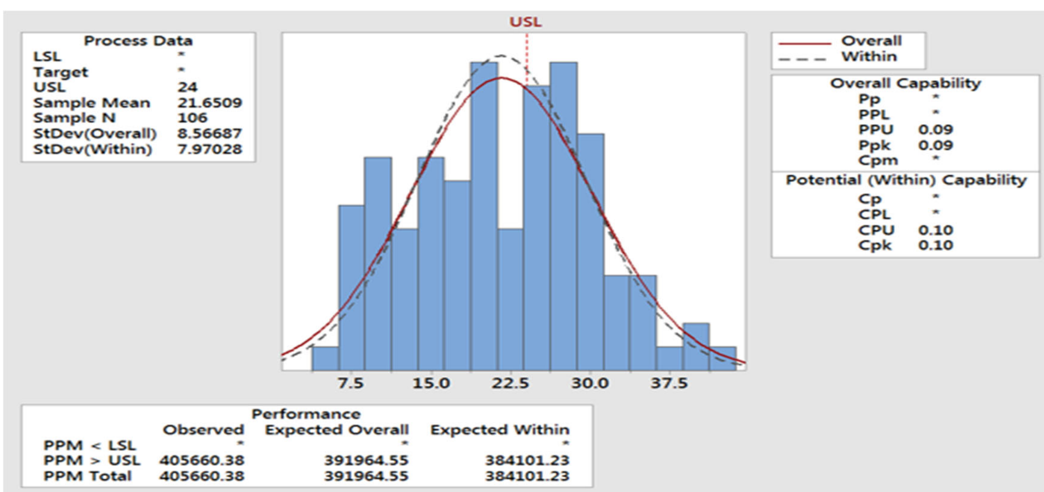

Figure no. 2. Process capability report (seconds/box) – after

Source: Authors' own contribution based on data provided by DSV Solutions Romania

4. Findings and discussions

The process standard deviation was reduced by 55.6% ($p < 0.05$). Also, the process mean changed significantly ($p < 0.05$) (table no. 3 and figure no. 3). The Z bench (the Z value that corresponds to the total probability of a defect) changed (from -0.45 to 0.27) and the PPM (the number of nonconforming parts in the process, expressed in parts per million) has decreased from 675237 to 391965.

Table no. 3. Process statistics – before and after

Statistics	Before	After	Change
Mean	34.571	21.651	-12.920
Standard Deviation (overall)	23.264	8.5669	-14.697
Actual (overall) Capability			
PPK	-0.15	0.09	0.24
Z Bench	-0.45	0.27	0.73
% out of spec.	67.52	39.20	-28.33
PPM (DPMO)	675237	391965	-283272

Source: Authors' own contribution based on data provided by DSV Solutions Romania

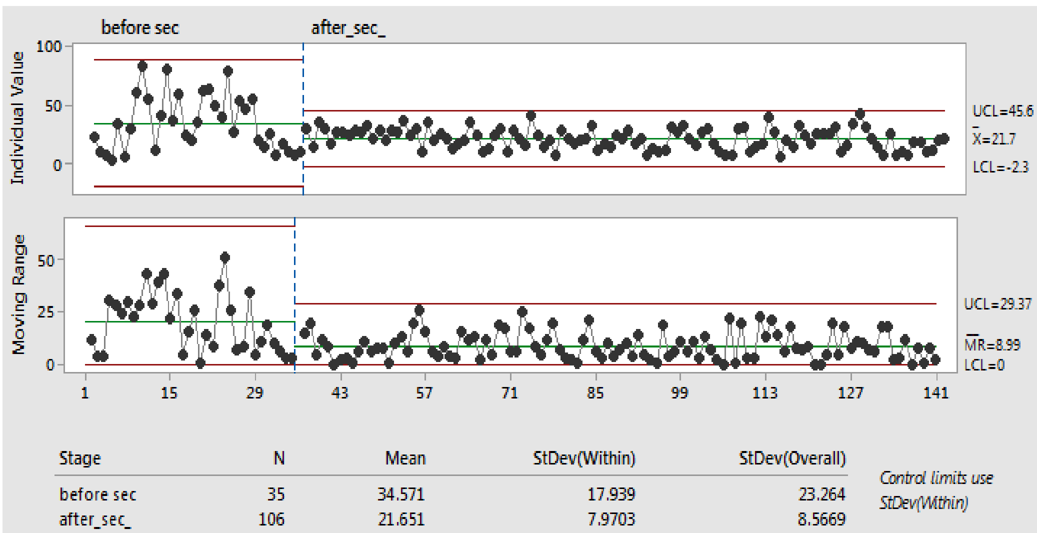

Figure no. 3. Mean and deviation - before and after

Source: Authors' own contribution based on data provided by DSV Solutions Romania

The *main conclusion* is that: the productivity has been improved. The aim of the project presented in this case study (to increase outbound productivity with approximately 40%) has been reached.

The increased efficiency has ultimately led to FTE (*full-time equivalent)* reduction, and thus become the benchmark for other projects. All these settings done for this client of the DSV and for this project can be applied to other similar projects without involving the same support team again.

Financial, the calculated benefit at that time was 10854 € /year. The outbound process is improved, leading not only to a positive financial result but also in terms of less waiting time and less time using man-up equipment for picking (almost 71% of total time/day the man-up equipment is available for other projects – 1043 €/month saving).

Now, for daily productivity, an Excel report is updated manually by the project manager. Since picking tasks are now performed with the RF terminal, the logistics department can develop a new report that contains the necessary details to follow the productivity dedicated per task. The project has been handed over to the process owner and follow-up will be done by the team leader and supervisor.

Conclusions

Given that *Lean Six Sigma* focuses primarily on eliminating waste and reducing defects and variations in an organization's processes and aims to increase customer satisfaction, productivity and quality, organizations that use *Lean Six Sigma* principles in their operations can be better prepared to react to events or unforeseen conditions that may endanger the organizational structure and the results of the firm.

The study has demonstrated how the principles of *Lean Six Sigma* and the *DMAIC methodology* can be applied in the case of logistics activities. Among the *lessons* that can be extracted from this case study are the following: without operational management involvement in this whole process of change, it would have been much more difficult to adopt Lean Six Sigma; the sense of urgency was very clear, and the project team worked very well together; Ishikawa tool results as the best one to work with the team and to obtain more root causes.

Likewise, it is important to mention regarding the practical implications that the Lean Six Sigma initiative presented in this article can be a starting point for other projects of the company and for other processes carried out in its warehouses. In addition, it can be an example to follow for other companies that are faced with the same logistical issues. This process of improvement present in this study can become a benchmark for other projects to increase efficiency of logistics activities.

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