

Methodological Procedure for Applying Dmaic Model of Six Sigma Methodology in A Beverage Company: A Case Study

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Abstract

This study aimed to describe the DMAIC model of the Six Sigma methodological procedure and demonstrate the practical application and results obtained in the process of palletizing loads in a Beverage Industry of the Industrial Pole of Manaus. This case study was carried out using a bibliographic survey of the concepts, methods, and procedures of the quality tools, Six Sigma. As a procedure for collecting information, secondary data were used. A Six Sigma application model based on the DMAIC methodology in the palletizing process was presented. The results obtained and the contributions to the improvement of the quality and efficiency of the processes were analyzed. It is concluded that through the application of the methodological procedure of the DMAIC model it was possible to determine and quantify the main defects and wastes, analyze the causes and establish improvement actions in the palletizing process in the Company, resulting in a 40% reduction in handling of the supply operators in the company's shipping area, the elimination of the lack of pallets in the shipping process, the elimination of solid waste disposal in the environment and the reduction of expenses with pallets by 56% in the Company in question.

Keyword: Six Sigma, Reverse Logistics, PIM

1. INTRODUCTION

Transport logistics is a strategic factor for any company in the business world. Due to these considerations, Company Y, a beverage industry in the Manaus Industrial Pole (PIM), constantly seeks to improve its processes, excellence in customer service, and the reduction of costs so that it remains competitive in the market.

Concerning the logistical costs of the city of Manaus, it is worth mentioning that they are higher than the national average due to the distance from the large centers that supply raw materials, as well as consumers of finished products (Silva *et al*, 2103).

In the line of analysis, which talks about creating competitive advantage in the business, there is a high cost in the logistics processes, the focus is on reducing these costs at some point in the logistics process and, this is considered as an objective in a company (BALLOU, 2001).

To improve the competitive advantages of organizations, several strategic models have become popular in the organizational world. The opportunity opens for the adoption of a specific and deterministic methodology *that* is exactly the focus of Six Sigma (Evans & Lindsay, 2015). According to this author,

Six Sigma (6σ) improves processes without losing sight of the strategic dimension of the business. This article seeks to describe the DMAIC model of the Six Sigma methodological procedure, to demonstrate the application of this DMAIC model in the cargo palletizing process through a case study in a Beverage Industry of the Industrial Pole of Manaus (PIM), as well as to demonstrate the results obtained through the practical application of the DMAIC methodological procedure.

This research consisted of obtaining secondary data from an exploratory case study that used as a specific procedure the data collection from the DMAIC model of Six Sigma methodology within the logistics process in a Beverage Industry installed in the Pole Of Manaus.

Then, a collection of data and information about the process of palletizing cargo for transportation was carried out in the studied company. The statistical and quality tools applied to the DMAIC model were analyzed. In this way, the practical results of the application of this procedure were analyzed and, finally, the compilation of this research was carried out with the presentation of the results obtained.

Every job is a process, every process has variability and every process has data that explains its variability, according to Barone and Franco (2012). According to this reasoning, it can be admitted that the transport process and its sub-processes can also be considered as business processes that can enjoy the benefits of using Six Sigma, which was relevant to the increase in operational efficiency achieved through the implementation of this Six Sigma methodological procedure at Company Y, which aimed to increase productivity (increase by 1600 min/day availability of the forklift operator of that process), reduce supply delays (eliminated the occurrence of pallets by 100%) and reduce waste (56% reduction in pallet costs and elimination of wood waste to the environment).

2. PRESENTATION OF THE SIX SIGMA METHODOLOGICAL PROCEDURE

In the context of implementing a Six Sigma project, the study of applicability can be a relevant resource, not only for improving the performance of production processes but also of business processes. For Smętkowska and Mrugalska (2017), they understand that although many of the tools for diagnosis and quality improvement that are also used in DMAIC are already well known in the literature and disseminated in manufacturing environments, there are still many problems about knowledge the applicability of the tools.

The DMAIC Diagram shown in Figure 1 incorporates the following phases: define, measure, analyze, improve and control. For Srinivasana et al (2014), an organization identifies a problem area, measures it, identifies its root cause, implements solutions to address these causes and finally evaluates and controls improvements.

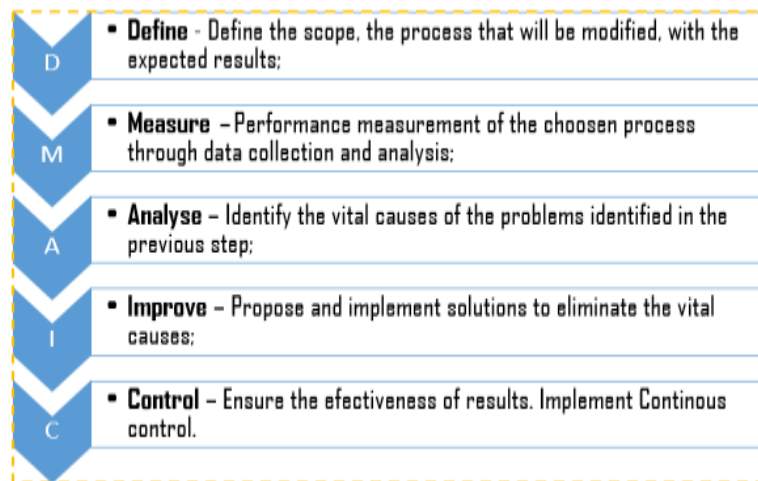


Figure 1- DMAIC diagram model

Source: Adapted from Neubauer *et al* (2019, p.768).

According to Eckes (2001), the DMAIC model is a version of Six Sigma for process improvement that widely uses the traditional statistics of quality control in five well-defined phases. Applying these phases, the present article presents a methodological procedure and its application as a solution to a specific problem in a process that already exists in the Company.

The purpose of this procedure is to facilitate the use of the DMAIC model in a company or any type of business organization. According to Brassard et al (2002), the common elements of the Six Sigmas initiatives are:

- Leadership commitment and involvement;
- Improvement activities are aligned with business objectives;
- Defects are defined based on customer needs;
- The focus is on reducing defects and variation;
- The use of disciplined improvement methodologies;
- Disciplined methodology to sustain gains;
- Data-based decision-making;

Following is the methodological process.

2.1 Define Step

According to Eckes (2001), in this phase, the customer, his CTQ (Critical to Quality) and the team's procedures must be defined, in addition to mapping core business processes. That same author affirms that in this phase the objective, the scope and the main, stages of the project must be defined, as well as delimiting the problem.

According to Brassard et al (2002), the most common tools used in the define phase are affinity diagram, charter, communication plan, control charts, CTQ tree, data collection, kano model, Pareto graph, trend graph, SIPOC, Revision (tollgate), $Y = f(x)$.

2.2 Measure Step

For Brassard et al (2002), in this stage, the main goal is to measure the current performance of the process and to reduce the problem area. The measure phase starts with a detailed process map. The project team collects data regarding defects, analyzes them and then narrows the problem area. This phase ends with the development of the Final Problem Definition, which includes the target for improvement and the financial impact (Evans & Lindsay, 2015).

2.3 Analyze Step

According to Brassard et al (2002), in this phase, the data and maps of the process must be analyzed to determine the root causes and opportunities for improvement. A tool widely used in this phase according to Unin and Bearing (2015) Brainstorming, also known as "storm of ideas", is a very useful tool for problem solving. It can be used to generate ideas. Then, as stated by Srinivasan et al (2014), the cause-effect diagram, also known as fishbone, or Ishikawa diagram, can be used to identify, explore, and graphically display, in ever greater detail, all the possible causes in a problem or condition, to discover its true root or roots.

2.4 Improve Step

At this stage, according to Brassard et al (2002), improvements must be created, selected and implemented, this author says that at this stage solutions must be implemented that eliminate the root causes of the problems. For Srinivasan et al (2014), one must identify and select solutions, analyze the cost/benefit, observing the risk, develop action plans for total implementation, develop a pilot plan, quantify pilot results, update exit indicators in ways that meet all customer needs to improve operational efficiency.

2.5 Control Step

Brassard *et al* (2002) say that at this stage, the improvement must be institutionalized and continuous monitoring must be implemented, the gains obtained with the implementation of improvements must be controlled, the control methods are standardized, and those responsible for maintaining the improvement of these processes must be established. At this stage, according to Zu *et al* (2008), the goal is to control the process to maintain the gains and the transition to the full implementation of the actions defined in the previous steps.

Below follows, the methodological procedure divided into five phases and presented in figure 2 in a summarized form in boxes to better understand its sequencing and also to facilitate its application in any process or sub-process with an opportunity for improvement in an industry or any other type of activity or business.

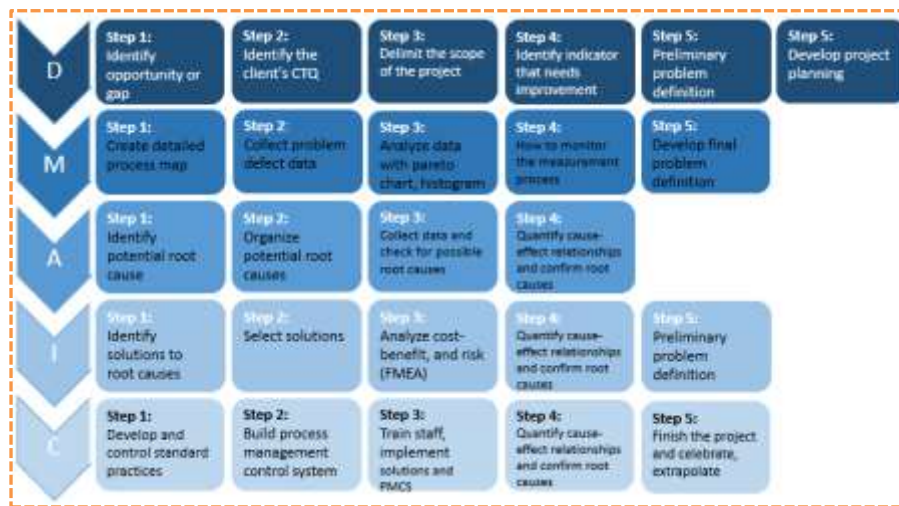


Figure 2 - DMAIC in steps

Source: Author (2020)

3. CASE STUDY

This topic presents a case study detailing a methodological procedure for using Six Sigma, that is, how the Company uses the model's tools to solve a specific problem.

The nature of this research is of an applied nature, that is, it aims to generate knowledge for practical application aimed at solving specific problems. It involves a real situation and it is intended to solve problems of interest to the industrial sector.

The case study method is appropriate in this work, as this research seeks to describe and analyze what are the impacts that must be observed in the application of the Six Sigma methodology and its impacts on the operational indicators of the company in question.

3.1 APPLICATION OF THE METHODOLOGICAL PROCEDURE - THE SIX SIGMA METHODOLOGY IN COMPANY Y.

The introduction of Six Sigma came to support the initiatives of the Integrated Management System, which is well consolidated in the company. This system is structured with international standards implemented and certified, such as ISO 9001 (Quality Management), ISO 14001 (Environmental Management), OHSAS 18001 (Occupational Health and Safety Management), ISO 22000 (Food Safety Management), in addition to of accreditation by the National Institute of Metrology, Standardization and Industrial Quality (INMETRO) of the ISO/IEC 17025 standard (Competence Management of Testing and Calibration Laboratories).

The Six Sigma methodology implementation initiative took place through a global project to improve the company's operational excellence. It was a strategy to improve the quality of processes and services and increase customer satisfaction, seeking to meet goals and sustain results, eliminating results that do not add value to daily work, reducing operating times and adding good results to the corporation.

In the implementation of the Six Sigma program, Company Y's indicators were reassessed to identify the company's main operational indicators. All indicators were aligned with the company's macro objectives.

The selected indicators are those that most influence the business of Company Y so as not to spend efforts on programs that do not bring significant results to achieve all corporate goals.

3.1.1 Six Sigma team formation

A multidisciplinary team was created so that all departments had representatives. This choice was based on the ability that each person has to influence, disseminate and apply the Six Sigma concepts in their work centers, as they functioned as multipliers and maintainers of the Six Sigma methodology in Company Y (Chart 1).

Table 1 - Relation Position & function in the Six Sigma group

Position at Company Y	Qt	Team Role	Responsibility
Managers, Directors	12	Leadership Team	Select, allocate resources, review progress and quantify project impacts
Managers	11	Sponsor	Supervise an improvement project, removing obstacles
External Consultant	2	Master Black Belt	Technical leadership in preparing Six Sigma
Supervisors, Coordinators	14	Black belt	Coordinate tasks, train <i>green belts</i> , and guide them in conducting the work
Supervisors, coordinators, analysts	39	Green belt	Assist <i>Black belts</i> in data collection, develop experiments and lead small improvement projects in their area of expertise

Source: Company Y, 2006.

As shown in Chart 1, the relationship between the positions in the company and the functions in the Six Sigma working group can be observed. It can also be seen that Company Y has 79 employees on its staff trained to perform activities related to Six Sigma initiatives. It is worth mentioning that people from strategic areas formed this team.

3.1.2 Choice of projects in the Company

With the team formed, with the associates trained in the tools proposed by the Six Sigma methodology and with the support of top management, analyzes were made regarding the company's processes that presented some opportunity for improvement and that could impact its results. This analysis linked the operational or process management indicators with the company's high-level indicators, which are the indicators with the greatest impact on the company's macro objectives.

A tool used for project selection was the Prioritization Matrix; its model can be seen in table 2.

Table 2 - Prioritization Matrix

Problem Area	Client (s)	Client Voice (A)	Process Voice (B)	Business Voice (\$) (C)	Overall Rating (D)
Delayed delivery					
High Waste					
Increased Complaints					
Slow Product Development					
Consider only problems under the team's responsibility and control	Anyone (internal or external) who receives a product or service	Rating based on the direct impact on customer satisfaction	Classification based on the difference between current and necessary performance to satisfy customer requirements	Classification based on alignment or relationship with strategies and policies	Multiplication result $A \times B \times C$ Investigate the best rankings
Classification:	1-Very Light	2 – Light	3 – Moderate	4 – Severe	5 – Extreme

Note: The voice of the business usually includes financial impact (\$)

Source: Setec, 2006.

At the Company, a problem was observed that was related to the process of palletizing costs in the company, after identifying this opportunity for improvements and thorough analysis of the decision tree, the leadership team decided to start a Six Sigma project using the DMAIC model to improve the palletizing process in the finished products shipping area. The decision tree (Figure 2) is a flowchart for choosing the type of project.

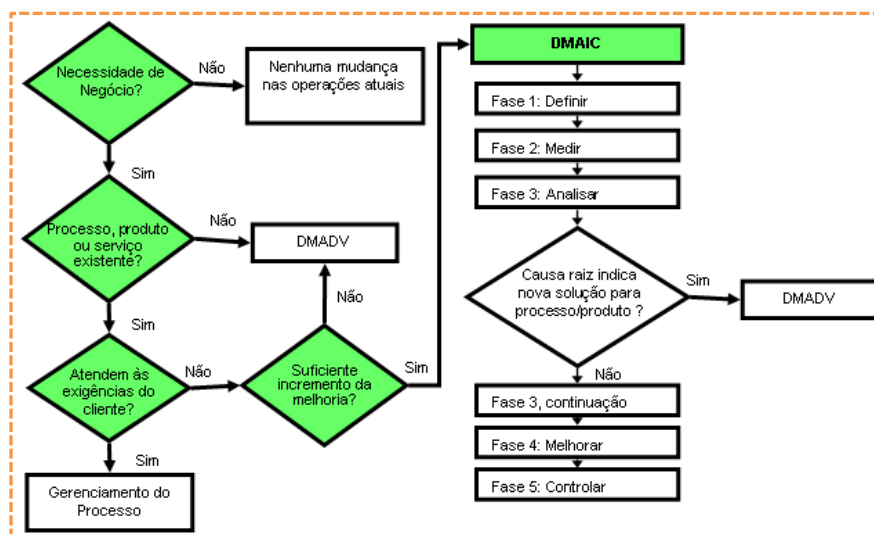


Figure 2 - Decision Tree

Source: Setec, 2006.

3.1.3 Application of the DMAIC Methodological Procedure in the process of palletizing finished products

All finished products produced by Company Y are sent to customers by road. It is the responsibility of Company Y to deliver within the agreed period, without damage, and with the documentation related to the cargo following customer requirements and legal requirements. To carry out these deliveries, the company has three transport companies that are hired to meet these requirements. In this activity, the need to develop a Six Sigma project was identified, which after the application of the decision tree it was determined that the project's characteristic would be for the palletizing process and the model used would be DMAIC. The tools of this model were used according to the stages of the project, as described in the following steps of this work.

3.1.3.1 Define Step

Step 1: Identify the opportunity or Gap

The team started the project and it was found that the number of occurrences in the report “Lack of Material” issued by the company referring to pallets, showed an increase of 585% in the period. This means that many loading processes have been impacted by the lack of pallets.

Step 2: Identify the Client's CTQ

After a survey conducted with forty-two customers, the leadership team defined that the Critical Quality Characteristics (CTQ) are:

- Impact on Pallet Cost;
- Availability of pallets according to need in time and quantity;
- Pallets according to quality specifications

Step 3: Delimit the Project:

After analyzing the impacts on the indicators, the team sought to demonstrate the breakdown of the company's main processes up to the sub-processes to be analyzed. It was observed in the analysis that from the “Distribution” process, one arrives at the “Shipment Configuration” sub-process, which will be analyzed according to the model methodology.

Step 4: Identify an indicator needing improvement

The “Snakes and Ladders” diagram is used to identify the limits of a DMAIC project and the Indicators (creating the problem) that need improvement. Follows Diagram of Snakes and ladders used to identify indicators needing improvement.

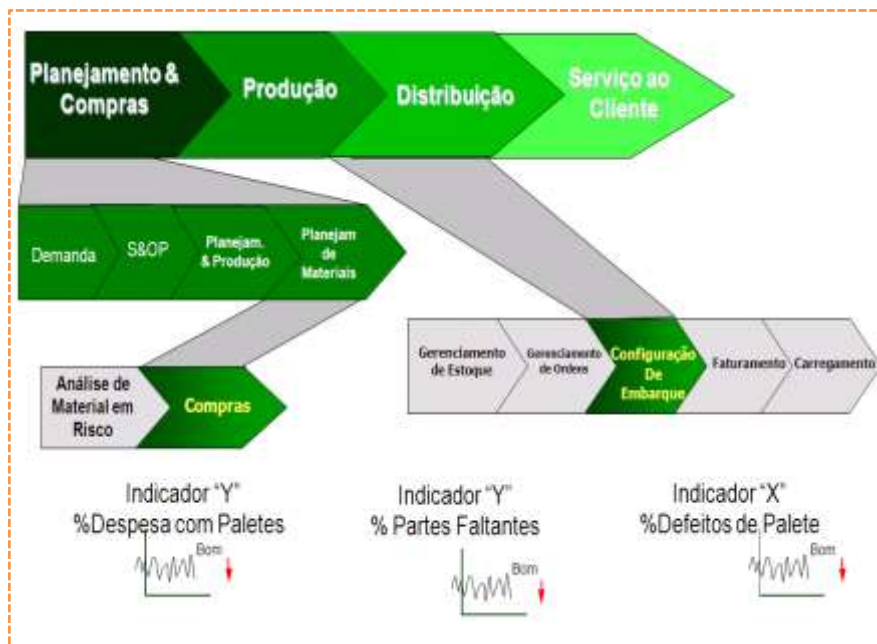


Figure 3 - Snake Diagram – Identification of Indicators
 Source: Company Y, 2006.

Figure 3 shows the indicators that need improvement in Company Y, which are the Percentage of expense on pallets, percentage of missing parts and percentage of defects in pallets. All three of these indicators are linked to high-level indicators of Company Y as they are indicators of sub-processes exposed from main processes.

Step 5: Preliminary problem definition

In this stage, the problem to be addressed was preliminarily defined based on the information presented in the previous step. The indicators affected by the problem were identified and an attempt was made to estimate the possible financial benefit of the project. Some data was analyzed before creating the preliminary problem definition, such as total pallet expenditure. The value of the expenses with pallets for two consecutive years was U \$ 605,964.00 and U \$ 693,741.00, respectively. This represented, in the period under analysis, an increase of this expenditure in the order of 14%. Figure 4 shows this information graphically.

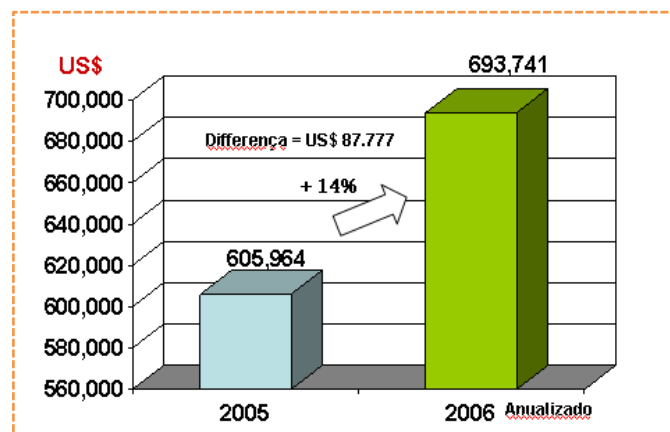


Figure 4 - Expenses with pallets between 2005 and 2006
 Source: Company Y, 2006.

After the presentation and studies of the data collected and presented at this stage, the preliminary definition of the problem was established and was presented as follows:

- The number of occurrences in the material shortage report increased by 585% in the period from January to August 2006;
- The number of rejected pallets grew by 419% compared to 2005;
- Total pallet expenses grew 14%, the greatest impact of which is represented by the 1.0m x 1.2m pallets used in the national transportation of finished products.

Step 6: Prepare the Project Planning.

In this step, a documented planning of the DMAIC procedure was made, which consists of a Project Planning Form (Figure 5). A communication plan was made in which the interested parties are communicated, defining what to communicate, when to communicate and how to communicate.



Figure 5 - Project Planning Form

Source: Company Y, 2006.

As shown in Figure 5, the project's schedule and development plan were also created, detailing the scope of the project, the phases, those responsible for each activity, the main quality tools used in each phase, deadline for project completion and business opportunity.

3.1.4 Measure Step

Step 1: Create a detailed process map.

Defects and process data were analyzed using the following tools: control graphs, Pareto graph, and trend graph, to support the Six Sigma methodology it was used the tools Value Flow Mapping (Current State) and Spaghetti Diagram.

Step 2: Collect data on defects and the process.

Data collection is defined according to indicators and measurement points as shown in the indicator table (Table 3).

Table 3 - Summary of the Data Collection Plan

Indicator	Measuring Point	What to Measure
Y1	M1	% Lack of Material Occurrence
Y2	M2	% Expenses with Pallets
Y3	M3	% Fumigated pallet without the need

Source: Company Y, 2006.

According to Chart 3, output indicators were established and subsequently analyzed. After analyzing these indicators, there was an increase in expenditure of 225%. When the same comparative survey was made for data referring to the number of pallets consumed in the same period, an increase of 11% was observed. This information complements the analysis of the Y2 indicator of total expenses with pallets but shows a disparity between an increase in consumption by 11% and that of expenditure, which was of the order of 225%.

Step 3: Analyze the data

The data collected in the period were analyzed at this stage of the procedure using Pareto graphs. The data refer to the consumption of pallets by the customer, or city served in Brazil and other countries served by the company. It can be seen that:

That manufacturers located in Jacarepaguá (RJ), Jundiaí (SP) and Belo Horizonte (MG), represent 33% of the total pallets consumed in the transportation of finished products, and that in export processes, shipments to Colombia and Venezuela represented 94, 2% of all shipments abroad in the analyzed period.

Step 4: Calculate Performance - Process Sigma

Specified by the company's top management that the final definition of the problem would be focused on the cost of pallets, a defect opportunity was established so that the process sigma can be calculated as shown in Table 4.

Table 4 - Calculation of Sigma (I)

Calculating Process Sigma		Pallet Cost
Unit defect opportunities	O =	1
Units processed	N =	57
Total number of defects that occurred	D =	29
Total number of defective units	DU =	29

Defects by opportunity (DBO)	$D / (N \times O) =$	50.8772%
Defects by Defective Unit (DBU)	$(UD / N) =$	50.8772%
Defects per 1 million defect opportunities (DPMO)	$DBO \times 1000000 =$	508771.93
Yield (Flawless Unit)	$(1 - DBU) \times 100 =$	49.12281%
	<u>Sigma =</u>	1.48

Source: Company Y, 2006.

The calculation of the process sigma describes the current capacity of the process. Table 4 shows that the current sigma of the process is 1.48. This calculation took into account 57 weeks from January 2006 to February 2007.

Step 5: Develop the final problem definition.

The last part of this phase was to present a final definition of the problem to be worked on in the next phases of the project, and by the decision of the leadership team of Company Y, the final definition of the problem was focused on pallet costs. Therefore, the final definition of the problem was following the topics below:

- The pallet expenses in 2006 was US\$ 693,741;
- From January to September 2006 consumption of 1.00 x 1.20 pallets represented 83% of shipped pallets and 85% of total pallet spending;
- 65% of the pallets used were used in transport for customers in Brazil. It means a wasted cost of US\$ 288.596;
- Wastage during the boarding process is equivalent to US\$ 88.000, that is, 5.580 pallets (annualized data).

3.1.5 Analyze Step

In this phase, the article sought to analyze the data and maps of the process to determine the root causes and opportunities for improvement.

Step 1: Identify potential root causes.

Brainstorming or even an idea box can be used to generate ideas. This quality tool was used as a method of generating several potential root causes, where it sought to identify through questions, which would be the reasons for the problem of high pallet expenditure.

All ideas were put on a whiteboard and then transcribed to an excel form.

Step 2: Organize potential root causes

In this step, the Cause and Effect Diagram was used to organize the potential root causes identified in the previous step. This diagram was chosen to structure the potential causes so that the root causes could be identified and corrective actions could be taken and thus provide an understanding.

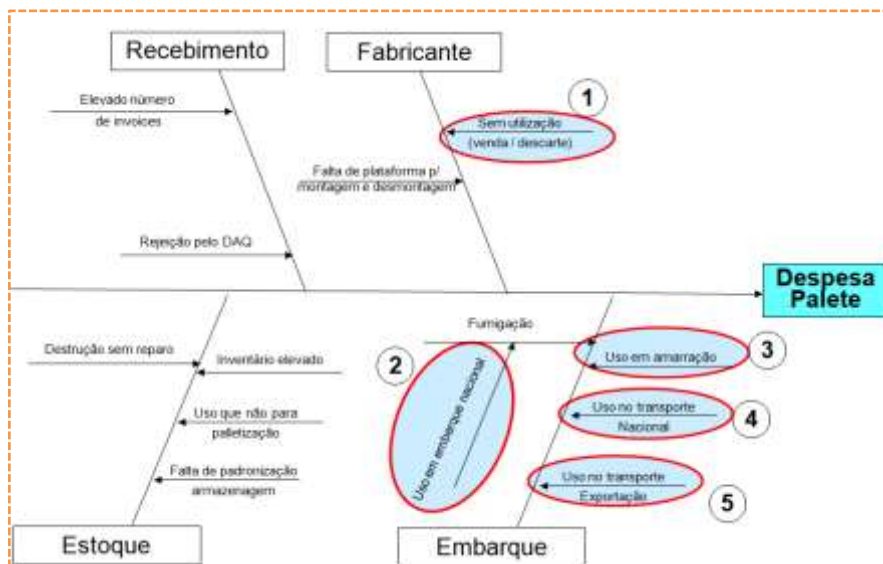


Figure 6 - Cause and Effect Diagram for Pallet Expense

Source: Company Y, 2006.

Analyzing the cause and effect diagram (Figure 6) for the pallet expense problem, five possible root causes for the pallet expense problem were considered. As a criterion for the validation of causes, the work team established a verification method, as follows: causes that had a statistical significance greater than 40% would be considered at this time as the root cause and others that had lower values would not be considered as possible causes. Below is the list of the causes ordered to be validated in the next step, of these only the first 5 were taken to the next step to be valid. They are:

- Cause 1 – The manufacturer does not use pallets sent by Company Y;
- Cause 2 - Fumigated pallet used for national shipping;
- Cause 3 - Use of pallet for securing cargo;
- Cause 4 - Pallets used in national cargo transportation;
- Cause 5 - Use in Transport for export.

Step 3: Collect data to check root causes

After identifying the five possible causes of the problem, information and data related to these causes should be collected.

The data related to cause 1, use of pallets in customers' inventory and according to the survey carried out with customers based in Brazil, it was found that 64% of these customers use a new pallet to store the finished products sent by Company Y, or due to internal requirements or even physical limitations, that is, 16 manufacturers discard the pallets sent by Company Y.

The data referring to causes 2, 4 and 5, it was found that all pallets (100%) are fumigated, including the pallets used in Brazil, this means an increase in expenses with fumigation of pallets, which is not necessary, since that there is a legal requirement that requires fumigation only for wood sent abroad.

- 83% of the pallets used in the transportation of finished products from Company Y are to serve national customers.
- The use of pallets in exports represents only 17% of the total volume of pallets used in transportation.

For the validation of root cause number 3, referring to the expense with pallets in the cargo lashing process. It is worth mentioning that the use of the pallet for mooring distorts the function of the pallet which is unitization and transport of goods and not for other purposes.

According to the analyzed data of pallet consumption for cargo mooring, average monthly consumption of 465pc was observed, this annualized number represents a total of 5,580 pallets used for mooring and paving loads, that is, 31% of the total pallets consumed in the process. This figure converted into monetary values represents an expense of US\$ 88,000 (eighty-eight thousand dollars) annually. Due to this high financial value, this cause was validated as the root cause.

Step 4: Confirm root causes

At this stage of the analysis step, the root causes identified must be confirmed. Through the data collected in the previous step, four of the five possible causes were validated.

Table 1 shows briefly which causes were validated and which methods were used for these validations.

Table 1 - Root Cause Validation for expenditure with pallet

N° of Potential Cause	Root Cause Description	Method of Verification	Root cause Confirmed (Y/N)
1	The manufacturer does not use (sells/discards)	Historical data Statistical Significance	Yes
2	Fumigated pallet for national shipment	Historical data Statistical Significance	Yes
3	Use in cargo or platform lashing	Historical data Statistical Significance	Yes
4	Use in national transportation	Historical data Statistical Significance	Yes
5	Use in export transportation	Historical data Statistical Significance	No

Source: Company Y, 2006.

As can be seen in Table 1, of the five main causes analyzed, four were validated as the cause of the problem with pallets. For these causes, necessary actions have been taken and will be demonstrated in the next phase.

3.1.6 Improve Step

The solution selection matrix was the tool used to choose the most propitious and feasible actions that would be taken to eliminate the root causes identified in the project's analysis stage.

Step 1: Identify possible solutions to the causes

The quality tool used at this time for problem analysis was *brainstorming*. A form divided into three columns and four lines (referring to the number of participants) was used, each participant puts three ideas, this way the ideas listed below were generated:

- Chep supplier evaluation;
- Acquisition of suitable specification pallet;
- Use of combined pallet (wood and plastic - Coplast);
- Evaluation of recycled wood decks or other materials (ecowood);
- Assessment of pine pallet pallets (cut) outside Manaus;
- Survey of legal requirements;
- Creation and acquisition of the new fumigated pallet;
- New platform development;
- New item creation and usage standardization.

Step 2: Select solutions

The solution selection matrix shows the relationship between the problem definition, the root causes, and the proposed solutions. The prioritization matrix helps to objectively evaluate alternative solutions through the analysis of three factors, the efficiency of each action, the ease of implementation, the costs of this action. The result of the product of these three factors is what will determine whether the action will be implemented or not, the greater the result of this product, the higher the priority for implementing the action.

In this step, the solution selection matrices for the failure modes are presented, according to the pallet expense problem, which is:

1. Manufacturer does not use (sell / discard);
2. Fumigated pallet for national shipment;
3. Use in cargo or platform lashing;
4. Use in National Transportation.

For cause 1, “Manufacturer does not use (sell/discard)”, five solutions were generated, identified through the cause-effect diagram, see Figure 7.



Figure 7 - Solution selection matrix

Source: Company Y, 2006.

As shown in Figure 7, it appears that for the root causes of problem 1, five solutions were established, and after using the solution selection matrix, in which the relationship is made between the cost of implementation, ease, and effectiveness of the action, action plans were validated for two of them, which are “Evaluation of the Pallet Pool” and “acquisition of a pallet of suitable specification”. The other three solutions scored low.

For all other causes, the same methodology was applied, with the generation of a solution selection matrix and in all other matrices, two solutions appeared repeatedly. For this reason, the next step will be presented only with the two solutions highlighted above.

Step 3: Analyze Cost-Benefit Ratio

The cost-benefit analysis was carried out for the two main tasks identified as solutions with the greatest impact on the pallet expense problem, solution 1 and 2. In this phase, Company Y's finance department was involved in the quantification and validation of such actions. The other solutions were identified as being of immediate application, not requiring this type of analysis for their implementation.

The analysis was performed for the solutions as follows:

Solution 1 - New pallet resized for transport only, supplied by a local lumber company;

Solution 2 - Pallet supplied by a national pallet pool.

After this cost survey, it was observed that solution 1 could show a 14% reduction concerning the type of pallet used by the company. However, in this analysis, it was demonstrated that solution 2, that is, pallets supplied by a pool of pallets would provide savings of up to 66% compared to current pallet costs. Therefore, option 2 became the best option for solving the pallet expense problem. Figure 8 illustrates this relationship.

Tipo Paleta (Fornecedor)	Paleta	Custo (R\$)		% Redução (R\$ anual)
		Médio Mês	Anual	
Paleta Atual (Fornecedor Local)	41	62,954	755,450	
Novo Paleta (Redimensionado)	31	47,585	571,020	- 24 %
Novo Paleta (Pool de Paletes)	21	32,235	256,193	- 66 %

Avaliação Custo baseado consumo 2006

Figure 8 - Cost-Benefit Ratio (Forecast of reduction)

Source: Company Y, 2006.

In Figure 8, the cost ratio based on the consumption of pallets in 2006 is shown only in the national loading processes. It lists the price per pallet, the average expense per month, and the annual value from the value of each pallet. It is worth mentioning that the consumption of pallets at Company Y averaged 1.535 pallets per month.

Step 4: Develop the planning and conduct the pilot project

Solution 2 (Pallet Pool) was identified as the best solution for financial gains. The cost-benefit ratio was favorable for joining the pallet pool (solution 2);

- **The pilot of Solution 2 - Pallet Pool Company Assessment.** The time required to comply with this plan was 55 days. The tests were carried out within the stipulated time and the pilot plan was closed.

From this moment, deadlines were established for closing contracts between the pool management company, Company Y and the customers involved in the operation. A 30-day deadline was established for closing contracts and implementing a service center in Manaus. With the completion of such steps, the company's top management authorized the start of the operation.

The operational flow of the pool works according to Figure 7, it demonstrates the operational flow of the pallet pool system which starts as follows: The pallet pool manager maintains repair and distribution centers in 14 cities in Brazil. From these distribution centers supplies the companies that hire the rental of pallets (in the case of this study, it refers to the Company Y), these companies, in turn, send their palletized loads to their customers, these customers receive and return the pallets to the pool manager who sends them back to the distribution centers for repairs. Subsequently, the distribution centers make pallets that start moving between companies that are part of this movement and supply system again available to the pool customers.

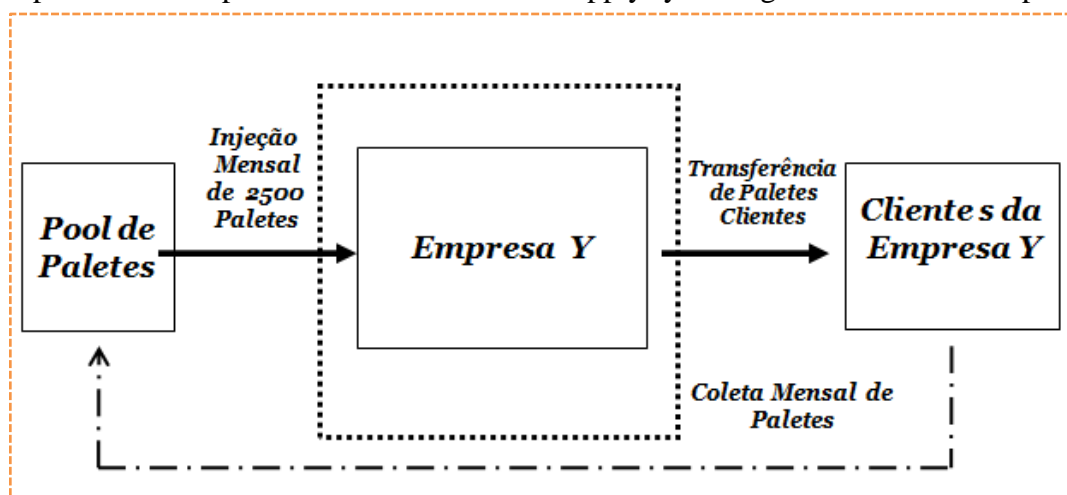


Figure 9 - Operational Flow in the Pallet Pool System

Source: Company Y, 2006.

The benefits of this operation can be:

- 1) Elimination of the lack of pallets, as the pool management company guarantees immediate replenishment of stocks;
- 2) Reduction of expenses with pallets in 66%;
- 3) Elimination of wood waste in the environment. This impact had not been quantified during the execution of the previous phases, however, in this phase, this result was evaluated and will be demonstrated below in the topic referring to the analysis of the results, item environmental impact.

● Choice of Solutions

After completing the pilot tests and evaluating the improvement actions, the Company chose to adopt the Pallet Pool as the main solution to the problems defined in the project's measuring phase, which was to

reduce expenses with pallets and eliminate the lack of pallets in the shipping process. The solutions for creating a new wooden platform and using kanban were also used to reduce the impacts of such problems. It is worth mentioning that, for the full adoption of the use of pallets using a Pool, The Company must sign a lending contract for their use in the process of transporting finished products to customers located in 41 different cities in Brazil. The Company hired to manage this Pool is a multinational company present in 45 countries, has extensive experience and offers guarantees of supply of pallets according to the customer's needs, as it has a distribution and repair center in 14 different cities. This company manages the pallet inventory and collections daily through an automated system that can be accessed via the internet. Its differential is the use of wood from managed forests, which represent a responsible and sustainable source of wood.

3.1.7 Control Step

Step 1: Develop and document the standard practice

Documentation for the new methods was created, with training for the new routines and standard work practices. A work instruction was created by Company Y's quality system to meet and cover new work routines.

These routines were added to the daily process of these people after formal training and started to compose activities according to their job descriptions. This stage is of fundamental importance for the maintenance of the practices implemented by the procedure since all involved will start to carry out their activities according to the established standard.

Step 2: Build the process management control system

According to the procedure, a system to control the process management must be created. The input indicators (X) must control the key subprocesses that impact the output indicator (Y). These, in turn, are directly linked to the company's high-level indicators.

Through continuous measurement, indicators can be controlled and improved. Together, these indicators tell you how well customer requirements are met and predict future performance.

This process management control system has 2 output indicators (Y): "meeting deadlines", and the most important "pallet expense". There is also 1 input indicator (X): Amount of defects recorded.

Step 3: Process Sigma

In this step, the performance and process sigma evolution can be observed. With the full implementation of the improvement that was the use of the pallet pool pallet, the following improvements can be observed: evolution of the yield to 84.61% and a sigma of 2.52. See table 5.

Table 5 - Calculation of Sigma (II)

Calculating Process Sigma		Pallet Cost
Unit defect opportunities	O =	1
Units processed	N =	52
Total number of defects that occurred	D =	8
Total number of defective units	DU =	8
Defects by opportunity (DBO)	$D / (N \times O) =$	15.3846%
Defects by Defective Unit (DBU)	$(UD / N) =$	15.3846%
Defects per 1 million defect opportunities (DPMO)	DBO x 1000000	153846.15
Yield (Flawless Unit)	$(1 - DBU) \times 100$	84.61538%
	<u>Sigma =</u>	2.52

Source: Company Y, 2006.

It is worth remembering that at the stage measuring the process yield was 49% and the sigma in that situation was 1.48. With the numbers presented in Table 5, when compared with the numbers presented in the measure phase, a considerable evolution can be observed in Yield and the process sigma.

Expenses with pallets in 23 weeks showed an average within the expected for the period, which was R\$ 9,200 per month, despite presenting some points above the line, a trend of growth of such expense was not identified.

Another way to monitor the expected financial result was to analyze the value of the savings achieved after the implementation of the Pallet Pool solution, figures shown through Figure 8.

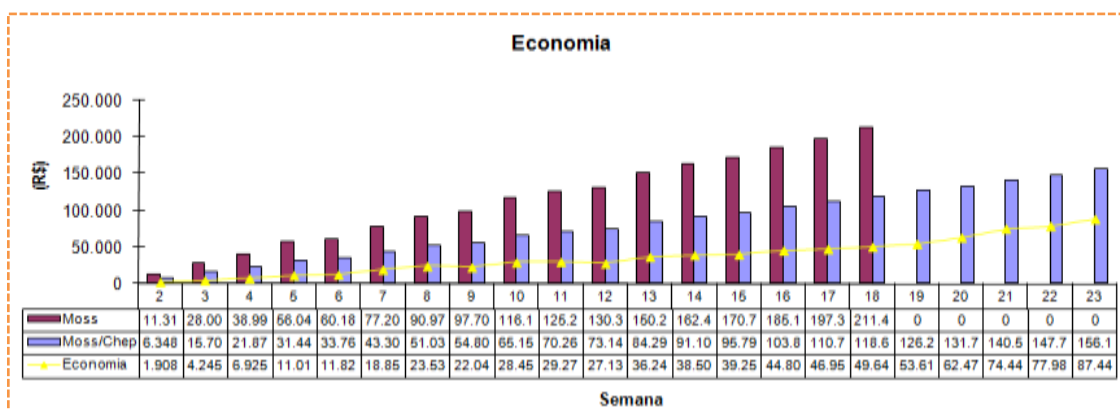


Figure 10 - Evolution of the Project Economy

Source: Company Y

As shown in figure 10, the accumulated savings over 23 weeks was R\$ 87,000. Given this fact, the economic projections were revised and the savings target proposed by the project at the end of a year was R\$ 260,000 and, according to the evolution of the economy shown in the graph above, this goal would be reached at end of 52 weeks.

Step 4: Finish the Project

At this stage, the Six Sigma team officially delivers the results obtained with the implementation of the methodological procedure and passes the responsibility to the area or “owners of the process”, such people will be responsible for the control of the PMCS and the expected results for the area. It is worth mentioning that through the PMCS it is possible to visually control the process, this tool gives focus to the team, and maintains the gains obtained through the improvements implemented.

4. GENERAL CONSIDERATIONS OF RESULTS

The main objective of this work was to demonstrate the use of the six sigma methodological procedure in a beverage company installed in the Industrial Pole of Manaus in the process of cargo palletization through an explanatory work in that company, to test the procedure and present the results obtained through the application of such methodological procedure.

This procedure followed three steps according to the theory studied: Team building, choosing the project and applying the six sigma methodological procedure. The results are described in the items that follow.

4.1 TEAM FORMATION

For the success of the Six Sigma project, the company provided a solid base of specific technical knowledge to a greater number of people in different areas in the company. It was observed that formal training was the basis for the formation of the company's leadership team and for the choice of people with the greatest potential to contribute to the success of the project. The scope and scope of this step resulted in a team of 67 people linked to different departments. This meant the formation of a base in which 42% of employees are qualified to coordinate and execute six sigma projects at Company Y.

4.2 PROJECT CHOICE

The company in question identified opportunities for improvement that could affect the company's results and related them to the high-level indicators that are the company's macro objectives. Following this logic, the opportunity to improve the cargo palletizing process in the transport logistics department was identified as a process of great impact on the company's “Total Manufacturing Cost per unit” objective. Then, using a tool called the decision tree, he established the DMAIC model as the methodology used to improve the palletizing process in the area of finished product shipment of the company under study.

4.3 APPLICATION OF THE DMAIC MODEL

Company Y used DMAIC due to a complex and recurring problem, without a known solution that was identified in the cargo palletizing process, and in the case study of the company under study, the cargo palletizing process presented opportunities for improvement whose solution was not yet known or should be valid according to the proposed methodology. It is concluded through this procedure:

In the define phase (**D**), opportunities were identified within the process, such as financial and environmental opportunities, such as expenses with pallets (R\$ 900,000) and the amount of solid waste

(1200Ton) as opportunities for improvement. In the case study, the tools used were: snake diagram, customer voice or CTQ tree, data collection or historical data graphs.

In the measure phase (M), the current performance of the process was measured and the problem area was reduced. In the present case study, six tools were used, as follows: Data collection, spaghetti diagram, value flow mapping, control charts, Pareto charts, project review with the application.

In the analysis phase (A), the main objective was to determine the root causes and confirm them with data. In this phase, nine different tools can be used, however, the case study identified the use of only three of them, which were: Brainstorming, Cause and Effect Diagram and Project Review.

In the improvement phase (I), the solution with the greatest impact on the problem was selected. The CHEP company presented a better result in the cost-benefit comparison and the implementation of this solution can be validated as follows:

Operating/Financial Results

The operational and financial results planned after the implementation of the solutions presented by the methodological procedure applied in the company can be viewed in summary form in the tables that follow.

Table 6 - Summary of Results (I)

Processes	Before	Projection	Improvement Result
Expenses with pallets (R\$/year)	755.450,00	386.820,00 (Reduction 66%)	423.052,00 (Reduction 56%)
Lack of Pallets	49/month	Zero	Zero (Elimination 100%)

Source: Company Y, 2007.

As shown in Table 6, it can be seen that, with the adoption of the solutions presented by the present work, the reduction of expenses with pallets by 69% was projected, although the reduction occurred, the result achieved was not the same as projected. Even so, this result represented a significant improvement in the indicator “total expenses with pallets”.

In the control phase (C), according to Brassard et al (2002), it is necessary to control the gains obtained with the implementation of improvements, standardize the control methods and establish those responsible for maintaining the improvement of these processes. As a result of this phase, standard practice was created for the new process, it was determined that a single person would start to control specific invoices, feed the database for inventory and collection controls, as well as the issuance of monthly reports for process controls. To obtain such results Brassard et al (2002) cites six most used tools, and in the case study four of them were used as follows: control charts, process management charts, trend graph and project review (Tollgate).

5. CONCLUSION

This study aimed to demonstrate a methodological procedure for applying the DMAIC model of the Six Sigma methodology to the cargo palletizing process, aiming at increasing the operational efficiency of transportation at Company Y.

In this way, the methodological procedure was tested through the application of the Six Sigma DMAIC model, explained in the phases to define, measure, analyze, improve and control. In each phase, the most appropriate tools were used according to the existing literature.

Through the application of the methodological procedure of the DMAIC model, it was possible to determine and quantify the main defects and wastes, to analyze the causes of the defects for the establishment of improvement actions in the process of palletizing national cargo in Company Y.

The study provided an opportunity to describe the application of the Six Sigma methodological procedure in a PIM company, enabling a sequential view of the steps to be developed in the planning and implementation of process improvements. With the application of this procedure, waste was eliminated and variations in processes were reduced.

In the define phase, several opportunities were identified, with the high cost of pallets being the central focus of the application of this procedure in that company. Therefore, in the improvement phase, the pallet pool system was implemented, that is, a pallet rental system through a specialized company with the capacity to manage the movement in the entire pallet's logistics chain since shipping from Company Y until the collection of these from its customers.

In the control phase it was possible to observe that the positive results proposed in the improve phase were consistent in the period in which they were measured, that is, it was evidenced in this phase that Company Y obtained a 66% reduction in the palletizing process costs.

This study also demonstrated the reduction of pallet handling time and the reduction of the environmental impact with the elimination of solid waste disposal.

Finally, it is concluded that this methodological procedure can be applied throughout the production chain regardless of the company's business segment, obeying the reality of each company or process.

The results obtained in this study can be seen as a source of consultation by people from both academia and business, as both the concept and the results achieved by its application are of great value for both segments.

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