Using Project Six Sigma and Lean Concepts in Internal Logistics

Daniela L. Antunes, Sérgio D. Sousa, *Member, IAENG* and Eusébio Nunes

***Abstract*—Lean logistics and continuous improvement methodologies, such as Six Sigma, are key subjects to reduce non added value activities and improve intrinsic processes in the supply chain of an organisation. The aim of this work is to identify the variables influencing the quality and performance of raw material supply process throughout a case study to propose improvements to reduce the number of process defects. To obtain better results and due to the problem complexity, a Six Sigma project was selected because of its organised structure for problem analysis and resolution. Using Six Sigma together with quality tools and lean principles helped the identification of the variables that influence the raw material supply process and the definition of the improvement actions for a more efficient and effective defect reduction. The implemented actions reduced the defects in 80%, improving the customer service and increasing productivity in *supermarket* and repacking areas.**

***Index Terms*—Continuous Improvement, Lean Logistics, Quality Tools, Six Sigma, Supply Chain Management.**

I. Introduction

In the context of the current market, where requirements and customer expectations are increasingly high and diverse, there are numerous organisations who seek out management philosophies that consider the entire company as the object of improvement and not just specific areas directly linked the core business (as the area of production), thus allowing a significant increase in the level of competitiveness, quality and customer service.

Relying on the principle that the more defined requirements are met by a product or service better is its quality [1], organisations are increasingly focusing on continuous improvement methodologies coupled with concepts of Lean Manufacturing philosophy. They seek to achieve improved quality, better performance of their processes and reduce their internal costs.

The application of continuous improvement methodologies, such as Six Sigma and Lean concepts together in the area of internal logistics, became the key points of the work presented in this article.

It is proposed to make a contribution in this area by identifying the variables that influence the supply components to an assembly line of car audio systems, improving the performance of the process consistently. The study focused on reducing failures inherent in the supply process and a clear definition of containment measures. Underlying these goals are two issues to be addressed:

(i) What are the variables that influence the quality and performance of the supply process of raw material to the assembly line?

(ii) How the different variables associated with logistics processes affect its performance?

Considering the questions and goals of the research project, the research methodology selected was the "Case Study", which describes the practical implementation of a Six Sigma project in the process of supply of raw materials to final assembly lines for car audio systems.

II. Literature Review

This section presents a critical analysis of literature and discusses topics of relevance to the study such as Logistics, Lean Manufacturing and Six Sigma.

A. Logistics

The field of logistics encompasses all operations necessary for the *delivery* of any product (or service) to the customer, except those directly associated with the conception of the product [2]. The logistics, as well as being responsible for the management of material flows between the different production areas (commonly called by *internal logistics* - IL), manages the flow of information intrinsic to the flow of materials, such as transaction operations, forecasting, production planning, etc.

In broader terms, supply chain is defined [3] as a system composed of people, activities, information and resources related and interconnected, with the goal of creating a product and deliver it to your customer. A supply chain reference has to be characterised that leads to excellence in response speed, quality, cost and flexibility [4]. Terms such as agility, adaptability and consistency must be present and are relevant in the management of supply chains where the focus on cost reduction is devalued at the expense of maximizing the "added value" to the customer [5].

Continuous improvement is defined by [6] as the study of what works, what does not, why and on what conditions. It is a systematic, organized and planned process of continuous change of existing practices in an organization to improve its performance [7]. It should be adopted focusing on

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S. D. Sousa is with Centro Algoritmi, University of Minho, Campus de Gualtar, 4710-057, Braga, Portugal, phone: +351 253 604 762; e-mail: sds@dps.uminho.pt.

E. Nunes is with Centro Algoritmi, University of Minho, Campus de Gualtar, 4710-057, Braga, Portugal; e-mail: enunes@dps.uminho.pt.

D. L. Antunes is with Centro Algoritmi, University of Minho, Campus de Gualtar, 4710-057, Braga, Portugal; e-mail: dslantunes@gmail.com.

production and quality. The continuous improvement process should not be assumed to be finite but as something that has to be constantly updated [8]. Also according to this author, companies using the continuous improvement process focus on the achievement of several small-scale changes, creating a large cumulative effect.

There are numerous methodologies and tools used for the purposes of this concept are achieved successfully. Among the most important and most used at the moment are: Kaizen, Six Sigma, 8D, PDCA Cycle (Caesar and Neto, 2009).

B. Lean

The companies' need for constant improvement and evolution leads to the search of management tools and methods to foster the development of customer service and to reduce the costs for all associated processes. Accepting this perspective of management, where the achievement of excellence through continuous improvement of procedures and processes and the search for new management concepts are emphasised, led several companies to engage in management strategies where the assumptions of the "lean" philosophy are key.

The basic concepts of the *Lean* philosophy arose initially from the 50s in Japanese companies and have been developing it up to today. These concepts are centred on just-in-time, where the only goal is the production of products only at the time they are requested [9]. The term "lean" is emerging as a new designation for production / management "philosophy" that opposes the concept of "mass production" [10].

The goal of *Lean* management is to improve the performance of industrial organisations, following two guidelines: the elimination of all waste present in all processes of an organisation and placement of humans in the centre of the process, taking advantage of their capacities at all levels.

According to [11], the processes within an organisation are distributed as follows: those that add real value to the product (5%), those that are needed that do not add value (35%) and those that do not add value to the product (60%). Given this, Jones and Rich [12], argue that to achieve optimum performance in the process of improving the current state of each organization they must address the 60% associated with procedures that do not add any value to the products.

C. Six Sigma

Six Sigma is a methodology to reduce the number of product defects and to reach organisational excellence. It helps the organisation to achieve a competitive advantage [13]. This is a structured methodology with systematic statistical-based techniques, which is used to improve the performance of processes / products or quality of a service by reducing process variation [14]. In addition to statistical techniques, the methodology also incorporates other concepts such as financial analysis and project planning [15]. To systematize the application of this methodology in process improvement is often used a formal method called DMAIC (Define, Measure, Analyse, Improve and Control) [16]. This method is a closed loop that allows for the elimination of certain phases of a process (those with no added value to the product or service) and allows concentration on new metrics and application of different technologies for continuous improvement. The use of DMAIC steps causes the realization of actions in a sequential and logical way, and in accordance with the scope of the project [17].

Many of the tools and techniques may be applied in more than one stage of the methodology, since their purpose may coincide with the objectives of the tasks of each phase [17]. The Six Sigma is a philosophy that has evolved gradually with the results obtained in various organisations (industry and services) [18].

One of the main factors when selecting a Six Sigma project involving services is positive financial impact and increased customer satisfaction [19].

Like any quality improvement methodology, there are limitations in its implementation. Moreover, the service sector exhibits an increased difficulty, since this sector has highly dynamic processes [13, 20].

There are many possibilities of implementing Six Sigma projects in the service sector. But it is important to strictly define the characteristic of the process that will be measured, to ensure that it is critical for customer satisfaction and for the level of service quality.

III. Project Context

The case study that follows, describes the practical implementation of Six Sigma methodology in the process of supply of raw materials to final assembly lines at a first tier supplier of the automotive industry which mainly produces multimedia products. It was developed in one of the sections, IL, of this company that is responsible for the overall internal flow of materials in the factory, including reception of material, storage of raw material and finished product, *supermarkets*, raw material supply to production lines (PL) and dispatch of finished product.

The performance of each of the areas is measured and controlled by indicators associated with productivity, delivery performance and cost of scrap. The internal flow of material of the organization is shown in Figure 1.

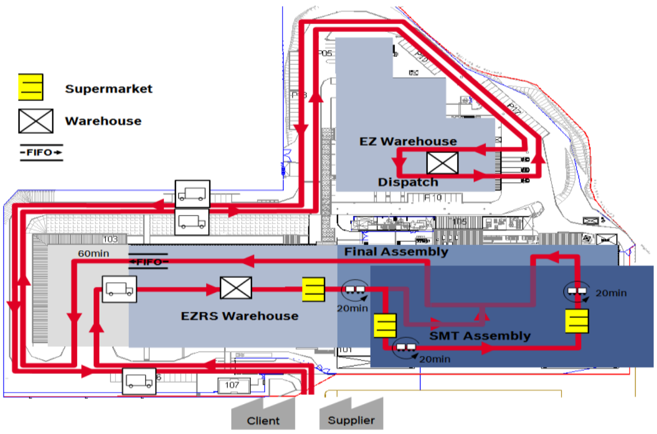

Fig. 1. Materials flow.

The logistic process begins in the reception area of

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materials, in the warehouse of raw material, from which are supplied *supermarkets* (stocks for final assembly lines) or to a second store which supplies lines of automatic insertion.

These lines, responsible for the first phase of the assembly of the product, are supplied in two ways: through the zone of preparation phase, where *starter kits* are prepared to begin production and through the warehouse, providing the raw material as this will be necessary in the insertion machines. Having completed this first phase, semi-finished components are placed in a supermarket to supply the final assembly. There are two supermarkets in which are stored all the raw materials that are used in final assembly. These materials, along with semi-finished components, are supplied to production lines by logistical trains (internally called Milk-Runs). Once completed product assembly, they are sent to the finished product warehouse where they will be dispatched.

The process of supplying raw materials to the final assembly lines is a pulled process, operating on a two-bin system. This procedure, in the lean logistics language, is called *empty-box full-box supply*. When a material is consumed an empty box is placed on a specific location providing a signal to an operator to restock again that post with that material.

Each box is supplied with a Kanban card identified that among other information indicates the storage location of the material in the *supermarket*. Given this information the operator does the picking of the material in the supermarket returning later to the line with the box full. This procedure is cyclic and standardized throughout the day. To eliminate transportation waste a *milk-run* is defined, with a preset route and a supply cycle.

IV. Improvement Project in the Material Supply to Production Lines

The main objective of this project focused on the development of improvement actions that directly influence the performance indicators of the process of material supply, based on the application of the Six Sigma and lean concepts (identification, measurement and analysis of faults and failures and implementation of improvement actions that are best suited to the reality of the problem).

A. *Definition Phase*

The first phase of the DMAIC method consists of, defining the project purpose. This phase allowed the definition of the fundamental problem and based on that information it was identified and defined information and requirements in order to initiate the project. It was necessary to define the team, understand the problem under study, understand the processes inherent to the problem and set goals. Part of this information was concentrated in the *project declaration* (Figure 2).

Performance indicators (PI) in the area of internal logistics (IL) are adherence to delivery cycle (material delivered within the stipulated cycle) and quality of delivery (the delivered material is the requested material). One of the strategic objectives outlined by the head of the department responsible for managing the IL is the improvement of the performance indicators defined for this area. The potential for improvement in these indicators gave the project the necessary motivation.

Business Case	Opportunity Statement (High Level Problem Statement
One performance indicator (PI) of IL to measure customer satisfaction is the quality of supply service. The current result of this KPI is not within the targets set by management being necessary to intervene in order to achieve the strategic objectives.	Improving the PI *delivery of raw materials to final assembly lines*. Cost reduction of scrap units. Reduce rework hours. **Defect Definition** Number of units not produced due to failures in (attributable to) IL.

Goal Statement	Project Scope
Identify the root causes for failures in IL leading to production losses, improve critical processes that contribute to the failures.	Process start point: 5/4/2010 Process end point: 30/4/2011
Expected Saving/Benefits:	In Scope:
Reduced number of units not produced; Reduced the number of failures in IL; Reduced scrap costs.	Performance supply of raw material Out of Scope: Scrap costs to the final product

Project Plan			Team		
Task/Phase	Start date	End date	Name	Role	Commitment
Define	4/2010	5/2010	Name 1	Project Leader	High
Measure	5/2010	6/2010	Name 2	Decision Support	Low
Analyse	6/2010	9/2010	Name 3	Black Belt	Low
Improvement	9/2010	1/2011	Name 4	Black Belt	Low
Control	2/2011	4/2011			

Fig 2. Project Declaration

The first step to facilitate a clear and effective project management was to create one plan with the objectives to be achieved and the resources available to carry out each task. The Gantt tool was the choice to perform the synchronization of all tasks and mapping the actions, serving also to do the follow-up project by checking if the timings are being met. The proposal is a project lasting one year in order to be able to implement a greater number of improvement actions.

The feasibility of a project is important, because if the costs associated with its development outweigh the expected benefits will not make sense to proceed with its development. Considering the relationship between the possible costs with the implementation of improvement actions and the ability to achieve the intended objectives, it was decided to go ahead with it.

The correct specification and detailed problem / defect is one of the critical success of the project. The delivery performance of IL is measured by the *number of units planned but not produced due to problems in the supply process*. When one or more units of raw material are not promptly delivered, arises as a consequence a stop in the production line. This downtime is converted into number of units not produced. Figure 3 presents a structured description of the problem.

The *SIPOC diagram* was created to better understand the whole process. Its key activities, inputs, suppliers, outputs and customers are identified (see Figure 4).

Problem Statement / Background Information	
What part, Product, Process or Service is involved?	Reception, storage and supply of raw material.
Explain the Problem(s).	Units not produced, which result from IL failures.
When in the life cycle of the unit is the problem detected?	In production lines / cells (Production).
To what percentage of the units or transactions does the problem occur?	1619 units were not produced. Lost 0.1% units (1 unit lost in 1000 units planned).
What Is -What Isn't (Information)	
What happened?	Number of products not produced as planned plan.
What didn't happen?	Production plan fulfilment
When does it occur?	During the production process.
When doesn't occur?	----------------------------
Who has it happened to?	IL and Production
Who hasn't it happened to?	----------------------------
Expectations	
What are the expectations (not solutions) of the team?	Reduced number of units lost under the responsibility of IL.

Fig. 3. Structured problem description.

SIPOC				
Suppliers	Input	Process (High Level)	Output	Customers
CI/FSR1 1-IB	System for controlling the cycle time of each supply route.	Start supply cycle Start route until 1st supply point Supply Production with filled boxes	Time to beginning supply cycle; Alert delays at the beginning of the cycle; Reports cycle time of each supply route.	Milk-Run Team Leader of supermarket
Milk-Run IL	Raw Material (full-boxes)	Collect empty boxes and kanban cards Advance to next supply point; repeat the 2 previous steps	Replenishment of the line/cell with raw material	Production lines/ production cells
MOE2 Lines/ Production cells	Empty-boxes - Kanban cards	Ending supply route? (NO: back to previous step)	Picking list for the next supply cycle	Milk-Run IL
		YES Return to the 1st point of picking in		
Milk-Run IL	Return lines / cells empty-boxes-	Remove empty boxes Start picking of new supply material There are cards for picking? (NO: back to previous step)	Cleaning and storage of empty boxes; Storage material partially consumed; Kanban cards to replenish	Supermarket Raw Material
Supermarkets of Raw Material	Raw-Material (full-boxes)	YES Start new supply cycle	Raw Material (Boxes Filled) for all points of the supply route	Milk-Run IL

Fig 4. SIPOC Diagram: supply of raw material

The *turtle diagram* is a tool that allows, in this case, to better understand the allocation of production losses to the IL process. Its key elements are:

– Materials / Equipment used;
– Inputs to the process (data used);
– Procedures and support processes;
– Resources involved;
– Deliverables;
– Performance indicators and satisfaction rates.

According to the *turtle diagram* in Figure 5 the key process materials / equipment were the boxes used for repacking, the lifting machinery used for picking of the material in the warehouse, the control system for dispatching Milk-Runs, the card that identifies the material (Kanban) and the Milk-Run responsible for the supply of raw material.

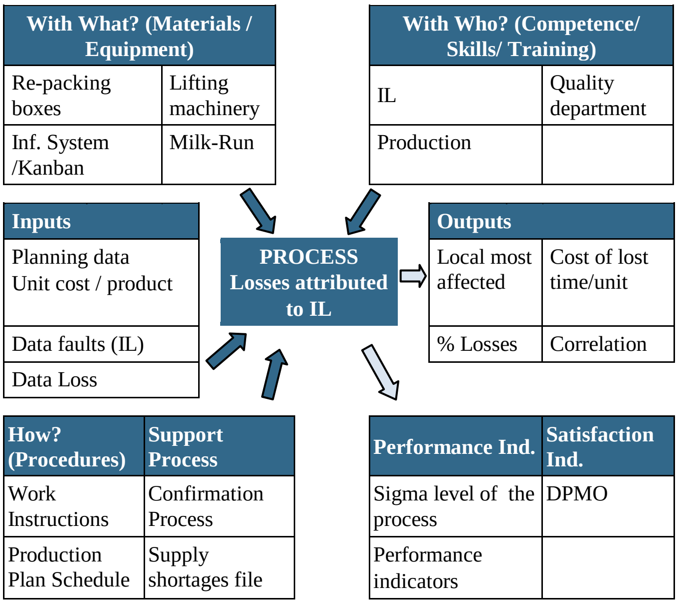

Fig. 5. Relations of the process of allocating losses

The data used for the process analysis are the failure records, registration of production impediments, data on planning materials and further data on the unit cost for each product.

The processes and procedures considered for analysis were work instructions for tasks related with the flow of material handling, confirmations process and information on supply shortages. The participants involved are employees of internal logistics, responsible for the problem, production that controls the process and experts in Six Sigma projects.

The expected results for the six sigma project were to achieve the identification of production lines / cells most affected, to quantify the percentage of production loss of attributable to IL, to define the cost per unit of losses and identify the possible causes. The main PI is the sigma level DPMO (number defects per million of opportunities, in this case one opportunity per one unit).

B. *Measurement Phase*

The objective of this phase is to understand in detail the current state of the process and collect reliable data on its performance, stability and cost associated with the causes of the problems.

The activities of this phase identify the critical to quality characteristics and quantify the process performance. It was performed a stratification of the problem to obtain a distinction of its potential causes. Data were grouped by categories of occurrences.

The inhibitions to production attributed to IL are grouped

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into three types of categories: supply delays (delivering the requested component with delay; supply failures (not delivering the expect component); and supply errors (delivering a component not requested).

Supply errors are the less frequent failure (30%) and also with less significance in the number of units not produced (9%). However, this failure is the most critical, because the impact of this error can effectively lead to a defect in the product detected only by the final customer.

The calculation of sigma level for a particular process is a metric commonly used to evaluate the performance of a process. The higher the sigma value, the better the performance of the process and the lower the probability of a defect. In this project, the value of sigma was calculated to measure the initial performance of the internal supply process. Figure 6 illustrates the result of this calculation.

PROCESS SIGMA CALCULATION							
Project	Production losses attributable to IL						
Collect Date	From 01-04-10			to 30-06-10			
Defects	Units	DPU	Opport	Total Opp	DPO	DPMO	Z
1619	1169653	0.0014	1	1169653	0.0014	1384	4.49

Fig. 6. Six Sigma level calculation.

In the studied company there is a rule for six sigma projects: to reduce DPMO by 50% if the current level of sigma is greater than 3. Thus, in this project, the goal it will be to achieve a DPMO of 692 (or less) corresponding to a sigma level of 4.7.

C. *Analysis Phase*

In this phase measured data were analysed in detail to allow identify the root causes of the problem. It allowed understanding some factors and process variables with potential for errors and therefore potentiating the occurrence of failures in the supply process.

To identify the root causes of the problem it was made one *Brainstorming* with the project team plus other elements with functions directly connected with the supply process (operator-Milk Run, team leader) and other functions not directly related to the process (re-packing operator, quality control, supermarket manager).

All potential causes for failures of the supply process were mapped using a *cause-effect diagram*. This tool allowed grouping the causes into five groups: Method, Machine, Manpower, Environment and Material. It was concluded that causes that contribute most to the problem are directly related to the working methods used in the supply process and human factors.

Given the extensive size of the list of potential causes, and not being possible to address all of them, became essential to identify and select those with bigger impact on problem. To identify such causes it was used a *cause-effect matrix* (see an excerpt in Figure 7), whose inputs variables were the causes identified in the *cause-effect diagram* and the outputs variables were four critical effects identified during the brainstorming: Y1-supermarket supply delays, Y2-supermarket supply errors, Y3-warehouse supply delays, and Y4-supply warehouse errors. This distinction between effects seemed relevant since it would allow a more focused selection of improvement actions. The definition of the relevance of the output variables was assigned according to customers' impact (through a scale 1 to 9, where 9 means the higher impact). In addition, to identify the level of relationship between the different causes and the effects a similar scale was used (1 to 9, where 9 means the higher relationship). After filling in the matrix, the top 10 variables identified as the main contributors to the problem were sorted (see Figure 7). As a result "identification of the material", "lack or failure to comply with work instructions" and "management the process of product change-over", were taken as the causes to be addressed in the next phase.

Inputs X1, …, Xn		Outputs Y1, … Yn				Total
		Y1	Y2	Y3	Y4	
		5	*9*	*4*	*8*	
X7	Material misidentified by reception	5	8	7	8	189
X8	Material misidentified by the supplier	5	8	7	8	189
X6	Parts allocated in the wrong place	5	9	4	6	170
X30	Non-compliance with work instructions	4	8	4	7	164
X33	Poor management of product changes by *production*	9	6	6	4	155
X12	Inventory differences	5	7	6	4	144
X31	Lack of work instructions for certain tasks	3	6	4	7	141
X37	Problems in generating Min / Max when material is locked in warehouse	9	4	7	4	141
X55	high turnover of new employees	4	6	4	6	138
X24	Lack of training program for employees of IL area	4	8	3	4	136

Fig. 7. Top 10 root causes (variables) with the greatest impact on the problem under study (excerpt of cause-effect matrix).

Despite the identification of the causes of greatest relevance to the problem, the *cause-effect matrix* does not show clearly the contribution of each one to the problem. To understand this impact a *Pareto diagram* was built, but it not revealed special causes particularly relevant compared to others.

To prioritize the focus of improvement actions another *Pareto diagram* was built based on the production lines most affected by the problem. This revealed the line with biggest problems and also identified the ones responsible for 45% of the problems. It was estimated that to reduce of 80% of the defects a set of actions should be implemented.

D. *Improvement Phase*

At this stage of the project, and considering the results in the analysis phase, solutions were developed and implemented to reduce or if possible to eliminate the causes that contribute to the defects in the process of material supply, while increasing process efficiency. There were implemented changes in the supply process (see Table I).

Other actions implemented were the change of work instructions and implementation of the confirmations process in the re-packing area. Other improvement actions are waiting for approval to be implemented. Particularly in the Analysis and Improvement phase Lean principles were the motto for work.

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TABLE I
PROBLEMS *VS.* ACTIONS IMPLEMENTED IN THE SUPPLY PROCESS

Problem	Action
Supply circuits without established standard on all shifts	Define supply circuits and apply standard on all shifts.
Supply cycle time not defined	Define supply cycle time. Control cycle supply.
Lack of confirmation/ control processes	Introduce the confirmation process of material supply standard.
Lack of organisation in transporting material	Identification of wagons with section to supply
	Introduction of "box-full, box-empty"
Difficulty of supply during product change over	Implement change management process to look over Completed

E. Control Phase

Improvement actions need to be monitored to assess the effectiveness of actions, to maintain benefits over time and to ensure the stabilization of the processes.

In order to verify the effectiveness of the improvements the sigma level was again measured and results compared with the initial data. Given that the implementation phase of actions ended in February 2011, the data used to make the measurement of process performance are for the months of March and April 2011.

The resulting sigma level is 4.97 (375 defects on 1444949 products), or DPMO equal to 260. This corresponds to a reduction on the DPMO of 80.7% which is higher than the value initially set as target (50% reduction of DPMO). It can be said that the actions taken were successful because the project objective was successfully achieved.

V. CONCLUSIONS

In view of the proposed objectives, the results obtained suggest that the approach of applying the Six Sigma methodology in combination with Lean concepts presents a high potential to be successfully applied in improving internal logistics (IL) processes.

The reduction of waste in all IL phases and performance improvement are important goals for which the Lean concepts give relevant contributions. Moreover, a structured way of addressing problems by the six sigma methodology allows better understanding of the problems by identifying the variables that influence the process. In this study, the variables that influence the quality and performance of the IL can be grouped into three types of categories: supply delays; supply failures; and supply errors.

Results evidenced performance improvement of IL in a consistent manner by reducing failures inherent to the process and by the definition of appropriate containment measures which make processes more robust and efficient. Thus, there is the conviction that the use in isolation of Six Sigma methodology would not produce such good results.

With this study it was also revealed that a Six Sigma project does not require a team with a high number of elements. Although they have been implemented only the actions that required low investment in human and financial resources, nevertheless, the results obtained were excellent. This suggests that the Six Sigma methodology can be used on any type of company (small, medium or large company) and in any sector wishing to improve their processes, notwithstanding the difficulties that arise at various stages of project development, namely the analysis phase of the potential causes of the problem. Often the lack of obvious causes complicates the process of defining improvement actions and requires the use of different tools and analyses to make such a definition.

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