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Order processing improvement in military logistics by Value Stream Analysis lean methodology

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Abstract

Military logistics is a complex process where response times, demand uncertainty, high variety of material references and cost effectiveness turn decisive for combat capability. Considered as the bridge between the deployed forces and the industrial base that provides materials and services that the forces needed to accomplish their mission, capacity and efficiency of delivery are required for its processes. The required flexibility could only be achieved by improving the Supply Chain Management (SCM) in order to optimize delivery lead times. To cope with these requirements, lean thinking can be extended to military organizations. This research justifies and proposes the use of Lean Six Sigma (LSS) methodologies from manufacturing to optimize logistics processes in the defense sector. In particular, the article presents the benefits and results obtained using Value Stream Analysis and DMAIC (Define, Measure, Analyze, Improve, Control) problem-solving methodology to improve the order processing lead-time as key performance indicator of a military unit delivery fulfilment.

Keywords: Supply Chain Management; Military Logistics; Lean Management; Value Stream Mapping; DMAIC

1. Introduction

Logistics and Supply Chain Management (SCM) suppose a challenging issue for worldwide organizations. In particular, military logistics is a specific case where the ability to provide human and material resources results crucial in terms of minimum time, unpredictable quantity and variable location of new conflicts. According to [1], five main aspects are mostly different between military and consumer supply: large number of different type of items, variable demand, supply managed according to priority matters (e.g. medical supplies, subsistence, repair parts…), necessity of equipment and supply readiness, and different theatre characterized by moving points. Hence, it is difficult to manage inventories under these market conditions, which could mean either overstocking or delay. Additionally, two more factors must be considered in military applications. The first one is related to the available funding that may be limited for each nation. The second one is the decisive supply, if it supposes a risk factor to human lives of combatants and civilians. According to the American report [2], the strategic approach of military logistics should be focused on the improvement in processes, information

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systems, organizational structures and advances in distribution and transportation technologies. Precise time, capacity and efficiency of delivery to the operations theatre are required for Armed Forces. In order to improve response times and to assure the required flexibility avoiding wastes, the lean philosophy can be extended to supply chain management in military organizations.

The origin of lean philosophy is generally attributed to the practices developed from the TPS or Toyota Production System [3,4], pioneered by Taiichi Ohno [5] and Shigeo Shingo [6]. Their lean principles related to philosophy, processes, people, partners, and problem solving allow organizations to implement the lean thinking concept at different levels, in view of their special features and considerations. TPS has influenced not only manufacturing concepts, but also supply chain management ones. The concept of lean supply is described in [7,8] as an operating attitude that need to be changed in relation with suppliers, so that the effect of costs associated to non-perfect processes will not be limited to the location of the execution. This approach targets a long - term customer satisfaction. Thus, supply chain optimization is possible according to the three main TPS goals: best quality, lowest cost and shortest lead-time, which are achieved by continuously improvement and increasing operations' benefit.

This work evaluates the use of lean six sigma (LSS) methodologies and their application to military logistics functions, focusing on supply chain management processes for spare parts. We present a case study where value stream analysis technique is implemented to improve military material order processing procedures. To structure the research project, DMAIC (Define, Measure, Analyze, Improve, Control) Six Sigma methodology was followed [9], whose aim is aligned to continuous improvement of lean thinking [10] integrating the approaches of lean and Six Sigma as presented in [11–13].

2. Background

2.1. Military logistics and processes

The concept of supply chain management is a horizontal strategic function that encompasses all the operations of the supply chain between customers and suppliers, distribution, manufacturing, procurement and planning, with the aim of giving an integrated answer to the competitive difference of the organizations.

Three main aspects of logistics need to be highlighted into the military logistics cycle (see Fig. 1). *Production* or *acquisition logistics* focused on the procurement of the material. Meanwhile *in-service logistics* links production and consumer logistics and comprises functions associated with receiving, storing, distributing and disposing material to the force. *Consumer* or *operational logistics* concerns the reception, storage, transport, maintenance and disposal of the material including the provision of support and services. Depending on the strategic, operational or tactical level of the logistic function approached, different activities are encompassed. There are also multiple logistic functions identified in the military field but we will focus in this work on the material supply logistic function that includes the determination of stock levels, provisioning, distribution and replenishment restricted in this case to operational and tactical levels. The military organization of this research study is referred to as ABC throughout this paper due to non-disclosure requirements.

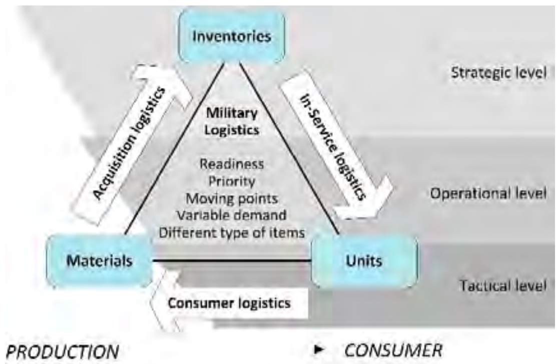

Fig. 1. Military logistics cycle: an overview.

2.2. Lean methodologies and tools

The lean thinking promotes a continuous-improvement culture being its tools and practices widely applied in different sectors and organizations. Lean is one of the most influential recent paradigms in manufacturing, and has expanded beyond the original application to other areas and sectors, either public or private. As mentioned before, the origin of lean philosophy is generally attributed to the practices developed from Toyota Production System. One of the first studies mentioning lean concepts comparing automotive manufacturing plants performance in Japan, United States and Europe was included in [14]. Since then, lean practices have been developed and extended worldwide.

The lean approach, its techniques and limitations were revised in the literature [15,16], remarking the necessity of an adequate implementation sequence [17] and the effect of a large-scale strategic management in lean deployment [18]. Several efforts were focused on the measurement of leanness by considering different dimensions [19]. The evolution of lean was also addressed in [20] not only as a concept but also in terms of its application.

The link between lean and the supply chain evolved from the value stream concept [21], and the concept of pull was extended beyond single manufacturing facilities to include the up and downstream partners. Focusing on supply chain management, different methodologies have been applied for logistics optimization purposes. In relation to lean logistics in defense, there is scarce literature available. The concept of pull systems applied to military logistics were questioned by the authors in [22]. A large accumulation of stocks in intermediate distribution points supposes the reduction of effectiveness maneuverability of the deployed combat forces. On the other hand, the "Just-in-Time" approach could bring and associate risk of late or even null deliveries, in view of the possible actions of the enemy. Bean et al. [23] discussed about the inventory management in the uncertain environment of military support. Considering stocks, additional problematic aspects are related to damage, degradation and obsolescence of the material, which mean monetary losses at the end.

2.3. Value Stream practices

The origin of the value stream analysis, i.e. VSM (Value Stream Mapping) and VSD (Value Stream Design) method, is TPS [5,6,24,25]. It is a visual tool that facilitates the continuous improvement of processes efficiency with the identification of value adding activities and the elimination or modification of adding waste tasks. Early publications showed during the 90's the benefits of value stream analysis as an operational approach for a lean enterprise and define specific lean tools for minimizing the seven wastes [26,27]. Despite it is a simple and standardized methodology, it presents limitations and challenges as it was review in [28]. Generally, four steps should be established to improve a process by using VSM and VSD tools. First of all, a particular process for a product or product family should be selected, due to particular factors (e.g. criticality, impact, efficiency, etc.). Then, Value Stream Mapping starts analyzing and drawing the current state map of the process, where activities with added and non-added value are exposed. The different activities, material and information flows are related and schematized in flow diagrams after walking along the actual process. The main key performance indicators (KPIs) of the process such as lead time are usually measured before VSM to establish a reference point of the initial situation. Value added, non-value added activities and inventories are evaluated in terms of their time contribution to the lead time of the process. After VSM, Value Stream Design (VSD) outlines the idealized solution for improving the studied process in order to reduce waste, lead-time, work in process (WIP), and inventories. At this phase, KPIs are measured again and an action list of improvement proposals is attained. To implement progressively the updated procedure, pilot series can be set up to validate the measures applied. Finally, the work plan and final implementation is carried out.

Nevertheless, thorough research revealed the scarce academic publications on evaluation of lean techniques such as VSM/VSD applied to the military field and moreover to their logistics processes. In this work, the case study addresses the use of lean tools such as VSM/VSD in military logistics processes to improve the material order processing lead time as key performance metric of the ABC organization.

3. Methodology

To structure the research, DMAIC (Define-Measure-Analyze-Improve-Control) methodology was followed, whose principles are aligned to *kaizen* or continuous improvement in lean thinking. DMAIC is a structured procedure used in Six Sigma and often described as problem-solving approach [29], to improve manufacturing and business processes by minimizing their variability when focusing on defects and their causes.

In this work, Value Stream Analysis was integrated into Six Sigma DMAIC structure for the project as it is shown in Fig. 2. We define in this way a list of the activities planned in the project which are structured into the five DMAIC phases. In addition, a definition of the lean tools that have been selected for the project is done, focusing mainly on *Gemba Walk* for the process audit and Value Stream Mapping (VSM) - Value Stream Design (VSD) for the supply process analysis and optimization.

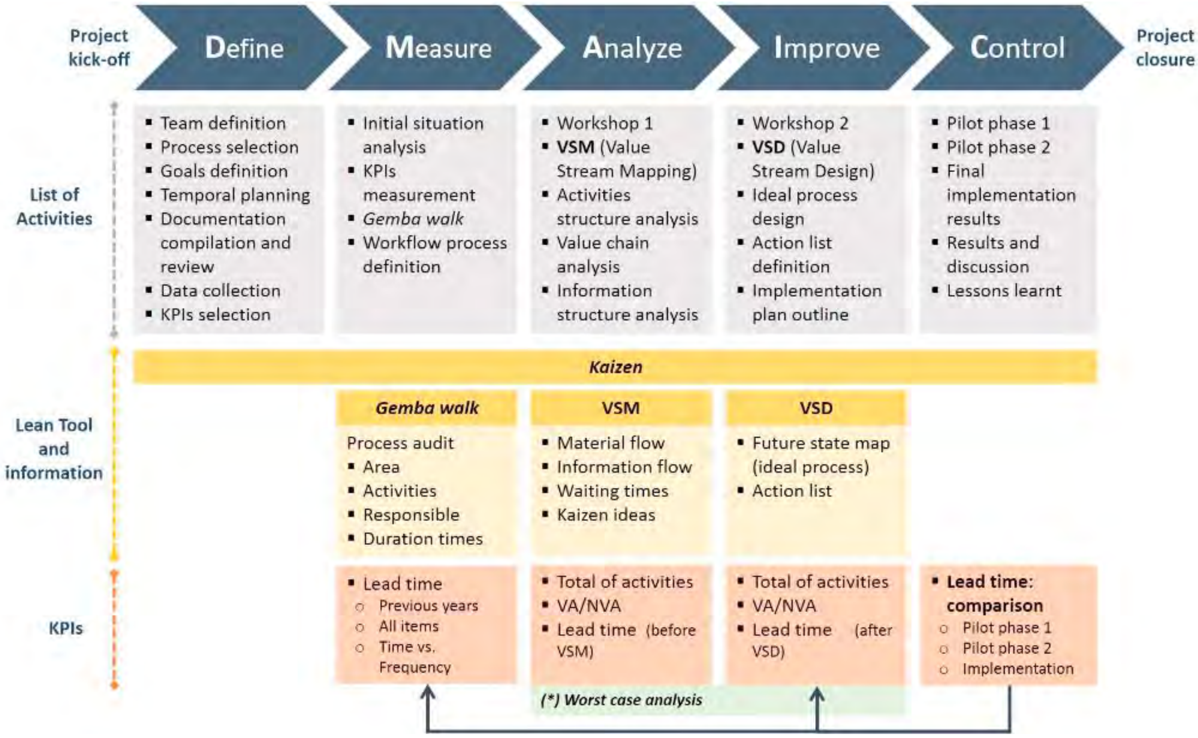

Fig. 2. DMAIC project structure: lean tools and project activities.

4. Case study

ABC is a military unit, in charge of the supply of a wide range of spare parts. Due to the importance of response times for Armed Forces purposes, the selected process to be improved is the order processing of spare parts and new materials that military units deployed in national and international locations demand. That means that we will focus on the procedure between the order generation from a military unit that requests the material and the transportation to the final destination.

In the Define phase of DMAIC and after constitution of the project team, the process under study was selected and data collection was done from the registered information in the main database of ABC. In this case, we considered the orders which are processed daily by the ABC unit. The Key Performance Indicator (KPI) of the process to be optimized is the lead time of the order fulfillment. Thus, it is assumed as lead time of the process the sum of the order's processing time and the sum of the waiting times that could produce delays or intermediate stocks along the process. Due to the different activities that are carried out in the process, the complete lead time is also subdivided into several intermediate times which are measured. Nevertheless, the lead time used in this work is calculated from the date when ABC receives the order until the date the delivery notification is sent to the requesting military unit.

Once defined the process to be analyzed and its KPIs of reference, the goals of the project can be established. The organization ABC has initially proposed to reduce the lead time of the order processing at the end of the project up to 0.5 days. Additionally, the following requirements and targets are settled:

- Non-value added activities in the supply process should be identified.
- The affected areas of the process and the required times of their activities should be evaluated.
- General process improvements should be identified and the effectiveness of the actions proposed should be validated.
- The new procedure should be documented by redefining activities, workflow, responsibilities and layouts.
- The requirements established by the own organization should be guaranteed.

The analysis of the current performance of ABC was carried out in the Measure phase based on the historical data of the years: 2014, 2015 and 2016. The ABC unit handles an average of 15.000 orders per year which could correspond independently to requests from national territory or from operation zone. Based on the origin of the order, a priority is assigned. The initial study calculated the average lead time of the process before the lean optimization to establish a reference value as zero point for the lead time indicator. The values calculated for 2015 are 6.76 days for the average lead time and 6.74 days for the standard deviation of the process in study. Worth to mention the high dispersion of the values measured. Therefore, an additional target for minimizing the high variability of the process was settled. Additionally, the main incidences in terms of time and frequency, material parts affected and their potential causes were identified. In this way, an analysis of critical materials is carried out for the most representative period (January to June 2016).

4.1. Current state map

Gemba is the lean term related to the "go-and-see" principle that refers to "real place", where the work is happening. Hence, *Gemba* walk is the tool to analyze processes with concerned people by observation at the value-add location. This also served as an opportunity to discover *Kaizen* ideas, whereas the different areas, managers, tasks and estimated times are recorded from the last process activity to the first one. In this case study, three departments of the ABC unit were audited: the supply chain control office, the internal material warehouse and the expedition area to the final military unit. *Gemba* walk finished with generation of the workflow diagram of the material order process in the ABC unit. This diagram represents all the activities revised in view of the affected departments and considering the critical path. This critical path is the worst case process in terms of time (longest lead time) and number of tasks (highest number of activities and intermediate waiting times).

Integrated into the Analyze phase and once the workflow diagram was obtained, the activities structure was analyzed. In this case, a total of 48 activities encompass the current material ordering process, being classified 21 as Value Added (VA), 21 as Non-Value Added (NVA), and 6 as Semi-Value Added (SVA). In addition, different types of wastes were identified in the process, representing the over processing of the material order in the different areas a percentage of 54% out of the total *mudas* identified in the process. It was clearly seen that overwork or redundant verifications were handled systematically along the process. Another remarkable wastes in the process were the waiting times between operations or sub-processes (22%) and the reworks (13%) due to failures in the process. Based on this analysis, one of the focus in the VSM/VSD was to eliminate redundancies that affect clearly the final lead time of the process.

Once the classification and time of all the tasks was defined and the complete workflow finished, the process time line was obtained and the key performance indicators of VSM were calculated. This is shown in Fig. 3, where the ABC current state map is simplified to summarize the obtained results of total and added value activities, lead time and *kaizen* ideas associated to each area of the process.

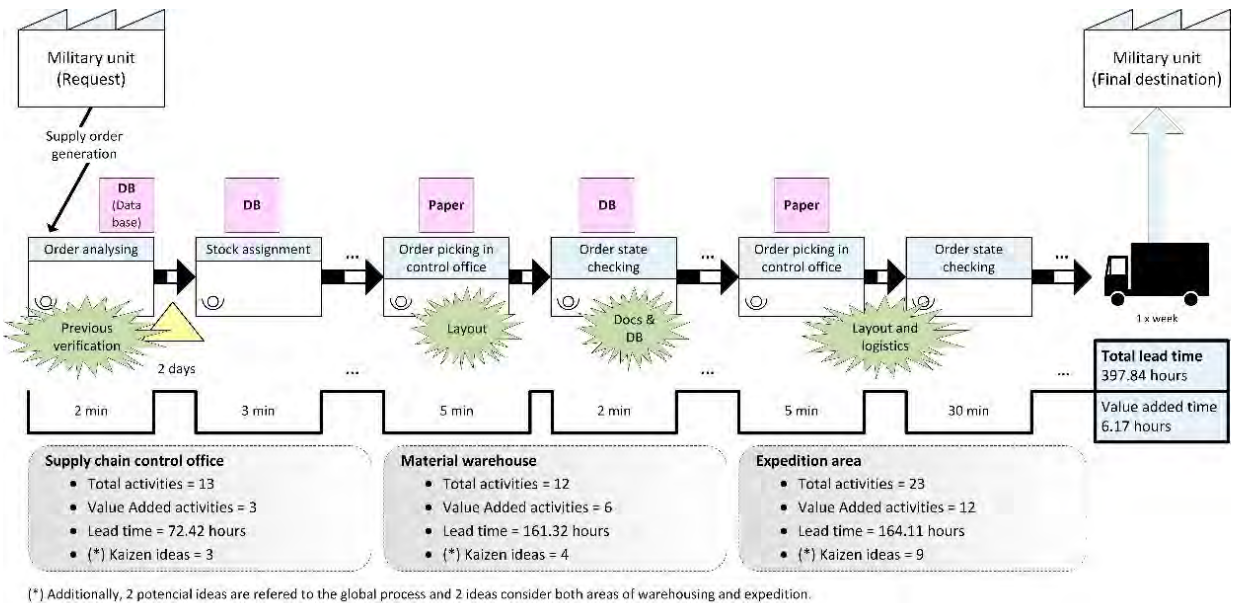

Fig. 3. VSM for material order processing procedure: simplified current state map.

The VSM confirms the excessive material transport and high administrative workload detected in the process because of the established organization procedures. Nevertheless, both aspects might be improved in the ideal case. In summary, 5 waiting times were identified in the material order processing procedure of ABC representing these inventories 13.84 days that the material order could be blocked in a worst case scenario. This could be due to delays in order's endorsement from superiors, pending transport approvals or further calibration or testing to be carried out to the material attached to the order. Over the VSM represented in the swim lane diagram, 20 *kaizen* ideas were tagged. The sequence of the activities presented in the current state map supposes a lead time of the process of 49.73 days. If the relation between added value (VA) and non- and semi-added value (NVA+SVA) is calculated, the obtained percentage is 1.57%. This result indicates the high improvement margin that exists in the process taking into account the small percentage of activities effectively devoted to the processing of the order and material requested.

The information flow and the mechanisms used are also a key issue to be analyzed and optimized with the Value Stream Mapping. Those mechanisms were indicated in the current state map, and the potential ideas to improve the value added in the information tasks were included in the action list. Information flow from customers, military unit that request the material in this case, to the ABC unit, was standardized in the official IT (information technology) logistic information system of the Army. A vast range of optimizations in the information loading process in the IT system were proposed by the ABC personnel. Also hard copies of the IT material order registered in the system were unnecessary printed, used as working paper along the process and finally stored. This could be solved easily working only with the soft order in the IT logistics system, idea which was registered in the action list from VSM. In this line, massive changes in the main SCM information system and a future elimination of additional existing data bases were considered.

4.2. Future state map

The design of the ideal process consists on defining and listing the activities that could improve the material order and information processing flow according to the critical points and potential upgrades identified in the VSM analysis. All these activities are included in the Improve phase of DMAIC. The degree of improvement is measured by the indicators, i.e. lead time of the process. Hence, to meet the requirement of minimizing the lead time, different actions are carried out to increase the value of the process. This is achieved involving people and key partners, optimizing the current activities and eliminating/minimize waiting times and inventories between tasks to create flow [21].

With the new list of process activities, the future state map out of value stream design (VSD) is schematized in Fig. 4, where the improvement obtained is shown in the total lead time of the complete process and in the particular areas, where also the number of their total activities is decreased.

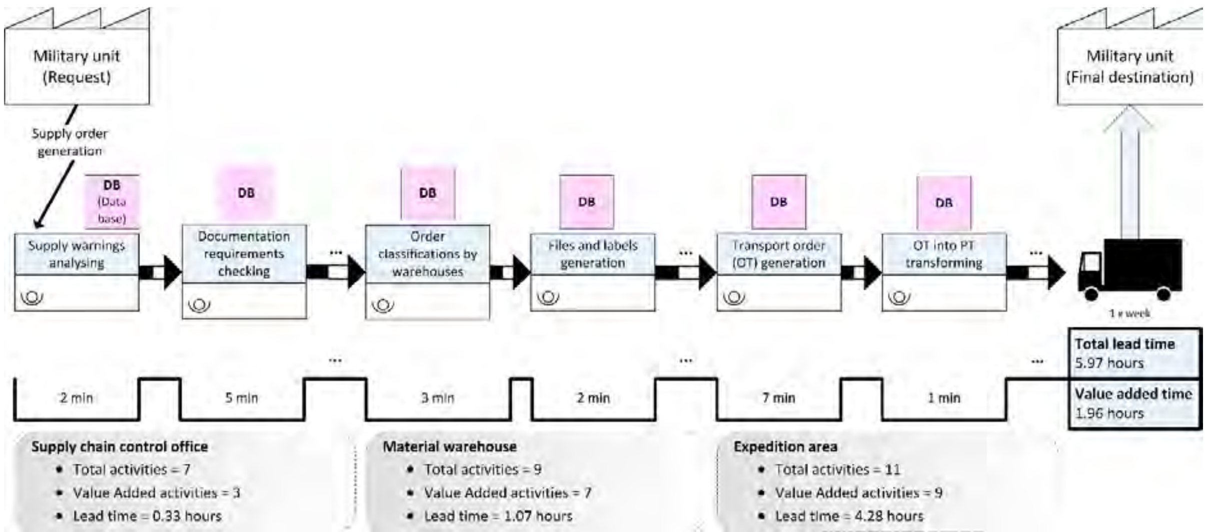

Fig. 4. VSD for order processing procedure: simplified future state map.

The number of activities was reduced up to 56% from 48 to 27, by minimizing NVA activities (from 21 to 5) and SVA activities (from 6 to 3). As a consequence, the value added of the process was increased. Considering the number of activities, VA tasks suppose the 70% of the whole process after VSD. The ratio between added value and non-added value operations is for the ideal situation 48.86%. This shows the optimization in terms of value in the whole process. The lead time of the process is also minimized from 49.73 days to 0.75 days. Therefore, the presented results indicate that the order processing procedure could be noticeably improved theoretically, by implementing the proposed actions. As a result, the ABC unit would be able to complete an order in less than one day in the ideal process situation.

Both flow *kaizen* value-stream improvement focused on material and information flow and process-level *kaizen* consisting of elimination of waste at the shop floor level were targeted. The summarized outcomes of the future state map were the following: (i) optimize material transport routes and procedures between warehouse and expedition area; (ii) eliminate redundant material checking and identification tasks; (iii) establish new standardized procedure for daily routine between the supply chain control office and the warehouse; (iv) personnel capacity balancing among departments based on tasks redesign and new assignment plan; (v) design of new material pick-up routes in the warehouse based on material location and volumes; (vi) generation of change requests package for routine administrative tasks in IT army logistics information system affecting the material order processing procedure; (vii) improve the information system of the process by elimination of material order printed documentation; (viii) elimination of waiting times between departments affected; (ix) monitoring and control of primary indicators of the process systematically; (x) increase visual management in the whole process.

5. Implementation plan

Value stream design concludes with the theoretical results obtained for the new ideal process. Nevertheless, to validate these results, the implementation of this new improved process should be attained. The kaizen improvement ideas have been included in the action list, where responsibilities and affected tasks were defined. Thus, there were 20 actions to be implemented in order to achieve the ideal process defined in the VSD. All of them must be carefully analyzed by the organization and the owner of the process in order to evaluate their impact, resources needed and potential risks to be avoided by means of a contingency plan.

After this study, two pilot phases of implementation have been defined in ABC before the complete deployment of the action plan in the whole process. Pilot phase 1 has been planned for 10 days to analyze around 25% of the total request orders processed with the new process. At the end of pilot phase 1, the method to be used for evaluating the effectiveness of the improved process implementation is hypothesis testing or sometimes referred to as significance testing with Student's t-test. A second pilot phase 2 will be carried out throughout the same time (10 days) increasing the percentage up to 50% of the total request orders processed with the new process.

6. Conclusions

The lean technique Value Stream Analysis (VSM/VSD) together with DMAIC methodology were applied satisfactorily to the material order processing procedure of the ABC military organization. The high number of material references, the absence of demand pattern and the high variation of the spare parts orders were the main challenges faced during the project. The critical activities of the process were identified and the times invested on each task together with the value added in the affected areas were assessed. Therefore, we carried out a complete evaluation of the value added chain of the order processing procedure in the project. This was extremely important to define the key activities to eliminate, improve or redefine with the ultimate target of increasing the value added of the complete supply chain. The development of a lean logistics concept, eliminating the waste and increasing the added value of the spare parts supply process, enables the improvement of the delivery fulfilment of the ABC organization to the requesting military units, qualifying the correct achievement of their missions in national territory or operation zone.

In view of the considered plan outline, next steps of the project will be the implementation of the actions derived from VSM/VSD in two pilot phases in the ABC organization. This will served as a basis for validation of the study presented in the work, which includes in DMAIC control phase the analysis of the indicators obtained as an important input to confirm if the project copes with the initially established requirements. Finally, if the pilot phases' results meet the main goals of the project, the final implementation of VSD action plan will be extended to 100% of the request orders in the process.

The implementation of lean management presented in this work in a military logistics procedure highlights the need of reinforcing these practices in the military context. We could conclude that lean six sigma methodologies could be further extended to other military logistics processes and units with the ultimate target of improving the military unit's delivery fulfilment.

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