Multi-Layer Stream Mapping applied to a productive system

Study on new approaches to integrate the logistics management operations on the MSM

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Abstract

The developed work consisted in the application of the Multi-Layer Stream Mapping methodology to a productive unit specialized in creating plastic injection parts with sanitary applications, OLI-Aveiro. This methodology, framed on the principles of lean production, seeks to assess the efficiency level that characterizes a productive system, mapping and analyzing the binominal "added value" versus "waste". The final results are displayed in scorecards that allow the interpretation of the results in a simple and intuitive way for easier interpretation making it accessible to any worker. In this work the methodology was first applied to a production unit characterized by the presence of injection and assembly processes. The application of the original methodology allowed to recognize some limitations associated with it and also the possibility of testing new approaches capable of overcoming these limitations. It was also developed a set of improvement actions based on the diagnosis performed to the productive system. A new approach that focuses its analysis on non-productive activities (usually classified as waste) and that were not previously included in the approach suggested by the MSM is then suggested in this work. This methodology, designated as MSM 2.0, if used together with the original MSM, should allow a more complete analysis of the production system. This new approach has made it possible to link the management of logistics operations with the MSM methodology and test new formats for the presentation of the final results. The original methodology is expected to become more complete and useful for future industrial application.

Keywords: Multi-Layer Stream Mapping (MSM), Lean Methodologies, Resources Efficiency, Visual Management, Wastes, Logistics Operations;

1. Introduction

Sustainability gained an increased concerning due to the current noticeable resource scarcity and general environmental concerns. Nowadays, companies that intend to remain competitive, must be concerned about the efficiency level that characterizes their system, trying to use the available resources on the most efficient way possible, minimizing the wastes.

The Multi-Layer Stream Mapping (MSM) is a lean tool developed to evaluate the eco efficiency level in industrial environment.

This work has the goal to study new approaches on the MSM methodology that should allow the original MSM to incorporate new features that can be used to connect the logistic management operations.

For such purpose, the MSM methodology was applied to OLI’s productive system which make it possible to identify limitations to the original MSM methodology.

Based on the limitations found and the assumed goal of incorporating the logistics operations it is suggested a new approach, based on the Lean
principles and focused on the identification and elimination of the wastes of the productive system.

2. Background History

The industrial revolution and the invention of the steam engine by James Watt marked an era of economic growth where, for the first time in history, the human work force was replaced by machines.

In the early 20th century, the founder of Ford Motor Company, Henry Ford was able to establish a new production system designated “mass production”. This productive system born in the United States soon spread to other countries, revolutionizing the industry and still widely used in the present [1].

Meanwhile in Japan, the automobile industry was still trying to catch up with the American automobile industry, which was more developed and competitive largely due to the contributions of Henry Ford [2].

Ford’s approach to the mass production had a strong influence on Taiichi Ohno, chief engineer of Toyota Motors Company. Based on the study of the mass production model and techniques practiced by Ford, Ohno and other engineers at Toyota created the Toyota Production System (TPS) [3].

Toyot a model allowed the Japanese automobile industry to produce better, more innovative and cheaper cars than their United States competitors [2].

The TPS was revolutionary at the time since it allowed a great variety on the manufacturing and also fitted on the economics circumstances of that time [4].

3. Lean Manufacturing

The Toyota Production System (TPS) developed in Japan since the late 1940’s, only later attracted attention from the United States as companies studied Japanese successful methods. Those methods and TPS practices were later embraced by the American automotive industry and gradually, as a more holistic approach to enterprise productivity was taken, the movement transitioned into Lean Manufacturing. [5]

The term “lean” concerns the demonstrated ability of the Toyota Motor Corporation to achieve impressive manufacturing performance levels. The designated term was coined later, in the early 1990s, by a group of academics that tried to find a word that captured what they saw – a system without ‘fat’ or waste as is also called. [6]

The Lean Manufacturing was developed in order to maximize resources use through the waste reduction. The common wastes happening in a production system were identified by Ohno as part of the TPS. The seven different identified types of wastes that must be eliminated are:

- Overproduction;
- Waiting;
- Motion;
- Inventory;
- Transport;
- Defects;
- Overprocessing.

An 8th type of waste related with human potential was later identified: Unused Employee Creativity. This type of waste is related with the loss of potential by not integrating the employees in the continuous improvement process resulting in the loss of time, skills, improvements, and learning opportunities [7].

3.1 Lean Thinking

The “Lean Thinking”, a book written in 1996 by James P.Womack et al., that explores the Lean philosophy, suggests to decompose lean principles to five:

- Identify customers and specify value
- Identify and map the value stream
- Create flow by eliminating waste
- Respond to customer pull
- Pursue Perfection

By following this five principles, an organization must be able to maintain or improve its high level of service without compromise its flexibility capability. The organization will be lead to an overall improvement by continuously reviewing...
their processes and making sure that is delivered actual value to the customer. [8]

3.2 Lean Tools and Techniques

Among lean principles, “value” is the most important point which can only be defined by the customers. Along with the Lean thinking, a set of tools and techniques that helps the organization identifying and eliminating the waste (actions that adds no value to the productive system) was created and developed over time [9][10].

3.2.1 5S’s

The 5S’s methodology is based on workplace organization. It tries to reduce wastes and improve people and procedures performance by using organizational techniques that involve and improvement of the visual control in the workplace while aiming to good safety practices [11]. The 5S’s name origin is related with five Japanese words that govern workplace organization and housekeeping: Seiri (Sorting), Seiton (Systematic Arrangement), Seiso (Spick and Span), Seiketsu (Standardization), Shitsuke (Self-Discipline).

The 5S’s is a simple yet powerful tool to eliminate distractions in the workplace by positively affecting visibility of processes, safety and worker performance. The number of defects associated with cleanliness should reduce and the throughput increase since the workers should require less time to find the tools [12].

3.2.3 Kaizen Events

A kaizen event is a focused, short term action intended to be an improvement to an already existing process. This type of event consists on periodic small events that should be brief in time duration and where managers and workers of a specific process should gather and work together to find ways of improving processes.

3.2.5 VSM

The VSM is a highly visual tool that allows the visualization and understanding of both material and information flow along the value stream associated with a specific product or service. The tool includes in its analysis the productive processes that the material goes by (in case of material analysis) and allows the identification of wastes present on the flow. The VSM output allows accounting of productive and non-productive time consumed by a product or service. Based on the results achieved, it can be planned future improvements, based on some other lean tools and techniques, to eliminate the previously detected wastes.

4. The MSM

The Multi-Layer Stream Mapping (MSM) is a lean tool developed in the framework of studying new methodologies used to evaluate the eco efficiency level in industrial environment [15]. The idea consists on following the classical VSM approach, by doing the value stream mapping, but instead of only focusing on the variable time, as the VSM methodology suggests, more variables should be taken in consideration to properly evaluate the efficiency. As a result from the application of the MSM, like the traditional VSM, it is possible to identify which processes within the flow are less efficient, thus contributing for decision making support.

The methodology is visually similar to a matrix “n x m”, where the “n” variable is associated with the different KPI’s used to evaluate the system and
the variable “m” stands for the number of processes that characterize the product or service being analyzed.

As can be perceived in the previous figure, each process (Pi) is divided by a line where the upper segment stands for the portion of the variable that adds value (ex.: PT: Process Time) to the product or process and on the other hand, the down segment is used to specify the portion of the variable that adds no value (ex.: WT: Waste Time) and for that reason can be classified as waste. Above the percentage box, the total amount used on each process of a specific resource is presented.

The application of the MSM consists on the following steps:

- **a)** Identification of the system boundaries;
- **b)** Identification of the processing unit(s);
- **c)** Identification of all relevant process variables and parameters;
- **d)** Definition of the associated KPI to each variable, always to be maximized and with values comprehended between [0-100%];
- **e)** Analysis of the results and identification of the process parameters and processing units with lower efficiency results;
- **f)** Study and prioritization the improvement actions;
- **g)** Implementation of improvement actions and assessment of the efficiency gains evolution and cost reductions.

The MSM methodology is characterized by constantly distinguish what “add value” and “do not add value” in each step associated with the flow of the product or service analyzed. The ratio (\(\phi\)) form used to achieve the efficiency level (%) is:

$$\phi = \frac{Value\ Add}{Value\ Add + Non\ Value\ Add}$$  \hspace{1cm} (1)

Based on the ratio results, the MSM displays the final results in a color scheme according to the figure:

**Figure 1 - Example of the Multi-Layer Stream Mapping approach**

**Figure 2 - Colors labels range for the MSM**

### 4.2 Key Performance Indicator’s

Key Performance Indicators (KPI’s) are important to monitor the performance in the industry and can at the same time be used to identify poor performance and the improvement potential existing in the current system. KPI’s can be defined for different targets such as individual equipment, sub processes and whole plants allowing the measurement of different types of performances including energy, raw-material, control & operation and maintenance.

The KPI’s can be classified according to the type of variable they are measuring. That classification includes:

- **Operation KPI’s**: indicators that translate the efficiency level related with equipment and systems;
- **Resources KPI’s**: used to measure the efficiency of the raw materials, energy consuming and all other resources that are consumed in the process;
• Flow KPI’s: represents the efficiency related with variables such as delivery dates, stocks and controls.

5. Methodology

This study aims to apply the MSM to OLI production unit. The case study allowed to identify some limitations of the original MSM approach which motivated the suggestion of a new one. The new suggested approach must be focused on waste activities, which were not previously present on the efficiency assessment. Combining the original approach focused on value with the new suggested, it will be possible to have a more complete analysis on the system performance. The focus on waste also allowed to integrate flow variables and logistic operations to the original MSM.

The assessment on the efficiency level included both resources and operational KPI’s. In order to assess the current performance of the system it was used the Overall Equipment Effectiveness (OEE), which is often used in the industry as a KPI. The OEE takes into account the parameters: availability, performance and quality. The final score is obtained by the product of those three different parameters [16].

![Figure 4 - Selected KPI’s for the classical MSM approach](image)

The results obtained by applying the MSM methodology alone are not sufficient to point limitations to the original MSM model. However, by an extensive monitoring of the entire product flow and involved teams, it was possible to find out that the apparent poor performance of a particular process, may not be the responsibility of the workers or machines involved in that specific process but rather the result of previous failures that were not taken into account in this MSM model. These detected failures are mainly related to the logistics of the operation, which plays a key role in the timely and correct connection between the various production stages, and for that reason can significantly impact all the productive processes.

6. MSM application

The MSM original approach was applied in OLI’s productive system, where the initially analyzed processes included:

- Injection
- Assembly
- Film Packing
- Shipping

These activities were ignored in the original MSM model since they do not directly add value to the final product and for that reason can be classified...
as waste. However, this non-productive activities are characteristic of the current product flow and represent a quite significant investment on the total resources available to the company.

The methodology steps suggested to apply is based on the original MSM, varying only the target of analysis that are now the waste activities, which are located in between the productive activities.

![Product Flow](Image)

*Figure 5 - MSM2.0 focus on “in between” activities*

Based on the type of activities assessed with the MSM2.0, two different analysis types are also suggested:

- **Flow**: analysis related with the properties of the material that is in circulation;
- **Support Structures**: analysis on the different structures that are used as a support to the productive activities;

Depending on the type of analysis performed, there are different KPI’s associated to each one of them.

### 7.1 KPI’s

The suggested KPI calculation method for the MSM 2.0, is then focused on reducing the wastes associated with the product flow. The ratio calculation form for the KPI’s proposed is:

- For KPI’s that should be minimized:
  \[
  \phi = \frac{\text{Target Value}}{\text{Current Value}}
  \]  
  \[ (2) \]

- For KPI’s that should be maximized:
  \[
  \phi = \frac{\text{Current Value}}{\text{Target Value}}
  \]  
  \[ (3) \]

Where:

- \( \phi \) - Efficiency level associated with the analyzed variable;
- **Target Value** – Value defined by the company;
- **Current Value** – Value measured;

The target value must be defined by the company according to their goals and the activity type that is being assessed.

### 7.2 Potentialities

The focus on the waste, promoted by the suggested MSM 2.0 approach, increases the potential of applicability of the MSM tool to the industry allowing a more complete analysis on the productive flow and relations between the different productive activities.

MSM2.0, can also be used as a 5S’s auditing tool in a future scenario where the MSM methodology had been fully implemented. The integration of support structures on the analysis and since the MSM methodology is intrinsically related to the lean concepts and tools, the proposed method, by including an assessment of the structure’s condition, ends up promoting a good organization of the work environment.

![MSM 2.0 features](Image)

*Figure 6 - MSM2.0 potentialities*

### 8. MSM2.0 application

To test the previously suggested approach, the same was applied to OLI’s productive system which included setups, storages and internal transport systems. These activities were managed by a logistic team within a company which is responsible for maintaining the right flow of material within the productive unit.
The selection of KPI’s to use to assess the performance of the “waste” activities and support structures were created so that the results could be used by the logistic management team to improve the current flow. The selected KPI’s were:

![Figure 7 - Selected KPI's for the MSM2.0 approach](image)

The results promoted by the use of the MSM2.0 approach made possible to test new options for the display of results achieved. The integration of those results on the lay-out of the unit is an example of that.

![Figure 8 - Layout Scorecard](image)

Other option for the display of the results includes scorecards on the shop floor level, right next to the workers. This way they can assess on real time their current performance.

![Figure 9 - Shopfloor Scorecard](image)

It was also tested a scorecard where the “wastes” should be minimized and for that, the color scheme used in the assessment must be the inverse of the one suggested by the original MSM.

![Figure 10 - Color scale suggested for the waste assessment](image)

According to this option, now the 0% is the perfect scenario, meaning no wastes exist in the productive system. In order to make possible this option, the calculation form for the ratio must be updated to:

- For KPI’s that should be minimized:
  \[ \phi = \frac{Current\ Value - Target\ Value}{Current\ Value} \]  
  \[ (5) \]

- For KPI’s that should be maximized:
  \[ \phi = \frac{Target\ Value - Current\ Value}{Target\ Value} \]  
  \[ (4) \]

The application of the suggested approach to OLI, allowed the detection of some problems regarding the material flow and the support structures used by the logistic team. Situations where the circulation material quantity was inconsistent with the information on the Kanban card, support structures with reduced occupation rate and not properly identified were also possible to identify.
Problems regarding the material supply time on the assembly line were also identified according to the suggested approach.

9. Conclusions

The original MSM methodology was applied to OLI’s productive flow, allowing to assess both the performance of the productive processes and the efficiency level of the resources consumption used on them.

The assessment done with the MSM methodology allowed to identify some limitations to the original methodology taking into account the productive scenario that characterized OLI and other companies with similar characteristics. Improvement actions were also suggested as result of the MSM application.

By comprehending the real dimension and importance of the logistic management in the productive process, it was suggested a new approach for the MSM that should now be focused in activities related with the logistics but were previously ignored by the original MSM methodology since they do not represent value adding to the final product.

The new approach suggested, the MSM 2.0 focused on waste, includes variables that allow both the assessment on the material flow within the facilities and the conditions regarding the support structures used in these activities. A noticeable aspect of the MSM 2.0 is that it integrates the identification of both material and support structures in the assessment, working as a promoter of an organized and identified work environment.

The new approach focused on waste also made possible to develop new MSM operationalization models which now includes new display options to present the achieved results. One of those options includes the integration of the MSM scorecards in the layout of the facility and on the shop floor level, where it should be easily accessible to the operators. These new options should be used to approximate a future implementation of the MSM tool to all the different workers and not only to management teams, promoting the involvement and integration of all the workers and different departments in the searching for a better performance around the productive system.

By joining the original approach, focused on the productive activities, to the new suggested approach, focused on the non-productive tasks that takes place in between the productive ones, it is possible to have a more complete and extensive assessment on the entire production flow. This feature is expected to make the MSM methodology even more appealing and used within productive systems.

10. References


