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Strategic Lean Management: Integration of operational Performance Indicators for strategic Lean management

Hector Cortes*, Joanna Daaboul*, Julien Le Duigou*, Benoît Eynard*

**Sorbonne Universités, Université de Technologie de Compiègne*
Department of Mechanical Systems Engineering, Roberval Laboratory - UMR CNRS 7337
France
{hector.cortes; joanna.daaboul; julien.le-duigou; benoit.eynard}@utc.fr

Abstract: Lean manufacturing has been widely used to increase operational excellence and performance in manufacturing systems. Nevertheless, this approach presents several limits, such as the lack of alignment between lean objectives and strategic management of a company, and the lack of justified measurements for futures Lean implementations. Nowadays, it remains difficult to evaluate the leanness of a manufacturing system due to the lack of relevant indicators and methods to evaluate them. This paper presents framework to overcome these limits: the Lean & Six-Sigma Framework (LSSF). It allows a company to evaluate, justify and enable future lean implementation in line with strategic missions and objectives of the company. This framework is based on real time information exchange with several information systems such as the Manufacturing Execution System and the Enterprise Resources Planning.

Keywords: Manufacturing System, Lean Management, Key Performance Indicators, Manufacturing Execution System, Information System.

1. Introduction

Nowadays, the enterprise environment is highly changing and uncertain due to many factors of which globalisation, shorter product lifecycle, increased product variety, etc. ; therefore the manufacturing systems have to be agile or flexible to face such changing environment while keeping high performance (Tyagi et al., 2015). For that end, the lean manufacturing approach was adapted by many enterprises to "do more with less" (Womack and Jones, 1996) meaning better utilise the system's resources. It has become a necessity to create added value with an optimal resources utilisation (Cheng and Weng, 2009). Nowadays, it is implemented by several companies if all sectors, and has been proven to be an effective approach in seeking operational excellence (Slomp et al. 2009).

The word "Lean" first appeared in the 90s in order to share the Toyota Work Philosophy. The lean philosophy is based on two main principles: waste elimination and value creation (Murman et al., 2002). A waste is defined as an event that does not generate any added value, and for which the client is not ready to pay (Womack and Jones, 2009). There exist three types of wastes: Muda (task with no added value), Muri (surcharges), and Mura (irregularities) (Womack and Jones, 2009). Ohno (1998) has proposed seven different types of Mudas (overproduction, wait, transport, stock, unnecessary activity, defects, motion). An eighth Muda, unexploited creativity, was added by Liker (2004). The overproduction is considered as the most problematic waste by Ohno (1998). It generates all other types of wastes especially stocks that limit the continuous improvement aimed by the lean philosophy (Liker, 2004).

Many tools and methods were created to reduce/eliminate wastes, and implement the lean philosophy within a manufacturing system (Monden, 1998). Lean decision making is made in a deterministic and static value chain observation using VSM (Value Stream Mapping). The proposed improvements are neither always as expected before implementation, nor are they aligned with strategic enterprise goals. This failure is aggravated by: (1) nonsufficient number of observations (data collection); (2) non reliable data, sometimes lean experts collect production data by hand methods which generate variability sources; (3) a lack of continuous real time data collection; and (4) performance targets are not enough aligned in each manufacturing decision level. This paper proposes an improvement of the traditional lean approach in order to overcome these four limits. The proposed approach, Lean Six-Sigma framework (LSSF) is plugged in information systems to collect real time statistically sufficient and reliable data. The LSSF is based on an alignment between operational performance and strategic development axis of a company. Finally, the LSSF proposes a decision making support by comparing proposed improvements via simulating the manufacturing system. Both statistic-reliable-real-timed-structured data and simulation based analysis enhance traditional lean weakness. In terms of management, this framework offers a management support in lean implementation to lead tactical and operational decisions in order to improve and maintain manufacturing performance.

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In this paper, a literature review is presented to highlight the current limits of the lean implementation. Then the proposed framework is detailed with a focus on the operational/strategic alignment. Finally a conclusion with future works is presented.

2. Literature Review

More than 60% of the enterprises that implemented a lean approach in their manufacturing systems reported a reduction in lead time and costs, and an increase in their market share (Struebing, 1997). And yet, many enterprises and in different industries, are still reluctant to lean implementation due to the absence of tools/methods to quantify the estimated gain of such an implementation and to the resistance to change by operators (Prajogo and MCDermott, 2005). The success of other enterprises in lean implementation is not always sufficient to convince decision makers and managers to invest resources (time and money) hoping for a similar success. In addition, it is difficult and highly complex to manage and control a lean project without an accurate measurement of its performance (Behrouzi and Wong, 2011). Till today, and up to our knowledge, there is no existing tool allowing neither the measurement of all lean indicators nor the accurate estimation of expected gain from a lean implementation.

The different research works on lean indicators and their use to justify the implementation of a lean approach can be classified into 3 main categories: 1) Lean indicators definition (Diego and Rivera, 2007). 2) Leanness Measurement, which is the level of lean implementation and its associated performances (Elnadi and Shehab, 2014; Bayou and Korvin, 2008; Wan and Chen, 2008). 3) Decision aid systems and validation of future implementations (Al-Aomar, 2011; Marvel and Standridge, 2009; Abdulmalek and Rajgopal, 2007). Each of these categories will be discussed hereafter.

2.1 Lean Indicators Definition

The definition of lean indicators or any other indicator is to be realised in adequacy with a predefined objective. In the case of improving manufacturing systems performance, this objective should be in line with the company's strategic objectives and in adequacy with the competitive environment and the market nature and characteristics (Ahmad and Dhafr, 2002). For example, an enterprise offering products with short time to market, should concentrate its improvement strategy on reducing delays. The identified KPIs for the evaluation and implementation of lean approach should reflect the enterprise strategic objectives and facilitate the alignment between strategic, tactic and operational performances (Ahmad and Dhafr, 2002).

Strategic KPIs could be classified for any type of industry into five categories: Cost, Quality, Flexibility, Stock and lead time (Corbett, 1998).

Focusing only on indicators will not lead in most cases to significant performance improvement. An indicator analysed alone, is not sufficient to evaluate a system's performance. Decisions only based on numbers, percentages and ratios can lead to reduced performance at the long term. Often, enterprises use some indicators to measure and evaluate performance. These incomplete set of indicators could lead to inadequate actions for performance improvement. Hopp and Spearman (2000) propose to use three lean indicators for the evaluation of a production system's performance. These are: Cadence, cycle time, and Work-In-Process (WIP). These three indicators are not sufficient to evaluate a production system which can be evaluated with much more indicators that correlated. Nevertheless, it is very hard and even almost impossible to evaluate all these indicators using stochastic methods (Al-Aomar, 2011). This is why lean indicators are measured or estimated with approximate methods, which leads to unexpected results, waste of energy and highly costing change (Al-Aomar, 2011).

There are two sets of indicators used in a lean approach: indicators used to evaluate a system's performance and indicators used to evaluate the level of leanness of a manufacturing system. These are presented in the following section.

2.2 Leanness Measurement

The literature includes many works on methods and models for leanness evaluation. Leanness is defined as the degree of adoption and implementation of the lean philosophy in an organisation. The proposed methods and models for leanness evaluation can be classified into three types: 1) Interviews /surveys, 2) benchmarking, and 3) fuzzy models.

The approaches based on surveys are based on qualitative techniques (Fullerton et al., 2014; Bashin, 2012). The main limit of this approach is the subjectivity of the collected answers. Thus the resulting analysis depends on the interviewed individuals. Moreover the planed and prepared surveys are not adapted to all manufacturing systems (Wan and Chen, 2005).

Benchmarking is used for leanness measurement by several researchers (Wan and Chen, 2008). Its main limits are the difficulty to define an appropriate manufacturing system as a model and to access all needed information which is often confidential. This makes this approach of little use and benefit except for the self-benchmarking (Behrouzi and Wong, 2011).

The fuzzy approach is a mathematical theory for modeling qualitative and quantitative data using fuzzy numbers (Klir and Yuan, 1995). Behrouzi and Wong (2011) describe the implementation of fuzzy models in manufacturing systems. It was also used by Ko (2010) to eliminate risks in production monitoring, and inaccuracies in quantities produces. Fuzzy models allow measuring separately the performance of each lean indicator, which permits enterprises to efficiently analyze different production strategies and potential improvements (Behrouzi and Wong, 2011). Nevertheless, lean indicators have direct or indirect impact on many production parameters, and are not independent from each other. Thus this method doesn't allow the analysis of the impact of improving one indicator on the other indicators and thus the entire system. This is a main limit of this method, which lead us to conclude that taking into consideration the three approaches, there is still a need for a method allowing the leanness measurement taking into consideration the interdependencies between indicators, and aiding managers with decision making regarding lean implementation.

2.3 Decision Aid Systems for Lean Implementation

The traditional lean implementation does not guarantee that the applied improvements/modifications on the production system will allow it reaching a certain performance objective due to many limits of this method (Marvel and Standridge, 2009). The traditional lean cannot satisfy the following:

- Taking into consideration irregularities and variabilities (for both demand and resources), as well as structured production failures (different product families with different production planning) (Maas and Standridge, 2005).
- Global data analysis in order to understand the manufacturing system nature.
- Evaluation of interactions between production system's components.
- Accurate validation of proposed future system performance before implementation.
- Identification of different possible future scenarios and thus alternatives.

One way of overcoming these weaknesses is the use of simulation. Adams et al. (1999) argued that the simulation used in a traditional lean approach will aid in: 1) Identifying problems in operational systems and in production. 2) Training collaborators on the improved working methods. 3) Classifying different improvement/modification alternatives. 4) Documenting the production process. 5) Forecasting the impact of different proposed improvements on the future systems performance.

The lean approach needs additional tools such as simulation. Several works proposed the combination of two approaches such as Abdulmalek and Rajopal (2007), and Al-Aomar (2011). VSM modelling allows distinction of value-adding (non-waste) and non-value-adding (waste) processes. it is a powerful yet simple tool to analyse the current manufacturing system situation towards lean aspects. Therefore VSM and lean manufacturing are a good combination for long lasting improvements (Rother et Shook, 2009). Dinis-Carvalho et al. (2014) present a modified VSM diagram in order to represent Waiting and Motion wastes. But VSM does not allow accurately estimating the manufacturing performance improvement due to lean implementation, which can be overcame by combining it with simulation.

2.4 Discussion

Even though there exist many works on the lean implementation in different production systems and for different services, the leanness evaluation is not sufficiently developed in a holistic approach and with a standardised method (Bayou and Korvin, 2008). Even if most enterprises successfully implemented different lean concepts, 90% of them state their incapability in measuring the resulting performance improvement (Bhasin, 2011). This problem is due to two main reasons: 1) the lean objectives are estimated and not accurately defined; 2) there is no unification of all measure in a holistic approach (Elnadi and Shehab, 2014). The leanness integration with the set of KPIs is the main success factor for lean implementation (Goldan et al., 1998). As a conclusion on the literature review, the lean approach has the following limits: 1) In lean indicators definition: the lack of a model for operational/strategic alignment. 2) In leanness measurement: lack of a holistic approach and of a standardised unified measurement method. 3) In Decision Aid Systems for Lean Implementation: lack of a simulation method integrating different indicators.

This paper proposes an approach to overcome these limits: the LSSF which includes built-in VSM simulations with automatic data gathering to support lean implementation. Why a combined Lean-Six-Sigma? The implementation of lean manufacturing allows definition of current wastes and problems to be solved, then Six Sigma method analyses the data using statistical methods and technology (i.e. information systems), and allows accurately identifying the wastes root causes. The two approaches can be easily organically integrated, and present complementarily advantages.

In order to use a six-sigma approach, a collection of sufficient and accurate data is required. This will be realised via the integration with different production supporting information systems such as ERP and MES. Goddard (2003) has proposed the use of ERP in lean implementation. An ERP permits production planning, scheduling, and stock management on a time scale of one day. An MES allows collecting and analyzing data in order to evaluate the different tasks and their associated flows planned by the ERP (Mcclellan, 2001). The MES measures how manufacturing is occurring (As-planned) and it allows the identification of performance gaps in each one of the manufacturing activities (As-is). This can highly aid in a lean implementation. The last MES generations are highly flexible which allows them to accommodate to the lean approach.

The real time data on the production system's performance provided by the MES allows to better implement a lean approach and to control the related improvements.

Some MES suppliers already integrate some lean tools in their offer. But there doesn't exist an integrated lean plugin in an MES permitting the improvement of the operational processes' performance (Cottyn et al., 2011).

In the following section, the proposed framework based on integration with six-sigma and MES / ERP will be described.

3. Proposed Framework: Lean Six-Sigma Framework

The proposed framework (Figure 1) aims at offering a complete set of tools/methods for lean implementation overcoming the traditional lean limits described in section 2.

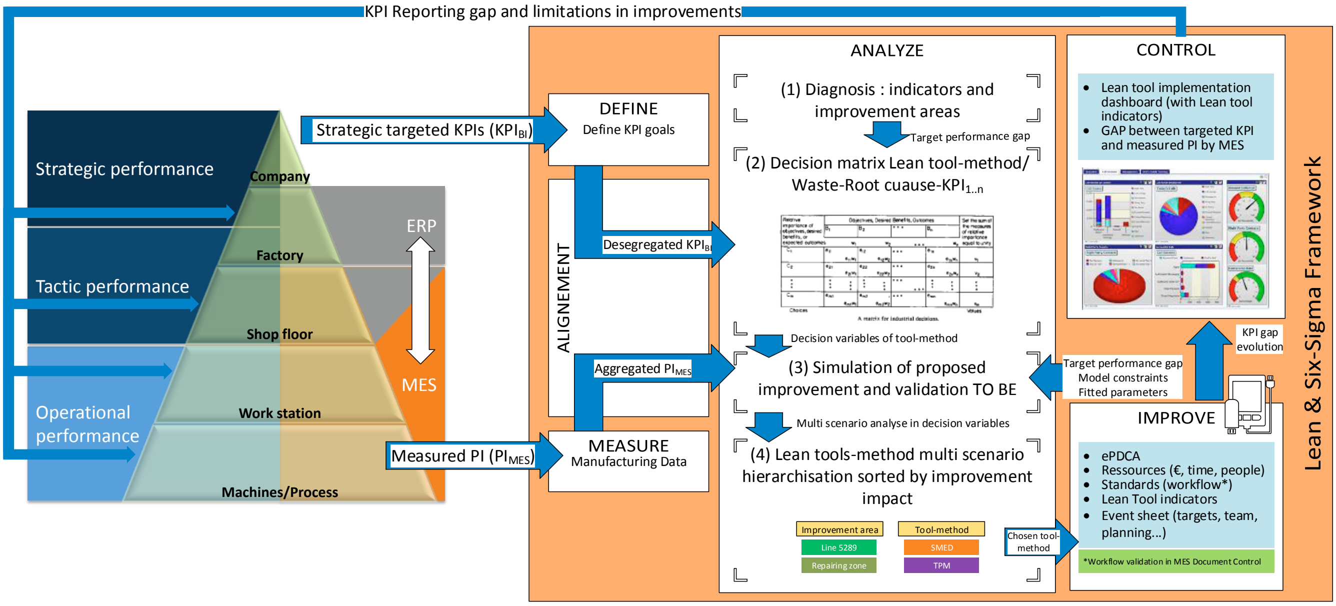

Fig. 1. Lean-Six-Sigma Framework (LSSF)

It is based on: 1) an alignment between operational indicators and strategic objectives of a company; 2) a collection of sufficient data for statistical analysis for performance evaluation via the integration with MES/ERP; 3)a simulation approach for evaluation of future system performance due to different proposed improvements; 4) ranking of proposed improvements; and 5) continuous and automatic monitoring of improvements and system's performance.

The proposed framework is formed of the 5 main DMAIC steps, and a 6th step being the operational/strategic alignment. Each step is based on several tools/methods/models. This paper focuses only on the first three steps which are: 1) define KPIs, 2) align operational indicators with strategic objectives, and 3) measure indicators. The remaining steps will be briefly described.

3.1 KPIs Definition

The KPIs definition starts with determining the company's strategic objectives, and identifying the company's different impacted levels. These are company, factory, shop floor, work station and machines. The KPIs should be classified according to the main fundamental lean aspects which are presented in Figure 3.

There exists different works developing evaluation and qualification models for defining and measuring PIs for the evaluation of lean implementation. Pakdil and Leonard (2014) model integrates qualitative and quantitative estimations and covers the entire production system wastes. This paper uses the model of Gopinath and Freiheit (2012) as a basis for KPIs definition. It is important to take into consideration the evolution of KPIs due to market/environment change. This is why the KPIs definition is to be continuously reviewed to ensure the adequacy with identified KPIs with the company's current environment/market.

3.2 Operational/strategic alignment

The aim of this step is to ensure that the improvements proposed at step three will have an impact not only on operational performance but also on the strategic improvement objectives of the company. The proposed alignment method consists of seven steps:

Step 1: Definition of the Vision & Mission of the factory by the management. These are the factory long term goals defined based on the company's strategic missions reflecting its image and market positioning. They are the strategic manufacturing goals.

Step 2: Definition of the Requirements by the management. Requirements represent the goals of the company in a functional manner for every mission and vision. They are defined by reformulating the missions/ manufacturing goals into strategic functional requirements (FR) which are associated with a measurable performance indicator.

Step 3: Definition of the KPI mapping. Each KPI associated with a functional requirement will be divided (mapped) into PIs. For each KPI, a target value will be identified. The PI mapping enables monitoring the KPI values.

Step 4: Definition of how, when and where Products, Processes & Resources (PPR) data are provided by sensors, information systems, simulation, surveys, etc. The data will be collected from different sources such as MES, ERP, Company standards, surveys etc. (Figure 2). The main objective is to collect real-time data from the production system.

Step 5: Choice of the KPIs which will be improved by Lean Manufacturing implementation. Not all the identified KPIs will be chosen for the analysis and lean implementation depending on many factors (management decision, priority, out of manufacturing perimeter…).

Step 6: Alignment between KPI & Lean Wastes. This step allows keeping two different views and analysis for the performance evaluation. Depending on the user of the framework, performance may be evaluated by strategic mission, or by type of waste.

Step 7: Definition of PI calculation. In this step, the PI formulas are identified or developed if needed. Dependencies and interconnections between different indicators are considered.

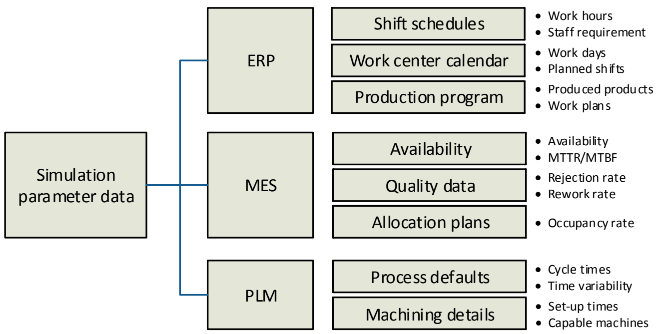

Fig 2 : Data sources, adapted from Stoldt et al. (2013)

Lean Waste	Definition	Metric	Formula definition	Parameters
Defects (Scrap)	Any product that is unacceptable to the customer. Handling and transformation defects are considered [Gopinath and Freiheit, 2012]	$\sum_{all\,process} \frac{S_i}{P}$	Scrap from the ith process	S_i Scrap from the ith process P Total units produced
Defects (Rework)		$\sum_{all\,process} \frac{R_i}{P}$	Rework from the ith process	R_i Rework from the ith process P Total units produced
Overproduction	Production ahead of demand, which is captured by the finished inventory [Gopinath and Freiheit, 2012]	$\frac{1}{T}\int_0^T FI\,dt$	Time-persistent measure of finished inventory	T Total horizon time FI Finished inventory
Motion	Operator's movement between workstations [Gopinath and Freiheit, 2012]	$\frac{T_m}{T}$	Percentage of time spent in motion	T Total horizon time T_m Time spent in motion
Transportation	Transporter's movement between inventories [Gopinath and Freiheit, 2012]	$\frac{F\,T_t}{T}$	Percentage of time spent in transportation	T Total horizon time F Transportation frequency T_t Transportation time
Waiting (customer)	Any resource staying idle during work hours [Gopinath and Freiheit, 2012]. It will also include employees or machines overload, in order to display Muri (Overburden) waste	$\frac{T_w}{T}$	Percentage of time spent waiting	T Total horizon time T_w Idle or waiting time
Waiting (material WIP)	Any resource staying idle during work hours [Gopinath and Freiheit, 2012]. It will also include employees or machines overload, in order to display Muri (Overburden) waste	$\sum_{all\,WIP} \frac{1}{N}\sum_{i=1}^{N} WQ_i$	The time spent waiting	N parts in the queue WQi ith part waiting time in the queue
Waiting (machine)	Any resource staying idle during work hours [Gopinath and Freiheit, 2012]. It will also include employees or machines overload, in order to display Muri (Overburden) waste	$1-\frac{\sum_{all\,process} T_{Ri}}{nT}$	Percentage of time spent waiting	T Total horizon time T_{Ri} ith Process operation time n Number of machines, buffers or workers
Waiting (operator)	Any resource staying idle during work hours [Gopinath and Freiheit, 2012]. It will also include employees or machines overload, in order to display Muri (Overburden) waste	$1-\left(\frac{T_w+T_m}{T}\right)$	Percentage operator saturation	T Total horizon time T_w Idle or waiting time T_m Time spent in motion
Inventory (Warehouse)	Raw materials not being processed [Gopinath and Freiheit, 2012]	$\int_0^T WH\,dt$	Time-persistent measure of raw material inventory	T Total horizon time WH Warehouse inventory
Inventory (WIP)	Work-in-process not being processed [Gopinath and Freiheit, 2012]	$\sum_{all\,WIP} \frac{1}{T}\int_0^T WIP_i\,dt$	Time-persistent measure of WIP inventory	T Total horizon time
Processing (capabiliy)	Processing more than the minimum required for material transformation [Gopinath and Freiheit, 2012]		Process capability (C_P, C_{PK})	
Processing (performance)	The OEE metric that originally described by Nakajima (1988), can measure level of equipment effectiveness, and also identify loss elements which are classified into six major groups. These six big losses are breakdown, setup and adjustment losses (downtimes), minor stoppage, reduced speed losses, defect/rework (downtime) and yield losses. (Muchiri, P., Pintelon, L., 2008).		OEE (Overall Equipment Effectiveness) (TRS)	
Unevenness (Mura)	It refers to waste of unevenness in production volume [Pienkowski M., 2014]		Stability in production scheduling volume	
Unevenness (Mura)	It refers to waste of unevenness in production volume [Pienkowski M., 2014]		Takt time / Cycle time	
Non-utilized talent	Denvir and McMahon (1992) defined staff turnover as "the movement of people into and out of employment within an organisation"		Labor turnover rate	
Non-utilized talent			Absenteeism rate	

Fig 3: List of KPIS, adapted from Pakdil and Leonard (2014); and Gopinath and Freiheit (2012)

3.3 PIs/KPIs measurement

This step consists of using the formulas predefined in step 2, and the data automatically collected in real time, in order to automatically calculate the current PIs and KPIs values. These are then compared to target values. A historical gap is displayed for every PI and KPI.

3.4 Analyse

The aim of this research work is to automatize the analysis step. It is formed of 4 sub-tasks. The first is the diagnosis of indicators, which will results in defining which areas in the production system to improve and which related performance indicators to consider. Following, a decision matrix based on a mapping between PIs, Lean tools/methods and root-cause will allow defining which tools/methods are to be used to improve the performance of identified areas and indicators. Based on that, a simulation of the production system will validate the improvement propositions and estimate possible gains. Finally the proposed tools/methods/improvements will be prioritised by using a multi-objectives decision method, the AHP (Analytical Hierarchy Method).

3.5 Improve and Control

The Improve step consists of actually implementing the proposed tools/methods, and improvements to the manufacturing system. A web application will permit to operators to access to all necessary standards, and project management tools. The control step consists of monitoring the lean project progress with a customized dashboard.

4. CONCLUSIONS

This paper proposes an improvement to the traditional lean implementation tools based on a six-sigma and simulation approaches. The proposed Lean Six-Sigma Framework overcomes several limits of the traditional lean approach, by adding an alignment between operational performance and strategic objectives, collecting sufficient data for statistical analysis via the MES and ERP, including a simulation to validate the proposed improvements and proposing an online tool permitting the access to all related needed documents and standards, and a continuous control and monitoring of lean implementation. The disadvantages of this approach are the complexity of strategic-operational performance alignment, this task could take significant time , and the estimation of improvements of tangible performance indicators. On the other hand main advantages are: identifying problems in operational systems and in production based on accurate and reliable real-time data; prioritizing wastes to eliminate; classifying different improvement/modification alternatives; and forecasting the impact of different proposed improvements on the future system's performance. Currently, the "Analyze" step of the framework is under development. Future works consist of developing the decision matrix and the simulation tool, in order to validate steps 1 till 4 of the proposed framework via a real case study.

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