

LEAN INTEGRATION IN MAINTENANCE LOGISTICS MANAGEMENT: A NEW SUSTAINABLE FRAMEWORK

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ABSTRACT

The current industrial constraints on production systems, especially availability problems are complicating maintenance managers' mission and making longer and further performance improvement process. Dealing with these problems in a wiser managerial vision respecting sustainability dimensions would be more efficient to optimize all resources. In this paper, and after addressing the lean/sustainability challenge in the literature to define main research orientations and critical points in manufacturing and then maintenance specific context, two case studies have been conducted in two production systems in Morocco and Canada, within the objective to set a clearer scene of the lean philosophy implementation in maintenance and within the sustainability scope from an empirical perspective. To activate the social dimension being often non-integrated in the lean/sustainability initiatives, the article authors reveal an original research direction assigning maintenance logistics as the leading part of our approach to cover all sustainability dimensions. Furthermore, its management is discussed for the first time in a sustainable framework, where the authors propose a new model considering the lean/sustainable perspective and inspired by the rich Human-Machine interaction memory to solve daily maintenance problems exploiting the operators' experience feedback.

KEYWORDS

Maintenance engineering, production systems, Man-Machine Interaction, lean philosophy, sustainability.

Introduction

Nowadays industrial challenges have made of performance notion a complex term but which remains tightly related to the system's availability. The mission of the major availability responsible part has become complicated as a result of the contradictory industrial reality and the sustainable development scope that both seem to most companies as farfetched as they are still suffering from maintenance problems and particularly human-machine problems. Practically sustainability objectives concretisation regarding the actual context, which is the most difficult and contradictory deal could become an industrial breakthrough when it starts to be seen as a lean/green perspective: lean as methodology and

green as its natural result. However, this perspective limits the sustainability framework and ignores the social dimension role in maintenance.

In the objective to set a clearer vision for maintenance management context it remains necessary to have a literature background surrounding the lean/sustainability challenge, moreover it remains primordial defining a first empirical scene via real case studies to have a complete vision and thus to set the path towards a new sustainable framework for maintenance management.

Methodology

In order to deal with lean implementation in maintenance management within sustainability con-

text, it is of relevant importance to set a first scene via both evidences bibliographical and empirical in a perspective to develop a new sustainable framework via the following steps.

The lean/sustainability challenge is dealt with in two contexts manufacturing and then maintenance to identify current research orientations and critical points especially in maintenance field.

Within the intention to draw a nearer image of industrial reality dealing with maintenance problems within the lean/sustainability challenge, two case studies were conducted in two different iron production systems from Morocco and Canada.

Evidence concluded from both literature review and case studies witnesses the social dimension squander. In fact the human factor stays so often unintegrated in maintenance new strategies implementation. This Evidence guides us towards a new research direction to start thinking about a sustainable maintenance management framework: maintenance logistics.

Finally a new managerial model is proposed to activate the social dimension, integrating the human factor via a hybrid vision lean and experience management in maintenance logistics context.

The lean/sustainability challenge

Sustainable Performance is a long term project in production systems and an important research issue having been explored in the last decades. Most analysed research papers have discussed the lean and sustainable manufacturing paradigms from a single or a double dimension vision discussing the economic benefits lean implementation in manufacturing or frequently the environmental perspective expending the green benefits of the lean philosophy.

Two main approaches have been supported and adopted over the last decades: lean management and green management, however less than 18% link the two approaches to firm value [1]. Whereas lean management points out value creation and maintain improvement via waste elimination.

Waste reduction initiative recalls the Lean green ones which Abreu, Alves and Moreira consider a “valuable approach to sustain and endure greener industrial activity”. Lean green is a value- efficiency combination concept in an operational environmental context [2]. In fact most lean green models objective is productivity improvement with less environmental impacts.

The literature review (Table 1) shows a limited number of papers discussing the lean/sustainability

aspects referring so often to the lean/green aspects in the industrial context. The fact that was also stated by Abreu, Alves, Anabela and Moreira identifying a limited number of lean/green models published since 2012 [2].

Most literature papers focus on the waste reduction concept summing up the benefits of the lean approach whether mentioning the economic impact of lean initiatives via costs reduction or expending these benefits to the environmental perspective reflecting the green impact.

Analyzing the different contributions, it was found that this thematic was dealt with in a way whether to prove the link between the two lean and green aspects, recognize the benefits of lean/green initiatives thanks to waste level reduction or rarely present a model of implementation that actually stays an alternative to a partial lean implementation concerning some manufacturing operations in the specific context of a chosen production system with an environmental perspective.

Main observations in manufacturing deduced could be recalled via the following points:

- The lean and sustainable manufacturing recognized positive impact on production systems performance.
- Lean and sustainability aspects are synergetic.
- Sustainability aspects were presented in a limited vision via a single or a double dimension (economic or environmental) whereas the social dimension was totally absent.

The lean/sustainability challenge was less frequently discussed in maintenance specific area as in the manufacturing context.

Maintenance management remains tightly related to sustainability challenges for a more efficient and sustainable maintenance processes.

Lean thinking is an alternative to project efficiency and excellence in maintenance. Moreover it is considered perquisite in maintenance for lean manufacturing systems [7, 8].

In spite of the earlier appearance of the lean maintenance term, most its related research literature stays limited and thus conducting more research in lean implementation in maintenance remains necessary [9, 10].

To explore how the lean/sustainability challenge has been dealt with in maintenance area, a literature review was conducted from which a summary is presented in Table 2.

Most analysed papers discuss the lean/sustainability challenge in a maintenance context in an alternative to bring the lean thinking benefits into maintenance field.

Table 1
Literature review summary of lean/sustainability aspects in manufacturing.

Reference	Lean area practice	Methodology	Studies aspects relevant to sustainability	Related (or mentioned) sustainability dimension	Results and conclusions
[3]	Manufacturing	Literature based paper.	The link between lean and sustainable manufacturing.	<ul style="list-style-type: none"> • Environment 	<ul style="list-style-type: none"> • Lean and sustainability synergy is supported by higher green results in lean systems. • A clear positive impact lean and sustainable manufacturing on performance was identified. • No evaluating methods for this impact were provided. • Social performance has not been widely explored.
[4]	Manufacturing	Two surveys were addressed to 31 automobile assembly plants in North America and Japan.	Reduction of air emissions of volatile organic compounds.	<ul style="list-style-type: none"> • Environment 	<ul style="list-style-type: none"> • Supporting the link between lean practices and resource efficiency. • Lean Management aspects may be related to environmental management practices.
[2]	Manufacturing	Literature based paper	Eco-efficiency within lean green models.	<ul style="list-style-type: none"> • Environment 	A limited numbers of lean/green models were identified. Main aim of lean/green models focuses on the systems productivity improvement.
[5]	Manufacturing (A case study in a production cell)	Case study based paper	Lean thinking and green practices integration to reduce environmental impacts by reducing production waste.	<ul style="list-style-type: none"> • Environment • Economy 	A new lean/green model proposition for a production cell leading to following findings after application in an international engineering corporation: Reduction of resource use from 30% to 50%. Reduction of the total mass and energy flows cost in a cell by 5–10%.
[6]	Manufacturing	Surveys with 186 in US manufacturing managers in US manufacturing plants.	Link between lean manufacturing practices, environmental and operational performance.	<ul style="list-style-type: none"> • Environment 	Lean manufacturing practices are positively associated with environmental and operational performance.
[1]	Manufacturing	Literature review for 126 articles from which 60 were relevant.	Lean push/pull with respect to green implementation.	<ul style="list-style-type: none"> • Environment • Economy 	The review suggests that the adoption of lean practices have a positive effect on both environmental and organizational performance. The concepts of lean and green are synergetic.

Sustainability was indirectly introduced through aspects related to its two dimensions (environment and economy) with a particular attention oriented towards costs reduction as result of lean implementation and wastes reduction, or more generally deriving from efficiency and global performance improvement. This latest perspective involves the econom-

ic dimension pointing out waste identification and costs reduction [7] the concept that was differently expressed by productivity without waste [11] by means of lean thinking initiatives incorporation in maintenance activities [12] aiming at achieving improvement and excellence in maintenance area [8]. The two dimensions have been discussed in way to

Table 2
Literature review summary of lean/sustainability aspects in maintenance.

Reference	Lean area practice	Methodology	Studies aspects relevant to sustainability	Related (or mentioned) sustainability dimension	Results and conclusions
[7]	Maintenance	General literature based paper, no sample was specified.	Wastes identification and Costs reduction	• Economy	<ul style="list-style-type: none"> • Lean in maintenance is requisite for lean manufacturing systems. • Eight types of wastes were identified. • Proposition of a roadmap for lean thinking application in a maintenance process.
[12]	Maintenance	General literature based paper, no sample was specified.	Maintenance strategies choice to promote regular performance monitoring and reduce environmental impacts.	• Environment	<ul style="list-style-type: none"> • Maintenance management role in pro environmental performance integration. • Maintenance methods and techniques contribution in environmental management via performance measurement.
[11]	Maintenance	General literature based paper, no sample was specified.	Productivity without waste or efficiency	• Economy	<ul style="list-style-type: none"> • Discussion of the concept of productivity without waste or efficiency. • A need for a different vision of lean in maintenance context is needed taking into account business dynamics.
[8]	Maintenance	General literature based paper, no sample was specified	Lean thinking incorporation in maintenance activities	• Economy	<ul style="list-style-type: none"> • Lean thinking stays a requisite for lean manufacturing systems. • Establishment of a scheme for lean maintenance tools to reach improvement and maintenance excellence status.
[13]	Maintenance	General literature based paper, no sample was specified.	Identification of common elements of the new paradigms.	<ul style="list-style-type: none"> • Economy • Environment 	<ul style="list-style-type: none"> • Understanding the synergy between the lean and green paradigms and overall improvement of maintenance efficiency. • Maintenance process outcomes have a double impact or related aspects economic and ecological.

understand the synergy between the lean and green paradigms [13]. Such lean/sustainable initiatives remain shallowly explored and limited to the two sustainability dimensions whereas the third dimension has been all the time ignored the fact that was equally noticed in the manufacturing field.

Main conclusions of the literature review analysis in maintenance field are represented by the following points from which some were commonly identified in manufacturing:

- Lean thinking stays requisite for lean manufacturing systems.
- Lean and sustainability synergy is proven via overall maintenance efficiency.
- Absence of the social dimension discussion in the analysed papers dealing the lean sustainability challenge in maintenance.
- Absence of maintenance management framework to promote lean thinking implementation regarding the three sustainability dimensions.

- No model was identified investigating the social dimension valorisation within lean thinking implementation in maintenance.

The implementation of the lean philosophy remains much more difficult in maintenance area for many critical reasons:

- Lack of collaboration between maintenance and production departments/services.
- Lean thinking is so often directly projected in maintenance field which could not guarantee a successful lean philosophy implementation without an adaption or contextualisation.
- The social dimension stays so often marginalised or shallowly pointed out targeted via lean principles in the absence of a collective standardised manner, this marginalisation is effectively considered a waste type reflecting the unused creativity of human resources.
- A practical managerial vision requires more focus to integrate pragmatically the third sustainability dimension (the social dimension).

Maintenance management

Maintenance management framework

Considering the important strategic position of maintenance and its management in organisations, it is becoming an urging necessity to start exploring in this field the relationship between research and practice [14]. Industrial practice farness from research is actually responsible for many problems due to random management ways of maintenance activities and resources which is often translated by high costs becoming the most alarming evidence in production systems calculations. In fact maintenance activity costs occupy from 15 to 40% of the total production cost [15], whereas maintenance function or department overall costs are about 15 to 70% of total production costs [14, 16]. In order to reduce these costs it remains necessary to revise and improve maintenance management. The fact of setting maintenance management models basically means working on maintenance performance to improve it continuously [17]. Though formulating strategies is an important mission in maintenance management, the link joining it to execution is the missing brick [18]. Lately maintenance management emphasizes on maintenance contribution in companies value [18][19]. In other words, maintenance management should be oriented towards value creation avoiding and eliminating waste sources. This principle becoming widely explored in manufacturing is very timidly discussed in management to stay talking about lean management shallowly.

The lean/sustainability challenge: two case studies from the Moroccan and Canadian industries

Main production system's performance into very low levels cannot be seen by a maintenance eye or a production eye independently. Both eyes are witnessing these problems having an impact on the system's availability and generally on its global processes performance.

To analyse more main problems causes in their relation with the lean sustainability challenge, three questions were addressed to their maintenance managers and two other questions to the production operators.

The first three questions addressed to maintenance managers are the followings:

- 1) Have you already implemented the lean philosophy in your production system?

Both companies have insured that they have not yet implemented the lean philosophy in their production systems.

- 2) How do you qualify production operator collaboration in new maintenance improvement strategies implementation?

To answer this question a five level Likert scale was proposed to evaluate the operator's collaboration level: from very low collaboration level to excellent collaboration level (very low collaboration level, low collaboration level, medium collaboration level, sufficient collaboration level, excellent collaboration level).

Here again it has been realised that both iron companies have chosen a low collaboration level to qualify the production operators reaction towards new maintenance strategies implementation concerning their equipment or production tool.

- 3) How do you judge lean philosophy implementation in maintenance?

This question has been answered by mean of a five level scale (very beneficial, beneficial, neutral, less beneficial, not beneficial).

Both have answered very beneficial.

- 4) How do you predict difficulty level of the lean philosophy implementation in maintenance within sustainability context and the actual operator's (particularly the production operator's) collaboration level?

Both companies have assured that this implementation would be difficult considering the actual collaboration level of the human factor in general and especially the production operator's one.

The question addressed to production operators and their answers are detailed as follows:

How frequently are you informed about maintenance new strategies and practices?

Five adverbs of frequency were proposed to answer this question (never, rarely, sometimes, frequently, always /systematically).

Most operators of both production systems have affirmed that the communication of new maintenance strategies and practices is not a systemic process in their company. In fact in the Canadian context 88.23% of operators have chosen “sometimes” to describe this communication frequency. The truth that was clearly confirmed by the Moroccan iron production system where 0.78% of production operators have described the communication frequency by the adverb “rarely”. This refers to an occasionally process when an event alarms the maintenance manager to express a persistent need to communicate more with operators.

Discussion

Via the two case studies main problems related to the lean/ sustainability challenge in maintenance were identified as explained by the answers given by maintenance managers and production operators in both Moroccan and Canadian studied production systems.

Both case studies results have demonstrated the following evidence:

- The human factor collaboration is still insufficient expressed by a low level in both systems (especially the production operator collaboration).
- Both production systems recognise the lean philosophy implementation benefits within the sustainability context even if they have not yet implemented it in production.
- The implementation difficulty was naturally predicted considering the actual collaboration level.
- The low collaboration level could be explained by a low communication level with production operators.
- Absence of a systemic communication standard involving collectively production operators in new improvement strategies in maintenance.

These results could be generally summed up by the absence of the social dimension integration in improvement initiatives or lean philosophy implementation in maintenance what supports the literature review conclusions.

This evidence addresses clearly the need for a new sustainable framework regarding all dimensions and particularly focusing on the social one.

Maintenance logistics: a new sustainable model to involve the human factor

Maintenance usually seen as a set of tasks, activities or even processes keeps many problems hidden and marginalized. Thus a more extended vision is strongly required to cover all problems and aspects of maintenance processes or projects as well. This is to express the need for an optimal maintenance logistics management instead of a foggy sight of maintenance.

Maintenance logistics: A systemic approach

Maintenance logistics (ML) definition being rarely identified and poorly mentioned in the literature, to be in need for a new definition considering ML a set of subsystems included in a larger system (industrial production system) were maintenance logistics manages material and non-material resources to allow a smooth running of maintenance activities. Maintenance logistics dealt with from a systemic approach vision could be a supporting system compound of three subsystems interacting with each other by means of ascendant and descendent flows [20, 21].

This new definition of maintenance logistics sets a new sustainable framework for maintenance management covering all resources and thus the tree sustainability dimensions giving more attention to the human factor.

Maintenance logistics management: towards a new sustainable model

Being convinced of the importance of maintenance logistics generic mission to control overall main system resources and improve its availability it is recommended to integrate the sustainable management path adopting a managerial culture which lands at green maintenance field and a more collaborative human factor as well as a more developed economy. Briefly, to build an effective sustainable model to solve maintenance problems and enhance continuous improvement in maintenance logistics system, it stays essential to focus on maintenance interactions and especially the Human-Machine interaction offering a memory wealth that should be sustainably exploited via the lean culture and experience feedback management or return of experience (REX) management. by the chart of Fig. 1.

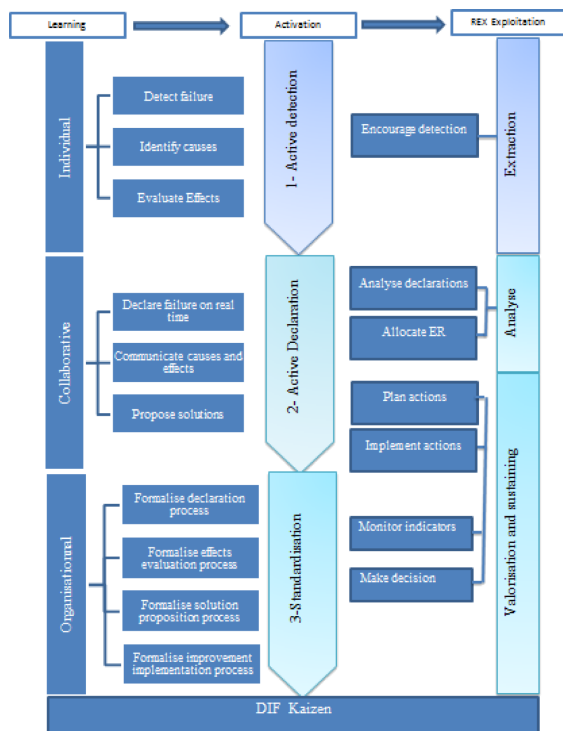


Fig. 1. Lean/REX Model for Experience feedback management.

Conclusions

Maintenance logistics management is a crucial confusing mission that a lot of companies fail to insure neglecting the importance of sustainability role in solving availability and other production system problems. After studying the bibliographical lean/sustainability challenge context and identifying empirical evidence through two case studies in the Moroccan and Canadian industrial environments, a new maintenance framework is proposed in this paper covering the three dimensions of the sustainable development to facilitate their management focusing on the social dimension for which a new sustainable model is being developed based on Human-Machine interaction exploiting its experience feedback within the lean culture implementation in maintenance area.

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