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Abstract: Market requirements and product diversity call for a lean approach that allows companies to meet customer requirements in terms of quality, cost and lead time. Lean management (LM) is based on the evolution of the culture and the deployment of tools to improve and optimise industrial performances. The objective of this paper is to present the impact of the deployment of LM on the working environment and the health of workers during a change or improvement of the process. This paper presents a new concept of continuous improvement which takes into consideration high performance improvement based on a new overall equipment effectiveness indicator. This new approach allows taking into consideration all the performance factors by treating non-conformities or non-quality, all types of non-value added (NVA), and improving the social and organisational side ‘ergonomic, safety, environment’. A practical case was studied will allow validating our new approach.

Keywords: lean management; safety; environment; ergonomic; overall equipment effectiveness; OEE; continuous improvement.

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1 Introduction

In 1990, James Womack and Daniel Jones developed the LEAN approach in their book 'The machine that changed the world' (Womack et al., 1990), which made a revolution in the industry. It prompted manufacturers to change the way they use their resources to improve quality, reduce cost, lead time, and finally increase the production rate (Sivananda Devi et al., 2018; Kumar et al., 2020).

Lean's tools and LM approach are a highly strong industry technique. The use of tools and techniques and the adoption of lean concepts and practices is the key to quality, cost and lead time optimisation, according to Olivier (2009) and Belfanti (2019). LM not only allows for cost gains but also prevents all types of waste by eliminating the causes of poor operational performance (Sivananda Devi et al., 2018; Rauch et al., 2020). It is therefore necessary to call on the most appropriate instruments to improve the researched process and to correctly define the indicators. 'Lean manufacturing has been proven to be considered the best manufacturing system of the 21st century' according to Rose et al. (2011). It also permits production deficits that are frequently reflected by micro and macro pauses, non-compliance or lack of quality, slowdowns, or loss of commitment to be reduced.

Lean is a human-driven management style that indicates that people are focused on decreasing waste and processing waste sources (Aydınoğlu et al., 2017; Alok et al., 2018; Sahoo, 2019). Lean is focused on effectiveness and aims for good quality and as fast as feasible services at the lowest possible cost (Anthony and Fergusson, 2008). It is also seen as a method to reduce risk accidents and improve ergonomic conditions of occupational. 'The initial results show that the lean process creates client satisfaction which in turn provides an incentive and competitive advantage for the organisation.' according to the professionals that led lean projects (Wahabi et al., 2015). Similarly, the work of Sivananda Devi et al. (2018), Kumar and Mathiyazhagan (2019) and Lauver et al. (2020) confirms that the implementation of a lean project within an organisation requires the involvement of all company employees including the company's management. Thus, the enhancement working conditions in the workplace should be privileged by involving the employees during all the phases of diagnosis and process studies (Aydınoğlu et al., 2017). Furthermore, Dos Santos et al. (2015) claim that integrating ergonomic solutions from every workplace improves employees' dedication and productivity and so enhances their satisfaction. For successful lean integration, workers' motivation and conduct are crucial prerequisites (Aydınoğlu et al., 2017; Alok et al., 2018).

This manuscript consists of four parts. In the first section we give a literature assessment of the evolution of the lean methodology and the many scenarios involved. The second half will focus on a bibliography on the correlation between the impact of personal involvement and the socio-economic environment on the lean approach mainly safety, ergonomics and the environment. In the third area we will discuss our new lean management plus (LMP) idea as well as the measures we will be taking to calculate the overall equipment effectiveness (OEE) indicator, which we will call overall equipment effectiveness plus (OEEP). The last step will be to validate our model with an actual case study.

2 Literature review of LM

Lean is a mindset that fosters a culture of continuous improvement, according to Pampanelli et al. (2014) and Kumar et al. (2020), which makes us think about the company's many resources in order to reduce waste. Alok et al. (2018) and Rauch et al. (2020) further state that the lean management (LM) strategy does not only allow cost-saving but also minimise waste because of frequent macros and micro pauses, non-conformities or non-quality, slowdowns or loss of commitment. Lean is a method of thinking and a strategy deriving from the experience of Toyota, which makes an important contribution to better working conditions. Hohmann (2009) said: "The corpus of what was to become the idea "lean" had been enriched by decades of testing and misinterpretation." We talk historically about a long period of development of industrial systems. He started with the model of Taylorism, created in 1880 by the US engineer Frederick Winslow Taylor. Later, Henry ford introduced a new model of organisation and business development called the Fordism in 1908, which will be replaced by the

Toyotism. This type has been in use in the 'Toyota city' factories since the 1960s, which have been founded by Taiichi Ohn, in which the production is pulled by the market demand. It is founded on the five zero principle: zero delays, zero defects, zero administrative documentation and zero stock. An enterprise that implements this approach works on a just-in-time basis: saving time without having stocks to satisfy customer demand. The formal application of Toyota is called: Toyota Production System (TPS). This model developed by the Japanese Car constructor during the oil crisis in 1973, also improved its management philosophy and practices. TPS organises the production and logistics of the manufacturer, including interactions with suppliers and customers (Alok et al., 2018).

In various industrial sectors around the world, lean has revolutionised the organisation by offering prospective benefits through progress and changes in the global market (Kumar and Mathiyazhagan, 2019). In truth, in terms of quality, pricing and delivery time, the market has undergone various changes. In fact, companies are under the challenge of producing products of high-quality, meeting deadlines at the best possible price and in good working conditions, in order to assure and guarantee their competitiveness (Bevilacqua et al., 2017; Kumar et al., 2020).

In this economic framework, lean tools are required to optimise continuous production processes and to eliminate non-value added (NVA) conditions under advantageous and motivating working conditions (Aydınoğlu et al., 2017; Alok et al., 2018; Mahesh Babu et al., 2020). "More than 7,600 people die every day owing to industrial accidents and illnesses; in other words, more than 2,78 million deaths a year," says the International Labor Organization (ILO). This means that we still have a long way to go to reduce or rather eradicate this serious problem that has a direct impact on the staff working environment.

At order to make the LM approach successful and reach the objectives specified in the top management, Alok et al. (2018) and Belfanti (2019) confirm that the LM tools need substantial workforce involvement between other key sources. This illustrates that employee engagement is one of the many factors needed for these changes to continue over time. In addition, the impact of ergonomics on employee engagement and motivation must not be forgotten which are two key variables in achieving LM projects (Dos Santos et al., 2015).

'Ergonomics brings together the knowledge of the action of the person in activity to design tasks, machines, tools, buildings and production systems' as defined in The National Agency for the Improvement of Working Conditions (ANACT); This factor has a significant role in improving working conditions, therefore a huge effort is needed to avoid all types of risks that can impact it. LM plays an essential role in numerous aspects of competitiveness by eliminating sources of waste and improving working conditions (Dos Santos et al., 2015; Bevilacqua et al., 2017 Francis and Thomas, 2020; Kumar and Mathiyazhagan, 2020). "In any deployment of the LM tools in order to ensure the project is successful, it is vital that the human aspect of all transformations is regarded, according to Tajri and Cherkaoui (2015). Human factors (particularly cognitive variables) successfully distinguish the firm's using lean from the companies who don't." That has been confirmed by Ramadas and Satish (2018), Rauch et al. (2020) and Lauver et al. (2020).

3 Bibliographical study of LM impact on the professional environment

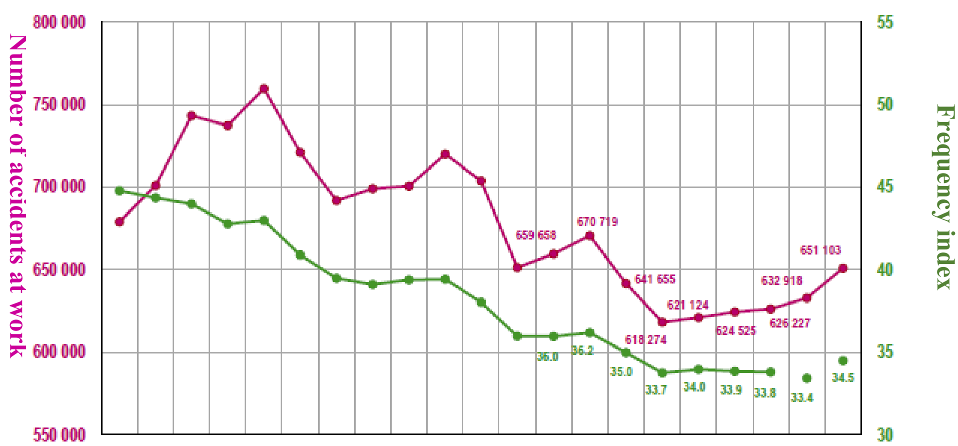
The improvement of working conditions in the company's strategy, notably in terms of safety, ergonomics, and the environment, currently plays an extremely important and crucial role. Furthermore, adjustments or enhancements in workstations that no longer are considered secondary factors have increasingly been included in the company's objectives. The current global pandemic (COVID-19), for example, has demanded the introduction and resumption of all activities worldwide of new personnel protective equipment (PEP).

3.1 Context of the study

This work covers an issue rarely discussed by researchers in the literature. It is a performance risk assessment: safety, ergonomics and the environment, which boost employee motivation (Francis and Thomas, 2020). Assessing the impact of LM on all performance factors is extremely complicated because of the quantity of variables and restrictions to be determined. First, to evaluate LM's impact on these aspects, we will present a new model. In order to avoid enhancing some factors and degrading others, we will also identify a primordial interest indicator that follows the evolution of each performance element. The analysis of every risk and the influence of LM and the quantification of changes on all factors should illustrate clearly this indicator. This is to provide a new tool for evaluating the different performance variables for LM investigators and pilots.

Despite the revolution and the development and protection of prevention tools, terrible results in accidents and occupational disorders are still documented. The costs for accidents at the workplace therefore remain extravagant for firms for example in France. For 794,400 claims that led to work stoppages, including 651,100 job-related accidents, 97,550 commute accidents and 45,750 occupational disorders, '9 billion euros of net Benefits have been played in 2018' [Sources: (SSD) Directorate for Social Security, 2019 edition: key social security figures in France].

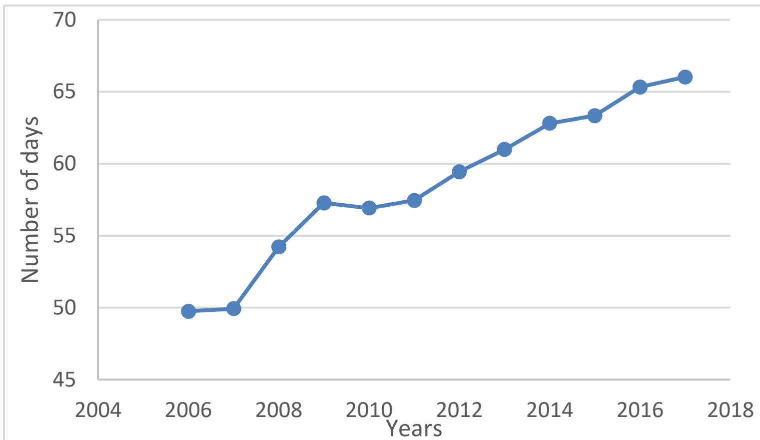
Figure 1 Evolution of the number of work accidents '1998–2018' (France) (see online version for colours)



According to the 2018 French Insurance Annual report on sickness and occupational risks figures for accidents at work, the average number of working days is shown in Figure 2.

Since 2013, the number of accidents at work (AT) has increased from 618,274 in 2018 to 651,103 AT, equivalent to +5%, which has not been achieved since 2012. At the same time, the average number of days off increased from 49.55 in 2007 to 65.91 in 2017, up 33%.

Figure 2 Changes in the average number of days '2006–2017' (see online version for colours)



According to the French Health Insurance, in 2017 at least 530 persons died on their workplace and did not consider the 264 who had killed themselves while travelling or the cases of suicide, which often demand a judicial passage as accidents at work. Therefore, more than ten deaths at work every week in France.

The Moroccan Labor Union (UMT) has stated that there remains tremendous concern regarding occupational health and safety. An average of 45,000 accidents including 3,000 deaths is reported every year. And, as stated in the CMIM, "professional risk prevention represents the optimal approach to increase business performance and human resources. This is a vital stage in that it leads both workers and businesses to concrete results."

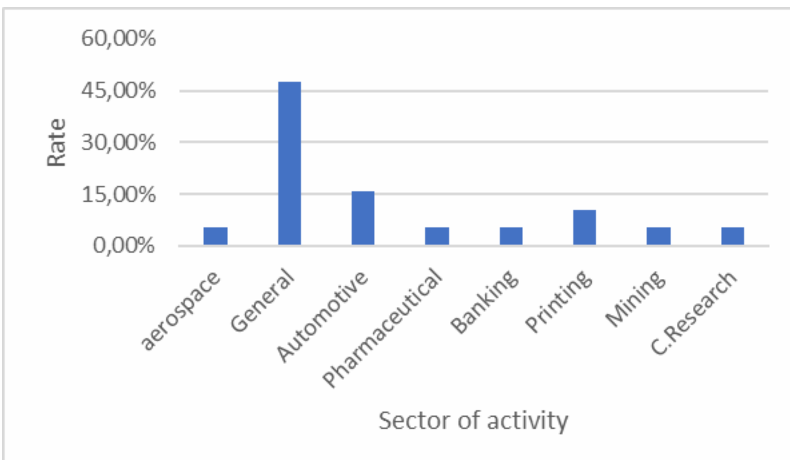
Sensitivity for environmental needs is required to safeguard the professional activity. Indeed, the impact of LM on it is likely to affect the environmental conditions we need to control and supervise to avoid degradation of this feature (Francis and Thomas, 2020; Mahesh Babu et al., 2020). Under ISO 14001 the goal is to set up a production, management and operational system that incorporates in the dynamic perspective of regulating environmental effects all sorts of organisations (businesses, associations, public services etc) (human and natural). This needs enterprises to integrate this factor into their goals to develop their systems and to adapt them to environmental demands.

The methods we have at present are not enough for the fundamental causes of accidents and work diseases and environmental harm to be assessed and addressed. Therefore, in addition to taking into consideration other factors: environment, safety and ergonomics of our workers, we thought about reinforcing and integrating these concepts of enhancing working conditions in our work project. The social partners are however progressively imposing an improvement in the quality of working life in the professional sector because most workers spend more than a third of their days in their workplace.

3.2 Analysis and statistics

The literature synthesis demonstrates that in order to remove the waste, the majority of the company's orientations converge towards the sole technical aspect of LM (Figure 4), in the light of the examination of various lean manufacturing papers (Figure 3). In order to meet the market needs and satisfy the consumer, researchers and managers are therefore interested in this element while neglecting the influence on the organisation and the social aspect of the staff. To evaluate the performance of the whole production chain, the quest for performance improvement is a continual task which can only be established by applying an LM approach. Consequently, all the workstations that constitute an important data source for the development of the company require a thorough diagnosis of this workstation.

Figure 3 Participation rate of articles by sector of activity (see online version for colours)



Quality, cost and lead time (QCD) criteria for customers require organisations optimise their costs and manage their resources and means Companies therefore favour LM's technical side in improving quality and reducing costs while respecting deadlines, without considering the working circumstances of its employees. Figure 4 presents an overview of the social and organisational components of the researchers' lean method. We may notice that based on this analysis:

- 53% of researchers focus only on the technical side of LM
- 16% of researchers present the work of LM and (Lean Six Sigma, lean mining, lean green...)
- 11% of researchers take into consideration ergonomics (E) in a LM project
- only 10% of researchers address LM and safety (S)

- only 5% of researchers treat ergonomics and safety (ES) in an LM technical improvement project
- 5% of researchers treat the environment (E) in an LM project.

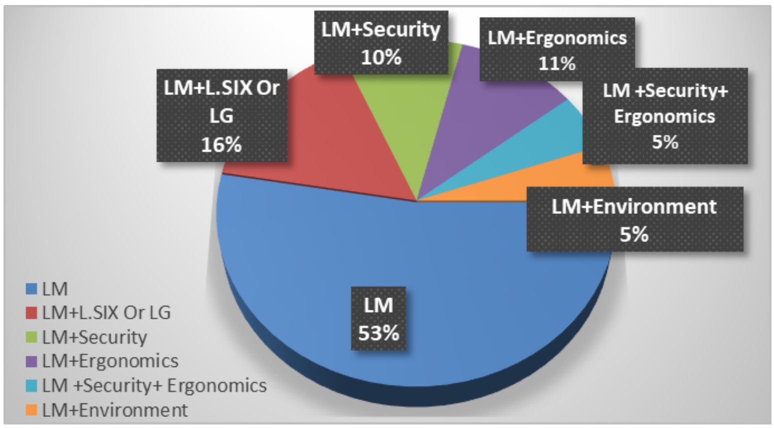
Table 1 Summary of the literature review of LM effects on the three ESE performance factors

10% of LM's impact on safety	*11% of LM's impact on ergonomic*	*5% of LM's impact on the environment*	*5% of LM's impact on safety and ergonomic*
*15%: • LM degrades safety. • LM is the source of accidents.	*23%: • LM negatively impacts ergonomics. • LM sources of fatigue and social degradation.	*10%: • LM degrades the environment.	*29%: • LM neglects safety and ergonomic. • LM is a source of degradation of safety and ergonomic.
* 55%: • LM improves safety. • LM prioritises safety over the other factors. • Security is a source of motivation and involvement of personnel.	* 52%: • LM improves ergonomics. • Ergonomic as a source of employee involvement and motivation. • Improved ergonomic has a positive impact on operator performance.	* 70%: • LM sources of environmental improvement. • L. green prioritises the environment over other factors of performance.	* 50%: • LM improves safety and ergonomic. • Safety and ergonomic are part of the improvement of the company's performance. • Safety and ergonomics as a source of employee involvement and motivation.
* 30%: • Changes in security impact the social axes. • Absence of an indicator to monitor safety developments.	* 25%: • Improve erg, reduce absenteeism. • Cognitive ergonomics considered. • Evolution of ergonomics impacts performance.	* 20%: • Lack of leadership and actions for the environment. • Each process change impacts the environment.	* 21%: • Missing safety and ergonomics tracking indicator. • Need for management commitment and to follow the evolution of these factors.

Table 1 summarises all the researchers' views on the LM's impact on these factors: ergonomics, safety, and the environment (ESE). This table is based on Figure 4 statistics.

In addition, numerous experts strongly advocate managers' engagement and participation to implement lean projects successfully (Alok et al., 2018; Kumar and Mathiyazhagan., 2019; Lauver et al., 2020). Furthermore, the development and implementation of a sustainable LM project requires the participation of the management of the organisation. Indeed, the growth of the LM culture within an organisation, particularly for managers and LM pilots, depends upon a strategy which assures training for all the workers as a first step. Secondly, the success of economic and social factors demands the planning, budgetary follow-up and engagement of the management. Integration of LM in an organisation is first followed by managers who must help their teams to identify targets, training sessions, benchmarks, resources... to provide them with all the means for the success of LM projects.

Figure 4 The percentage of LM impact work on the ergonomic, safety and environment factors since 2013 (see online version for colours)



This literature evaluation, in summary, confirms the impact of a highly competitive market on business directions. This drives many investigators to focus solely on the economic and technical approach as a continuous improvement methodology while neglecting the impact on social and cultural parties. For this reason, we propose to broaden our field of study under a practical concept that addresses several factors: LM technique (QCD), and social (ESE). These elements influence the process of continuous improvement, employee development and social and organisational level greatly (Dos Santos et al., 2015). This new approach will have a new indicator known as OEEP. This new indication will allow firms, involving all actors of the company, to use their LM approach and achieve improved performance.

Table 1 shows the necessity to have a new concept to manage these ESE elements and to facilitate monitoring of the evolution of these factors. This new approach establishes mechanisms that assess all sorts of LM effects and changes on those factors in the processes. We also propose standard indicators to track the developments of all performance parameters, such as quality, cost, delay, ergonomics, safety and the environment (QCDESE).

4 Proposed concepts for new LMP model

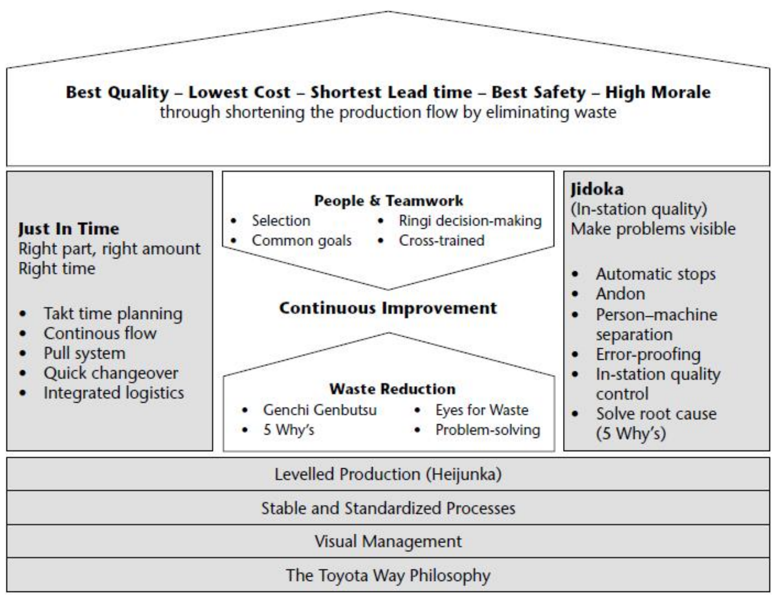
Irrespective of the system, professional organisations need to work to assure that all QCDESE variables achieve the best performance possible. LMP ensures a search for excellence in a healthy environment and with a good team spirit. This requires the measurability of these objectives as the level of compliance of each unit or entity through an OEEP indicator needs to be represented.

4.1 Presentation of a new LMP model

We suggest a new LMP model in this section for the improvement of the industrial system through lean tools. Similarly, LM's philosophy and principles are based on the continuous search for perfection, quality improvement and waste elimination, thus, a strategic and modern organisation that provides a motivating environment and favourable working conditions (Aydınoğlu et al., 2017; Kumar and Mathiyazhagan, 2020).

Based on the literature review study, most systems for economic performance monitoring have been evaluated on three primary dimensions and are readable on the QCD triangle (Anthony and Fergusson, 2008). Within this setting, organisations require a new approach to the emphasis of direct managers in any continual improvements to social and organisational aspects and future changes, Figure 5. LMP is a method that assesses the initial condition of the workstation in order to detect and address all the gaps in the QCDESE factors.

Figure 5 Current lean model



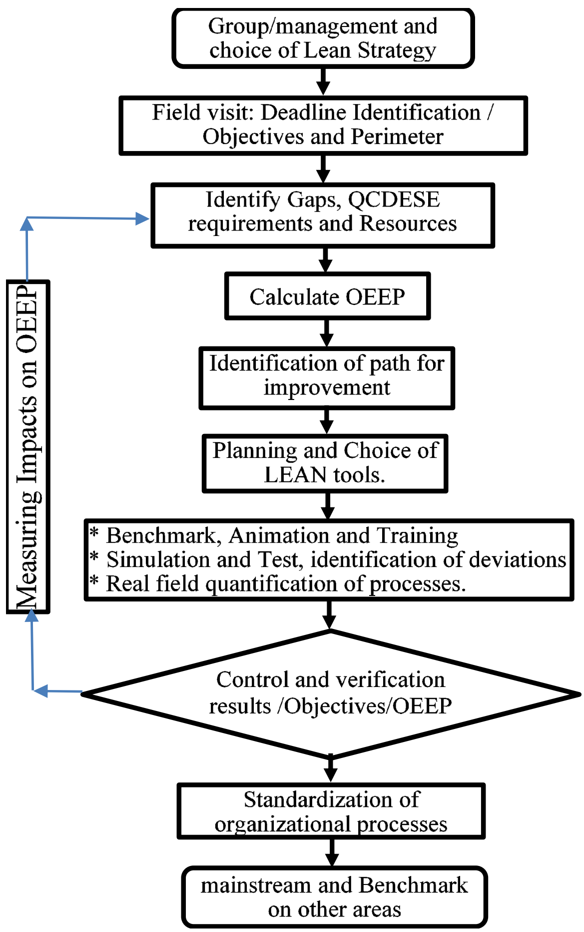
Source: Pillet et al. (2011)

This new LMP approach responds to the needs of the pilots of continuous improvement project, and as indicated by the current house of lean 'Toyota' Figure 5, there by guides managers to accomplish technical and social requirements. This performance management system includes all QCDESE factors (quality, cost, delay, ergonomic, safety and environment). Figure 6 shows the key phases of LMP operation. This strategy can be applied in a Kaizen framework, where employees are motivated and where social and cultural issues are respected. This improves the environment and the quality of working lives of employees. The LMP project implementation must be done in the field, by the operational staff themselves, bearing in mind the different performance factors and all the team's remarks instead of being based on financial or theoretical calculations.

The diagram displays our strategy using the OEEP indicator (Figure 6) to monitor and assess the effectiveness of our actions. OEEP is a key indicator for the implementation of this concept. It also enables the prioritisation of the criteria and the choice of the suitable LM instrument for a full diagnosis to be made.

This diagram outlines our new LMP model which is a guidance for the LMP pilots and teams (Figure 6). First of all, under the management commitment of the company, it is necessary to invite all players to agree on joint technical and social objectives (Kumar and Mathiyazhagan, 2019). The commitment of managers and the staff's engagement are the key to the success of every LM project, according to Alok et al. (2018) and Belfanti (2019). Subsequently, LMP provides a highly motivating environment for the staff and a strong involvement of all the company's actors in order to achieve these objectives.

Figure 6 Detailed diagram of LMP implementation (see online version for colours)



In order to attain the goals established by the company's management and agreed on by the LMP team, the following phases shall be observed:

- Make an inventory of all indicators of performance and collect ergonomic, safety and environmental data via employee integration.
- Identify, by using the initial OEEP calculation, the deviating QCDESE factors and the constraints encountered in the field, which are the major indicators for developments monitoring in QCDESE. This is one of the key elements for the choice of the corresponding LEAN tools.
- Identify the solutions and measures required to achieve our goals by controlling OEEP developments.
- Coaching, training, and tests are the measures to put in place in order to ensure the achievement of the project lean's fixed objectives (Ramadas and Satish, 2018).
- Compare initial and end value of the OEEP indicator to check and validate the field results.
- In conclusion: standardise and mainstream.

This strategy properly fits managers and researchers in order to fix the gaps and improve the results of all QCDESE factors.

The success of an LMP project hinges on the firm staff's strong involvement (Tajri and Cherkaoui, 2015). Consequently, the operators will feel that these improvements of the working conditions are carried out by them by improving the performance of their workshop's indicators and ensuring the maintenance of these changes. According to the researchers, if the staff does not find its personal interests in a process transformation, it is obvious that these changes will not be sustainable, due to their lack of commitment and participation (Lauver et al., 2020; Drew et al., 2014). Unless the business assures staff that they have participated in defining the LMP objectives and improving the work plan, all such changes may fade in the short term (Kumar and Mathiyazhagan, 2019). However, management must consider social and technical (ST) objectives in order to assure the sustainability of these improvements. A new LMP approach that guarantees the durability of LM project's changes must be developed. This new LMP model is based on its structure:

- integration of all stakeholders in the organisation since the early LM project phase in identifying ST goals
- consideration and implementation of the social objectives by the LM pilots using the OEEP indicator
- a collection of ST constraints identification proposals and prospects for improvement
- identify and treat all changes that affect the social aspect and technical variations
- setting up an OEEP indicator to monitor LM targets, to stop working conditions being damaged
- monitoring and verifying the progress of the ST goals at each stage of the LM project by using OEEP
- ST advantages for all actors of the company must be identified and presented

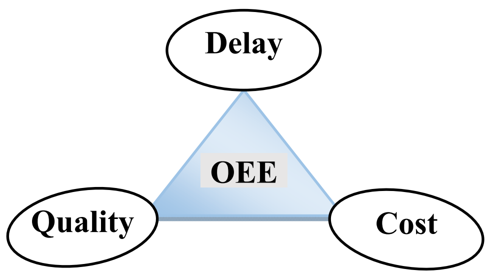
- lean project members' contributions must be rewarded and recognised (Antomarioni et al., 2019).

In order to track and monitor the development of any QCDESE performance factors, the LMP model needs an indicator. Most organisations must recognise and apply this indicator to help implement the recommended model. There are currently various characteristics varying from one organisation to another organisation. We shall offer a new indicator in the next paragraph to satisfy our needs.

4.2 Determination of the new OEEP indicator

The OEE is the world's most well-known and effective indicator in controlling the performance evolution of a process or a professional activity (Figure 7). The OEE defines the ratio of the useful time to the time required by standard NF E60-182.

Figure 7 The three classic OEE levers (see online version for colours)



The conventional OEE reflects entirely the state of the production site equipment and is frequently used in production to examine machinery's efficiency (He et al., 2018). It is built on three pillars, Quality, cost and delay in its standard formula given by equation (1):

$$OEE = T_D * T_P * T_Q \tag{1}$$

T_D availability rate

T_P performance rate

T_Q quality rate.

However, the social and organisational dimension of a broad, intricate industrial chain cannot be taken into consideration with this indicator. The new OEEE index provides a comprehensive insight of industrial processes as regards availability, performance, quality, and sustainability, according to Domingo and Aguado (2015).

Thus, we need an indicator, in which additional factors are addressed, namely ergonomics, security and the environment, if we seek at operational excellence. The social climate and working conditions are affected by these elements. In fact, nothing is unlikely to occur than what was previously anticipated or identified as a source of abnormality, especially on a manual line with complicated means and a very high number of operators. In order to better include and safeguard our employees, it therefore appears extremely natural and consistent to consider the ESE criteria in our new OEEP indication.

The LMP concept enables this social necessity to be addressed and work conditions to be improved by using the OEEP indicator. The operational excellence in all the QCDESE factors is controlled and supervised by OEEP. For this matter, the OEE formula is developed in order to assess the performance of the individual workstations by taking those factors into consideration. This new OEEP indicator has a role to play in controlling modifications, process transformations and waste disposal resources in better working conditions. It also identifies leads and enhancements for any abnormalities or anomalies discovered.

In order to implement the LMP operating approach (Figure 6), we present its new OEEP indicator, which represents the ratio between actual output and maximum possible output [equation (2)].

$$\text{OEEP} = \frac{\text{Actual output}}{\text{Maximum possible output}} \tag{2}$$

The functional relationship between OEEP and OEE is as follows [equation (3)]:

$$\text{OEEP} = \text{OEE} * T_{Er} * T_S * T_E \tag{3}$$

T_{Er} real rate between 0 and 1, related to the ergonomic of the personnel

T_S rate between 0 and 1, related to security

T_E rate between 0 and 1, related to the environment.

Finally,

$$\text{OEEP} = T_D * T_Q * T_P * T_{Er} * T_S * T_E \tag{4}$$

The OEE is a control indicator of all types of changes in project mode or serial life. The OEEP calculation is divided into two parts:

Classic OEE is known and used by most companies. The operational mode and activities of the company varies from one firm to another (seasonal, industrial or office automated, manual or automatic...).

The rates (T_{Er}, T_S, T_E) are monitoring indicators of workstation improvement procedures and changes.

4.3 Expression of the OEEP indicator

4.3.1 Rates (availability, performance, quality)

According to equation (1), the OEE is the multiplication of the three rates (availability, quality, performance). They are defined as follows:

Availability: T_D

According to the NF EN 13306 standard, the Availability Rate of an equipment or system is given by:

$$T_D = \frac{\text{Actual production time}}{\text{Possible production time}}$$

where

$$\text{Actual production time} = \text{Possible production time} - \text{downtimes}$$

With

$$\text{downtimes} = \text{fault time} + \text{maintenancetime} + \ldots$$

So

$$\mathrm{T_D} = \frac{\text{Possible production time} - (\text{Fault time} + \text{maintenance time} + \ldots)}{\text{Possible production time}}$$

$$\mathrm{T_D} = 1 - \frac{\text{Fault time}}{\text{Possible production time}} - \frac{\text{Maintenance time}}{\text{Possible production time}}$$

$$\mathrm{T_D} = 1 - \mathcal{L}_p - \mathcal{L}_{\text{mtn}} \tag{5}$$

where

$$\mathcal{L}_p = \frac{\text{Fault time}}{\text{Possible production time}} \quad \text{and} \quad \frac{\text{Maintenance time}}{\text{Possible production time}}$$

Quality: T_Q

The quality of products, material goods or services, is an essential factor of competitiveness for any company. The standard definition of quality in ISO 9000 refers to all the characteristics of a product or service that are required by the customer

$$\mathrm{T_Q} = \frac{\sum(\text{Compliant Product})}{\sum(\text{Compliant Product} + \text{Non-Compliant Product})}$$

$$\mathrm{T_Q} = \frac{\sum(\mathrm{PC})}{\sum(\mathrm{PC} + \mathrm{PNC})} \tag{6}$$

- Compliant Product: PC
- Non-Compliant Product (PNC): all non-conforming ‘scrap’ parts or a part that requires retouching or corrections and which affects the quality of the product.

Performance: T_p

This indicator varies from one company to another, depending on the type of activity of the company, the number of manual or automatic stations, as well as the choices and priorities of the company’s management.

$$\mathrm{T_P} = \frac{\text{Cycle time} - \sum \text{Time No Value Added}}{\text{Cycle time}}$$

$$T_P = \frac{T_C - \sum T_{NVA}}{T_C} \tag{7}$$

T_C cycle time.

T_{NVA} non-value added.

For the workstation to be efficient, the T_p must converge towards 100%. So, we must try to eliminate all the NVA.

Classic OEE equation becomes:

$$\text{OEE} = \left(1 - \mathcal{L}_p - \mathcal{L}_{\text{mtn}}\right) * \frac{\sum(\text{PC})}{\sum(\text{PC} + \text{PNC})} * \frac{T_C - \sum T_{NVA}}{T_C} \tag{8}$$

4.3.2 Rates (safety, ergonomic and environment)

We will use the failure mode, effects and criticality analysis (FMECA) tool to assess (safety, ergonomic and environmental) rates. It is a specific strategy that identifies the modes of failure of a product, process or system, to prevent problems before they occur.

The following criticality equation will be used to evaluate the 'safe, ergonomic' or an 'environmental' risk:

$$C = G * F * M * S \tag{9}$$

C criticality

G gravity

F frequency

M mastery

S sensitivity of the environment (reserved for the environment).

The evolution of C relates to the risk of the analysis failures. The following formula provides therefore for the determination of the compliance rate of the ESE factors:

For each ESE performance component, the calculation of the risk or impact rate is determined by:

$$\beta_i = \frac{M_i * G_i * F_i * S_i}{M * G * F * S} \tag{10}$$

Then, the compliance rate will be calculated according to the following formula:

$$\tau_i = 1 - \beta_i = 1 - \frac{M_i * G_i * F_i * S_i}{M * G * F * S} \tag{11}$$

However, the compliance rate for all identified risks (n) is the product of the compliance rates for all risks in a zone (workstation, line, workshop, etc.) under assessment:

$$\tau_i = \prod_{i=1}^{n} \left(1 - \beta_i\right) \tag{12}$$

where

$M*G*F*S = C_{max}$	maximum value for a major risk, which makes the compliance rate become critical in case the risk or impact is with maximum values
I	aspect, risk or constraint in verification
N	number of aspects, risks or constraints in evaluations.

Rate of the environment: T_E

According to ISO 14001, Chapter 6 (1–4), the organisation shall address its significant environmental aspects that are a priority to achieve the expected results of its environmental management system. The environmental assessment requires considering the middle, for an objective to properly estimate the most significant aspects or risks to which corrective or preventive actions must be taken.

The calculation of the rate of an environmental aspect k is given by:

$$\beta_k = \frac{M_k * G_k * F_k * S_k}{M * G * F * S} \tag{13}$$

The environmental impact rate of an aspect k will be calculated according to the following formula:

$$T_{E(k)} = 1 - \frac{M_k * G_k * F_k * S_k}{M * G * F * S} \tag{14}$$

where

k	environmental aspect in check
M	control of the environmental situation (M is the value in critical situations)
G	the gravity of the impact of the activity on the environment (G is the value in major condition)
F	the probability of occurrence, frequency of occurrence (F is the value in strong state)
S	the sensitivity of the environment in relation to the activity (S is the value of a highly sensitive environment).

Rate of the ergonomic: T_{Er}

According to the researchers, there is a strong contribution of ergonomic in the improvement of working conditions and the preservation of the health of workers or users by methods and techniques to adapt the human being in his workplace. This makes it possible to improve quality, system reliability and production efficiency with a view to sustainable performance (Dos Santos et al., 2015).

Ergonomic constantly seeks balance between two objectives:

- a performance objective for organisations: quality, reliability, efficiency, productivity
- an objective of comfort, safety, physical and mental health of people (operators).

The ergonomic risk rate (T_{Er}) of a constraint or risk l is given by:

$$T_{Er(l)} = 1 - \frac{M_l * G_l * F_l}{M * G * F} \tag{15}$$

l ergonomic risk or constraint exposed or identified

M control of the ergonomic situation with means or protections against this risk (M is the value in critical condition)

G the gravity of risk or the impact of the activity (G is the value in very serious condition: maximum)

F the probability of occurrence, frequency of occurrence (F is the value in a strong state).

Rate of the security: T_S

The identification of the safety risks at the workstations makes it possible to map all these risks, in order to treat them or to set up protections to control these risks. Mapping will be a better visual tool for safety factors in order to create a cloud of points to be prioritised according to the level of criticality and the riskiest area. The aim of occupational risk assessment is to reduce accidents at work and occupational diseases.

The security risk rate (T_S) for a risk j is given by:

$$T_{S(j)} = 1 - \frac{M_j * G_j * F_j}{M * G * F} \tag{16}$$

j identified security risk

F_j the frequency of a risk j (F is the value in very high state: maximum)

G_j the gravity of risk j (G is the value in very grave condition: maximum)

M_j control and vulnerability of a risk j (M is the value in uncontrollable state: maximum).

According to the equation (3):

$$\begin{aligned} OEEP = OEE * \prod_{k=1}^{z} \left(1 - \frac{M_k * G_k * F_k * S_k}{M * G * F * S}\right) \\ * \prod_{l=1}^{z} \left(1 - \frac{M_l * G_l * F_l}{M * G * F}\right) * \prod_{j=1}^{m} \left(1 - \frac{M_j * G_j * F_j}{M * G * F}\right) \end{aligned} \tag{17}$$

z number of environmental aspects under study

n number of ergonomic constraints in evaluations

m the number of security risks identified.

4.3.3 The OEEP indicator

The new OEEP formula for our new LMP model will be as follows:

$$\text{OEEP}=\left(1-\mathcal{L}_p-\mathcal{L}_{\text{mtn}}\right)*\frac{\sum(\text{PC})}{\sum(\text{PC}+\text{PNC})}*\frac{\text{T}_\text{C}-\sum\text{T}_\text{NVA}}{\text{T}_\text{C}}$$
$$*\prod_{\text{k}=1}^{\text{z}}\left(1-\frac{\text{M}_\text{k}*\text{G}_\text{k}*\text{F}_\text{k}*\text{S}_\text{k}}{\text{M}*\text{G}*\text{F}*\text{S}}\right)*\prod_{\text{l}=1}^{\text{n}}\left(1-\frac{\text{M}_\text{l}*\text{G}_\text{l}*\text{F}_\text{l}}{\text{M}*\text{G}*\text{F}}\right) \tag{18}$$
$$*\prod_{\text{j}=1}^{\text{m}}\left(1-\frac{\text{M}_\text{j}*\text{G}_\text{j}*\text{F}_\text{j}}{\text{M}*\text{G}*\text{F}}\right)$$

This new OEEP formula will be an excellent tool's asset to support LMP pilots in the improvement of working conditions. Equation (18) enables all QCDESE performance factors to evolve becoming a decision-making and track identification database in the LMP project.

The impact of production risks and hazards on any performance factor (QCDESE) influences the overall process performance of the company. The detailed root causes analysis of this anomaly in an LMP project needs the application of the OEEP indicator. This allows the realisation of a situational analysis and the diagnostic of all types of anomalies of the following factors: quality, cost, delay, environment, safety and ergonomics.

The OEEP will be a richer dashboard than the traditional OEE in term of controlling the factors that deviate from the objective set by the decision-makers. The proper measures for such anomalies must be proposed through the implementation of adequate solutions and investments that prioritise the most penalising deviations without deteriorating the starting state (Kipper et al., 2019).

In order to guarantee work environment quality, lean project managers and pilot will also be able to monitor all of the QCDESE factors by developing a modern LMP model and an OEEP indicator. However, the social factor has a big impact on the participation and commitment of the company's employees (Lauver et al., 2020). Therefore, the new LMP model enables continuous improvement programs in firms to be successfully implemented. In this approach, social variables can be taken into consideration and technical and economic performance improved. This not only helps to the success of the LM approach, but also to all sorts of continuous improvement to achieve the targeted objectives.

5 Case study in the automotive sector

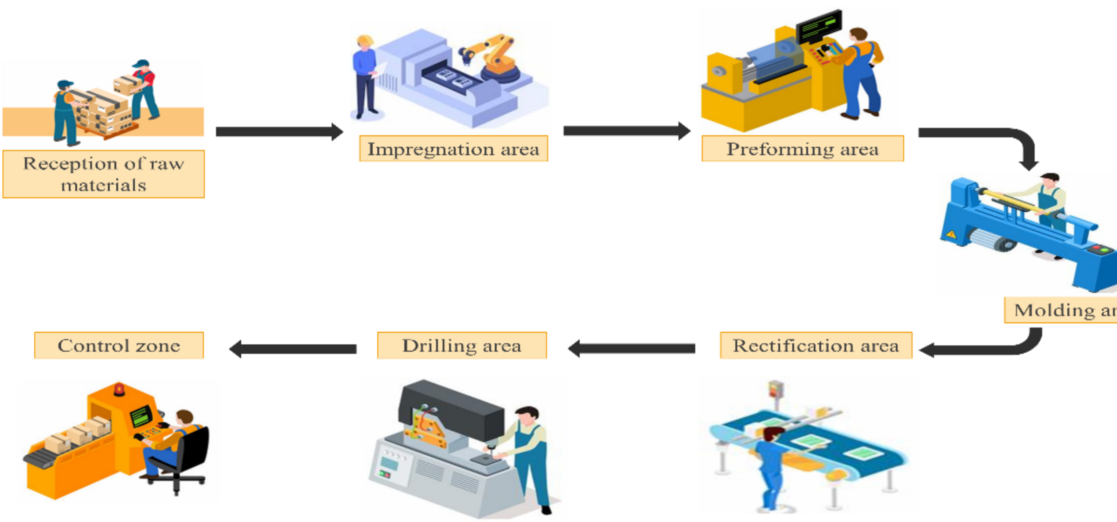
A case study proposed in Moroccan SME to deploy this concept. It is a production chain in the automotive industry. We have chosen a seven workstations production line containing two workstations with bottlenecks. So, the change in tools and stoppages in connection with bad working conditions has too much impact on the performance of the chain, Figure 8.

5.1 Context of the study

After various meetings with the company's different support services and the staff of the manufacturing line, pilot training for this new LMP model has been provided. To validate the effectiveness of this new approach, we allowed the development of an LMP project.

A multi-disciplinary team of operators, technicians, pilots, logistics, manufacturers, quality, and process engineers were formed on the suggested model (LMP, OEEP). We began by identifying the root causes of the abnormalities, information and data collecting with the supervision of the management. This first step allows the various processes of the line to be understood to eliminate defects and production stops. The safety, ergonomic and environmental failures could thus be reduced or eradicated.

Figure 8 Process of the studied production chain (see online version for colours)



5.2 Application of the proposed model

Since the firm management has started a KAIZEN initiative, we carried out a diagnostic on all the gaps identified by the team and treated as usual the QCD economic aspect for the first phase. Indeed, the adoption of single minute exchange of die (SMED) enabled us to meet the goal of decreasing changing times on two bottleneck workstations (less than 10 min by SMED). The traditional OEE improvement on this line has therefore been attained, from 77.9% to 93.9%.

In the second step, we set up small groups to monitor and detect deficiencies in all performance categories, including ESEs as outlined in our LMP approach. These factors have been collected and reported by organisations during the last two years, but no action or implementation has been taken. We therefore identified workstations in difficulty and critical operations in which maximal stops or occupational dangers are present. Table 2 summarises the outcomes of this analysis, with the aim of identifying the starting rate (ESE) and the brainstorming to determine all the actions to be carried out.

5.3 Analysis of the rates (safety, ergonomic and environment)

In particular, training, sensitisation and integration of all actors of the company had been recommended as preparatory measures by the LMP. Without ignoring the management commitment of the organisation since project start-up, we have noted the involvement of all workers during the implementation of actions to deal with the anomalies and risks identified previously. Table 2 is the outcome of the gathering and classification of all social risks (ESE). Then, we calculated τ through the equation (12), while the equations (14; 15; 16) calculated every risk indicated by the LMP team. Finally, through Equation (17) we deduce the rate (ESE).

Table 2 Calculates rates of the environment, safety and ergonomic of the initial state

	Risk or impact	*Nominal indices*							
		G_i	F_i	M_i	S_i	C_i	β_i (%)	τ_i (%)	*T(ESE) (%)*
Environment	Increase in the energy bill: natural resources	1	1	2	1	2	2.47	97.53	93.9
	Increase in the volume of landfills (cardboard and plastic): Waste	1	1	1	2	2	2.47	97.53	
	Regulatory non-compliance	0	0	0	0	0	0.00	100.00	
	Drought + water price increase	0	0	0	0	0	0.00	100.00	
	Air pollution	1	1	1	1	1	1.23	98.77	
	Floor contamination (hazardous product spills)	0	0	0	0	0	0.00	100.00	
Safety	Carabiners that are degraded and do not comply with the risks of falling parts or packaging.	2	2	1	NC	4	14.81	85.19	62.7
	Dangers related to moving equipment and materials	2	1	1	NC	2	7.41	92.59	
	Non-compliant hoist risk of falling packaging	2	1	1	NC	2	7.41	92.59	
	Risk of slipping due to the presence of oil leaks from the moulding machine.	1	1	1	NC	1	3.70	96.30	
	Danger of falling or crushing between carts and incorrectly stored packages	1	1	1	NC	1	3.70	96.30	
	Risk of tripping or injury from nuts and rails on the floor.	2	1	1	NC	2	7.41	92.59	
Ergonomics	Professional fatigue and lumbar pain (back pain)	1	1	2	NC	2	7.41	92.59	57.60
	Risk of visual problems. ending certain accidents.	2	1	1	NC	2	7.41	92.59	
	Too much displacement > 14 m/ min and weight handling >10 kg.	2	2	1	NC	4	14.81	85.19	
	Noise emitted by machines, compressors, tools, engines, etc.	1	2	1	NC	2	7.41	92.59	
	Pain related to poor posture (neck, back and upper limbs)	2	2	1	NC	4	14.81	85.19	

5.4 *Result and analysis of the OEEP*

Table 2 indicates that safety and ergonomics might be hindered by many risks which leads to random shutdowns, non-added values, unidentified rhythm reductions, and the possibility of demotivation of workers. The overall performance will be significantly impacted, particularly in economic and technical terms.

The approach taken by our new LMP model resulted in the active participation of employees in the definition of technical and social goals. This ensured the smooth running of the different phases and the success of the LM project, as claimed by Alok et al. (2018), Alkhoraif and McLaughlin (2020) and Kumar and Mathiyazhagan (2019). In fact, this atmosphere is prevalent in discussions with stakeholders, especially when the route towards progress is identified. In fact, we were given several straightforward and robust solutions in Table 2 by this production line operators to address these social hazards. For example, we can quote:

- establishment of a 5S project on this production line
- ground signalling of moving equipment location
- the ports of appropriate labour equipment must be used and respected
- establishment of a 'preventive and corrective' maintenance plan for all means and machines
- postural revisions on all stations
- workstation reorganisation and enhancement
- reviews of commitments of operators (travel, difficulties, risks, etc.)

Under the supervision of the OEEP indicator, most of the highlighted problems have been addressed after 13 weeks of the implementation of the actions. These measures have enhanced the diverse performance factors of QCDESE, in particular:

- improved ergonomic conditions for postures, motions, and undertakings
- involvement of all participants with highly beneficial social (ESE) consequences, to ensure their sustainability
- management and reduction of safety risks that are considered as hurdles to overall performance development.

We also noted that the factors (QCD) have increased the classic OEE from 93.9% to 97.3%. The results of the classical OEE and OEEP before and after the application of these enhancement measures are presented in Table 3.

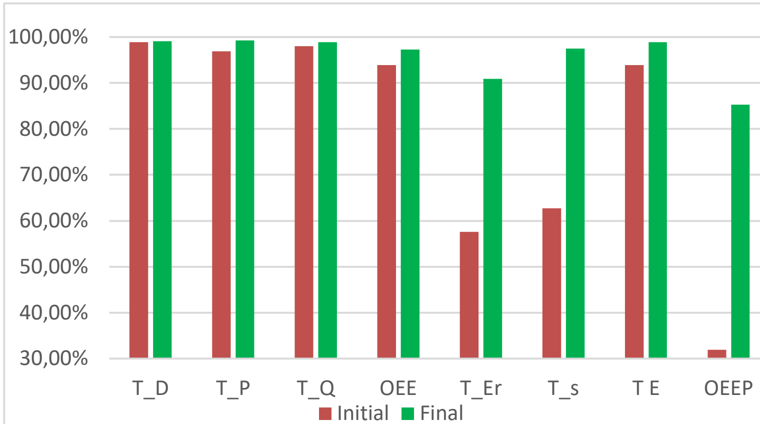
Table 3 Calculation of classical OEE and OEEP

State	*OEE classical (%)*				*OEEP (%)*			
	T_D	T_P	T_Q	*OEE*	T_{Er}	T_s	T_E	*OEEP (%)*
Initial	98.90	96.90	98.00	93.90	57.60	62.70	93.90	31.90%
Final	99. .10	99.30	98.90	97.30	90.90	97.50	98.90	85.30%

As a result, The LM team was persuaded to implement the ESE factors. This will contribute to the employee's participation and project success in all QCDESE factors.

In summary, the new LMP strategy has developed a professional structure and a team culture that enables stated targets to be achieved. We have indeed seen improvements in all the performance factors in this field and the establishment of a highly stimulating staff environment, Figure 9. The LMP strategy ensures the sustainability of these benefits through the training and integration of staff.

Figure 9 Evolution of classic OEE and OEEP (see online version for colours)



6 Conclusions

The literature analysis indicates in this research that there are several LM practices, which have a detrimental effect on business excellence, since the contribution of ergonomics, safety and environment in the company's development projects is not taken into consideration.

The implementation of our new LMP model fits more to a sustainable development approach, a well-structured performance in an inspiring framework. This LMP strategy improves product/service quality while reducing costs and the delays in any development or any continuous improvement of the LM project. The OEEP indicator was designed to monitor and control all QCDESE performance factors in order to assure the proper functioning of LMP. This innovative technique enables the benefit of LM to be exploited by preventing degradation of ESE components and ensuring their sustainability.

Lastly, LMP has been installed in the automotive industry on a production line. All QCDESE factors deliver satisfactory results. In fact, the conventional OEE was improved by 3.4% while the safety rate was boosted by 34.8%, the ergonomic rate was increased by 33,3% and the environmental rate by 5%.

Although the performance indicators are significantly improved, certain constraints have been raised, for example the social elements that have been mentioned in this article and that influence the results and success of the LMP strategy are ESE only. However, other aspects such as culture, abilities, and training must be monitored. Improving the relevance of the outcomes and upgrading the working circumstances will grow by extending these factors.

The perspective of this study is to widen LMP's scope in additional areas, both public and private to evaluate how this paradigm is integrated into other cultures and countries. Finally, to ease the computation of the OEEE, LMP needs a computer application that matches Industry 4.0, implementing the LMP.

This paper improves the research database by determining the social factors that influenced the LM projects implementation. In order to integrate this new LMP model in diverse industries and processes, the perspective of this study needs surveys that select hurdles and essential results thus, test and examine other social aspects, to integrate and determine the sources of failure to achieve the goals of an LMP project.

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Annex

$C_{max} = 3 * 3 * 3 * 3 = 81$				
Cotation	G_i	F_i	M_i	S_i
0	Minor: little influence on safety	Low: impact occurring once or several times per year or in low quantity situation	Controlled Situation	Negligible
1	Medium: impact with medium influence on safety	Medium: impact occurring once or several times per month OR in significant quantity perfectible	Situation: possible improvements	Low: the environment is less sensitive to impact
2	High: impact with significant influence	Important: impact occurring once or several times per week OR in significant quantity	Fragile situation: sensitive points not mastered	Medium
3	Major: strong influence on safety	Strong: impact occurring daily or in large quantities	Critical situation: notorious insufficiencies and / or regulatory	Deviation strong: the environment is very sensitive to the impact