Logistic and Operation Management, Vol. 2 No. 2 (2023)
https://doi.org/10.31098/lomr.v2i2.1921

Check for updates

Research Paper

Contribution of Lean Manufacturing on environmental performance in Moroccan Industry

Yassine Bouazza[1], Azza Lajjam[1]
[1]National School of Applied Sciences Tetouan, Morocco

Received: April 12, 2023	Revised: Oct 20, 2023	Accepted: Nov 18, 2023	Online: Nov 30, 2023

Abstract

In the context of globalized competition, sustainable development has become a crucial goal for manufacturers, necessitating a balance between economic, environmental, and social factors. The evolution of production system efficiencies and government policies has been pivotal in mitigating the environmental impact of manufacturing activities. This paper explores the role of Lean Manufacturing in enhancing environmental performance within organizations. It presents the concept, tools, and models of Lean Manufacturing, discussing its contribution to environmental sustainability. The paper bases its findings on a literature review and validates them through two case studies in Morocco. The first case study examines the implementation of Lean tools in a Tangier-based company, highlighting significant reductions in waste and energy consumption. The second involves interviews with managers from Moroccan automotive industries, revealing a positive correlation between Lean practices and environmental performance. The conclusion drawn is that Lean Manufacturing not only reduces pollution and energy consumption but also boosts productivity, thus aiding companies in becoming more profitable and environmentally responsible.

Keywords *Lean Manufacturing, Environmental performance, Industry*

INTRODUCTION

Thanks to Lean manufacturing, companies have reduced waste efficiently and increased profitability. However, with new environmental concerns, companies have started focusing on sustainable development to respect future legislation and adopt environmentally friendly policies.

Lean manufacturing can be defined as doing more with less. Based on the Toyota Production System, Russell and Taylor (1999) define waste as anything other than the minimum amount of equipment, effort, materials, parts, space, and time essential to add value to the product.
Lean Manufacturing eliminates activities that consume resources without creating Value, called wastes.

However, the objective is to understand if lean practices may lead to sustainable development and analyze the relationship between Lean Manufacturing and environmental performance.
The literature review will analyze the relationship between one or some of the lean practices and the environmental performance.

In parallel, the presented hypothesis will be tested with two case studies done in Morocco. Regarding the outcome of these studies, most of them pointed out a positive relationship between

Corresponding author's email: yassinbouazza@gmail.com

lean manufacturing practices and improvements in environmental performance.

LITERATURE REVIEW

Lean manufacturing aims to improve the performance of processes by exploiting the methods, techniques, and practices already available to industrial production managers. In addition, in the literature review, the contribution of these tools to environmental performance will be studied.

Lean Model

Lean manufacturing can be defined as doing more with less; based on the Toyota Production System, Russell and Taylor (1999) define waste as anything other than the minimum amount of equipment, effort, materials, parts, space, and time that is essential to add value to the product.

Taïchi Ohno (1988), the founder of the Toyota Production System, has defined 3 families of wastes:

- Muda (task without added value but accepted)
- Muri (excessive task, too complicated, impossible)
- Mura (irregularities, fluctuations)

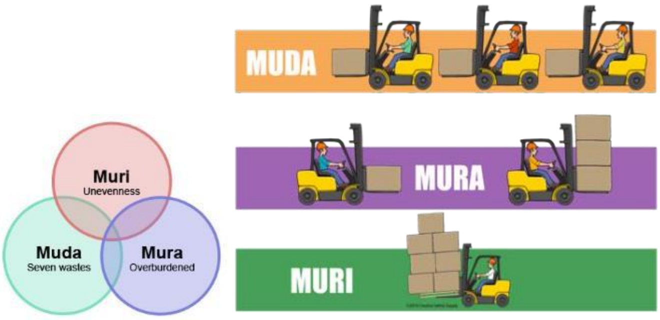

Figure 1. 3 Families of wastes

Taïchi Ohno (1988), in his research on Lean Manufacturing, presented in Table 1 Seven types of waste: overproduction, inventory, mistakes, quality defects, waiting, over-processing, unnecessary transport, and unnecessary movement. Currently, seven types of waste are enriched by yet another – untapped potential employee, Womack & Jones (1997).

Form	Description
Overproduction	Instance of producing too much of something
Human resources	Not getting people involved
Transportation	Unnecessary moving of products
Inventory	materials or information, includes WIP and finished goods
Motion	Excess of people's movement of people
Corrections	Reworking and repairing products
Over-processing	Additional work and task above the requirements
Waiting	Time delays for information or people and materials.

Table 1. Lean Model

Overproduction:

- Produce more than the customer's needs.
- Produce before the order.

- Perform a task that does not meet any demand or customer requirement. Worst waste because other sources of waste
- Causes slowing or even stopping of the flow.

Example of overproduction:
- Unsuitable batch size, producing too many pieces that will end up in the stock or the trash!
- Produce an unnecessary document or report.
- Double indicator entry.
- Develop an IT tool that is too complex for the client's needs.
- Prepare training that is too complicated and too long for the target population.
- Drugs sold in fixed quantities, not retail.

Overstocking or Unnecessary Stocks :
- Everything that is not essential to completing the task at the right time.
- Caused by overproduction, but also poor planning.
- Caused by unmaintained wait times. Capital immobilized.
- Occult and prevents problem-solving.

Examples of overstocking:
- Stock dead due to poor sales forecasts.
- Expected files, often because of a multitasking organization.
- Invoices, pending expense reports.
- IT features not finalized.
- The printing of training materials is more significant than the number of participants.
- Stocks of medical equipment are in hospitals for fear of lack.

Useless Transportation and Travel:
- Moving materials, parts, products, documents, or information that does not bring value to the customer.
- Consumer of resources and time.
- Risk of degradation.

Examples of unnecessary transportation and travel:
- Make a trip "empty."
- Intermediate storage that requires 2 transports.
- Send an e-mail to an extensive distribution list, even though the subject only concerns a few people.
- Document signing path for validation.
- Training, meeting in a place far from the participants.
- Moving patients to a hospital.

Useless Treatments or Sur-processing:

- Tasks steps are done for nothing.
- The process is too complex compared to the selling price.
- Too much quality, too much material, too much information.
- Lack of clear and standardized instructions or specifications.

Examples of unnecessary treatments:
- There are too many controls in the manufacturing process.
- Use two packages instead of one
- Reports too long, too complete, too perfect.
- Unnecessary meetings, with a lot of blah blah.
- Validation process requiring too many signatures.
- Computer programs are too long and complicated to use.
- Dashboards with too many useless indicators.

Useless Movements:
- Movement of natural persons, useless and which does not bring value to the customer.
- Caused by poor ergonomics of the workstation.
- Bad storage, mess, disorganization.
- Material or information incorrectly listed.

Examples of unnecessary movements:
- The toolbox is incomplete, requiring multiple roundtrip maintenance technicians.
- Lack of printers or photocopiers and poor positioning generate user displacements.
- Computer directories are poorly organized and not up-to-date.
- Need to move to collect information.
- Outlying nurses' office.

Errors, Faults and Rebuts:
- Defects that require retouching, additional control, scrapping, customer dissatisfaction ...
- Customer return
- Loss of time and money and risk of being unable to provide for the customer.
- Loss of credibility.
- Do it right the first time.

Examples of errors, defects, and rejects:
Product that does not comply with customer requirements (aesthetics, use, breakdowns ...)
- Errors in data entry
- Breaks, accidents
- Computer bugs
- Lack of hygiene in a hospital

Waiting time:
- Products or people who have to wait between 2 tasks or steps.
- Idle operator while the machine is running or during an interruption.
- Slow machine rate.
- Serial change time too long.

- Incorrectly synchronized steps.
- Bottlenecks.

Examples of waiting times:

- Operators are inactive during a machine failure due to lack of training or precise instructions.

- Time required recycling a room.
- Sending and receiving mail to validate a decision.
- Calculation processing time.
- Person late for an appointment.
- Administrative tasks impacting the care of patients.

Lean Tools

This review will present articles on tools and methods of lean manufacturing such as VSM, 5S, SMED, Kanban, and Kaizen philosophy by Taïchi Ohno (1988).

Table 2. Lean tools

LEAN WASTE REDUCTION TOOLS AND TECHNIQUE (MOST KNOWN)
5S
Value Stream Mapping (VSM)
Kanban
Kaizen
Pokayoke
SMED (single minute exchange of dies)
Total Productivity Maintenance (TPM)

Value Stream Mapping (VSM) is a tool for instantly mapping a company's physical and information flows. This is generally done within the company itself, although it is initially planned to be carried out throughout the supply chain.

In a Lean transformation, VSM will be the first step to achieve. It will give the company a holistic overview of the current state of the process.

5S method:

The 5S organization method is not just a tool or a methodological approach but a culture that must be implanted to improve the environment and working conditions continuously. Each person, from top to bottom of the hierarchy, is thus targeted.

SMED – Single Minute Exchange of Die:

During a manufacturing change, the starting part (the beginning of the manufacturing process) can represent an essential part of the manufacturing process, and the setting part is unproductive. The goal is to reduce time spent tuning for quick tool changes or instant adjustments.

There are two types of adjustment:

- Internal settings/times: they correspond to operations that are done machine stopped, so out of production.
- External settings/times: They correspond to operations done (or can be done) by the machine in operation, so production.

Standardized Work:

Standardized work is a set of validated and accepted procedures that define the best and most reliable practices, the steps of each process, and the tasks of each employee. Standardized work is a tool to use human resources and machines best while maintaining a production rhythm adapted to customer demands. Any step in a Lean Manufacturing process should be defined and practiced repeatedly and identically. Variations in a function will create quality problems, which will be expensive to repair. The standard work will determine the most efficient production methods using equipment, people, and materials.

TPM – Total Productive Maintenance:

TPM is a company policy whose interest is reinforced by the end of mass production. On the one hand, making profitable, costly equipment with small-batch production is more challenging. On the other hand, the increasing cross-functionality of functions.
If we tackle waste, producing more and better without additional productive investment is possible. This observation permeates all Japanese methods, and if it is brought back to the driving of machines, it means seeking to maximize adequate time, reduce non-productive time due to stops and failures, maintain optimal speeds, and reduce non-quality. TPM uses these three levers: availability, performance, and quality.

Kanban:

The Kanban method imposes a pull flow system triggered by the client's consumption. It is, therefore, a matter of producing a requested product when requested and in the quantity ordered.

It is, therefore, necessary to limit the production of a post upstream of a line of work to the exact needs of the post downstream. The downstream station must only produce to meet customer demand. The Kanban system is. Therefore, the information system that makes it possible to trace downstream upstream needs quickly.

The Kanban approach allows for visually controlling the workflow. It is about observing how the company works to improve it later. In addition, this flexible method allows the team to suspend the production process at any time to solve a blocking problem or an emergency.

Poka-Yoke:

Poka-Yoke is a system which, when properly designed and properly used, cannot allow any error, be it human or mechanical, to occur. A sound keying system must make it possible to achieve "zero defect." It must have the purpose of eliminating the quality controls that are present to detect production defects. Implementing a keying system in a process already in place is complex. For this reason, it is interesting to incorporate an anti-error system in developing the process. A keying system is put in place to prevent any conceivable defects. A poka-yoke should allow the operator to focus on his work without the need to do unnecessary actions for error prevention.

Contribution of Lean Manufacturing on Environmental Performance

King and Lenox (2001) demonstrated that lean manufacturing could decrease pollution costs—their study was based on a sample of US companies from 1991 to 1996. The survey's results confirm its hypotheses, which correlated lean manufacturing to environmental practices.

Chiarini (2014) empirically observed five European companies engaged in lean and environmental management that produce motorcycle components. The ecological impacts of the production processes of the five companies were observed and measured before and after the implementation of Lean tools: Value Stream Mapping (VSM), 5S, Cellular Manufacturing, Single Minute Exchange of Die (SMED), and Total Productive Maintenance (TPM). The Analysis of the before and after quantitative results shows that VSM, In particular, is used to map the environmental impacts of production processes. 5S can help reduce oil leakage and improve waste management. Cellular manufacturing will lead to a decrease in electricity consumption. In addition, TPM can help minimize the impact of machines, such as oil leakage and emissions of dust and chemical fumes into the atmosphere.

Boson et al. (2023) presented the Assessment of Green Supply Chain Management Practices on Sustainable Business in Ethiopia; their study concluded that GSCM procedures strengthen managerial innovation leadership, boost organizational efficiency, and enhance the company's reputation. By ensuring that goods are delivered on schedule and by standards of quality, supply chain visibility seeks to improve overall performance.

Faulkner and Badurdeen (2014) focused on the environmental impacts of an essential lean production tool, Sustainable Value Stream Mapping (SVSM). SVSM is an extension of conventional VSM that adds energy-related metrics to value stream maps. The study aimed to present a comprehensive methodology to develop SVSM by identifying suitable metrics and methods to present it visually. The SVSM methodology was validated through a case study of a local manufacturer of television satellite dishes. The most significant result of the study was that the proposed SVSM method is considered adequate in the visual evaluation of production lines' sustainability performance.

In addition, Pampanelli (2014) proposed a new model called the Lean and Green Model that integrated environmental sustainability into lean thinking. The model used a Kaizen approach to improve energy flows in poor manufacturing environments. The model was designed for and was limited to the cell level, the first stream level of a manufacturing business that supports the principles of the lean thinking model. The model was validated using a case study of a major global engineering company that services Brazil's automotive and aerospace industries in 2011. The critical finding of their research was that this model increased productivity as it could reduce resource use from 30 to 50% on average and had the potential to reduce the total cost of energy flows in a cell by 5 - 10%.

In the same direction, Ng, Low, and Song (2015). It proposed an approach that integrated metrics derived from Lean and Green implementation in one “Carbon-Value Efficiency” metric. Using a case study of metal stamped parts production, the results showed that Carbon-Value Efficiency can be improved by 36.3%, given an improvement in production lead time by 64.7% and a reduction in carbon footprint by 29.9% Abu-Bakr et al. (2017).

Also, Thanki Govindan & Thakkar (2016) applied an analytical hierarchy process approach to investigate the impact of selective lean (TPM, Kaizen, and 5S) and green practices (ISO 14001, 3R, and DFE) on the overall performance of Indian SMEs. Data were collected through a questionnaire to a sample of eleven industrial experts and one academic expert in some Indian SMEs. The results concluded that total productive maintenance (TPM) was the most critical lean practice, while ISO 14001 was the most significant green practice. In addition, On-time delivery/ quality control was the most critical criterion for leanness, and a reduction in emissions/energy consumption was the most essential criterion for greenness, Abu-Bakr et al. (2017).

In the same context, Chiarini (2014) and Vinodh, Arvind, and Somanaathan (2010) stated some lean principles/tools and the sustainable benefits of each one. This is cleared, as shown in table 3.

Lean principle/tool	Sustainable benefits
Just in time	Reduction of work-in-process, Elimination of perishable products that can generate waste , Optimization of space use.
Cellular manufacturing	Reduction of change-over and set-up time for the references Energy consumption reduction, Energy consumption reduction, reduce defects
Value Stream Mapping	Reduction in waste through fewer defects, Optimization of resources use
Total preventive maintenance	Reduction of hazardous waste caused by spills and leaks of equipment's, extend life of machines du maintenance
5S	Reduction in lighting consumption when having clean windows, reduced over use of materials.
Six sigma	Products have more reliably & durability with less defects so less wastes generated
Pre-Production planning	Reduction of waste at design stage, usage of right sized equipment's, reducing the complexities of production processes and product design.
Kaizen	Eliminates non-value-added activities and hidden wastes
Visual controls	Identification and elimination of unnecessary departments, so less material usage and wastes.
Lean supplier networks	Existing suppliers using lean manufacturing can contribute to an environmental benefits.
PoKa YoKe	Less scrap and less waste due to reduction of defects or detection in a prior phase

Table 3. Environmental benefits of lean principles

The Environmental Protection Agency (EPA) discussed a correlation between the seven types of lean waste and the environmental impacts they can create, as shown in Table 4.

Table 4. Environmental impacts linked with type of manufacturing waste

Waste type	Environmental impact
Defects	Raw materials consumed in making defective products. Defective components require recycling or disposal. More space required for rework and repair, increasing energy use for heating, cooling, and lighting.
Waiting	Potential material spoilage or component damage causing waste. Wasted energy from heating, cooling, and lighting during production downtime.
Overproduction	More raw materials consumed in making the unneeded Products. Extra products may spoil or become obsolete requiring disposal.
Movement and transportation	More energy use for product transportation. Emissions from transportation. More space required for work-in-process (WIP) movement, increasing lighting, heating, and cooling demand and energy consumption. More packaging required to protect components during movement.
Inventory	More packaging to store WIP. Waste from damage to stored WIP. More materials needed to replace damaged WIP. More energy used to heat, cool, and light inventory space.
Complexity and over processing	More parts and raw materials consumed per unit of production. Unnecessary processing increases wastes, energy use, and emissions

METHODOLOGY

The first case study is a project implementation of LM Tools on a company located in Tangier, Morocco, and it discusses the results.

The second case study will use empirical evidence and opinions collected from Industrial leaders/practitioners from Morocco, carefully selected to represent a diverse range of industrial backgrounds/experiences and interviewed independently.

FINDINGS AND DISCUSSION

Case Study 1: Energy Management in a Moroccan Manufacturing Plant through Audits.

The chosen industry is a company located in Morocco Tangier.

This company produces ceramic products, which need an essential amount of energy.

A detailed analysis of the quality of the power supplied by the electricity distributor at the level of the electrical network, both on the supply side (transformer stations and low voltage general panel) and at the level of the plant's divisional cabinets and rotating machines. To this end, all the anomalies responsible for electrical losses leading to overconsumption and overbilling have been identified.

Results

1. Electric motors:
   Replacement of standard IE1 class motors with IE3 class high-efficiency motors.
   - Analysis :
     - An inventory of electric motors has been made. The majority of Motors are Class IE1.
     - The installed capacity is 1,998 kW.
     - There are 649 motors installed and a total power of 3264 kW.
   - Proposed Improvement:
     - Installation of variable speed drives (VSD) on variable load machines.
     - Use high-efficiency motors in case of replacement (class IE2 or IE3).
     - Replacement of motors rewound more than 2 times.

2. Compressed air:
   Sealing of compressed air leaks
   - Analysis :
     - 5 compressed air compressors. The total power of these compressors is 626 kW.
     - Sealing the leaks will reduce the power consumption of the compressors by up to 10%.
     - The absence of compressed air flow meters: Consumption can neither be known nor controlled.
     - The pipes between the compressors and the storage tank are not flexible.
     - The GA 90 VSD compressor sub-meter is defective.
     - Several leaks exist in the circuits, equipment, fittings, junction, and pressure switch.
   - Proposed Improvement:
     - Installation of air flow meters connected to a control room;
     - The air flow meter is for monitoring the efficiency of the compressors.
     - Installation of network pressure indicators (possibly linking them to the control room).
     - Install traps at low points in the air system.
     - Repair of the electrical sub-meter of the GA 90 VSD compressor.
     - Installation of new sub-meters upstream of the compressors connected to a central measuring station
     - Conduct a leak detection campaign and proceed to sealing (periodic).

- Conduct a compressed air leak detection campaign.

3. Potential Gain:
   500.000 kW / year, which is almost 50 Keur /Year with an initial investment of 70 euros, with the return on investment in less than 2 years.

Discussion:

Even though lean tools are nowadays considered standard tools, the study shows that these tools contribute to reducing cost and help the company be environmentally friendly". Such projects are closely related to operating costs. Therefore, analyzing the long-term benefits from economic and environmental perspectives is essential.

The case study shows considerable savings by implementing some maintenance improvements.

It should also be noted that an initial investment would be required to install the motors; however, savings and a reduction in annual energy consumption can determine the breakeven point. With the ever-increasing energy demand, energy costs will tend to evolve in the future, and regulations will be stricter. Only factories committed to green will overcome these changes. Therefore, It is becoming increasingly important for companies to assess their energy consumption through regular audits and adopt sustainability.

Additional costs could be saved energy and reduce gas emissions by implementing photovoltaic systems (Gandhi et al., 2022)

Case Study 2: Assessing the Relation of Green Manufacturing and Environmental Performance in Moroccan Automotive Industry

Quantitative data method collection has been used for this study. The main objective of this research is to give an in-depth understanding of organizations in Morocco related to lean manufacturing and environmental performance based on questionnaires held by similar studies (Syafriana Effendi et Al., 2023) & (Olawale Gazal Hammed, 2018).

This study includes 50 automotive sector employees; more than 100 manufacturers were contacted. Note that this manufacturing sector is usually explored in the sustainability literature. The choice of the automotive industry was predetermined to confirm that companies have already used one or some lean tools.

The companies surveyed are in the region of Tangier and Kenitra in the north of Morocco, where almost all automotive companies are located.

Data collection was primarily conducted using open-ended surveys with managers inquiring about manufacturing and environmental practices inside their company. All the interviewees were debriefed to ensure they had the same understanding of the context of the study. Physical business characteristics such as company age and size (number of employees) were also noted.

The nature of the study made it appropriate to use a non-probabilistic purposive sample. Thus, this paper does not attempt to draw statistical generalization from the results; instead, it presents empirical evidence about how manufacturing companies in Morocco's automotive sector carry out production management and environmental practices. It should be mentioned that this study merely focuses on the type of practices used and does not investigate their implementation process.

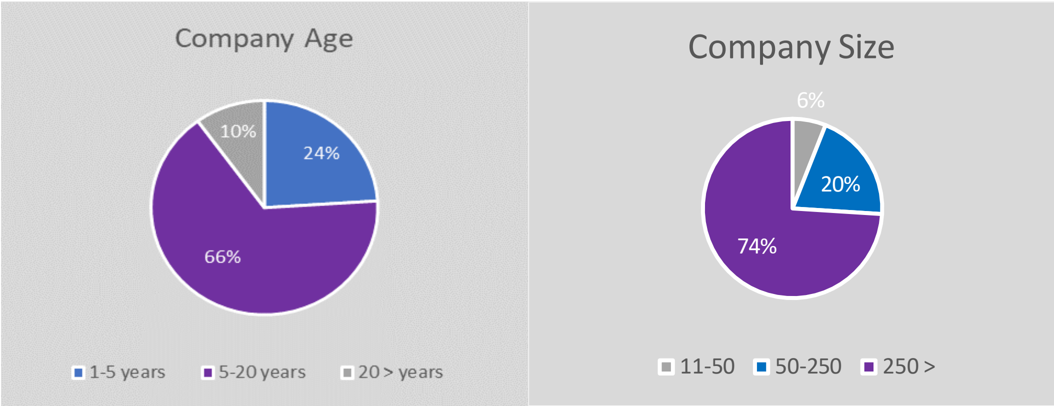

Figure 2. Age and size of manufacturing companies

From this first data, 90% of automotive companies are under 20 years old, and only 10% are above. Most companies started their implementation when Renault automotive constructors settled in 2008 and started their production in 2012, and after that, the second constructor, Peugeot- Citroen, was established in 2018. For the size of companies, 74% have more than 250 workers. This can be explained by the type of industry which requires a large workforce.

Results:

This section presents the empirical findings and discusses the environmental and manufacturing practices found in the evaluated manufacturers.
Figure 3 shows the number of respondents related to the impact of lean manufacturing on environmental performance.

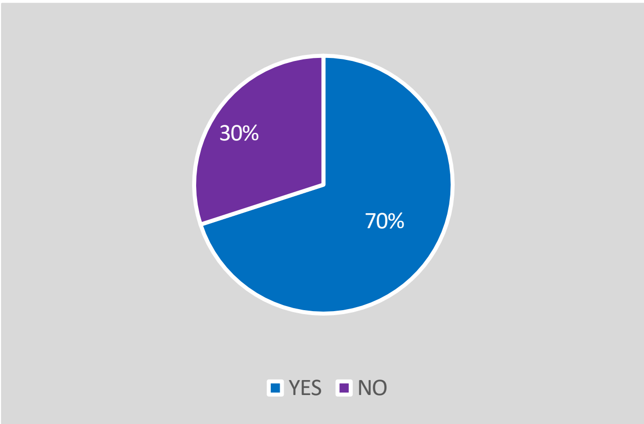

Figure 3. Relation between lean manufacturing (LM) and environmental performance (EP)
The majority, 70%, acknowledge the positive contribution of LM towards EP.
The respondents' opinion leads to a conclusive relationship between LM and EP. The respondents believed that the development of both concepts is related and shares similarities, even though they may have different focuses, one being on production/service optimization cost-effectively and the other being on environmental improvement, with a much broader perspective than just the economic benefit.

However, they believe they seem to relate to the practical output. Participants believe in the synergies between LM and EP, but there is mixed reasoning on the linkage between the seven wastes of LM and EP.

Q: What do you think about the impact of the implementation of these practices on your company's sustainable performance?
All the majority acknowledge the positive contribution of LM toward EP.
Some examples shared by respondents are:

- Implementing these practices can significantly impact the company's productivity and resource optimization.
- The implementation of these practices will have a significant impact on global performance.
- These practices allowed our company to improve processes and activities by minimizing waste and resources.
- The Use of metallic packaging instead of wooden was adopted under lean due to the short lifecycle and less durability of wooden pallets. This improved EP by utilizing reusable material (metal) and preserving resources by not using wood.
- The increase in several products per palette through packaging optimization has reduced the number of deliveries and thus contributes to reducing the Emission of CO2 and fuel Consumption.
- The adoption of the JIT concept has helped to minimize the obsolescence of products that were scrapped, generating environmental impact.
- The utilization of Kanban systems to optimize supply to the following works station and reduce the usage of Clarks by reducing their movements.
- optimizing robot paths in the assembly line reduces the use of energy and raw materials and reduces toxic discharges.
- The application of TQM helps reduce defective products, thus resulting in the preservation of energy consumption for repair and waste generation.
- Optimization of oven temperatures helped reduce energy consumption.
- The localization of suppliers near automotive manufacturers has helped to work just in time, which helps to reduce the storage area and energy consumption.

- The implementation of JIT has helped to eliminate old stock and obsolete that are generated during changes or modifications of products and that were scraped
- In our case, more than 30% of kaizen projects have a direct or indirect impact on the optimization of energy consumption
- The installation of automatic lighting has reduced energy consumption
- The 5S has directly contributed to better waste management
- Lean tools can reduce waste and, subsequently, the generation of waste
- Optimization of the injection process has reduced the use of raw materials
- The modification of the molds made it possible to reduce the number of scraps in the stamping plant and to generate less waste
- The reorganization of plant layout and process flow has made it possible to reduce forklift flow
- Reduction in wood and cardboard packaging has resulted in less waste.
- Replacing paper tape with reusable elastics has reduced waste

Discussion:

The automotive industry plays a vital role in the economy and provides opportunities for employment and better working conditions. The study explains whether Lean Manufacturing influences the environmental performance of the Moroccan automotive industry. The results reveal significant positive effects of Lean on sustainability benefits. These results show that Lean Manufacturing can be used to achieve sustainability.

The positive relationship between Lean Manufacturing and performance is already established from previous work, and this study further confirms this in Moroccan automotive companies (King & Lenox, 2001), Chiarini (2014); The positive relationship of Lean Manufacturing and performance is already established from previous work (Abu-Bakr et al. (2017)) and (Muñoz et al., 2018) this study further confirms in Moroccan automotive companies. The results are significant as one of the developing countries where automobiles play a crucial role, and authorities promote sustainable development.

CONCLUSION

Based on the previous studies presented above, the impact of Lean manufacturing on environmental performance can be summarized as follows:

Table 5. Effect of 7 wastes lean on environmental performance

Lean Waste	Impact	Benefit
Overproduction	Perform a task that does not meet any demand or customer requirement. Generate extra waste and emissions.	Without overproduction, we can reduce energy consumption and raw material use and generate overstocks that can become waste.
Over-processing	Over-processing leads to the use of extra parts and raw materials to produce the same part, generating more waste and energy consumption	Improving processing to use the necessary materials for production reduces waste and emissions.
Waiting	I am waiting to contribute to the over-use of energy such as electricity and heating. It can cause damage to some unique parts.	Reduce lead time, which will contribute to better energy use.
Transportation	Transportation leads to extra consumption of energy and, therefore, extra emissions.	Optimizing transportation leads to reduced costs and less energy use.
Inventory	An inadequate inventory can generate outdated and non-conforming parts that will become wastes and should be thrown away. In addition, they have a significant inventory demand for additional energy.	With less product inventory, organizations can use their plant space more efficiently (saving heating and cooling demands) while consuming less packaging and raw materials. Lower inventory levels also reduce the risk of waste due to obsolescence and undiscovered defects.

Defects	Defect parts generate waste and demand extra energy or material for repair or new production.	Minimizing product defects means organizations are using fewer raw materials to manufacture products, which equals less energy consumption.

Motion	Motion requires more space, increasing heating, cooling, and lighting demands. It can also increase the time to produce a product, resulting in increased energy requirements.	Reducing any effort of lifting things unnecessarily for the needing to walk an excessive distance back and forth to find tools or complete a task means the organization will use less energy.

Source: Hallam & Contreras (2016)

After examining the relationship between lean and green practices and their impact on environmental performance, some important conclusions can be presented:
Most of these studies confirm the relationship between one or some of the lean practices and environmental performance. In addition, these studies were applied to different business environments. The USA, Europe, India, Brazil, and Morocco are among these environments.

Regarding the outcome of these studies, most of them pointed out a positive relationship between lean manufacturing practices and improvements in environmental performance. To confirm this relationship, the First presented case study shows tremendous savings and reduced energy consumption by applying lean tools.

The main aim of the second case study is to assess the relationship between Lean and environmental performance through the interview. Managers should follow these systems and methodologies to keep the innovation strategy. The interview result generally shows a relationship between lean manufacturing and environmental performance.

These studies are a starting point for future research in the same region. They contribute to the actual discussion in the literature on environmentally friendly manufacturing by demonstrating that companies could efficiently engage in proactive participation in environmental management inside their organizations if they use lean manufacturing practices.
In conclusion, although this study brings some evidence regarding environmental management within manufacturing companies, future studies should consider other methodologies contributing to adopting proactive environmental activities. Researchers and academics should continue investigating the interrelationships between the practices described in this paper.

REFERENCES

A. Chiarini (2014) “Sustainable manufacturing-greening processes using specific Lean Production tools: An empirical observation from European motorcycle component manufacturers.” Journal of Cleaner Production, Vol. 85, pp. 226-233, 2014. https://doi.org/10.1016/j.jclepro.2014.07.080

A. King, M.J Lenox, (2001). “Lean and Green? An Empirical Examination of the Relationship between Lean Production and Environmental Performance”. *Production and Operations Management*, Vol. 10, pp. 244–256, 2001. https://doi.org/10.1111/j.1937-5956.2001.tb00373.x

A. Pampanelli, P.Found& A. Bernardes. (2014) “A Lean & Green Model for a Production Cell.” Journal of Cleaner Production, Vol. 85, pp. 19-30, 2014. https://doi.org/10.1016/j.jclepro.2013.06.014

C.R.A. Hallam, C. Contreras (2016). “The Interrelation of Lean and Green Manufacturing Practices: A Case of Push or Pull in Implementation, "2016 Proceedings of PICMET '16: Technology

Management for Social Innovation the University of Texas, San Antonio, USA. https://doi.org/10.1109/PICMET.2016.7806669

G. Hammed Olawale (2022) "Assessment of Supply Chain Management Practices and Sustainable Food Security in Nigeria" Logistic and Operation Management Research (LOMR) 1. 52-64 https://doi.org/10.31098/lomr.v1i2.1059

J.P. Womack, D.T. Jones (1997). "Lean Thinking: Banish Waste and Create Wealth in Your Corporation." *Journal of the Operational Research Society,* Vol. 48, pp. 10–57, 1997. https://doi.org/10.1038/sj.jors.2600967

L. Boson, Z. Elemo, A. Engida, S. Kant (2023). "Assessment of Green Supply Chain Management Practices on Sustainable Business in Ethiopia." Logistic and Operation Management Research (LOMR). 2. 96–104. https://doi.org/10.31098/lomr.v2i1.1468

M. A. Abu-Bakr, M.G. Abdel-Kader, A.F. Elbayoumi (2017). "Measuring the Impact of Lean Manufacturing Practices on Sustainability Performance: A Proposed Model " Cairo University International Conference on Business Sciences (CUCBS 2017): Roadmaps for Sustainable Businesses: Cairo, Egypt. https://doi.org/10.2139/ssrn.3633507

M. Syafriana Effendi, V. Firdaus, N. Edi Utami, J.Apri Emarawati, D. Maison, Roosdiana (2023)
"School Environment Impact on Entrepreneurial Intention Mediated By Financial Literacy and Entrepreneurial Characteristics." *International Journal of Entrepreneurship and Sustainability Studies* (IJEASS), Vol. 3 No. 1 (2023). https://doi.org/10.31098/ijeass.v3i1.1554

O. Gandhi, & Rodríguez Gallegos, Carlos & Zhang, Wenjie. (2022). "Life Cycle Greenhouse Gas Emission Assessment of Photovoltaic System in Indonesia." Logistic and Operation Management Research (LOMR). 1. 77-88. https://doi.org/10.31098/lomr.v1i1.969

R.S. Russell, B.W. Taylor (1999). "Operations management creating value along the supply chain." Allyn & Bacon, 3rd edition, 1999.

R. Ng, J. Low & B. Song (2015). "Integrating and implementing Lean and Green's practices based on the proposition of Carbon-Value Efficiency metric." Journal of Cleaner Production, Vol. 95, pp.242–255, 2015. https://doi.org/10.1016/j.ijpe.2018.03.030

S. Thanki, K. Govindan, K. and J. Thakkar (2016). "An investigation on Lean-Green implementation practices in Indian SMEs using analytical hierarchy process (AHP) approach." Journal of Cleaner Production, Vol. 135, pp. 284–298, 2016. https://doi.org/10.1016/j.jclepro.2016.06.105

S. Vinodh, K. Arvind, M. Somanaathan (2010). "Tools and techniques for enabling sustainability through Lean initiatives." Clean Technologies and Environmental Policy. Vol. 13, pp. 469-479, 2010. https://doi.org/10.1007/s10098-010-0329-x.

T. Ohno (1988). "Toyota Production System: Beyond Large-Scale Production" Productivity Press.

US EPA. (n.d.). US EPA. [Online] Available at: https://www.epa.gov/

V. Muñoz, J. Andrés, Santos, E. Viles, M. Ormazabal (2018) "Manufacturing and environmental practices in the Spanish context." Journal of Cleaner Production. Volume 178, pp 268–275, 2018. https://doi.org/10.1016/j.jclepro.2018.01.026

W. Faulkner and F. Badurdeen (2014). "Sustainable Value Stream Mapping (Sus-VSM): Methodology to visualize and assess manufacturing sustainability performance." Journal of Cleaner Production, Vol. 85, pp. 8–18, 2014. https://doi.org/10.1016/j.jclepro.2014.05.042