Methodology for Eliminating Waste Combining Lean Logistics and 4.0 Technologies With a Case Study of a Warehouse of a Food Company

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Abstract

The combination of Lean and 4.0 technologies in logistics is more and more presented as an essential solution to improve productivity and guarantee the economic performance of the supply chain. Several organizations have already implemented, either completely or partially, solutions based on the Lean approach. The two approaches are different and do not lead to the same desired performance results. Big questions are currently being asked if the two methods are complementary or independent and what is the right approach to implement Lean Logistics 4.0.For the development of Lean Logistics 4.0; this research work presents a methodology that combines Lean Logistics and 4.0 technologies in three steps: diagnosis, integration of Lean tools and 4.0 technologies.

Keywords

Logistics 4.0, Industry 4.0, Lean, Technologies, Warehouse.

1. Introduction

The improvement of the supply chain processes is one of the first concerns of the logistics principals: always minimize the cost, satisfy the customers, ... One of the most successful optimization approaches applied in industry is undoubtedly the Lean approach, which was born in Japan at Toyota in the 1950s, after the Second World War (C. Roser et al. 2016). With the increased competition of car manufacturers and extended logistic chains with several participants, operations are becoming more and more complex. In this context a new system was invented: the "Toyota Production System", or TPS, to efficiently organize manufacturing and logistics, including interaction with suppliers and customers to minimize costs and waste. The system is also known by the more generic terms "Lean Manufacturing" and "Just-in-time production". This TPS organization model is less pyramidal and relies on collective intelligence (C. Roser et al. 2016). An extension of Lean Manufacturing, Lean Management, allowing the optimization of the business strategy and related management methods (production management, personnel logistics management, etc.), based on the Japanese continuous improvement process called "Kaizen" (R. J. Schonberger 2019).

The practice of Lean has become an essential way of industrial and logistic competitiveness worldwide. It allows to reduce costs without relocating, relying on the involvement of the company's people to identify and eradicate problems (P. Bédry 2009).

At the same time, a new paradigm called Industry 4.0 or the fourth industrial revolution has recently emerged in the manufacturing and logistics sector. It enables the creation of an intelligent network of machines, products, components, properties, people and ICT systems across the value chain to have a smart factory. This paradigm offers new perspectives to companies on the elimination of waste in both production and logistics. The combination of these two production paradigms, called Lean 4.0, will be the subject of our study.
Lean Logistics consists of identifying and eliminating activities that do not add value to the Supply Chain, its objective is to eliminate all types of waste and reduce inventories and cycle times so as to accelerate flows, reduce costs and provide better responsiveness to the supply chain, it is said that Lean Logistics allows a company to optimize its logistics (M. Daniel 2006).

1.1 Objectives

The objective of this work is to develop a Lean Logistics 4.0 method, simple to implement in the warehouse to reduce waste while combining Lean tools and 4.0 technologies. This approach will be developed in three steps, diagnose the different processes of the supply chain it is 'a warehouse of a food company of drinks in our case, implement the principles of Lean and implement the 4.0 technologies. To validate this approach, we will apply it to a food company that has a warehouse that has technical and management difficulties to better manage its warehouse and meet customer expectations.

2. Literature Review

With the emergence of the fourth industrial revolution known as Industry 4.0 to connect the physical world to the virtual world, there are many opportunities to integrate and connect supply chain processes and their respective resources to increase performance in terms of time, money and resource utilization. As digitalization is the trend where everything is connected, a new version of Lean has emerged: Lean 4.0. It is a combination of Industry 4.0 technologies and Lean Logistics principles that allows to fully exploit the benefits of both paradigms(M. Daniel 2006). A study was conducted on the SCOPUS platform to find out the number of publications of the different technologies in Lean Logistics 4.0. The results of this study are illustrated by the graph above figure 1.

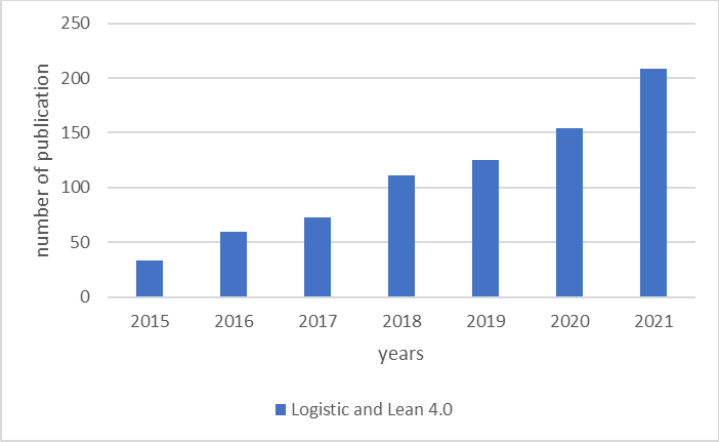

Figure 1. Numbers of publications between 2015 and 2021 on Lean Logistics 4.0

According to our research study, the number of publications on Lean Logistics 4.0 has evolved progressively over the years, surely due to the importance of this field in Industry 4.0. Lean is a widespread approach to improve industrial performance, and its integration in logistics represents an important field of progress for manufacturers. We notice that the publications on Lean Logistics are still weak compared to those on Lean Management (LM). This fact makes our study even more important, as it could potentially be the subject of a lot of research work.

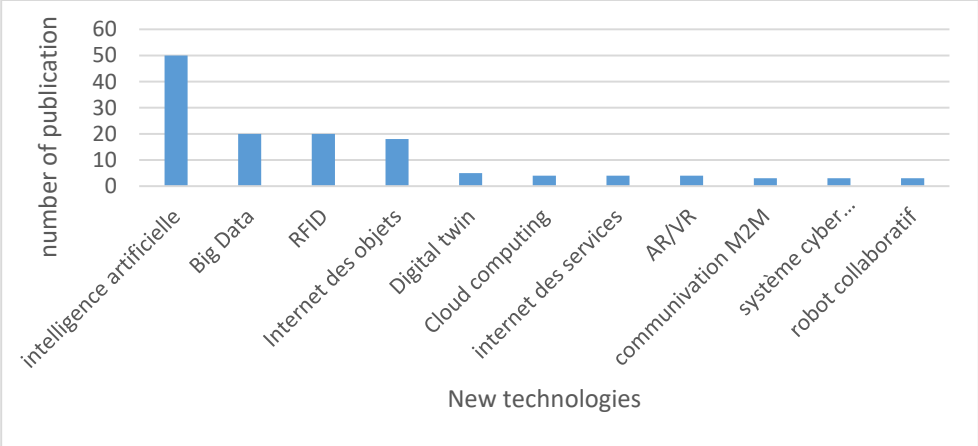

Figure 2. Number of publications in Lean Logistics and new technologies

Figure 2 shows that there is a low volume of publications on the degree of implementation of these technologies in lean logistics. Nevertheless, it can be seen that the dominant technologies used to optimize the management and elimination of waste in the supply chain are: artificial intelligence, Big Data and RFID. The 4.0 technologies do not have the same degree of importance according to the branches of Industry 4.0, hence the relatively low number of articles on certain technologies, but we note a strong use of four technologies AI, Big Data and Internet of Things. The following table summarizes recent work that shows the contribution of technologies in the supply chain.

Table 1. publications retrieved from the Scopus platform

	Title	**authors**	**Year of publication**	**Type of publication**	**Main idea**
1	Implementation of the lean concept and simulations in SMES – A case study	Tanasic et al., 2022	March 2022	Newspaper article	The article illustrates a simulation model by the digital twin to apply it in Lean tools
2	Competence Requirements in Manufacturing Companies in the Context of Lean 4.0 (F. Dillinger et al., 2022)	Dillinger et al. 2022	April 2022	Conference article	An approach was discussed to develop a Lean 4.0 model for companies.
3	From lean production to lean 4.0: A systematic literature review with a historical perspective	Gil-Vilda et al. 2021	November 2021	Newspaper article	A literature review that summarizes the transition from classical Lean to Lean 4.0.
4	Lean six sigma approach for global supply chain management using industry 4.0 and IIoT (A. Jayaram, 2016)	Jayaram 2016	December 2016	Conference article	The methodology addressed consists of integrating IoT and Cloud computing into Lean and Six sigma methods at the Supply Chain level.
5	The architectural design and implementation of a digital platform for Industry 4.0 SME collaboration	Liu, Zixu; et al	June 2022	Newspaper article	The paper presents an architecture of a collaborative Industry 4.0 platform in supply chains.
6	Analysis of the Challenges of Artificial Intelligence of Things (AIoT) for the Smart Supply Chain (Case Study: FMCG Industries) (H.	Nozari et al	April 2022	Newspaper article	The study identifies and analyzes the impact of the adoption of new technologies such as artificial intelligence

	Nozari et al., 2022)				and IoT... in the development of sustainable and smart supply chains.
7	An Exploratory Case Study on the Metrics and Performance of IoT Investment in Japanese Manufacturing Firms (M. Fukuzawa et al., 2022)	Fukuzawa Mitsuhiroet all	March 2022	Newspaper article	Study clarifies an IoT integration methodology and industrial decision making system to improve logistics chain
8	Integration of Visual Management in the Industry 4.0: Case Study	El Manti et al, 2022	March 2022	Conferenc e article	This article discusses the fusion between Visual Management (VM) and Industry 4.0 to develop Lean 4.0
9	Value Stream Mapping-based Logistics 40 Readiness for Thailand Automotive-Part Manufacturers (G. Boonsothonsatit et al., 2020)	Boonsothons atit et al. 2020	April 2020	Conferenc e article	Switching from classic Lean to Lean 4.0 by integrating new technologies in the VSM tool.
1 0	HATS project for lean and smart global logistic: A shipping company case study (E. Frontoni et al., 2020)	Frontoni et al,2020	January 2020	Newspaper article	Cloud computing integration for instant access to data to achieve Lean Logistics 4.0
1 1	The Role of Digital Connectivity in Supply Chain and Logistics Systems: A Proposed SIMPLE Framework (M. M. Queiroz and S. FossoWamba,2020)	Maciel M. Queiroz et all	April 2020	Conferenc e article	The article illustrates the interconnection in the supply chain and logistics systems
1 2	Applicability of Lean and Green Concepts in Logistics 4.0: A Systematic Review of Literature (A. Edirisuriya et al., 2018)	Anuradha Edirisuriya et all	December 2018	Conferenc e article	The article presents important Lean practices and green concepts that should improve the operational performance of logistics functions
1 3	A framework for the impact of lean six sigma on supply chain performance in manufacturing companies (G. D. PardameanGultom and E. Wibisono, 2018)	Gihon Davilia et all.	November 2018	Conferenc e article	Impact study of Lean and Six Sigma on supply chain performance.
1 4	Lean Six Sigma approach for global supply chain management using Industry 4.0 and IIoT(A. Jayaram, 2016)	Jayaram, A. et all	December 2016	Conferenc e article	The article illustrates the importance of Industry 4.0 and IIOT in the Lean Six Sigma approach in the supply chain to make it fully autonomous.

2.1 The 4.0 technologies applied in logistics

We are going to present three very interesting results from the literature that can be used to fine-tune our approach and serve as decision support tools for principals to implement this approach in their warehouses:

1- Table 2 presents the Lean tools and their contribution to logistics.
2- In table 3 we present the relationships between Lean tools and 4.0 technologies
3- In table 4 we present the contribution of 4.0 technologies on Lean tools.

Table 2. 4.0 technologies applied in logistics

N°	Technologies 4.0	Definitions
1	**Big Data** (S. Benzidia et al.,2021)	- Performs fast, real-time processing of massive data from logistics processes or data collected by IOT technologies
2	**Cyber-physical systems** (F. Ounnar and P. Pujo,2019)	- Capable of acting on physical processes by means of actuators. -Connected to each other via digital networks. -Able to use remote services to assist them.
3	**AI** (I. Affia and A. Aamer,2022)	In a warehouse, it can help us to : -Generate supplies -Anticipate customer orders -Interpret warehouse data.
4	**Scan 3D** (Zhong et al., 2017)	Allows to: - Perform scanning and 3D modeling of stored products - Analyze the objects or their close environment to collect information. - Facilitate the quality control of the goods.
5	**Cyber Security** (Cheung et al., 2021)	Allows you to store this data in an accessible and secure manner.
6	**Augmented Reality** (AR) (Cirulisand and Ginters,2013)	Allows to: - Overlap with the existing environment. - Display virtual and real information, previously acquired with the cameras- -Create an interface between employees and stored products or digital equipment.
7	**Virtual Simulation** (VS) (Tounsi,2011)	Allows to: - Model data in real time - reflect the physical world in a virtual model that includes machines, products and humans.
8	**RFID** (Popova et al., 2021)	Allows the identification and tracking of objects without physical contact from their frequencies.
9	**IoT**(Katoch, 2022)	Allows the identification and tracking of objects without physical contact from their frequencies.
10	**Automatically Guided Vehicles AGVs** (Mehami et al., 2018)	-Reception of goods and handling of raw materials -Automated storage and retrieval. -Transport to/from automated storage.

We note that 4.0 technologies clearly contribute to the improvement of the supply chain and provide efficient solutions for forecasting the flow of supplies, sales, distribution and location of products in the warehouse.

2-2 The Relationship between new technologies and Lean tools

Table 3. Relationship between 4.0 technologies and Lean tools

N°	Technologies 4.0	Definitions
1	**Big Data** (S. Benzidia et al.,2021)	- Performs fast, real-time processing of massive data from logistics processes or data collected by IOT technologies
2	**Systèmes cyber-physiques** (F. Ounnar and P. Pujo,2019)	- Capable of acting on physical processes by means of actuators. - Connected to each other via digital networks. - Able to use remote services to assist them.
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Following this study, we notice that each technology is linked to several Lean tools, which allows us to say that the two approaches are complementary and can bring a plus for an efficient management of logistics processes.
Now we'll visualize the contribution of each 4.0 technology on the main Lean logistics tools.

Table 4. The contribution of 4.0 technologies on Lean tools

JIT 4.0 (Valamede et A. C. S. Akkari,2020)	Big Data Analytics	-Real-time data interpretation -Continuous flow monitoring -Greater transparency of the process
	The cloud	-Intelligent dispatching of logistics-related tasks -Data storage and processing
	AGVs	-Data storage and processing -Reliability of routes and logistics, responsiveness
	Augmented Reality	-Supply chain supervision -Provide real-time data
KANBAN 4.0 (Valamede et A. C. S. Akkari,2020)	VS	-Real-time planning of new Kanban projects -Wide and integrated supply chain -Identification of supply chain parameters
	AGVs	-Minimized intermediate inventory space -control of material batch loading levels in the warehouse
	Big Data	-Holistic integration and data sharing between supply chain links -Analytics contributes to real-time monitoring of production flows, which provides automated logistics with intelligent inventory control. -Combining target and actual values to eliminate unnecessary inventory.
Poka-Yoke 4.0 (Valamede et A. C. S. Akkari,2020)	Cyber Security	-Security assurance in the execution of tasks -Prevention of human errors
	AR	-Improved speed and reliability in operations -Reduced defects, rework and inspection
VSM 4.0 (Valamede et A. C. S. Akkari,2020)	The cloud	-Quick detection of logistical problems -Constant updating of the map via the data network -Real-time product location
Kaizen 4.0 (Valamede et A. C. S. Akkari,2020)	Cloud	-Gather and share information across the supply chain -Provide real-time data on production flows
	Big Data Analytics	-Using data collected from the cloud in analytics applications -Using data to improve customer service -Use data to eliminate non-value added tasks
	Virtual Simulation	-Significantly reduces human error in the various warehouse processes -virtual testing of new technological solutions before their physical application
	Augmented Reality	-Real-time assistance in manual operations -Provides a better industrial man-machine interaction.

According to this result, we can see that each Lean tool can be combined or associated with several technologies and brings more efficient solutions.

3. Methodology

3.1 Industrial case study and the contribution of 4.0 technologies to Lean

We present the methodology to follow for the implementation of Lean and 4.0 technologies. This work is based on an approach (methodology) in three stages. In the first step, it is to diagnose the warehouse to highlight the waste in logistics management and the existing difficulties for efficient management. In the second step we will implement the Lean logistics and in the last step we will implement the 4.0 technologies, those on which the companies must invest for a better piloting of the logistic chain in a warehouse and the related indicators.

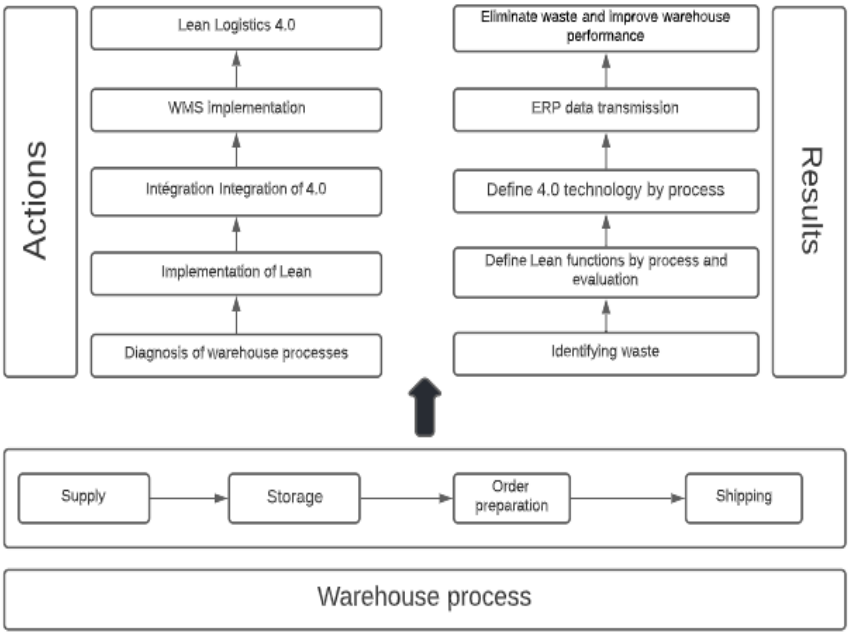

Figure 3. Lean Logistics 4.0 implementation process

As presented in the figure above, the different actions of this implementation process lead, each one, to concrete results allowing us first to identify the waste and then to bring the solutions provided by Lean and 4.0 technologies, with the objective of eliminating the waste and improving the performance of the warehouse.

3.2 Diagnosis of the warehouse processes

a. Presentation of the company

We chose an international beverage manufacturing company. The company agreed to participate in this exercise by providing us with space, time and data on the production and logistic activity of its warehouse. The company produces beverages of 72 products with 12 flavors. The average number of productions per day is 400,000 units and reaches 500,000 products per day for certain seasons (peaks). These products are stored in a warehouse (which is our case study) and shipped to customers.

b. Warehouse analysis

The analysis of the different processes is done in order to detect waste. This analysis allows us to initiate a performance improvement approach for the warehouse, whose process is composed of procurement, storage, order preparation and

shipping (figure 3). The results in figure 5 confirm the presence of defects and waste in the different processes of the warehouse, we find:

Figure 4. Waste identified in the different processes of the warehouse

3.3 Implementation of Lean and 4.0 technologies

According to the diagnosis carried out and according to the studies presented in tables 2, 3 and 4 above, we have developed the Lean functions in the various processes. All the staff of each process contributed to the choice of these functions and their implementation, which significantly improved waste. It turned out that Lean has a limit especially at the level of the prediction of the sales, the localization of the products..., it is for this reason that the integration of the technologies 4.0 is necessary. The results obtained are presented in Table 6 with a synthesis that shows that if we combine Lean and 4.0 technologies, we can achieve a performance.

5. Results and Discussion

Table 5 describes the process of our approach, integrating the tools of Lean as 5S, Kaizen, six Sigma, Just in time ..., this step has shown that certainly the integration of Lean has improved the warehouse but without achieving the degree of improvement targeted. The implementation of technologies born in the rise of industry 4.0 such as Big Data, Augmented Reality, Artificial Intelligence ..., will allow in a warehouse to predict the quantity to produce, sales, shipping time of orders ... The combination of Lean tools with 4.0 technologies has allowed us to conclude that the tools of Lean 4.0 are very effective. At the data management level we have introduced a WMS software which is connected to the ERP, and for handling a stacker crane is introduced for high storage.

Uncontrolled inventory: The diagnosis of different warehouse tasks, using a questionnaire, interview with managers and analysis of the history, has found a disruption of the stock in previous years either an excess of products or shortage of products which is generally due to a non-controlled forecast of production and sales and is highly dependent on the seasons. The case of overstock leads to an important space which generates an increase of logistic costs and a loss of time. The case of out of stock generates customer dissatisfaction.
In order to control the relationship between the production and the warehouse; the application of the J.à.T tool answers perfectly the need of products in the requested quantity at the requested date. This tool consists in synchronizing the production processes of the warehouse logistics. The production rhythm is adapted according to the demand and the available time. Overproduction is thus eliminated, which means that waste is eliminated. A second 5S tool, at the warehouse level, played a very important role in the organization of the warehouse. By applying the principles of Lean, we have seen a 10% improvement in storage space.

In the second step we introduced the 4.0 technologies. These new technologies improve the space saving by using the stacker crane to store in height. Big Data and Artificial Intelligence technologies which are based on the data provided by the company for the past years. A computer application is developed by developing algorithms based on python lange have allowed to:
- predict the production capacity and reserve the storage area according to the seasonality
- predict the resources needed for peaks in activity.
- solve the problem of over-stocking or out-of-stock situations by producing just the orders received.
- predict sales much more accurately, reactively and precisely.

With these new technologies, space management is well controlled and a gain in space has reached 20%.

Waste of time: The execution time of the different tasks in each process is quite high due to a bad localization of the different products requested by the customers which generates a waste of time and painful work. The use of Lean 5S and the integration of the WMS software has shown an improvement of the processing time of 8%. The augmented reality tool has allowed to:
- Process and organize large numbers of products.
- Optimization of the workload of each operator.
With this 4.0 technology solution, we have a better localization of the products, whose processing time has reached 12%.

Unnecessary displacement: The operations related to the preparation of orders in the warehouse take the most time on a daily basis. This is why a bad planning of the preparation lines can impact the productivity of the warehouse. The application of Lean 5S, six sigma and kaizen have brought an improvement:
- The integration of handling equipment such as stacker cranes is an excellent solution to reduce the time spent on intralogistics transport and allows to increase the safety of operations.
- WMS software to plan the order preparations have reduced the movements and facilitate the organization of the picking routes in the warehouse in this case the activity is improved by 8 %.
The integration of AI has allowed to plan orders and production according to the seasons, the augmented reality has reduced these displacements since the products are well located. A net improvement of these displacements the improvement reached of 19% and which a positive impact on all the activity: reactivity, preparation of the orders**.**

Defect related to orders: The errors of preparation of orders lead to high costs and low quality of service, in this case, the WMS as software of picking decreases considerably these failures and increases the global level of quality of the service an improvement of 5% is noted.
The use of BIG DATA and artificial intelligence has made it possible to predict the failures of certain products and the types of complaints, false addresses, the return of products, by the customeran improvement of 15% is noted after the integration of technologies.

Safety and hard work: Handling, especially stacker cranes, 5S tools and good management of order preparation planning by the WMS has reduced the risks by 9%. On the other hand, the 4.0 technologies, using artificial intelligence, have clearly reduced the risks in the warehouse by 29%, this is due to the prediction of failures that may occur, failed products, number of product returns, reshipment of new products, treatment of obsolete products.

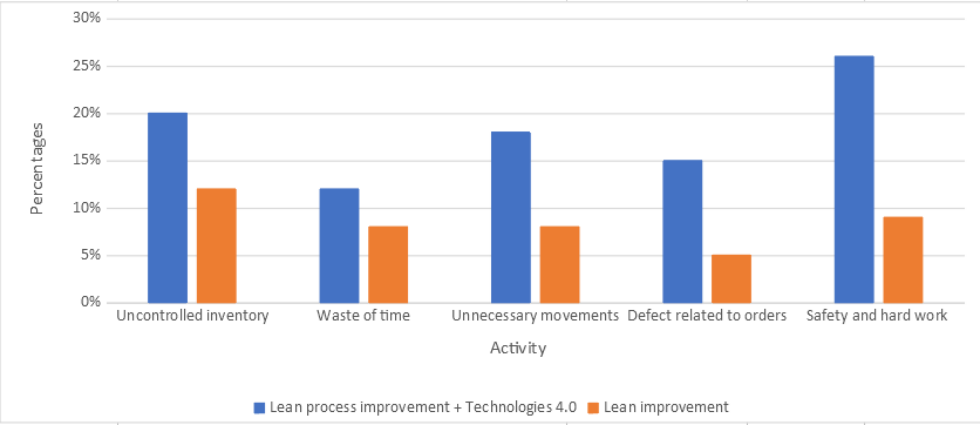

Figure 5. Comparison of the contribution of Lean and Lean combined with 4.0 technologies

The integration of WMS software is of great importance for warehouse management, it is useful to solve any kind of waste detected. Its integration has allowed gathering data from 4.0 technologies of different processes and connecting with ERP.

Table 5. Results obtained

Waste detected	cause waste	Impact sur l'activité d'après le diagnostic	Lean tools Applied step 1	results of the application of Lean	integration of 4.0 technologies step 2	results obtained combining Lean and 4.0 technologies
Uncontrolled inventory	-excess production -poor sales and supply forecasting -high time	-lack of space -increased logistics costs and product storage -risk -Increases depreciation costs	**-Just-in-time** for production and orders **-5S** obstacle removal	-space saving10%. -forecasting of peak quantities,... -better inventory control -reduction of lead time	-Big Data (BD), -Artificial Intelligence (AI), -Augmented Reality	-space saving -forecasting of production and sales quantities
Time management	- obstacles -non localisation des produits -accidents	-increase in the load of each operator -tedious tasks	**5S:** reduce waste ,optimize time	-reactivity, -localization	-bar code, -Augmented reality	-reactivity, time -easy location of products
Unnecessary moves and movements	-poor planning of preparation lines -unnecessary travel -handling	-Decreased productivity of the company - unnecessary travel -Employee injuries -Increases delivery time	**5S:** time saving and optimization of the working environment	-less risk -gain in time	augmented reality	-less risk -save time
Defects related to orders	-Order picking errors -difficulty in forecasting	-reduce the overall level of service quality -additional work - generate waste	**Six sigmas:** improve the quality and efficiency of processes **Kaizen:**continuous improvement of processes	-avoid repetitive tasks -good quality of service	IA, BD	-avoid repetitive tasks -good quality of service
Safety and hard work	-Accidents -Risk of injury	-loss of time -absenteeism	-5S -Six Sigma	-Less accidents -Motivation	Augmented reality, AI	-Reactivity -quick localization

6. Conclusion

This work presents an approach to improve the performance of a warehouse. This approach is based on a three-step methodology, diagnose to identify waste, implement Lean principles and implement the appropriate 4.0 technologies. A case study was conducted in a warehouse of a food company. The results obtained are very satisfactory and can encourage companies to invest in these new technologies for a better management of the supply chain of a warehouse. We recommend a combination of Lean and 4.0 technologies, step by step, to have better results in eliminating waste

in a warehouse and reach the highest level of operational excellence. As perspectives we will apply this approach for other industrial companies and test the contribution of 4.0 technologies.

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