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How to use lean manufacturing for improving a Healthcare logistics performance

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Abstract

Most companies in the world are focused on their global performance for being competitive on the market. Lean manufacturing is one of the main methodologies used by them for increasing their supply chain and logistics performance. Indeed, Logistics performance improvement implies the definition of KPIs (Key Performance Indicators) for measuring at each transformation level, the evolution of the logistics system. Thus, Industry 4.0 and logistics 4.0 concepts are defined for implementing new technologies, tools and organizations in companies in order to define their future. A new framework, based on lean manufacturing and DMAIC methodologies, with sustainability as its kernel has been developed in Icam, A Higher education school, for SMEs. In addition, European population is growing older day by day and they are regularly visiting hospitals. In this context, the treatment of patients in good conditions (quality, cost and lead time) is necessary as much as the hospital global performance. In this frame, a project is ongoing between FEI, a Brazilian University and Icam for defining and implementing Healthcare Logistics 4.0 (including lean manufacturing).

This paper presents concepts, methods and tools of healthcare logistics 4.0 for improving a hospital performance. Examples on medicines tracking, medicine and food dispatching will be given as result and detailed for illustrating concepts presented.

Keywords: lean manufacturing, serialization, performance improvement

1. Introduction

Due to globalization, concurrence and competitiveness are actually important for companies in Europe. SMEs are mostly concerned because of the low level of task force cost in Asian continent. This necessity of performance optimization is required in all sectors. For instance, Europe consumption in optical, mobile, manufacturing or pharmaceutics products is highly impacted by the Chinese crisis on corona virus. Then, for being competitive SMEs have to improve their performance. Lean manufacturing methodology is able to transform these companies. In addition, the use on industry 4.0 and logistics 4.0 concepts specially will help them to be more competitive. Icam, a Higher educational school develop a framework with sustainability as the kernel of company future transformation in order to take into account SME expectations and in the same time including advantages of industry 4.0 and logistics 4.0 concepts implementation such as new technologies, tools and organizations.

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This paper proposes to use these concepts and methodology for solving technological, economical and organization problems in hospitals. Indeed, European hospitals have to improve their performance because the population is being older and have regularly to stay in hospitals. For instance, patient conditions, medicines procurement and dispatching, medicines tracking, patient flows, bedrooms and beds management, or food management have to be optimized.

After a literature review, this paper will focus on how lean manufacturing and healthcare logistics 4.0 concepts, methods and tools being developed by Icam and FEI university (Brazilian university) could improve healthcare performance. Then, examples based on medicines tracking, medicines and foods dispatching will be detailed.

2. Literature review

Lean manufacturing and Industry 4.0 and logistics 4.0 concepts are based on theory of systems, and in this frame, a company could be considered as a system. The idea of this project is to adapt the pervious concepts to healthcare logistics. This chapter presents the concepts and methods of the literature, required for elaborating the global methodology for improving healthcare performance. Indeed, lean manufacturing and mudas, Industry4.0 and logistics 4.0, value Stream Mapping and artificial intelligence will be exposed.

2.1. Lean Manufacturing

Lean Manufacturing is a methodology based on the elimination of all non-value added in the supply chain. It was developed by Taiichi Ohno, executive of Toyota in the 1950s in Japan (after World War II). Lean is based on eliminating waste in the process, based on understanding customer needs. It is a management philosophy that seeks to reduce waste and increase productivity and quality as presented in [1].

This methodology is used in companies that are always looking for continuous improvement, cost reduction, production agility, increase in productive capacity and improvements in the working environment for its civil servants as shown in [2].

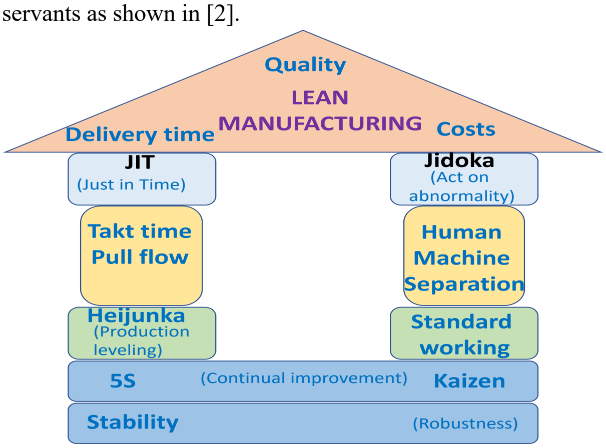

Fig. 1. Lean manufacturing house

This methodology defines seven main points of waste (the seven mudas) and makes it possible to implement the tools to reduce them. The seven wastes are as detailed in [2, 3]:

- **Overproduction:** producing more than the demand demanded, the consequence is the loss of profit compared to products which are not sold and the loss of storage space. The production schedule must be adjusted on demand.
- **Over-storage:** accumulating raw materials and products, it is said to be wasteful for overstocking, because these stored products cause unnecessary expenditure. We have to balance production and demand.
- **Unnecessary displacements:** losses for unnecessary displacements happen when the products are transported in an unscheduled, useless way or from inadequate systems. We need to improve production layouts to reduce losses.
- **Unnecessary treatments:** losses for unnecessary treatments concern the unnecessary stages of the production process which can be eliminated without compromising the product. It takes in-depth process analysis to work on real needs.
- **Unnecessary movements:** errors in orientation in the execution or poor distribution of tasks and the lack of study of the parameters in relation to the times of execution of activities can cause unnecessary movements of officials in the production processes. To resolve this type of loss, it is necessary to plan the appropriate schedule and work logic, then determine an average time for the execution of each step and eliminate unnecessary steps in the process.
- **Errors:** when the product is outside the standards required for sale, there is a waste by mistake. This causes a waste of financial resources and the possibility of cost overruns for repair. This can be caused by the poor quality of equipment, the low qualification of employees or tools outside the standard.
- **And waiting times:** loss by waiting time corresponds to time lost (waiting) between one step and the next and which is caused by a queue in front of the production station (products to be finalized). This can be caused by large time gaps between processes and is one of the most wasteful mudas. However, this can be remedied by analyzing and finding a balance in each process.

Value Stream Mapping (VSM) is a Lean Manufacturing tool that brings together all the value added and non-value-added actions that bring a product from an initial state to a final state. This tool aims to work on a whole and not a part: on a production line, the VSM does not attack a machine of the line in particular but the whole line as shown in [4]. Its goal is to take a photo of the manufacturing actual organization. That means, the elaboration of an existing system cartography. This photo could be analyzed for detecting inconsistencies (non-added values) and describing added values. Then, a future system could be elaborated based on VSM concepts (Takt time, pacemaker, interval, supermarket, FIFO, etc.)

Lean manufacturing methodology could be used on Healthcare logistics for solving problems and improving its global performance by exploiting concepts presented above. Indeed, different hospital sectors are concerned in this transformation, but also call for their resolution to transversal knowledge involving several disciplines, concepts, methods and tools. The transformations for obtaining the future system needs to use industry 4.0 concepts.

2.2. Industry 4.0 and logisitics 4.0

Industry 4.0 and logistics 4.0 concepts were developed in German, and then in France for helping German and French company to improve their performance, even if they have a disadvantage of high taskforce cost. Many researchers have worked on this topic and concepts for defining different frameworks. But most of them are focused on new technologies as the kernel of industry 4.0. For instance, in [5], the paradigm of industry 4.0 is outlined around three dimensions:

- The horizontal integration across the value creation network,
- The end-to-end engineering across the product life cycle,
- And the vertical integration combined with networked manufacturing systems

Then Micro and macro perspectives presented are based on organizational and technological aspects. Thus, advantages and objectives of industry 4.0 are focused on digitalization, new technologies as presented in [6]: Cyber-physical systems, big data, real time data management, ICT, Internet of Things, Distributed and decentralized control, RFID, etc. The concept of smart factory, and smart manufacturing is developed in detail in this context [7]. Economic aspects are also developed in [8] for presenting processes used for improving company global performance in terms of cost reduction and turnover increasing

2.3. Artificial Intelligence

Artificial intelligence is a big and complex structure that has plenty of diversified branches of studies. As described in [9] there is a significant enthusiasm for Artificial intelligence regarding its potential, based on machine learning and deep learning. Indeed, Machine learning is used for developing new algorithms that can automatically make decisions by relying on patterns and inferences, without requiring any explicit instructions. This family could be divided into supervised algorithms requiring availability of labelled data from which to learn and unsupervised algorithms based on similarities patterns and differences without any prior information. As presented in [10], the fundamental principle of machine learning is the ability of a computer to improve upon its own capabilities by continuously analyzing its interactions with the real world. The Natural Language Processing (NLP) is used for analyzing the human language and helping a machine to understand, interpret and manipulate human language.

Deep learning is the comeback of Artificial Neural Networks as explained in [11]. For instance, in 2015 Alphago, a program developed by Google, was able to beat the champion in the board game go by using deep learning. This concept is used for image or speech recognitions. As detailed in [12], deep learning approaches are able to work on processing data in their raw and eliminate the need of hand-crafted features. These approaches are used on semantic segmentation of images and are easy to use because of faster central processing units (CPUs) and graphic processing units (GPUs). Even if these concepts are interesting and efficient, machine learning concepts are adapted for being used for developing a user interface in order to facilitate interaction between a decision aided tool and a user.

In addition, it will be easier to combine machine learning with expert system approaches developed as exposed in [13] and shown in Fig. 2. The expert system is viewed as a method that can provide the expert-level diagnosis knowledge to solve the diagnosis tasks of machines instead of huge human labor.

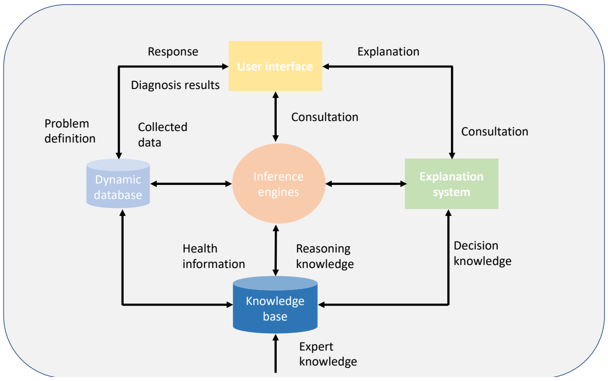

Fig. 2. Architecture of an expert system for diagnosis

The following chapter will show the architecture of the decision aided tool being developed in Icam for supporting the healthcare logistics 4.0 concepts implementation in addition to the global methodology presentation.

3. Global Methodology and tool

3.1. Methodology

The framework elaborated in Icam for implementing industry 4.0 and logistics 4.0 concepts in SMEs, in opposition to many architectures of the literature, considers sustainability as the kernel of industry 4.0 concepts implementation in SMEs. As shown in Fig. 3, new technologies (RFID, IoT, Robots, Cobots, etc.) & tools (WMS, ERP, MES, etc.) are important for increasing the company performance, and represent one industry 4.0 and logistics 4.0 implementation axis. New organization (Blockchain, etc.) and flexibility & changes management represent the second one. But sustainability entirely defined by environmental, social and societal aspects is the center of the company transformation in order to increase the company performance.

Each sub-system of the SME will be studied, and its performance increased continuously by respecting the company expectations and objectives but also industry 4.0 and logistics 4.0 concepts. At each step of the framework utilization, the loop elaborated around sustainability will continuously be used. Healthcare Logistics 4.0 corresponds to the adaptation of these concepts to the hospital. The hospital in this case is considered as a system and for increasing its performance, rules defined in the frame of SMEs sectors could be used. Then, for supporting this global methodology based on lean manufacturing and industry 4.0 and logistics 4.0 concepts, a specific software tool is being developed.

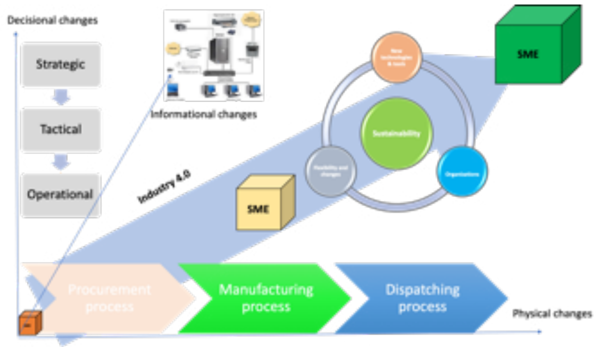

Fig.3. Framework for industry 4.0 and logistics concepts implementation in SMEs

3.2. The architecture of the decision aided tool

The Fig. 4, presents the architecture of the tool in development. This tool is required for managing all data acquired during a hospital evolution, to offering to a hospital best changes suggestion, to manage to enrich the transformation processes by capitalizing existing case and reuse the as an aid for new transformations.

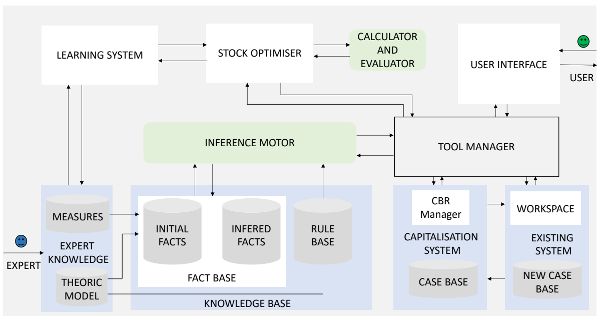

Fig.4. Architecture of a decision aided tool for supporting healthcare logistics 4.0

3.2.1. Learning System

As explained above, the algorithms of machine learning can be divided in two different main groups, being them the supervised-learning and the unsupervised-learning and their difference is on the use of explicit feedback in the learning process. Still following their work, the algorithms of the supervised-learning are those that receive a complete base of data, with indications, meaning that it uses predefined input-output pairs to works out what is an input and what is an output. In addition, in the case of unsupervised-learning, data received are a raw, not categorized and not in a database. It will create its own categories and characteristics. Then, there is no predefined input the algorithm will learn to detect patterns.

Both concepts are used in the learning module for characterizing, interpreting all information and integrating in order to solve stock problems.

Indeed, all information that the system will receive related the hospital logistics will be decoded and processed adapted solutions will be defined. But also, all unknown information (not in the database) will be treated for aiding the user. For instance, stock management, the input could be the quantity of medicines in the stock (stock level) according the order threshold, and the output would be next medicines procurement planning.

3.2.2. Stock Optimizer

This module contains stock optimization algorithms (operational research). In this module, all information (supervised and not supervised) will be exploited for finding the optimized solution. Then, it can reach to a history of decisions already made (in other times) to create a pattern and from that keep making the new decision. The predefined input-output pairs will be stored and the new elaborated.

3.2.3. User Interface

The user interface is used for relating the tool being developed with the user. It has to be able to acquire user expectations and interpreted them in order to define the good response. But also, it has also to be able to give to the user solutions and instructions for implementation. For instance, patient information could be entered there, and right solution for the patient management will be defined and transmitted to hospital workers.

3.2.4. Inference Motor

An inference motor is used for elaborating deductive reasonings. It is the place for conducting logical ratiocination and designing responses from the knowledge base and facts. It is the heart of the expert system, because facts and rules bases end up communicating and become extremely important for analyzing and solving problems.

3.2.5. Tool Manager

The tool manager is exploited for managing each module of the system. It creates interaction with each part and participated to the efficiency of the system. This tool will uniformly organize all data and integrate (or extract) them in the system, storing them in a database

3.2.6. Expert Knowledge and Knowledge base

3.2.6.1. The expert knowledge module

The expert knowledge module is used for acquired in real time expert knowledge. This explicit or implicit knowledge could be transformed into rules or facts for the knowledge base. This module will allow to make interviews of workers, or to exploit knowledge of lean manufacturing and industry

4.0 and logistics 4.0 implementation specialists. The module is also connected to the learning system for giving to this system information that would be interpreted and treated.

3.2.6.2. Knowledge base

The knowledge module contains rules and facts required in the healthcare domain. It is a specific **expert knowledge**, with a defined, precise and known knowledge and that could be directly exploited through the inference module for solving healthcare problems. It contains rules adapted to lean manufacturing and industry 4.0 and logistics 4.0 concepts implementation, but also specific hospital characteristics.

3.2.7. Capitalization System

The capitalization system contains old cases treated. The idea is to make them able to be used as reference models during the study and the transformation of a new hospital. It is based on Case-Based Reasoning and the adapted and similar old case would be extracted during a new study. The exploitation of experimentations and transformations in other hospital is a good opportunity.

3.2.8. The existing system

This module is used for modelling the actual organization of the hospital being transformed and make him able to be analyzed and transformed by the decision aided tool.

4. Illustrations

4.1. Tracking case

The Indoor Pharmacy (PUI) of one French hospital of Ile de France region must set up a serialization system to control medicines and make traceability.

The first motivation is to avoid patients being treated with counterfeit medicines. The second motivation is to comply with the new standard which requires all suppliers of drugs to set up two mandatory security devices, an anti-intrusion device and a serialization system (an identifier corresponding to a serial number), starting from February 9, 2019 (as presented in Fig. 5).

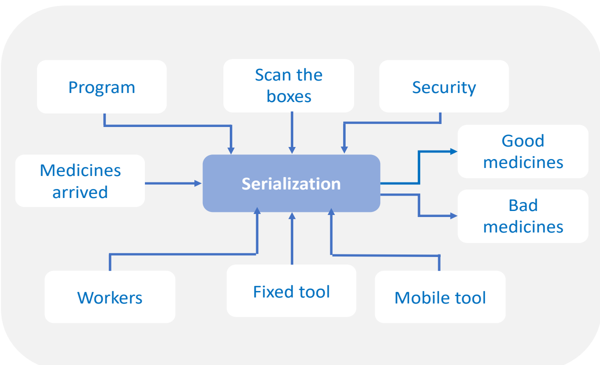

Fig.5. Diagram of serialization's process

The main challenges of this subject are that some laboratories are not fully regulated (some of their boxes do not have the SN code or some of their medicines cannot be serialized). This new added step will require more time for storekeepers who will have to balance their work routines.

First existing technologies have to be explored to find a solution that will automate the reading of bar codes (the codes that are in the boxes) and then the objective is to propose a solution adapted to the architectural layout and the constraints of the interior reception area of the pharmacy to perform the serialization operation.

The process time before the modifications is 2 minutes, this time has been timed during a visit, the process corresponds to the time of: the reception, the verification of the delivery (the storekeeper checks the name of the laboratory on the delivery slip , conformity of the address, number of packages), physical verification of the packages (integrity inspection and also the control of the correct delivery address), acceptance of receipt (of that there is a concordance between the voucher and the physical integrity of the box, the storekeeper accepts it), the validation of the receipt (the traceability of the receipt is made by sticking a label on the delivery slip), the control of the receipt (a preparer ensures that: there is a concordance between the purchase order and the delivery slip, the quantity ordered is received, it is indeed the product ordered), the opening of the carton (the carton is opened and the boxes of drugs comes out), the computer reception (step where the entry of the drugs in the computer stock is made) and finally the storage of the drugs.

This actual situation was modeled by using Flexsim, a simulation tool for representing flows from medicines reception to transfer in storage. Fig. 6 shows the result a graphical modelling with this tool. The advantage is that from this existing system simulation, scenarios could be studied by changing parameters. The good solution would be found by testing scenarios.

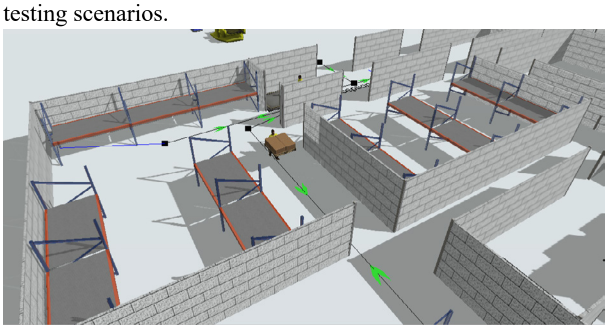

Fig.6. Simulation of the existing system

The main objective is to set up a new system but in a more automated way where time will not be changed since a new stage will be added, serialization.

On February 9, 2019, European rules relating to the fight against falsification of medicinal products for human use will be applied.

The European directive on the serialization of medicines 2011/62 of June 8, 2011, known as "Falsified medicines", indeed provides for the measures to be put in place to secure the distribution chain of the medicine in the European Union. Delegated Regulation (EU) 2016/161 specifies all the provisions of this directive.

These rules are based on the establishment of an anti-intrusion and authentication device to be affixed to the packaging of prescription drugs.

Concretely, this means that each box of prescription drugs must have a serial number, loaded into a data storage system.

To set up this so-called traceability system, the delegated regulation provides for the establishment of a governance body at European level (called EMVO, European Medicine Verification Organization) and in each member state (NMVO, National Medicine Verification Organization), responsible for managing, respectively, the system at European level (called EMVS European Medicine Verification System) and that of each member state (NMVS, National Medicine Verification System).

In order for France to comply with European regulations on February 9, 2019, the development and implementation of this system in France has already started.

The industrial representatives (LEEM, GEMME, LEMI) decided to entrust the implementation of the Delegated Regulations to the CIP (Club Inter Pharmaceutique), within which was created, in accordance with the provisions of European legislation, governance, France MVO (France Medicine Verification Organization) whose responsibility is to set up, administer and ensure the security of stored data and operate the French verification system called France MVS.

The consequences of the implementation of this regulation for manufacturers are as follows:

- Affixing authentication and burglary devices on boxes
- Funding for system development and maintenance.

For this hospital performance improvement and a better patient treatment, medicines tracking impact is increased. Indeed, a European regulation was issued in 2016, to ensure the high quality of medicines available in hospitals for patients. The main requirement of this rule was that all pharmaceutical manufacturers and producers have to define a unique code in each individual packaging (for products identification), a serial number, a batch number and an expiry date. This new regulation is effective since February 2019. All European hospitals have to transform their medicines procurement process for respecting this regulation.

4.1.1. Existing system analysis

At first, a modeling of the existing system has to be made. The stages and their times (from the moment the storekeeper receives the delivery until the time of storage) have been studied as shown in Fig. 7.

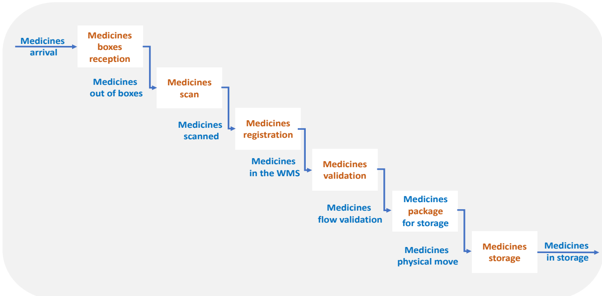

Fig.7: Actigramme of the reception process.

With this data it is important to explore existing technologies and find a solution that will automate the reading of QR codes (the codes that are in the boxes). Then, the objective is to propose a solution adapted to the architectural layout and to the constraints of the interior reception area (as shown in Fig. 8) of the pharmacy to carry out the serialization operation.

The process corresponds to the time of:

- Reception
- Verification of the delivery (the storekeeper verifies the name of the laboratory, compliance of the address, number of packages on the delivery slip).
- Physical verification of packages (integrity inspection and also checking the correct delivery address).
- Acceptance of receipt (as long as there is a match between the voucher and the physical entirety of the box, the storekeeper accepts it).
- The validation of the reception (the traceability of the reception is carried out by sticking a label on the delivery slip).
- Control of receipt (a preparer ensures that the purchase order and the delivery slip match, if the quantity ordered is received, if it is the product ordered).
- The opening of the box (the box is opened, and the boxes of medicines taken out).
- IT reception (step where drugs are entered into IT stock).
- Medicine storage.

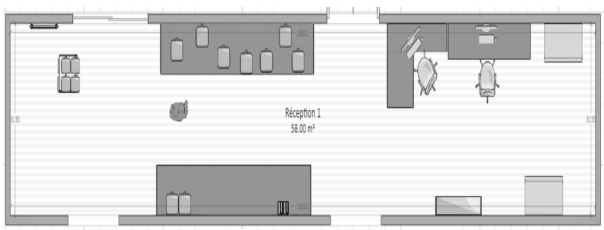

Fig.8. Plan of the reception

4.1.2. Studies Carried Out

The main objective is to set up a new system but in a more automated way where time will not be changed since a new stage will be added, serialization.

Three important studies (as shown in Fig 9) are carried out to find a good solution:

- A time study, where the time is analyzed from the moment that the storekeeper takes products, receives the order with the boxes of the laboratory until the end of the serialization. The time of each step was measured.
- A process study, a first group consisted of all the cartons containing the medicine boxes and a second group from the moment when the reception control ends until the end of the serialization, which corresponds to the time when the boxes are removed from the boxes, stored in the cart, scanned and the data entered and finalized.
- The last study was ergonomics, the position in which the trainer must do all the serialization is not the best solution for good posture, because the chair and the table are low, and the trainer must therefore be lowered. In another point, the table where the drugs are located and the table where the serialization is carried out has a certain distance (10 steps round trip) and, for this, the person who makes it must get up each time an order is finalized to look for other drugs, causing even greater fatigue.

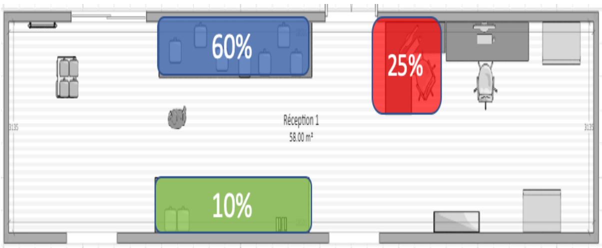

Fig.9. Studies for improving the reception

Finally, our third study was the reception area (as presented in Fig. 10), where the arrangement of tables, computers, electrical outlets and other objects was studied. The intention of this study was to find a better place to carry out all the steps, counting on better optimization and better ergonomics.

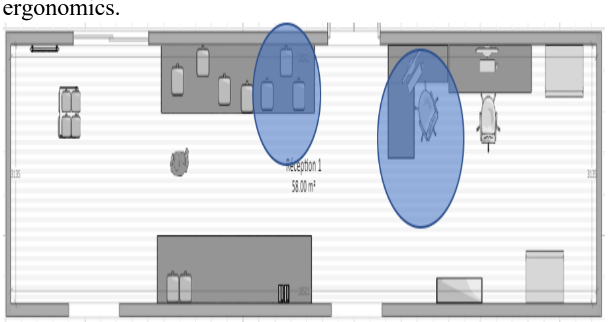

Fig.10. Concentration of work

4.1.3. Input data

The input data are the number of drugs that the pharmacy receives per day, the decreed standard, a study of the time, a study of the area and the reception area, as well as a study on optimization and the automation that can be done to improve and save time at the end will be carried out an occupational health study.

- Number of drugs:
  - So that we can study the technology and a solution;
- Decreed standard:
  - To respect and verify the application of rules at the time of implementation;
- Time study:
  - The time that people working at the reception take to process each cardboard that arrives and secondly a study of the time after the installation of the spray system to compare and analyse the different scenarios;
- Surface study:
  - A study to understand the space to set up a system that is well adapted and specially adjusted for reception;
- Optimization and automation study:
  - These two studies will be carried out after the implementation of the solution to seek possible improvements and with less time.
- Occupational Health Study:
  - Ergonomics study to improve the performance of storekeepers, where they can feel comfortable at work

In synthesis, the immediate solution that was implemented is shown in Fig. 11. This solution takes into account ergonomics of the operator. The solution final solution which will be implemented has been tested with flexsim simulation for this area. It is to install an automated system at the entrance of the reception. The operator, after opening the boxes will only put them on a conveyor. They will follow one way for being scanned automatically and he could obtain directly the references for storing the product. All products with bad tracking keys will be oriented to a waste storage for being analyzed by a specialist later. This integration of new technologies will increase the operator ergonomics conditions in addition the previous organization. The purchasing phase is undergoing.

Fig.11. Ergonomics solution for operator

4.2. Human-Robot collaboration food and medicines distribution

The second example studied in the hospital for validating the use of lean manufacturing combined with industry 4.0 and logistics 4.0 concept was nurse time and ergonomics management. Indeed, they actually have to transport medicines and food for taking care of patient. The existing system analysis has shown that patient number is increasing in the hospital, without the augmentation of the number of nurses. Then, they are full and could not spend more time with patient. The hospital has to pay supplementary hours to nurses (about 2700h). Due to respect of economic criteria, the situation and their number will not change. The study, once again by using Flexsim simulation, shows that by using Automated Intelligent Vehicles (AIVs) as presented in Fig. 12, the hospital will make economy of 8 persons who actually spend their time by bringing food and of 5 persons for medicines.

There are five floors in the hospital and the investment in 4 AIVs will be sufficient for ensuring the food service and medicines dispatching. Indeed, both food and medicines are bringing at different times and the same AIV could be shared for both tasks.

This solution is good on the economic point of view, because AIVs could work every time without being tired, nurses could focus on their tasks and being more efficient, patient would be satisfied, and the performance of the hospital will increase.

Fig.12. Mobile robot for food logistics

5. Conclusion

In this paper a new framework for industry 4.0 concepts implementation in companies is presented. This framework is based on lean manufacturing combined with new technologies and organisations. But the kernel of the framework is sustainability. This framework developed is used for defining healthcare logistics 4.0 concepts in order to improve hospital performance.

An example has been given on stock optimization and serialisation (medicine tracking) for illustrating how to use the framework for optimizing healthcare logistics performance and indubitably the hospital performance. A second example has been presented for showing how human could be at the center of new transformations and how this could be combined with new technologies for increasing hospital performance.

A decision aided tool is being developed for supporting the healthcare transformations and facilitating data and rules management. For instance, the serialization case needs to know all rules on this tracking, to optimize medicines orders for decreasing the operator charge, and make an inventory of the medicine storage. This would be easier with an aided tool.

The next step will be the test of the methodology for improving waste management in the hospital. Due to Corona virus the end of study has been postponed.

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