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Simulation for Decision Support in Process Reengineering in the Automotive Industry

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Abstract
With globalization and the high competitiveness faced in a business environment, adopting technological solutions to satisfactory respond to an increasingly demanding customer is the watchword for organizations. With technological advances and an increasingly volatile society, it is mandatory for industries to ensure agile production processes capable of responding quickly and assertively to consumer expectations. Industry 4.0 with its technological pillars comes up to boost company to have more flexible and agile processes. This work results of a project developed in an automotive factory that will be producing a new mechanical part. The definition of the best layout of the production line was carried in an instable environment characterized by budget limitations, security and space restrictions that forced the company to study and discuss four possible layouts to define the future line. The goal was to ensure that the line was able to produce 3625 parts/week with an Operational Income of 87%. Moreover, it was also important to consider the cost of implementing a new line in the company. With this study it is proven that in an automotive industry where flexibility is required in an unpredictable environment during a decision-making process, analyzing the impact and possible consequences of every change in a layout definition phase is a great asset, where alteration like adding a conveyor, Automated Guided Vehicle or Robots can be made easy and quickly, and important conclusions can be taken from this analyze with less effort. Finally, 2 criteria were created to examine every variant and a decision was made.

Keywords- Industry 4.0, Simulation, Layouts, Decision-making process, Automotive industry.

1. Introduction

Due to the increase of the complexity and turbulence of globalized business environment, companies are facing a massive challenge to optimize and innovate their business process in order to gain advantages from their competitors in a subsequently competitive market (Viriyasitavat et al., 2020). In fact, manufacturing companies time life is measured by their agility, focus on product quality, efficiency and responsiveness to customer preferences (Salam, 2019). These challenges need industries capable of having virtual and physical structures that supports the whole process from innovation to production and distribution (Ganzarain & Errasti, 2016).

Nowadays, we see a change in the global production industry towards digitalization and decentralization operations from shop floor to office floor and across company networks (Kannengiesser & Müller, 2018). Whereas industry activities contribute highly in the development of any economy as far as sustainability is concerned we are still a long way off (Jamwal et al., 2021a, 2021b, 2021c). Sustainable manufacturing (SM) is a structure and a set of activities to produce good products with the least use of resource and with sustainable resources ensuring people, employees and customers safety (Jamwal et al., 2021a, 2021b, 2021c). Moreover, this philosophy of minimal use of resource seems that the objective is to reduce negative impacts on environment (Jamwal et al., 2021a, 2021b, 2021c).

The term Fourth Industrial Revolution or commonly call "Industry 4.0", has been introduced to denote the digital transformation in production and its impact on the industry essence (Kannengiesser & Müller, 2018). The Industry 4.0 guides to a better daily decision making process since it has technologies that allows companies to increase efficiency and productivity (Oliveira & Afonso, 2019). Industry 4.0 technologies have an extraordinary role for sustainable value creation in environmental and social aspects of sustainability since it enhance the rational use of resources (Jamwal et al., 2021a, 2021b, 2021c). Technologies like Data analytics, Artificial Intelligence and Internet of Things are impacting SM applicability in the Industry 4.0 age, in fact these technologies in SM context contributes on maximization of energy consumption and reduce labours inputs (Jamwal et al., 2021a, 2021b, 2021c).

Also, one of the technologies of Industry 4.0 is simulation, a methodology that helps to anticipate and predict the behaviour of a real or an imagined system (Rodič, 2017). Many companies are aware that to better understand the drift of the business, simulation is a powerful tool to operation and strategic planning level avoiding potential problems (Kljajić et al., 2000). In fact, production planning is a really big challenge for the managers since an error or a bad plan culminate in catastrophic consequences to the industry (Teerasoponpong & Sopadang, 2020). In addition to that, Industry Systems are becoming more and more complex which means simulating and modelling is imperative to analyse outputs reducing time of developing and production (Prist et al., 2020). Simulation is the perfect choice when we want to optimize the number of resources that potentially increase the productivity or when we want to project the best location to produce a certain product (Gunal, 2019).

The objective of this paper is to answer 4 main questions. First, how simulation tool can be hand by hand in the decision-making process in an organizational environment; second how the different elements of the layout interact and how changing their position can impact the line; third how many pallets were needed for each of the variants; forth answer which of the 4 layouts variants gives the best result and could better represent the future line. Finally, this paper aims to demonstrate the potential of simulation tool in a practical context and analyse 4 possible layouts of a future production line in an automotive industry, all of this achieved by a deep analyse of some performance measures.

2. Literature Review

2.1 Industry 4.0

The Industry 4.0 is a term used to define the production digital metamorphosis, it impact and role in industry (Kannengiesser & Müller, 2018). Terminology as "Digital Transformation", "Smart Factory" and "The Fourth Industrial Revolution" are used to denotate this digital paradigm (Culot et al., 2020). The concept of Industry 4.0 was first presented in 2011 in a Hannover Fair, resulting in a German strategy to reaffirm their leadership in the industrial sector (Xu et al., 2018).

According to Kamble (2018) this new perspective brings a big lesson to the companies as those technologies can perform together with the industry in order to gain more production with the less effort and resources. This digital paradigm brings technologies and apps that allows sustainability in production, resources, energy efficiency and demographic changes grating productivity and efficiency (Ganzarain & Errasti, 2016). Therefore, these technologies have been applied in different business models as manufacturing industry, retail, and services.

Corallo (2020) annunciated that Industry 4.0 connects Information and Communication Technologies (TIC) and production, allowing the process and product data merge with machine data unlocking communication between those machines. This TIC component contains technologies like Cyber Physical System (CPS), Cloud Computing and Internet of Things that represents the evolution of a system environment with a whole virtual and physical space (Kamble et al., 2018). According to Rüßmann (2015) based in the German Industrial Automation leader Industry 4.0 has 9 pillars technological, as shown in Figure 1.

In Table 1 is presented a description and an example of application of each of the 9 pillars of Industry 4.0.

Table 1. 9 pillars of industry 4.0.

Technology	**Description**	**Source**
Simulation	According to the author "Simulation is defined as the process of designing a model of a real or hypothetical system to describe and analyze the behaviors of the system". It presents a set of methods and technological tools that can predict the performance of products, processes, and projects.	Ferreira et al. (2020)
	Simulation is an excellent method to solve optimization problems, due to its ability to test different scenarios when a set of input parameters are established. It´s dynamic perspective is a huge advantage compared to traditional methodology characterized for being static.	Uhlemann et al. (2017)
	Application: Simulation tools used to monitor and optimize production system by Airbus. Or by Siemens where simulation is used at planning, operation, and maintenance systems.	Ferreira et al. (2020)
Horizontal and vertical system integration	This pillar defends that sectors, functions and resources will be more connected in the industry since their data network develops and consequently its value chain will be more automatized.	Rüßmann (2015)
	The Horizontal system integration is the cooperation between the company and its external partners that integrates the different elements of the productive system. The Vertical integration is between the internal intervenient of the line or factory such as people, equipment, products, and departments (sales, marketing, and services). Thus, both systems can change and share information in a heterogeneous environment.	Pereira et al. (2020)
	Application: The aerospace companies Dassault Systèmes and the BoostAeoroSpace introduced the AirDesign platform, a collaborative design and production European defense program that manage the change of product and production data between them.	Rüßmann (2015)
Autonomous robots	The autonomous robots are programmed machines that perform repetitive tasks with high and consistency level of quality, promoting productivity and process automation. They are the best substitutes in dangerous tasks or the one should not be performed by a person.	Akkaya and Kaya (2019)
	They are indispensable in industries due to its reliability in performing tasks with precision and high speed. For example, in welding, assembly, painting and material handling.	Ong et al. (2020)
	Application: A robot called Roberta with 6-axis that can work in compact areas, Kuka robotics a company that produces robots capable of interact between them and Yumi robot, from the ABB company that interacts with human beings.	Menendez et al. (2020)
Cybersecurity	The Cyberspace is a virtual environment where is created, stored, and shared digital information through online communication thanks to tangible infrastructures built. Therefore, its users, infrastructures, and information are vulnerable to threats as data exposure, identity theft.	Chowdhury et al. (2019)
	Cybersecurity embraces a set of tools, technologies, and practices to	Sarker et al. (2020)

	protect and preserve the integrity of software programs, computers and data against damage, unauthorized access, and attacks.	
	Application: In systems like Industrial Automation and Control Systems (IACS), Information Technology (IT), Industrial Control Systems (ICS) and in software application presented in industry and in any device connected to internet.	Corallo et al. (2020)
The cloud	According to the authors companies used to have cloud- based software, however with the phenomenon Industry 4.0 it becomes essential to Cyber-physical System (CPS), allowing companies to share information more quickly and efficiently. Thus, the technologies based in cloud will be more effective.	Menendez et al. (2020), Rüßmann (2015)
	This pillar offers to the companies smart and digitalized processes, where the data collected is sent, analyzed, and stored in the cloud to be processed and present relevant information to the user.	Udayangani et al. (2019)
	Application: Cloud computing and other technologies can convert a traditional assembly line to a smart one, where operation cycle time data is collected, processed, and stored through a wireless network and for example, Yamazumi Diagram can be generated automatically.	Udayangani et al. (2019)
Big data and analytics	Industry 4.0 demands collecting, storing, and sharing an enormous volume of data, which require a set of techniques of advanced analysis to support the decision process-making from the interpretation of information coming from relevant data.	Oncioiu et al. (2019)
	An amount of data is generated in the Industrial System, and it need to be processed so the user can extract information. The 5 characteristics that define Big Data are: velocity, volume, veracity, variety, and value.	Cui et al. (2020)
	Application: companies can measure and evaluate their skills, strategies, and experiences through the evaluation of data analysis tools.	Oncioiu et al. (2019)
Additive manufacturing	Prototypes allows to produce different components and shapes before validating a product, so it allows to test a product´s performance before it turns to mass production and 3D printing is a technique that materialize geometries in a short period of time, boosting production speed, customization, and automation in industries.	Mehrpouya et al. (2019)
	3D printing brings personalization, flexibility and fast prototyping that offer gaining of time and costs shorting normal slow steps of productive process.	Kabir et al. (2020)
	Application: In biomedical industry this technology is applied to produce implants for patients. In automotive industry to build some cars components and Architecture to produce prototypes of some buildings.	Mehrpouya et al. (2019)
Augmented reality	"Augmented Reality (AR) superimposes virtual objects onto real images that are captured through a mobile device." This technology allows higher levels of efficiency and productivity, at the same time avoids mistakes for example, when a logistic operator wants to pick an item from the warehouse. Also, it saves time and costs.	Menendez et al. (2020)
	AR brings a virtual environment where the users have the perception of being in a physical world that is not the real scene at the time, that can be provided through some devices like smart glasses.	Zarzuelo et al. (2020)
	Application: Siemens use this technology to train their employees reaction when there´s an emergency or a problem in a machine. In production can be used to see replicas of real devices to ensure if the quotas are inside the acceptable parameters and if is not, it can help to identify a problem.	Menendez et al. (2020)
Internet of things	IoT represents the interconnection between "things" or physical objects like CPS, where those "things" has software, connectivity, electronic hardware, and sensors that allows them to collect and change data. Those things have a single and unique computer system for their identification.	Janiesch et al. (2020), Petrasch and Hentschke (2016)
	IoT connects different physical objects like machines, watches, cell phones and sensors through internet and those objects or things can communicate in a virtual world that allows them to access and post information about themselves. So, those data need to be controlled and tracked.	Venkatakumar and Schmidt (2019)
	Application: IoT systems have been applied in various economic segments as production, retail, and medical applications.	Fleischmann and Stary (2019)

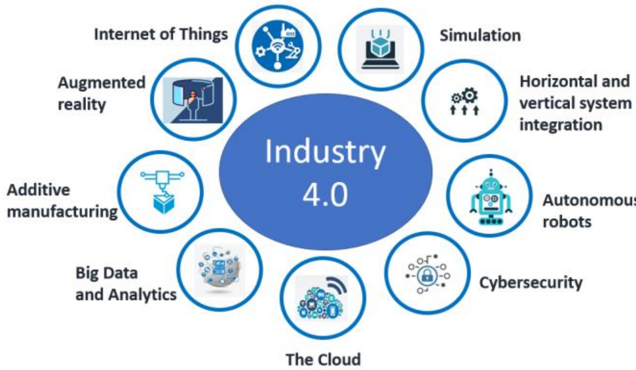

Figure 1. The nine technological pillars of Industry 4.0 (Adaptable from Rüßmann (2015)).

According to Fettermann (2018) those technologies offer gains to production and service companies since it brings huge advantages to the organization. Thus, it encourages the industries to pass from simple producers to providers of services with a high personalized and individualized products for its customers. It is consensual that Industry 4.0 contribute to reduce operational costs however, the cost of its implantation (initial investment) isn´t easy or cheap as expected (Kamble et al., 2018).

2.2 Challenges and Sustainability of Industry 4.0

Industry 4.0 encourage companies to transform themselves and go from being simple producers to service providers with a high level of customization and individualization of costumers products (Thuemmler & Bai, 2017). As cited in Corallo studies (2020) "Industry 4.0 transformations have the potential to create value for companies with efficiency improvements of 15–20 percent". According to Schwab (2016) Industry 4.0 is impacting the global economy of countries, in jobs since mechanical and repetitive tasks move from man to automated processes that will demand an increasingly creative and social professionals. Industry 4.0 boosts mass customization, promotes the concept of sustainability and encourage the dematerialization of services and physical products to digital designers (Culot et al., 2020).

It is consensual in the two works of Jamwal et al. (2021a, 2021b, 2021c) that Industry 4.0 helps to create sustainable value in three dimension of sustainability required by government policies and costumer pressure namely, social, environmental and economic level covering processes, products and systems bosting simultaneously economic gains and more sustainable industries. The final objective of Industry 4.0 is to optimize supply chains, support customer service and favor recycling and sustainability practices (Kamble et al., 2018). Sustainable manufacturing (SM) is a structure and a set of activities to produce good products with the least use of resource and with sustainable resources ensuring people, employees and customers safety (Jamwal et al., 2021a, 2021b, 2021c). Technologies of Industry 4.0 merged in a SM results in optimization of energy consumptions and labors inputs (Jamwal et al., 2021a, 2021b, 2021c).

Industry 4.0 brings so many advantages to industries but there´s many challenges behind its application. Nowadays, one of manufactures big challenge is innovating their process to accomplish sustainability in their business (Jamwal et al., 2021a, 2021b, 2021c). Moreover, there is a huge variability on customer demand and the need of efficient supply chains and sustainable productive system that saves energy consumption (Mehrpouya et al., 2019). Finally, one of the major challenges in implementing Industry 4.0 is the fear of losing jobs and human labor, especially for the fragile lay of society with low level of education (Khanzode et al., 2020; Sung, 2018).

2.3 Simulation

The word Simulation comes from the Latin word "Simulāre" which means "Behave as if " or "Making like" performed in a physical or virtual environment (Gunal, 2019). Then, simulation comes with the aim to predict a situation in the future. Long before the computer age, simulation was present in the decision-making process, for instance at the army when soldiers simulated a war in order to identify strategical and tactical defense and attack (Gunal, 2019).

In fact, simulation has been evolving for decades, it pass from an analytical and optimization tool with complex programming languages to a simpler decision support tool to be used recurrently built in a software that contains simulators (package with graphics) that don`t require the pure programming from its users (Law & McComas, 1987; Rodič, 2017). Figure 2 shows the evolution of simulation along time.

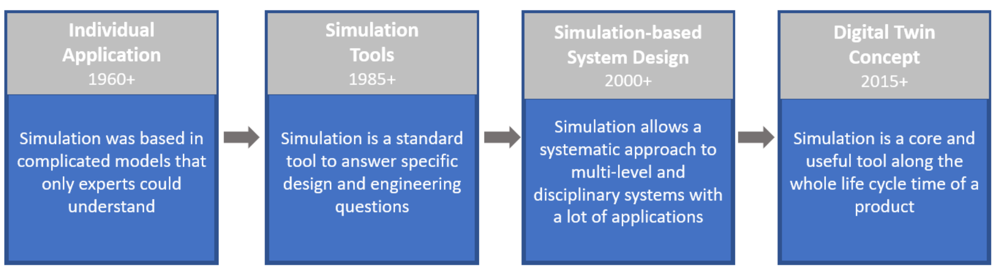

Figure 2. The evolution of simulation along time (Adaptable from Rosen et al. (2015)).

With Industry 4.0 it is obvious that simulation would go to other level, and nowadays we find simulation in the highest level referred to the Digital Twin concept. Digital twin as cited in Stark (2017) work is the digital representation of a machine, product, service or system that their properties, conditions and behavior can be changed through the modelling of its data. Also, this concept means using simulation in all phases of the life cycle time of a product, from the development step and virtual tests to the final case (Rodič, 2017). Digital Twin is the new integrated approach of modelling, simulation, and technological optimization. Simulation is applied in Engineering and Science because of its advantage like reducing cost and time of developing, increase of products quality and helps in the knowledge management (Rodič, 2017). This tool, takes advantages of the supplied data in a virtual model from a mirror of a physical model constituted of machines, products, human resource which brings optimization and an increase of quality (Bahrin et al., 2016). It is important to remark that if we want to obtain the desired model it is essential to have correct data and information otherwise, the output analysis will not reflect the reality we want to simulate.

The simulation with animation package helps to make the specificities of the real system become more visual and simpler through the model and the decisions are not made only by the outputs of the models as well from the dexterity coming from the graphical animation (Kljajić et al., 2000). Mostly, the simulation software is oriented to the industry and a none level of programming is required to build the model (Law & McComas, 1987). The developers of this kind of software's created an interface that facilitates to build the model, promoting personalization with realistic graphical animations that allows the users to make statistics and optimization analyzes of dynamics models that reflects conditions of the real world (Aomar et al., 2015). Examples of those software's are Witness, Arena, AnyLogic, Simio, Plant Simulation (Gunal, 2019). This study was performed in Witness software, belonging to the Lanner Group.

2.4 Simulation in Layout Planning

According to (Näfors et al., 2017; Naranje et al., 2019) the definition of a factory layout is a big problem that costs significant losses of money, time and efficiency when wrongly implement and the right equipment location contributes for a more productive efficiency. The layout study is a vital phase to achieve an efficient productive system and requires a multidisciplinary team to contribute with important perspectives (Näfors et al., 2017). A production line configuration is the set of the dependence between each stage of the process, which means the description of the different stations performance in a factory (Hardin et al., 2016).

Pinto et al. (2017) affirm that a good location and distribution of machines in a line can contribute for a good productive flow and for a reduction up to 50% in operational costs and, simulations tools are very useful to evaluate the benefits and performance of different layout configurations. Afterwards, factories are pushed to have the best layout at first, inefficiency and errors may have severe consequences in the material flow and security of operators (Oyekan et al., 2015).

In fact, defining a layout project is a hard task in an increasingly competitive market, which requires the combination of different needs, perspectives, functional and geometrical harsh constraints (Shariatzadeh et al., 2012). It is indisputably that modification along the project will appear and would be impractical such alteration being tested in the tangible world which would incur huge costs to the company and, in this meanders simulation is an excellent choice to study and test the performance of the future real system (Naranje et al., 2019). Simulation gives information in the project stage with the aim of optimize the production and its processes for a specific industrial goal while evaluating numerous scenarios with some confidence to support the decision-making process (Peruzzini et al., 2020).

In automotive industry, layout alternatives are evaluated based in certain parameters that test and evaluate different models to obtain preponderant information about complex systems before being implemented (Mourtzis et al., 2014). So, simulation is a tool that helps industries to project the best layout, reaching a global view of different alternatives anticipating what can happen in shop floor, providing information about the best scenario , with low cost , high flexibility , less risk, optimizing the production and its processes (Naranje et al., 2019; Peruzzini et al., 2020).

3. Case Study

3.1 Contextualization

The case study was performed in an automotive industry. This company is going to produce a new mechanical component and the big challenge is to define the best configuration of the line considering some constraints of physical space, budget, and material flow. This part is new in the company, which is going to replace one of the parts of an engine. The pressure of choosing the best layout at first is high, since the factory does not have more space to implement a new line and wants to reuse some deactivated equipment. The goal is to use an old space of an inactivated line to project the whole new line, and in this case all equipment should be redeployed (Zone 2). On the other hand, taking advantage of the space of this inactivated line (Zone 2) to deploy a part of the equipment and the rest of equipment would stay where they are in a line nearby (Zone 1) and in this case the equipment wouldn´t be moved. Along the project, four possible configurations emerged, and it was imperative to compare them.

3.2 Methodology

This paper was conducted with an Action Research methodology. A methodology that fits in an industrial environment, due to its collaborative way in identifying problems, where the researcher works with the company with the aim of identifying solutions for the problems presented (Näfors et al., 2017). This practical research methodology wants to solve a real problem , where from an investigation there´s an action performed culminating in a reality modification (Coutinho et al., 2009). This methodology follows 4 steps, we started with Planning the study, then implementing the Action, Observing the results, and finally Reflecting the results. It is important to highlight that this study is an iterative cycle between the 4 steps.

3.3 Project Development

3.3.1 Design of Layout Variants

The following explanation around the 4 layouts that could describe the objective of production, results from the evolution assisted during the development phase of the project. At first, the idea was to have the line compressed in a single line, which means the first machines that starts producing the raw should be moved from where they were implanted to this new spot. Afterwards, the project team realized this implies civil works to reimplant the machines and doubts about this configuration appeared. Then, a second propose came to split the line in 2 separates lines, the first 4 machines (Machine A1, A2, A3 and A4) should stay in the place they are implanted (Zone 1), and other machines could be moved (Zone 2). Once again, this variant was discussed due to some security and budget restrictions and 2 more variants came to the discussion table. At the end, 4 possible layouts could describe the line and the aim is to have the best line, with a good material flow, keeping the operators safe. In the last 3 variants, where the line is divided in two, the transport between the zones is guaranteed by the AGV (Automated Guided Vehicle). A simulation study was performed to better understand the behavior of each of the 4 layouts and analyze which of them could be the best choice. The project objective is to find a line capable of producing 3.625 parts/week with an Operational Income (OI) of 87%.

- **Layout 1: Machines A and B are Together in Zone 2**

In this first variant, showed in Figure 3 the Machines A1, A2, A3 and A4 will be moved from where they were before (Zone 1) to this new spot (Zone 2) and Machine B will be taken from the central workshop of the factory to be implanted in this area (Zone 2). This layout is characterized to have all the machines together compressed in one single zone.

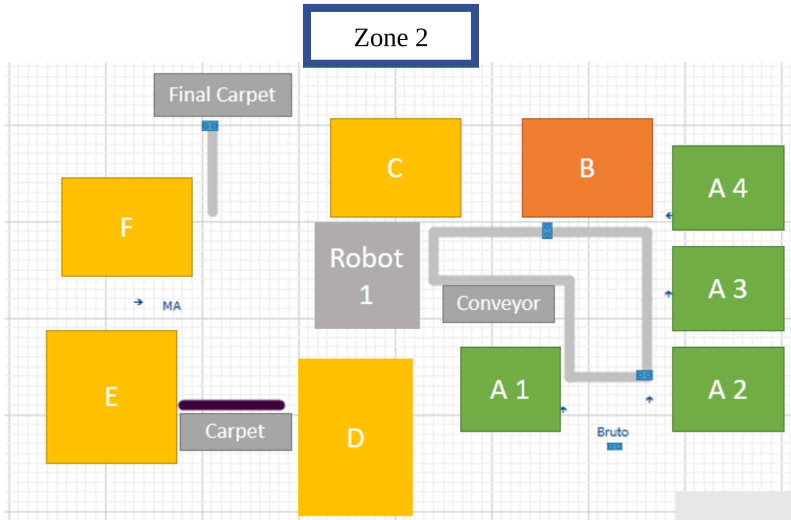

Figure 3. Layout 1 (Machine A and B together in Zone 2).

- **Layout 2: Machines A in Zone 1 and Machine B in Zone 2**

In this second variant as we can see in Figure 4, the Machines A1, A2, A3 and A4 are not moved and stay exactly where they were (Zone 1) and Machine B is implanted in Zone 2. The rest of the machines are implanted also in Zone 2 and there´s 2 robots in this zone.

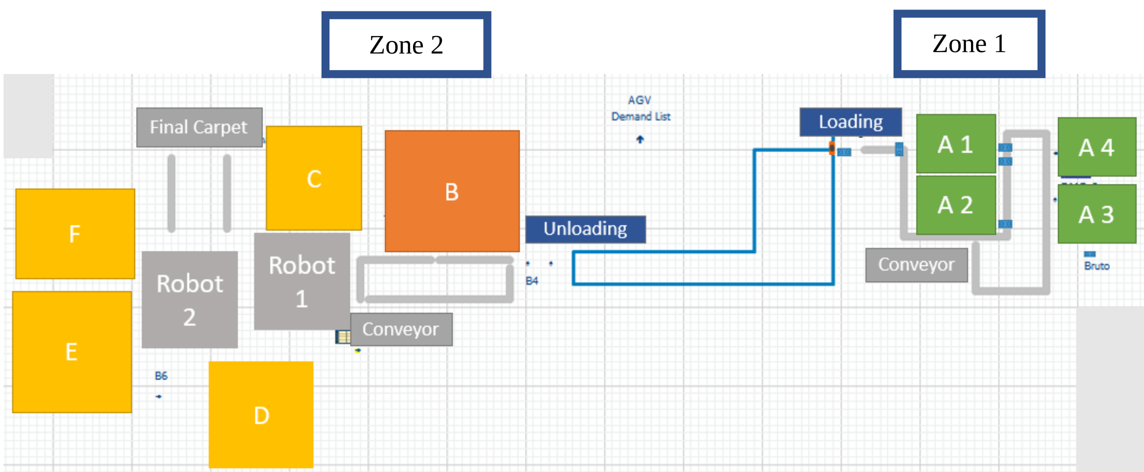

Figure 4. Layout 2 (Machine A in Zone 1 and Machine B in Zone 2).

- **Layout 3: Machines A and Machine B in Zone 1.**

In this third variant represented in Figure 5 the Machines A1, A2, A3 and A4 and Machine B are together in Zone 1 and the rest of machines are implanted in Zone 2. There´s 2 conveyors in Zone 2.

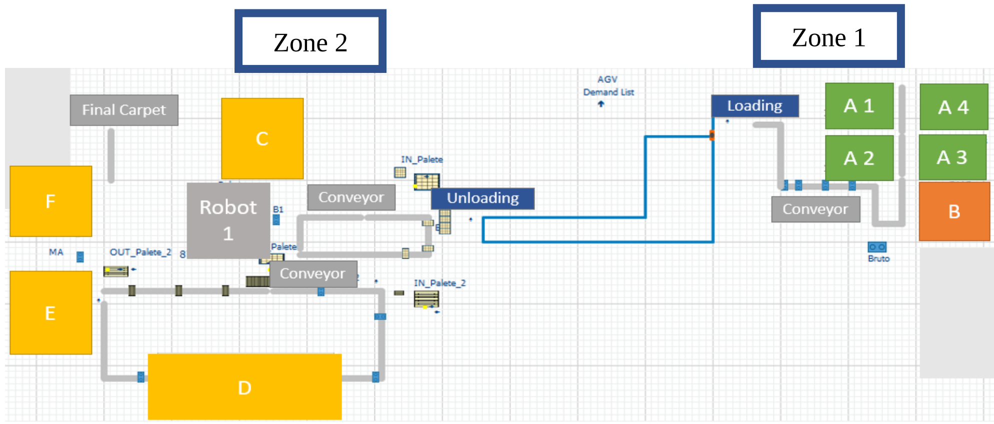

Figure 5. Layout 3 (Machine A and Machine B in Zone 1).

- **Layout 4: Machines A and Machine B in Zone 1 and a single conveyor**

In Figure 6, the last layout variant is shown and the Machines A1, A2, A3 and A4 and Machine B are together in Zone 1 and the rest of machines are implanted in Zone 2. There´s 1 single conveyor, covering the whole Zone 2.

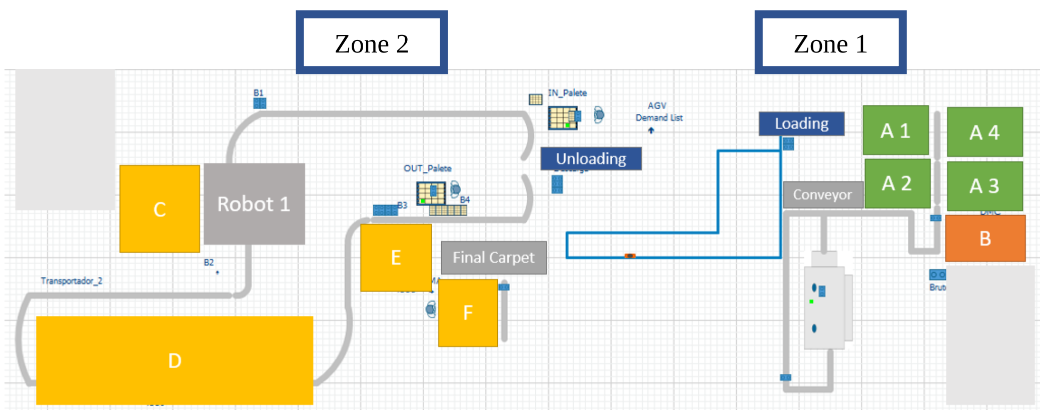

Figure 6. Layout 4 (Machine A and Machine B in Zone 1 and a single conveyor).

3.3.2 Evaluation of the Layout Variants

The 4 layouts variants can guarantee the volume of 3.625 parts/ week as shown below in Figure 7. Also, we can see that Layout 1 is capable to produce more 114 parts (3739 – 3625 = 114), Layout 2 more 122 parts, Layout 3 with the highest volume of production with 3780 parts and finally layout 4 can produce 3744 parts. With this result, there´s no doubt any of the 4 variants can respond positively to the production volume goal.

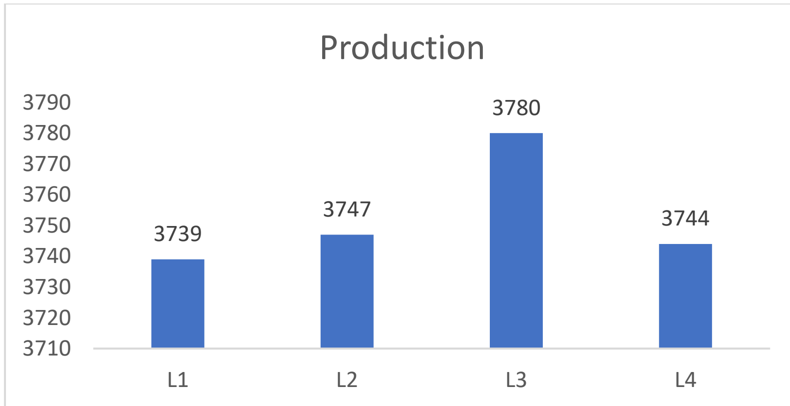

Figure 7. Volume of production.

In Figure 8, we can observe the results related to Lead Time measurement. L1 shows the best lead time, which means the shortest one with 20.306 minutes which is completely normal since this is the compressed line and all machines are together and near to each other and there´s no transfer between zones. In the following layouts, there´s the need to transport the parts from Zone 1 to Zone 2, so it is expected to have a late lead time. The time going and back of the AGV will increase the lead time, since this transport takes parts from a zone to another, which means a part will take longer from line entrance to line exit. As we can prove in Figure 8, where these last 3 variants have the highest lead time compared to L1, namely L2 has de best result of the 3 of them with 42.465 minutes, then comes L3 and finally L4 with the worst lead time of 50.331 minutes. Regarding the OI, represented in Figure 9, the results are similar around the 87% for L1, L2 e L4 and is remarkable Layout 4 with the highest OI with 88,175%.

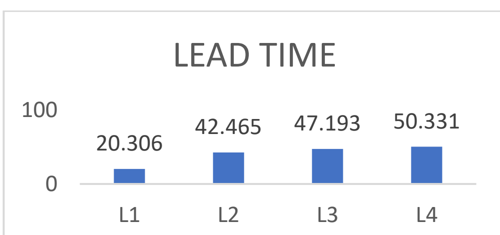

Figure 8. Lead time compilation **.**

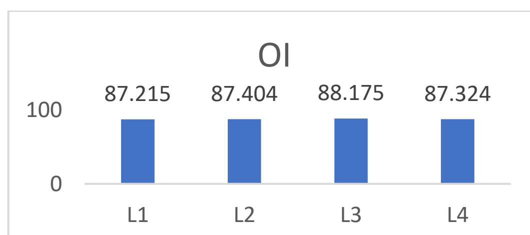

Figure 9. Operational Income compilation.

Next, is presented Figure 10 showing an example of the occupancy rate of Layout 1 machines. This graphic was taken directly from Witness software statistics.

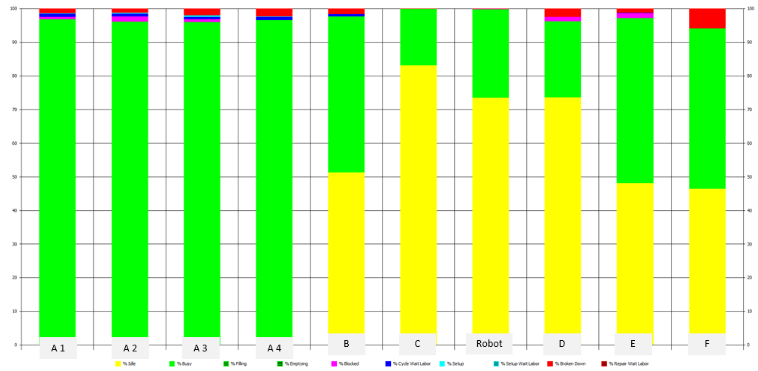

Figure 10. Example of the occupancy rate of Layout 1.

Below in Figure 11 is presented a graphic made in excel that represents a compilation of the occupancy rate for each machine. It is obvious that the first 4 machines A1, A2, A3 and A4 have the best busy rate around 97% in average. Then comes machines B, E and F around 47% and the rest of machines with the lowest occupancy rate, less than 30%, in special machine C with the lowest busy rate, around 16% in the 4 variants. The reason behind this low busy rate can be due to many factors, machine C can have the lowest cycle time compared with all the machines or, it has few breakdowns or blockages in the line. In order to simplify the visualization and analysis of this graphic a different approach was folowed.

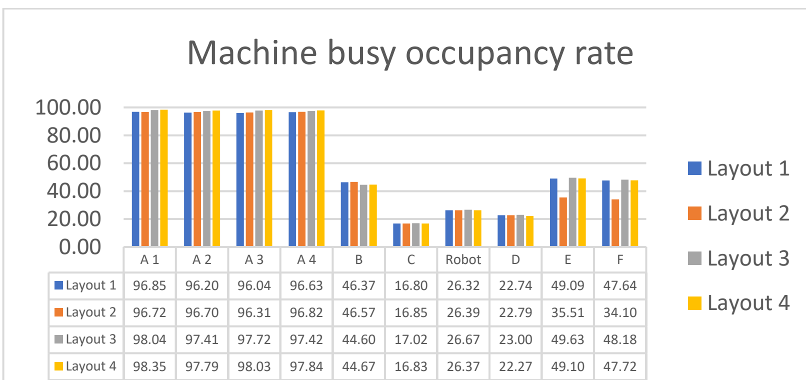

Figure 11. Machine busy occupancy rate.

The approach to simplify this visualization was to create an Average Occupancy Rate (AOR), a measure that join machines into groups, the first group composed by the first 4 machines (A1, A2, A3 and A4) where was performed an average of busy occupancy rate. The second group composed by the rest of the equipment (B, C, Robot, D, E and F).

In Figure 12 we can see these 2 groups and the AOR is presented. Obviously the first group represented by L1, L2, L3 e L4 have the best AOR, L4 with 98%, L3 with 97.65% and then 96.64% and 96.43% to L2 and L1 respectively. Going through the second group it is noticed the rest of machines has on average the lowest occupation rate, around 34% in all layouts except for L2 with an average of 30.37% occupancy rate.

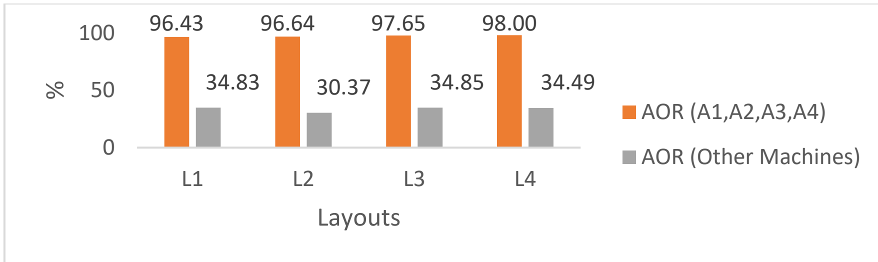

Figure 12. Average occupancy rate (AOR).

To better understand the software display is presented in Figure 13 an image taken from Witness software, in this case it is a print taken directly from the Witness software, showing the display of the second variant of layout. As we can, although the image is not clear it is presented an example of Witness display where machines, conveyors, tracks from where AGV circulates were drawn to understand the dynamic of the line. Besides, in the right side is presented some variables like RO, Leadtime that are continuously update along the simulation clock. Those variables are in the front side only to help the analysis of the model, to see how they change along time but, it is not necessary to do, it is just a way to help to make it much visible. This image in Figure 13 gives a better comprehension and visible output of the layout variant, as we can see below. It is important to highlight that each variant had its own model, and the results are presented in Table 2.

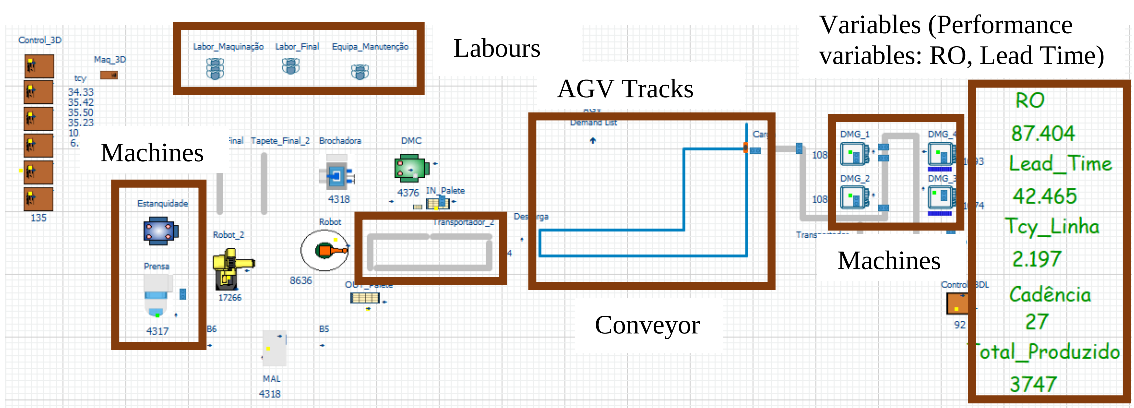

Figure 13. Witness model of layout 2.

Table 2. Performance measures of the 4 layouts.

Performance measures	**Layout 1**	**Layout 2**	**Layout 3**	**Layout 4**
OI	87,215 ± 0.085	87,404 ± 0.172	88,175 ± 0.165	87,324 ± 0.111
Lead time (min)	20,306 ± 0.220	42,465 ± 0.567	47,193 ± 0.119	50,331 ± 0.247
Line cycle time (min)	2201 ± 0.010	2197 ± 0.004	2177 ± 0.004	2199 ± 0.004
Cadence (parts/h)	27 ± 0,000	27 ± 0.000	27 ± 0.000	27 ± 0.000
Production (parts/week)	3.739 ± 0.000	3.747 ± 0.000	3.780 ± 0.000	3.744 ± 0.000
AOR1 (A1, A2, A3, A4)	96,430 ± 0.000	96,638 ± 0.000	97,648 ± 0.000	98,003 ± 0.000
AOR2 (Other machines)	38,347 ± 0.000	34,155 ± 0.000	38,438 ± 0.000	38,122 ± 0.000
Number of pallets	16	10	18	30

In Table 2 is presented a compilation of all performance measures between the 4 layouts, measures such as OI, Lead time, Production, Average Occupancy Rate (AOR) and so on. It should be noted that the optimal number of pallets to guarantee this volume was also provided by the software, as we can see in the last row of Table 2.

The table above shows that Layout 1 has the lowest OI, Line Cycle time, Production and AOR1 for the 4 Machines (A1, A2, A3 and A4) but the best Lead time for being the shortest one. In contrast, Layout 3 seems to have the best measures compared to the rest, have the best OI, Line cycle time, production and AOR2. Curiously Layout 4 has the best AOR1 with 98.003% and the highest Lead time of 50.331 minutes, the best and the worst scenarios.

According to all the information presented a conclusion could be made and obviously Layout 3 would be the chosen one. Undoubtedly, money is a sensitive issue to company and all investments need to be well studies and fundament. In this context, it was a unanimous decision to find a way to punctuate the cost behind the implementation of any of the variants. So, it was decided that we would use 2 criteria to punctuate each layout and then a final decision would be made. One of the criteria would be called technical criteria, represented by the measures we saw before, OI, Lead Time, Production etc. The other one, monetary criteria that express the level of investment or cost of implementation of each layout, to buy equipment or building some architecture. These 2 criteria were filled, and the final score is present in Table 3 and Figure 14.

Table 3. Final score of the 4 layouts.

Criteria	Layout 1	Layout 2	Layout 3	Layout 4
Technical	23	31	43	27
Monetary	12	10	6	8
Final score	11	21	37	19

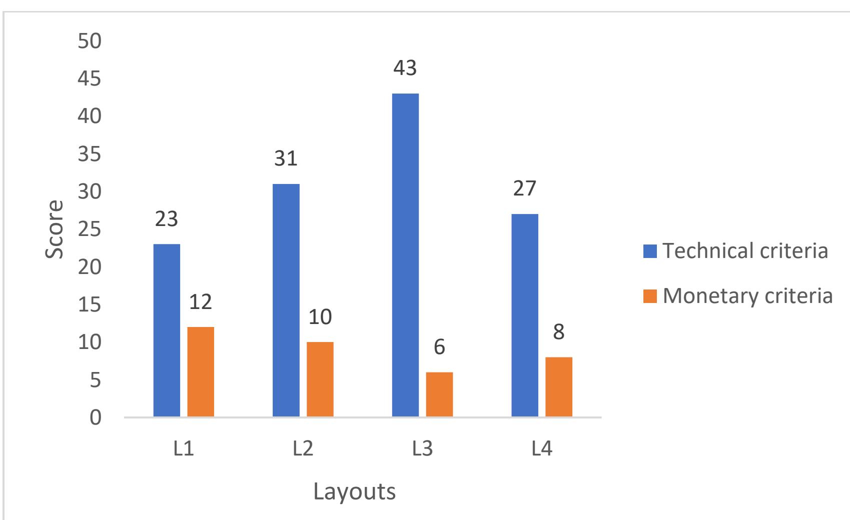

Figure 14. Comparation between the 2 criteria.

3.3.3 Suggestion of the Best Layout

According to Table 3 or Figure 14, Layout 1 is the most expensive one compared to the other 3 layouts and, layout 3 is the cheapest. In Technical criteria we realized that layout 3 is the best one with a score of 43 points, next layout 2 with 31 points, then layout 3 with 27 points and finally layout 1 with 23 points. There´s no doubt that globally layout 3 is the best of the best and this could be the best option for the company. Much more than that, the objective of 3.625 parts/week with an Operational Income of 87% is achieved in any of the layouts, which is a good aspect that proves to the company that the team project was in the right path when they were drawing each of the 4 configurations.

4. Social Implication of the Work

With this work, our goal is to appeal to industries with a practical application case to make them be aware of technological advances of Industry 4.0 that came to optimize their work lives. Without this simulation study, the company could implement, for example, the first layout without deeply analyzing some particularities of this variant, for example excluding some aspects that could happen in the line that simulation considered. In addition, the company would expend several resources to relocate the equipment or buy more pallets than necessary, in which case it would be a waste. In practice, with simulation study strategy it was possible to save human resources efforts, save money and even at environmental level, using the resources in the correct way allows for long-term gains. Instead of deploying the wrong layout that would bring severe consequences in the future or changing the location of equipment and spending resources unnecessarily, a priori study helped to predict, control, and prevent future harm.

5. Conclusion and Suggestion for Future Research

Industry 4.0 is the new philosophy and came to revolutionize the industrial sector, bringing with it new ways of thinking and being for organizations that strive to become increasingly intelligent and digital. One of its technological pillars, called simulation is a tool that came to help companies to unlock some situations. When there´s uncertain about a future situation, simulating is the best option, due to its capability of predicting a behavior without being implemented in the tangible world. Simulation has been around us long before Industry 4.0 but with this digital paradigm, it become a much easier tool to use with commercial software package with a high capacity of animation and with low or no programming level required. Simulation can test different scenarios without changing the real system, it is dynamic, flexible in a low-cost way when changes are made, it saves time since little and big changes can be made without much effort, and it is a robust tool that plays an important role in decision making- process.

With this project, the factory understood how helpful simulation is and how it can give important highlights that static tools cannot and with no additional cost, 4 different studies were carried to better understand and view the impact of having each of the 4 layouts. The project team knew from the beginning that the goal of production volume and operational income goal could be achieved by any of the variants, but the main problem was to understand deeply how blockages, breakdowns and AGV route could impact the line flow. Besides, how many pallets needed to be bought to ensure the production volume. Before the study the company felt a huge difficulty to understand how each of the variants would behave, how the different equipment interacts and the line dynamic. With simulation, it became so much easier to compare and analyze the dynamic of the line, also according to its performance we could scale the conveyors, to understand points of saturation and scale the number of pallets need between 2 machines. Also, analyzing the bottleneck the company was able to understand the limit from where the line blocks, since the bottleneck is in the beginning of the line (Machines A1, A2, A3 and A4) has the highest cycle time.

This study had some limitation due of the missing of some data related to the velocity and size of conveyors, information about machines breakdowns and some data that needed to be extrapolated and consequently the results may have some deviation. Also, even though simulation is gaining all this prominence in the market, it is still a nightmare to have this tool working hand by hand in the company where the project was performed. In fact, the project team was resisted to use and explore the potentialities of the software, only a small portion of the company knows how to work with the tool and even for them, it is uncomfortable to manage it. Witness is not a common software in the market and there´s a very few information about its utilization, which culminated with a harder mission to this research.

The 4 questions raised in the project were answered. First one, it is important to have simulation tools in daily lives, being actively used in all project development phases with an expertise team capable of carrying this kind of studies and analysis before an important decision- making. Second, in real time the software animation expressed the expected dynamic of the line. Third, the optimal number of pallets that needed to be bought were defined and finally, the technical criteria shows that layout 3 has the best results in terms for example of OI, Production and AOR. Forth, layout 3 is the one we would recommend according to the final score of 37 points. For future research, we could develop more studies about Witness software, its particularities, constraints, and its potential in a shop floor reality, where real life examples could be explored and implemented to prove how robust simulation can be and particularly the power of Witness software. Also, at this stage some new data was released and would be an interesting approach to update them in the models and see if its changes are impactful or not.

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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