FACULTY OF SCIENCE AND TECHNOLOGY

MASTER'S THESIS

Study programme / specialisation: **Industrial Asset Management**	The *spring* semester, *2023* **Open** / Confidential
Author: **Laura Patricia Gonzalez Nava**	
Supervisor at UiS: **Prof. Jayantha Prasanna Liyanage** Co-supervisor: ------ External supervisor(s): -----	
Thesis title: **Digitalization for Quality Improvement for Manufacturers**	
Credits (ECTS): **30 pts**	
Keywords: **Quality** **Manufactory Industry** **Lean** **Green Manufacturing** **Digital Manufacturing**	Pages: 49 + appendix: Stavanger, *June 15th, 2023*

Digitalization for Quality Improvement for Manufacturers

Laura Patricia Gonzalez Nava

Supervised by: Prof. Jayantha Prasanna Liyanage

Faculty of Science and Technology

University of Stavanger

Stavanger

June 15th, 2023

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my professor and supervisor for his invaluable patience, guidance, and feedback. This master thesis would not have been possible without his reinforcement. I dedicate this work to my family and loved ones, who supported me and always believed in me, for nobody has been more important to me for the accomplishment of my degree. Their unconditional love has been my motivation to keep going and fulfill my dreams. Thank you to everyone involved, it's an honor for me to share this work with you.

ABSTRACT

This thesis examines the impact of digitalization on quality improvements in lean and green manufacturing. Through a literature review and case studies, the study analyzes the benefits and challenges of digitalization in optimizing manufacturing processes, reducing waste, and improving product and service quality.

The findings suggest that digitalization can enhance manufacturing efficiency and sustainability, by enabling real-time monitoring and control of the production systems, improving supply chain visibility and total collaboration, and facilitating data-driven with decision-making analysis. However, the successful implementation of digitalization requires addressing several challenges, such as data security and privacy, workforce skills and training, and organizational change management.

The study also highlights the importance of integrating digitalization with lean and green manufacturing principles to achieve synergistic benefits. Overall, this project contributes to the growing body of knowledge on digitalization and manufacturing and provides practical implications for managers and stakeholders seeking to enhance manufacturing competitiveness and sustainability.

TABLE OF CONTENTS

1. INTRODUCTION

Digital transformation was known as a topic of the future, but it has now become a need for our current situation as a high priority for Top Management and Stockholders to maintain the industry in market. The impact of digital transformation is inevitable and must happen to be able to keep up with all the customer and market needs, it all starts with a change of culture to be able to update processes and products and innovate as a Business.

The implementation of new digital technologies is a benefit for industries to remain competitive in the market, increase productivity and efficiency, lower costs and improve processes. Manual processes often have delays, human mistakes, and inefficiencies. It's the embrace of old business models by potential digital technology, to collect the data, identify patterns and make smart fast business decisions.

A manufacturing organization that is focused on reducing waste and continuous improvement of their process armed with only traditional tools, such as Lean Six Sigma, will encounter some limitations over time, with the embrace of digitalization, resulting in digital lean, organizations can expect great improvements in quality, productivity, investment, and others.

Keywords: Quality, Industrial Digitalization, Digital Lean, Lean Manufacturing, Green Manufacturing.

1.1. OBJECTIVES

The main purpose of this study is to identify the different strategies that could be of used for quality improvement in the Manufacturing industry by digital transformation and implementation of other technologies with the final vision to obtain the best results and improvements in the processes, product and in the market.

Similarly, the improvement and advantages in quality with the use of digital, lean, and green technologies will be discussed and studied in a Manufacturing example, where it will be discussed how this transformation is only possible if there is a change in the business model culture, process, and technology. Meaning all the levels of business need to be aware of the upcoming changes and the benefits that come with it, to have an open mind to change and have the same purpose to move the business to the wanted direction and goal.

This research will evaluate the advantages and requirements for organizations to embrace the new technology wave, and would try to answer several questions, such as:

- What benefits and results can be obtained from Quality?
- What areas of Manufacturing industry can Quality be implemented?
- What is the best way to implement Quality to obtain the best results?
- How digital technology impacts Manufacturing industry?
- What is the role of quality in digital transformation?

1.2. METHODOLOGY

1.2.1. STUDY DESIGN

This paper uses a qualitative study design approach, where the aim is to understand a specific context and put to test the predefined theory in a specific population. With this study we seek to identify different strategies to use digital system tools in the manufacturing industry to improve the quality by using grounded theory approach, measuring variables in experimental and in real-life industrial examples and describing the relationship between them.

1.2.2. DATA COLLECTION

The information used for this research has been extracted from books, scientific articles and lectures related to the quality and digitalization in the Manufacturing Industry to improve the processes and generate strategies to obtain an improvement. Besides the information extracted, personal data and experiences are going to be used as examples for the comparative.

1.2.3. STUDY CASE

Once that the information and data needed have been gathered to put to test the hypotheses for the study, a discourse analysis will take place to focus the data into the correct context by using the observation method of own experience in the manufacturing industry as a quality engineer and comparing the theory with Industrial cases in different countries.

The examples that are going to be used in this scenario are the following, for personal experience will be as a Quality Engineer in a Paper Packaging Manufacturing and as a real-time experience will be for Industrial Cases in Lean, Green and/or Digital Manufacturing in countries in the Americas, Europe and Asia.

1.3. LIMITATIONS

One of the limitations that arise in this research was the cultural constraints between the information extracted from European and Norwegian books and the personal experience in the Mexican industry, as it has some difference in the way some business and manufacturing takes place. In Mexico we are someway behind in the search for the minimum waste. Therefore, this research is a bit of conflict trying to use the advantage of the Norwegian culture in the Latin American Manufacturing Industry.

The second limitation concerns the inability to put into full practice the strategies as it was not done hand to hand with a company, but most of the research has been from past experience, knowledge, and examples actually used in the industry world to come with the results of the investigation.

2. THEORY

2.1. WHAT IS QUALITY?

Quality is an extensive term to define, every quality expert defines it in a different way, depending in the perspective that's been based on, in the most common used one, quality can be defined as the degree to which a set of characteristics have been established to fulfill or exceed a customer requirement, expectations or necessity. Meeting customer expectations results in a satisfied customer, but there's no competitive market or advantage in that, therefore we push to exceed their expectations. Let's use a restaurant as a basic example, you would choose from a list of restaurants the one that would satisfy you, but satisfying customers merely keeps the restaurant in the market game, exceeding customer expectations or delighting is what keeps them in a competitive advantage over other restaurants in the market with having a great ambiance, lower prices, bigger portions, or the extra service provided.

In the quality field it has been developed a list of dimensions to define the quality of a product or a service, which serves a good starting point in the understanding of this term, although it can vary for each industry, in this case we will focus quality for the industry, in specific the manufacturing industry. To ensure the consistence of always providing the same quality of products or services throughout the organization, we need to implement a Quality Management System (QMS) and Quality Control Management (QCM) to ensure the company delivers from every process to product under the same goal.

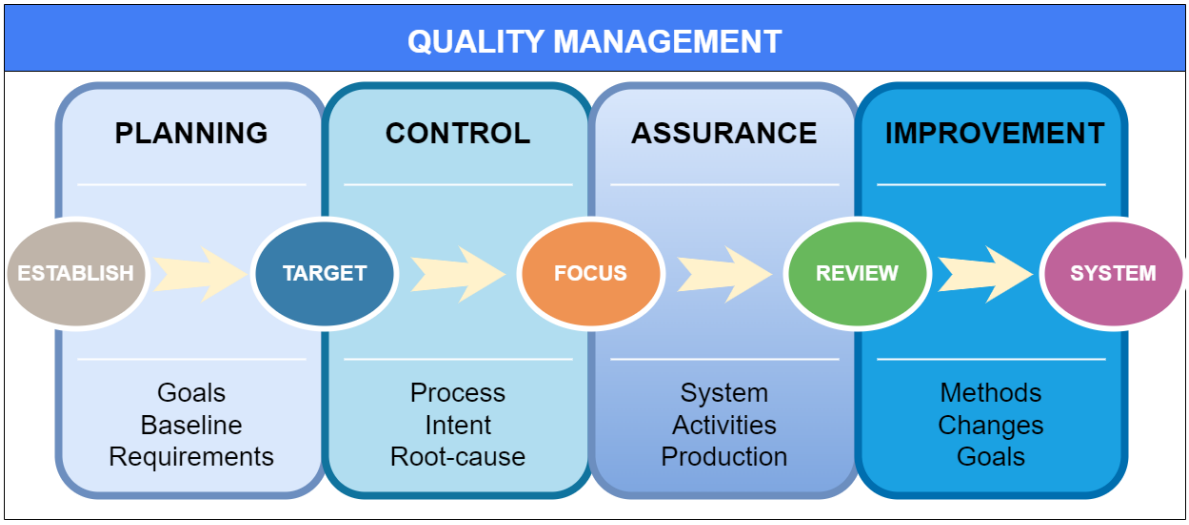


Figure 1. Quality Management Key Components

Explained, QMS (Figure 1) can be divided into four key components to be understood and effective to the fullest. These are the following steps and the methods that could be used for each one to make the job easier:

- Quality Planning: helps to identify the goals and establish the baseline wanted, determine the standards, the requirements necessary to meet those standards and the procedures that would be used to check the set criteria.
    - Methods: Cause-effect diagram, flowcharts, check sheets, pareto diagrams, control charts.

- Quality control (QC): its focus is more specific than QA, the target is on the process of the production for the product or service, with the main intent on eliminating the problems

causing the defects. According to ASQ[1], QC includes operational techniques and the activities sustaining the quality of a product or a service that satisfies the given needs.

- Methods: Six Sigma, Lean, Kaizen.

- Quality assurance (QA): a concept that focuses on the quality system from input to outputs, meaning suppliers and consumers. Including all activities in the middle concerning the production of products and services. According to ASQ, QA includes all the planification and actions required to provide confidence that a product or service will satisfy the needs. [Source: ASQ Statistics Division]
  - Methods: ISO accreditations, Kaizen, Ishikawa diagrams, Statistical sampling.

- Quality improvement: Review the findings of the quality control process and find a way to improve the methods, make changes if needed and maintain a desire for continual improvement as a goal. Repeat the process as a cycle to end up with a better product and satisfied customers.
  - Methods: Root-cause analysis, PDSA, 5 Why, 5S Pillars

- Quality management (QM): the overall functions involving the determination and achievement of quality.
  - Methods: TQM, Six Sigma, Kaizen, CoQ, EFQM

[1] ASQ: American Society Quality

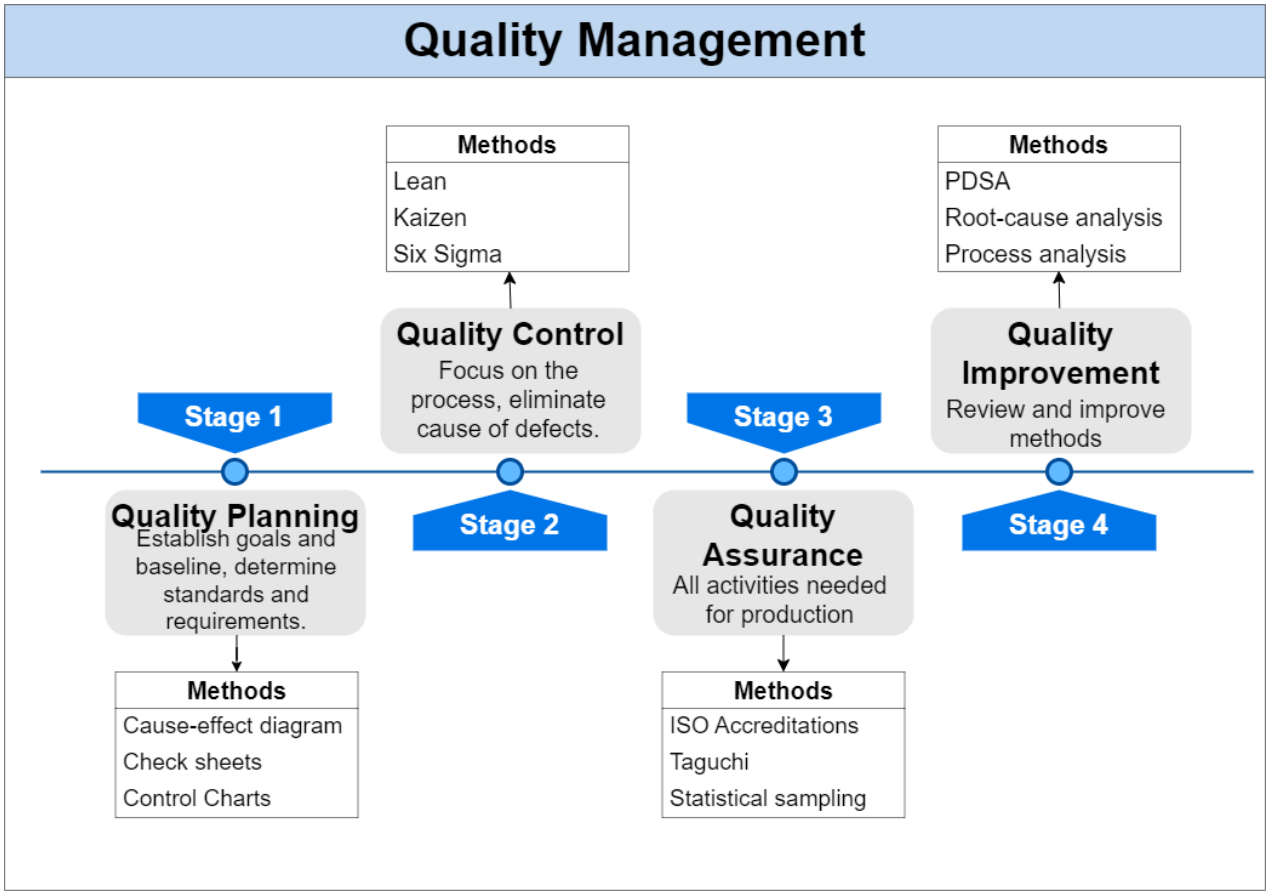


Figure 2. Quality Management Key Components and Tools

Now to have a better understanding of the Methods, here is a list of what each one of them is used for and how it works essentially, to choose wisely which one will suit better for the organization, considering time, easiness, or specificity.

As it can be seen in Table 1. many of the methods can be used in different stages or even in all the QMS, as some of them have techniques included that might help in the implementation of quality and its methodology. Another thing we can notice is that many of these methods, use statistical analysis to identify patterns and have a better understanding of the processes and then implement the methods for problem solving if any situation arises and improve processes and therefore results.

Table 1. QMS Methods description

Quality Management Methods

Methods	**QP**	**QC**	**QA**	**QI**	**Description**
Check sheets	x	x			Organize information to focus or particular attributes that could contribute to identified problems.
Control Charts	x	x			Determine if processes are in or out of statistical control.
Flowcharting	x	x			Show steps in a process to determine potential problems in planning.
Cost-benefit analysis	x		x		Analyzes the trade-off of providing quality.
Cost of Quality	x				Analysis of all the costs to conform quality and of nonconformance to find the balance.
Cause-effect diagram	x	x	x		Determine how various factors relate to a potential problem.
Statistical sampling	x	x	x		Selection of items for inspection by frequency and analysis of results.
ISO Accreditations			x		Quality audits is a review of activities to identify good practices in processes and projects.
Process Analysis			x	x	Application of procedures defined in the improvement plan to identify areas of improvement.
Lean	x	x	x	x	Optimization of resources by prioritizing continuous improvement.
Kaizen	x	x	x	x	Elimination of waste by improving processes.
Six Sigma	x	x	x	x	Combination of statistical process control to remove defects in process, product, and service.
Root-cause analysis			x	x	Collection of techniques to identify a situation's root cause. (Incl. 5 Why's)
PDSA				x	A technique to test an implemented solution.
Taguchi			x		Planning of activities, design, and development to lower the frequencies of faults and errors.
TQM	x	x	x	x	Strategy to focus on quality in all processes from low to top.
EFQM	x	x	x	x	Model that supports quality, efficiency, and sustainability in all processes.

The Quality Management System (QMS) helps achieve the organizational objectives and goals, incorporating internal and external processes to provide a procedure to monitor, manage and document quality processes and ensure that products are within standards and do not contain defects.

2.1.1. QUALITY STANDARDS

To keep defining commonly used terms, a standard can be considered a model of what has been established by a form of authority or by a general agreement. Standards define characteristics or performance; they instill confidence in the reliance or acceptance of products. Therefore, we can understand standardization as the process of generating an agreement to guide the creation of a product or a service based on an agreement between the interested parts in the industry. The importance is to ensure that goods or services have consistent quality and comparability in the same industry.

Businesses put quality standards to use to ensure that the product matches the expectation with the customer requirements, guarantee reliability of the product or service and avoid defects and deficiencies in the results.

Standards can be classified according to their function, which can be useful for understanding the effects, most of them can serve several purposes and therefore cannot be classified in only one category. Some categories for standards are:

i) Measurement standards: help establish a common technical language to compare physical attributes and technical information.

ii) Variety-reducing standards: help define the common characteristics of two or more subjects, as a way to provide a scale and learning in production.

iii) Compatibility standards: help define physical or virtual relationships between subjects for interoperability or communication.

iv) Quality and safety standards: allow consumers to assess the quality or safety of a product.

2.1.2. LEVELS AND EXAMPLES OF QUALITY STANDARDS

According to ISO (International Organization for Standardization) there has been developed a concept to give standards a more uniform structure called the High-Level Structure (HLS), where management standards have come from. Management standards support the organization in management strategies and with daily activities providing certain guidance and control throughout the processes, to work more efficiently and ensure customer satisfaction. Once the certification has been guaranteed it helps with the credibility for the organization among customers and the market.

There are different levels and categories for the standards, the levels are divided by the penetration they have in the market and the categories define the standards for the industry they can support.

The levels of standards are divided in three:

- De jure: refers to the standards established by law and approved by an official organization, therefore undergo audits from time to time.
    - Examples: IETF, ANSI, ISO, IEC, API.
- De facto: standards based on facts but not formally recognized, adopted by industry and the market. These are more market-driven, arising when they're well enough to collectively use them.
- Property: "standards" property of a corporation, with low recognition from the market. These may be closed or open allowing anyone to use them.

The de jure standards are the most commonly used among the industry as they are acknowledged in the market by official organizations, giving the organization a high value, and these standards are divided into

categories depending on the expertise in their subject matter and the needs for the organization, customers, users, and/or regulators.

For instance, the standards are divided into 6 categories (ISO Organization, 2023), such as:

- Quality Management Standards: Help do the work more efficiently and reduce failures.
- Environmental Management Standards: Aids to reduce environmental impacts, waste and be more sustainable.
- Health and Safety Standards: Help reduce workplace accidents.
- Energy Management Standards: Reduction of energy consumption.
- Food Safety Standards: Prevents contamination and risk in food production.
- IT Security Standards: Helps maintain sensitive information secure.

In Figure 3. We can see some examples of the most commonly used standards for each category that are applied in the manufacturing Industry. For more information it can be found on the International Organization for Standardization Webpage.

Figure 3. Management Standards

2.1.3. BENEFITS OF STANDARDIZATION

So, what benefits can be obtained from using Quality and its tools? Implementing a Standard Management System focused on quality improvement offers numerous benefits for the business owners, increasing the efficiency and productivity of the processes and giving the organization a higher opportunity in the marketplace.

Among the advantages of process standardization there is:

- Avoiding variation
- Meeting requirements

- Delegating responsibilities
- Improving results
- Cost reduction
- Process learning
- Increased profits and customer satisfaction

Standards help achieve long-term goals, sustain success, and focus on meeting needs and expectations for stakeholders and every party interested in the business.

Besides all the benefits it can be listed of the use of standards and management system, there are also disadvantages that have to be considered. The challenges that come in the implementation of standards and management include:

- Investment cost of certification
- Implicated time for monitoring
- Resistance to change from involved parties.

Considering the disadvantages are mainly investment of time and cost, choosing the right system is important to contemplate the needs, products, and objectives of the business and the industry is focused on, as some systems may suit better than others.

2.2. THE MANUFACTURING INDUSTRY

Among all the different types of industries, this research is going to focus on the Manufacturing Industry, where the possibilities of production are indefinite, and is the one that is used as an example in the next chapters.

By definition we can understand Manufacturing as the transformation of goods, the industry that creates products from raw materials with the help of third parties such as manual labour and/or machinery. It could also be denoted as the assembly of components into finished products.

In basic terms Manufacturers are companies that transform and assemble raw materials, parts and components into a finished product, with the use of machines, computers and human services to meet a customer's demand. There are also different types of production industries, such as:

- Make-to-stock (MTS): Traditional strategy based on historical sales data to plan according to forecast demand.
- Make-to-order (MTO): Strategy with low risk for excessive inventory, process starts when an order is received, allowing the customers to customize products but have longer waiting times.
- Make-to-assemble (MTA): Strategy combining MTS and MTO, based on demand forecast to stock product, assembling when the order is received.

For the strategies to work properly a good data history is essential to foresee how much finished product needs to be in stock ready to be sent to the customer, but also which and how much raw material needs to be in stock for production and assembly of these products. And the way to keep the shop and production floor running smoothly is with the use of technology and digital improvements. As a business keeps growing

and needs to stay on top of the market to be able to respond to any customer o needs, technical solutions have to be set up. The process might get complicated, and here is where the system management comes into play with continuous improvement and industrial trends.

Industrial Manufacturing Complex (IMC) success is powered by continuous digital improvements helping systems and processes with their complicated structures required for technical solutions. It includes diverse industries and ranges from beginning and products post-production.

With IMC we can reinvent the organizational experience focusing in 5 areas of interest:

1. Analytical solutions
2. Talent management is of great aid in performance assessment and career development,
3. Improvements in supply chains
4. Operational costs
5. Complex technical solutions

Figure 4. Manufacturing Industry Trends

The technology trend allows real-time manufacturing process data to be captured to analyze simultaneously for real-time decisions. Which in the moment helps for corrective responses and in the future for predictive analytics to improve processes and products. Normalizing preventive maintenance and failure focus.

If the goal is to keep in the market the industrial trends need to be followed, maintaining the talent inside the business as they have knowledge in the industry, the inclusion of new technologies, reducing waste for sustainability but keeping a good number of supplies for production and avoid time waste.

A manufacturing organization that is focused on reducing or eliminating waste and continuous process improvement with the work of traditional tools, such as Kaizen, will have great initial progress, but eventually its productivity will decrease over time, as it will come to a stop in the necessary tools. With digital lean, technologies, and machine learning they will be able to solve unsolvable problems and come up with possibilities for unreachable solutions.

2.2.1. GREEN MANUFACTURING

The green manufacturing is an industry approach to improve the manufacturing processes and dynamic, establishing environmental-friendly operations in the field, which means to use fewer natural resources, lower emissions to reduce pollution, therefore start recycling and reusing materials to minimize waste in the processes.

"Green Manufacturers research, develop, or utilize technologies and practices to lessen their impact on the environment" (University, 2016).

Following current manufacturing predictions, green manufacturing is a growing practice among professionals and consumers, who are turning their attention to businesses that are refining their processes towards the good of the environment and responsible production. Therefore, many industries are practicing eco-friendly methods, and consumers choose them over other manufacturers.

The main goals of a green manufacture are:

- Use few natural resources.
- Reduce pollution.
- Recycle and reuse of materials.
- Reduce the number of harmful gases.

Transforming a business to green, seems like a big investment, and organizations often wonder if it's worth all the effort, but there are several reasons to switch to a green manufacture and benefits to expect from it, first we are helping the environment by reducing pollution and the number of harmful gases that are exposed into the atmosphere, and the public relations may improve as it helps customers, workers and other companies see us differently and want to make business with us.

A positive image towards the public could be very helpful for more than selling products, it also motivates employees to care and proudly work for the organization. And if that is not enough to convince you to do good for the environment, going green might give you tax benefits, as some governments offer financial incentives that could encourage manufacturers to follow green practices.

To make a transition in the company or to start as a green industry its important that the workers have an introduction of what being a green manufacturing means, so that they can understand what it is needed from them and the importance of their cooperation. Therefore, the best way for that is to have a proper "Green training" teaching practice, some strategies that could be helpful in the transitions are:

- Design for remanufacture or reuse: design of process line and products so in case of non-conformance they can be remanufactured, separated and parts used again for new products, to avoid waste.
- Product and process technology: Process line and parts per product reduction to minimum, and smart work design meaning the space and time to go from one process to the other more efficient.

- Systematize supply chain: Obtain source materials and parts locally, avoid big concentrations of inventory using MTA[2] strategy.
- Water and energy efficiency: with help of energy management software and upgrading processes, upgraded office equipment, and renewable energy models.
- Recyclable or biodegradable materials: Joining with another organization to supply or recycle waste products, meaning an implementation of product separation is needed.
- Innovative software: technology tools to help track inventory, stock, procedures and movements, to have control and improve the processes.

In case the organization wants to be recognized, there are some standards that could be followed and get certified, or Management Systems could be of aid for this, such as Lean or Kaizen.

2.2.2. LEAN MANUFACTURING

In chapter 2.2 digital lean was mentioned, as an approach to solve unsolvable problems. But what is lean? And therefore, what is digital lean?

Lean as mentioned in chapter 2.1 is a methodology used to optimize resources (people and materials), effort and energy of an organization to create value, its methods are based on continuous improvement, reduction of waste and process variation and software development.

[2] MTA: Make-to-assemble is a manufacturing strategy mentioned in chapter 2.2.

This methodology applied to the industry, it transforms into Lean Manufacturing, which is a production process with a high production ideology with minimum operational waste. Using the Lean principles, it essentially takes away everything that doesn't add value to the customer or the product.

So, how does Lean Manufacturing work? First, the types of waste need to be identified in all areas including processes, activities, products, and services. These could be excess inventory and therefore wasted space, ineffective procedures meaning wasted time and materials, underused talent such as wasted knowledge. By removing wastefulness, it should provide improvements in many areas of the organization.

But the implementation process is a challenge, as it requires input from all employees at all levels of the organization, starting with top management. A commitment must be made to improve and implement the system for it to be successful.

How to begin with changes

Before any changes are made, top management needs to analyze the key areas that need improvement which are crucial to the process and customer satisfaction and transfer the information to senior management, who will determine the needs and design the system around these.

Once senior management are aware of the upcoming transformation, they need to pass the information forward to middle managers and therefore all other employees and be consistent with the values and goals of the transformation. Let them be ready for all the benefits that come from it, but also for the changes and preparedness that is needed to absorb the information. Now, all the chain of command is ready to start with changes.

Start small, scaled pilot helps realize value and capabilities, determine the order of the assets, lines, and develop plans. When solutions measured value doesn't meet expectations, identify reasons why. Therefore, with a pilot process looking for a solution to an already existing critical problem is measurable and capturable and where the people, process and technology are ready for change. An analysis of current processes must be done and here is where the management system, methods and technology come in handy to know what needs to be implemented. A team of talented individuals (internal and external) are highly necessary to develop the implementation plan.

Documentation has to be considered for training and historical data, such as procedures, quality policies, work instructions, etc. If certification is required, then document control and its versions need to be in order.

When the pilot has shown the benefits, then the system can be deployed into other areas maintaining the same management system and with continuous improvement of the processes. Using the talent you have inside the organization, middle management will monitor the compliance with policies and procedures, reviewing regularly to ensure compliance and continuous improvement.

Waste in industry can come in many forms (see Figure 5), sometimes we are so self-absorbed in how things have been done that we don't stop to consider why they are done like that. When you have been a long-term worker in a company you just do things automatically, until a new employee comes and asks you, why things are done like this instead of like that? That's when you start considering if the used tactics might be antique, or maybe you are doing unnecessary work. Whether is lines or assets with bottlenecks, quality defects, idle workers, poor processes, unused materials, operational issues, etc. lean manufacturing aims to eliminate everything that drains on productivity.

(Deloitte)

Figure 5. The seven kinds of waste (Deloitte)

Characteristics to consider:

The motivation will vary on necessity, whatever the over-achieving motives that lie behind, there are the characteristics that need to be considered as keys to lean manufacture:

- Elimination of waste: with pursuit of perfection (Kaizen[3]) and culture of doing things correctly on the first try, resources will be used appropriately, lead-times, costs and production cycles will improve.

[3] Kaizen: Lean production method of eliminating waste. Mentioned on chapter 2.1.

- Improve quality: complying with standards lets us be ahead of the competition in the market and meet customers' needs, raising our value and maximizing profits.
- Reduction of time: bottlenecks in the production line means inefficient work practices, by removing barriers a flow is created ensuring constant stream for production and service delivery.
- Reduction of cost: Correcting waste, quality and time helps with cost reduction, sometimes investment in technology and training is beneficial in the long run.

By using Management Systems (QMS) and the desired methodology, waste is eliminated naturally, by focusing on improving the operational structure of the organization, but at some point, just using a methodology comes to a halt and needs help. Therefore, other approaches can be considered, for example:

- Automation
- Digitalization
- Visual Control
- Flexibility
- Production flow
- Statistical control

Although lean methodology is a great strategy to optimize resources, labor productivity in manufacturing industries appears to have stalled, compared to industries that have been revolutionized with technology, via Smart Factories unlocking productivity and innovation.

2.3. INDUSTRIAL DIGITALIZATION

The impact of digital transformation is inevitable and must happen to be able to keep up with all the customer and market needs, so if stakeholders of companies are not aware that accepting technology is best for their business they'll be struggling with revenue, obsolete equipment, and outdated processes.

So, what is digital transformation? It's the implementation of new digital technologies in an organization to improve all aspects of a manufacturing process, with the use of software applications and digitization. Although it seems simple, digital strategy requires expertise, investment, and experience for a successful implementation.

As for every implementation into an industry, a strategy is needed to make it successful. Digital strategy approach means the application of new technologies, digital capabilities, and software systems to existing activities to enhance the supply chains efficiency, increase the customer positive experience, internal alignment, and management. So, what components are needed for a correct strategy?

- A clear adaptation plans.
- Optimized cloud services.
- Data-driven analysis and prediction
- Statistical control for monitoring
- Customer relationship management platform
- Integration of device communications

All this information might be overwhelming, and some might try to add every new technology that comes into the market, but you don't need every technology in existence. Instead, decide what is the most important in

your organization and find the system and technology that is able to fulfill your needs, but leave space for agility to keep adopting process changes.

Industry 4.0

The digital revolution has arrived and it's an inspiration for the manufacturing industry, as there are some great trends to follow, some of them can be seen in Figure 6. Industrial Technology.

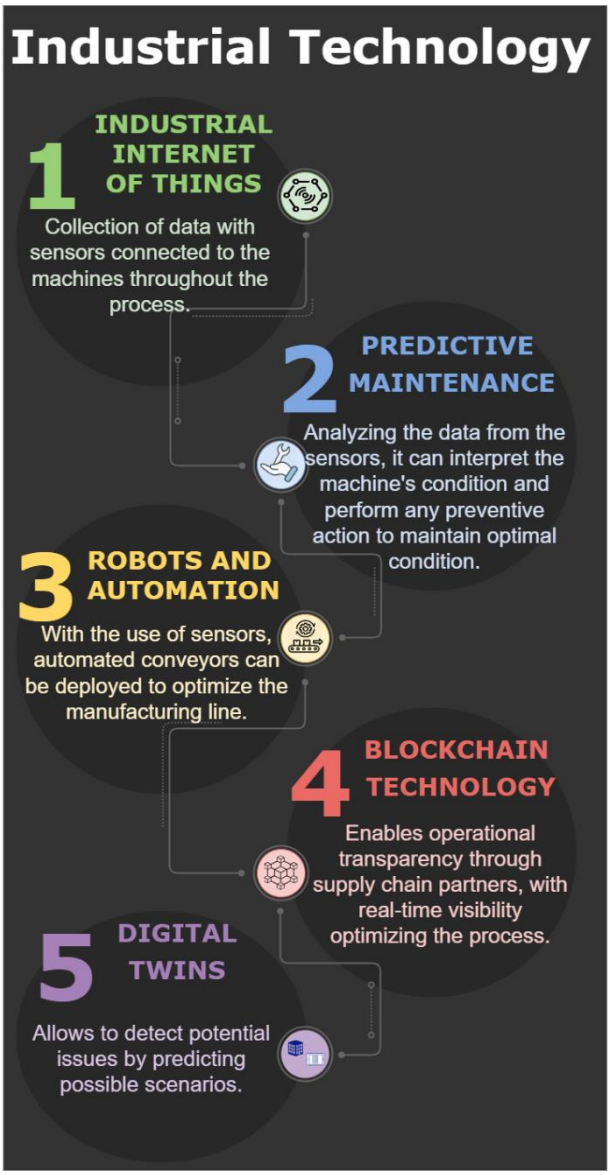


Figure 6. Industrial Technology

Industrial Internet of Things (IIoT)

One of the biggest trends in the industry is the “Industrial Internet of things”, where it takes advantage of the technology to enhance the manufacturing process, by connecting devices (e.g., sensors) throughout the process setting to collect data and analyze the information to optimize the process and predict needs to reduce downtime or align the maintenance to avoid complications.

Predictive Maintenance Innovation

In a traditional setting, manufacturers would schedule a routine check on equipment for any unnoticed malfunction, resulting in halted production and therefore, loss of money and workflow. Or they would act upon correcting any malfunctions, giving the same result. Now with investment in internal sensors, a real-time alert and response system the technology for predictive maintenance catching any mechanical failures before they occur.

Automation and blockchain technology

By collecting data through machines and with the use of Artificial Intelligence (AI) which replicates “human” behaviors of learning, the algorithms they learn gives it the ability to perform quick actions of problem-solving, decreasing the human error. So, by combining AI with other machines, automation could be made possible, for example with the use of conveyors for moving products in real-time and correcting workflow.

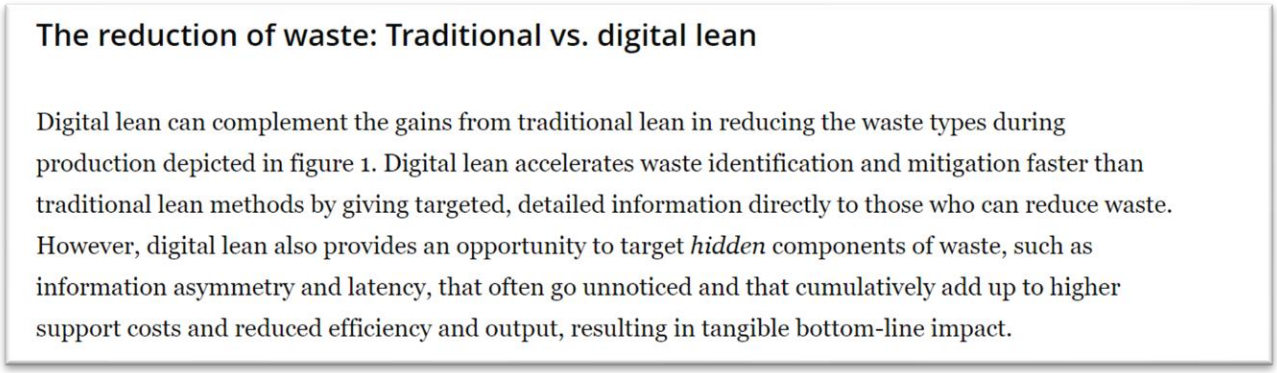
These are some other benefits of digitalization that should be considered for the application.

- In safety: less injuries and accidents
- In quality: reduce rework, less waste, increase satisfaction
- In process: improve productivity, innovation, and sustainability in the market.

Digital Lean

Now, let's combine two great approaches to support each other, combining digitalization with lean manufacturing. In theory we can find that lean is the foundation for digitalization, as it takes the same principles with different tools to come to a very similar if not the same result. So, we can argue that digital technologies benefit from a high-level lean implementation and could potentially raise its maturity to a higher level in an organization.

(Deloitte)



The reduction of waste: Traditional vs. digital lean

Digital lean can complement the gains from traditional lean in reducing the waste types during production depicted in figure 1. Digital lean accelerates waste identification and mitigation faster than traditional lean methods by giving targeted, detailed information directly to those who can reduce waste. However, digital lean also provides an opportunity to target *hidden* components of waste, such as information asymmetry and latency, that often go unnoticed and that cumulatively add up to higher support costs and reduced efficiency and output, resulting in tangible bottom-line impact.

Digital lean provides new ways to eliminate waste and make processes, people, and technology more productive, with a value-driven approach, higher efficiency, and low operating costs than could even be possible with traditional lean manufacturing. So, the benefits that we could take when digital lean is successfully implemented, are to reduce costs, improve quality and productivity, have a stronger return on investment, etc.

Following the plan to implement this strategy, there are some key components needed, as:

- Data collection: To unlock the digital lean full potential it requires a combination of information and operational technology integrated, bringing the plant and the operations into one with the technology and users.
- Standardization of processes: Discipline and enforcement of the new processes will help provide accurate and continuous data; therefore, leadership is needed among workers to enable a correct and continuous use of the processes.
- Enabling of platforms: Integration of systems, machines, people and data have to be correlated and properly managed to truly benefit from the technology.

3. OPERATIONAL STRATEGIES

Not all organizations are ready to succeed in the industry 4.0 environment, part of the challenge is to have the skills necessary to succeed in a constantly changing world. So, what are the strategies to implement in an operational situation to get the best results?

The operational strategy is composed of various smaller operations that will lead to the company's goal, meaning a lot of planning, monitoring and coordination is required. The focus will be on long-term goals and objectives and break down all the tasks needed to achieve them. Once the outline of the project is set, a budget is necessary to confirm the viability of the work and set the time stamps for each task. A set of leading indicators will be needed for management to track activities and outcomes for their tasks.

Communication between teams and management is crucial in the development of an operational plan. To obtain insights in the process of the plan, some ideas or views have not been considered that could help, in an operational design the workers are the ones with great observation, lets remember they are the ones using the machine and instruments all day and every day, so it should make their work easier and give management the information they require.

Monitoring of the progress and proper documentation proves valuable points to track performance and avoid going off-track the schedule. Always keep in mind the flexibility of the project, as challenges often arise and resilience is crucial for the completion of the project.

Sketching a Digital Transformation

The goal is to take a traditional manufacture industry and add the digital initiative to improve the quality of its processes and therefore its results.

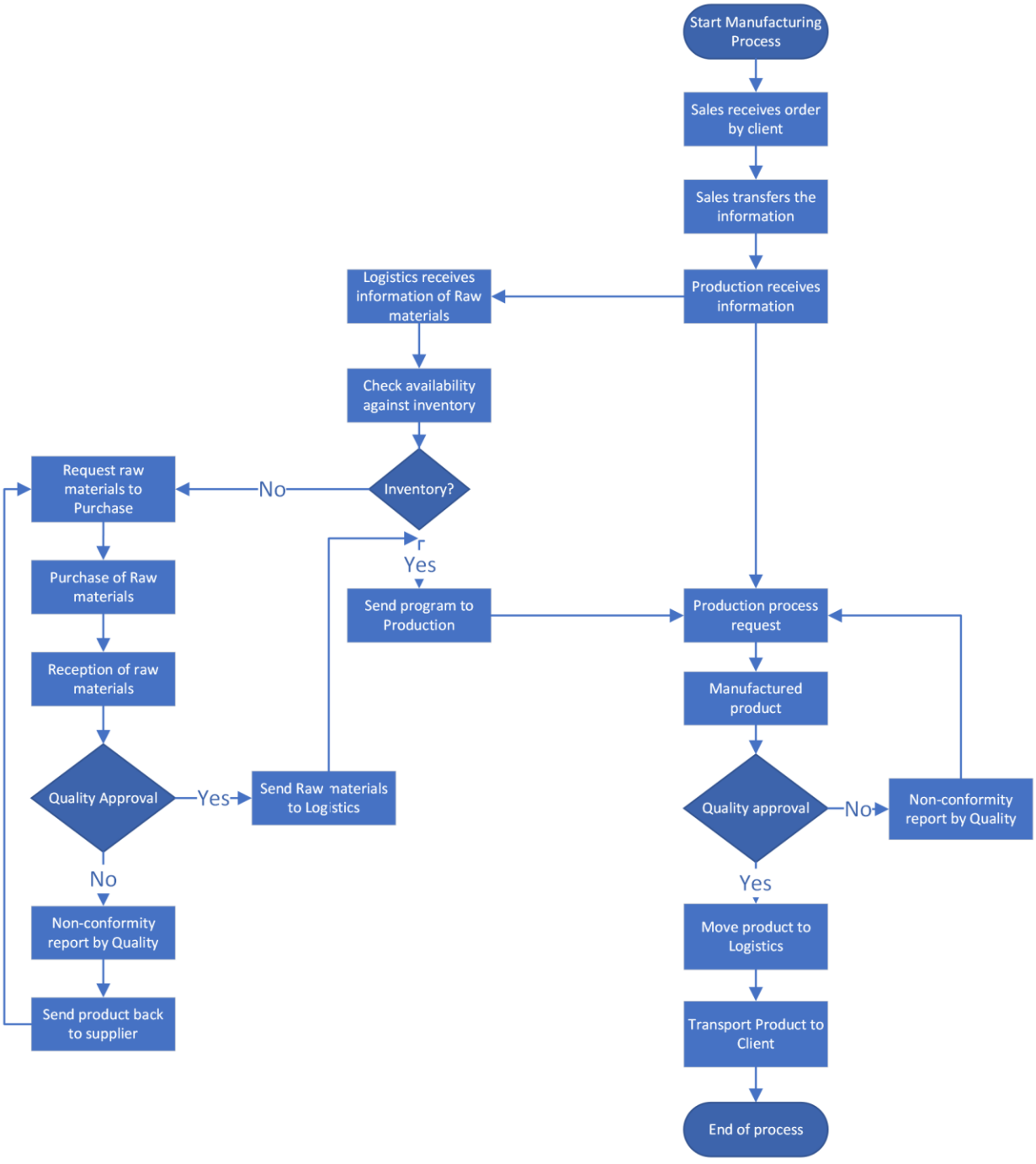


Figure 7. Manufacture process

4. INDUSTRIAL BASED CASES

Some companies have had successful digital transformations and advocate the process they underwent and keep moving forward. The process has been long, the investment was high, and the changes were many, but they can guarantee positive outcomes.

In 2019 a study was launched by Deloitte and MAPI[4] to determine productivity pursuit Smart Factory[5] initiatives to drive business and quantify the impact it has in the productivity and contribution. (Deloitte). The study was performed to manufacturing companies with headquarters in the United States that have a global footprint. The samples were classified into two segments for the study – group 1 Traditional manufacturers with no ongoing SF initiatives, and group 2 Manufacturers with some form of ongoing SF initiatives.

Some of the findings from this study were:

- Business value can be gained from smart factories initiatives.
- There is a gain in manufacturing output, utilization, and productivity by investing in smart factory initiatives.
- Value contribution is higher than the risks, and this can be mitigated through a change in management strategies, concepts, and investments.

[4] MAPI: Manufacturer's Alliance for Productivity and Innovation
[5] SF: Smart Factory

PFIZER

This manufacturing business has been working on its transformation for over a decade long. The company has many sites all over the world (42 sites), which were impossible to connect to each other and communication between them was complicated, sharing information between them was a challenge, as they had different systems. Deploying automation technologies transform its operations into a seamless data-driven engine. The systems deliver the information into the company system directly, so all the sites have the same data and management, making possible its collaboration.

Their biggest challenge to verify their digital transformation advantages was credited with the manufacture of three million plus doses of COVID-19 vaccine before scheduled time. I believe is safe to assume the transformation brought great quality to their processes.

But they´re not done with the transformation, the next step is building a stronger cybersecurity infrastructure across their manufacturing sites to protect their digital assets.

LEGO

Almost 20 years ago, the company Lego was close to bankruptcy, as their production lines were having many delays, and downtime and therefore their manufacturing costs were sky high. As a challenge they took on themselves, they digitized its supply chain processes to analyze the root-cause of their problems. Later on,

an enterprise-wide system[6] was introduced to the employees and production, giving them a better insight of the factor impacting productivity.

By 2016, they had an infrastructure that could support digital solutions, so they integrated technologies that could facilitate the communication between customers and management to get suggested ideas and improve sales and customer satisfaction.

SCHNEIDER ELECTRIC

This manufacturing company just became a smart manufacturing facility that led to a 90% reduction in paperwork (green approach) and improved their service repair time by 20%.

This was possible by extending automation in the organization to improve the productivity of the machine centers in 1990, this was not enough on the road to full integration, but it was a good start. Later on, they automated material handling, that led to data integration for a flow-based process.

With the help of centralized systems for data sharing, the company can now track and measure the overall equipment effectiveness of the assets, and the employees can access the operational data to analyze the capabilities. Then Artificial Intelligence was combined to build augmented reality and intelligent training algorithms.

PORSCHE

[6] Enterprise-wide system: large-scale application software package that supports processes, information, and data analytics in a complex organization. (Eg. SAP)

This German automotive manufacturer known for their high-performance cars set their goal to become a high-performance industry. “We need digitalization – for our products, our customers and our employees.” Says Lutz Meschke, Deputy Chairman of the Executive Board and Board Member for Finance and IT. Porsche intends to adopt blockchain technology, artificial intelligence, and augmented reality to become a leading provider of digital mobility solutions.

Their focus to meet this goal is set to:

- products and services: adding mobility infrastructure and services, meaning designing a smart infrastructure to transport materials and goods through the work floor easier and faster, with conveyors, automation, etc.
- customers and trade: digitalization in sales, building an interface to have better communication between customers and the organization.
- The company: building an efficient infrastructure that allows the digitalization in the processes to make them efficient.

UNILEVER

The benefits of transformation are now visible and are impacting their brands efficiently. The foundation was set through a 5C framework, helping them build connections, communities, and powering commerce.

The use of tools has helped enhance the quality of their investments, capabilities, and growth. E-commerce has grown faster than expected, and now the challenge is to manage to keep pace with it. To counteract this challenge, a culture transformation was set enabling a mentoring program with senior to young leaders, helping each other learn and keep motivated with the trends.

FAILURES

Although there are many more industrial examples to study, the failed ones also need to be study to avoid making the same mistakes. When digital strategies lack a structured system, for them to function it will lead to a failure in the transformation, no matter the innovation or solutions applied to the processes.

According to a Mckinsey study, 70% of digital transformations fail, often due to resistance from employees, as despite the projects aligned to the goals the leadership to follow set goals was lacking.

5. EXPERIMENTAL CASE

Let's analyze this single case study (See Figures 8, 9 and 10), where QMS and digitalization was applied to the process of a Paper packaging Manufacturing company.

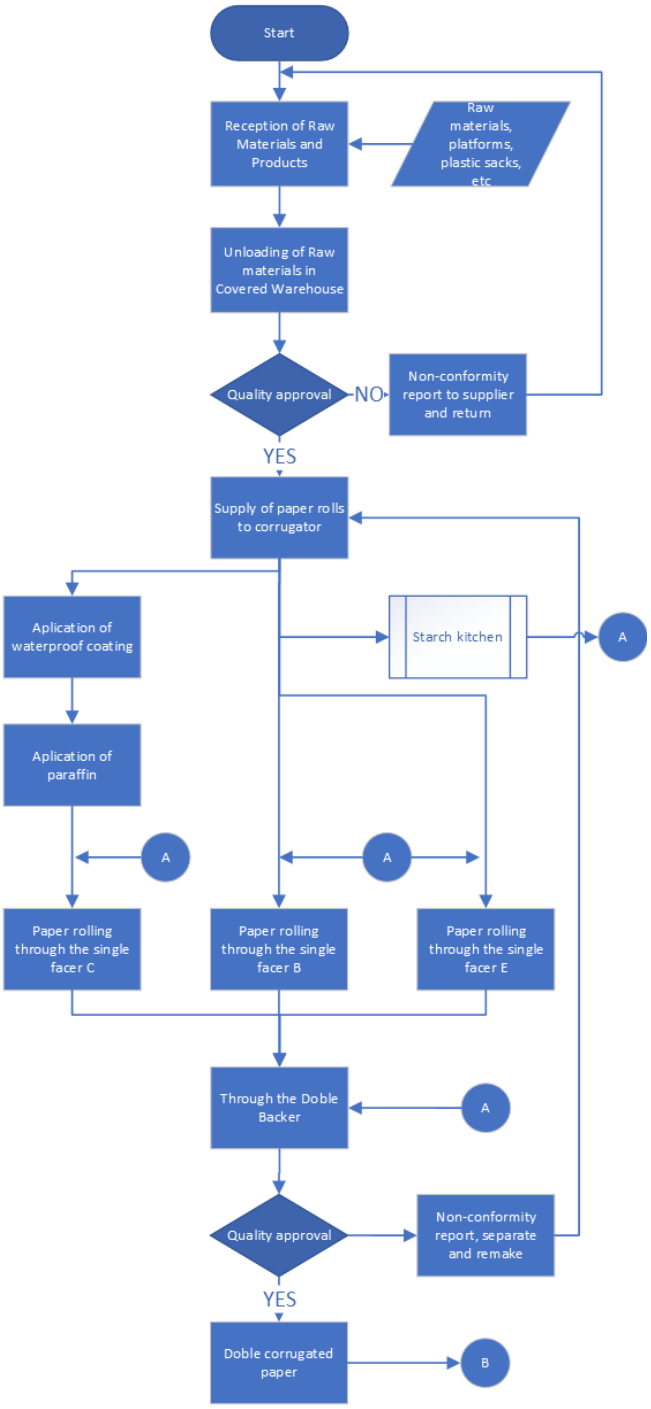


Figure 8. Packaging manufacturing process flowchart A.

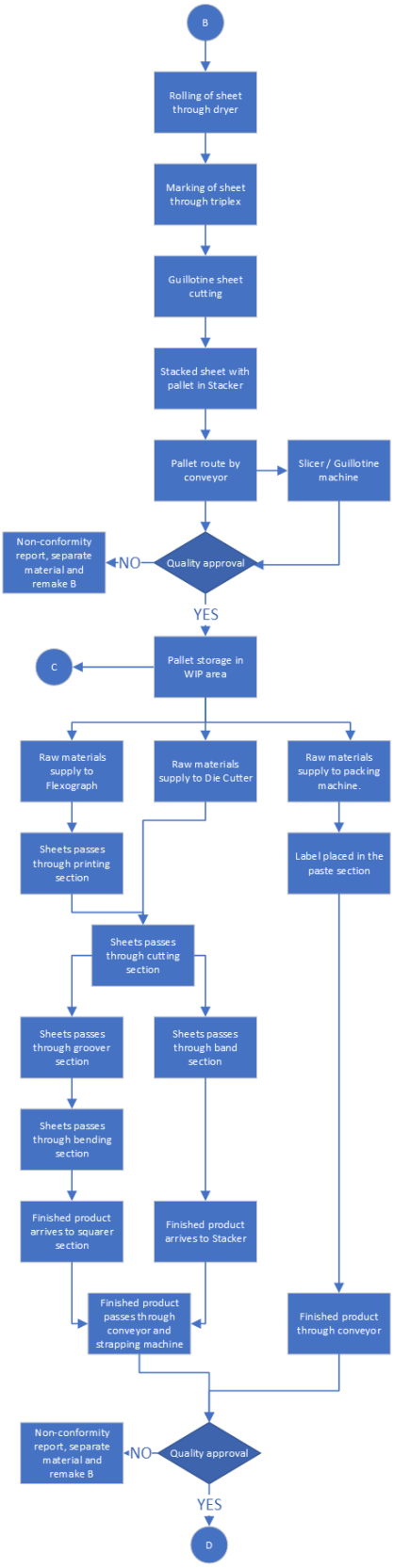

B
Rolling of sheet through dryer
Marking of sheet through triplex
Guillotine sheet cutting
Stacked sheet with pallet in Stacker
Pallet route by conveyor
Slicer / Guillotine machine
Non-conformity report, separate material and remake B
NO
Quality approval
YES
C
Pallet storage in WIP area
Raw materials supply to Flexograph
Raw materials supply to Die Cutter
Raw materials supply to packing machine.
Sheets passes through printing section
Label placed in the paste section
Sheets passes through cutting section
Sheets passes through groover section
Sheets passes through band section
Sheets passes through bending section
Finished product arrives to squarer section
Finished product arrives to Stacker
Finished product passes through conveyor and strapping machine
Finished product through conveyor
Non-conformity report, separate material and remake B
NO
Quality approval
YES
D

Figure 9 Packaging manufacturing process flowchart B

Figure 10 Packaging manufacturing process flowchart C

This is a manufacturing company that had been functioning properly for decades but was falling short recently due to non-conformance and customer complaints, the goal was set to diminish waste and failures. The Lean strategy was first applied, setting Quality control checks in almost every step of the processes. But also, the design was transformed, so that some materials could be reused or reprocessed.

With the implementation of waste control, money was saved, and waste was low and customer satisfaction was rising as they stopped receiving bad products.

Digitalization was on sight, so the strategy was now to train everybody and introduced them to the digital approach, training and talks about the benefits and the importance of following the structure was implemented to all levels of the organization, over and over until it was clear that everyone was following the same goal.

Later on, digitalization arrived, and new machinery was set into place, a structured data-driven system was applied, and all the employees received proper training. Sensors were set into place throughout the processes and machines and a statistical analysis ran to study our constant failures and do a root-cause analysis and eliminate future inconsistencies.

6. CONCLUSION

In conclusion, this thesis provides valuable insights into the role of digitalization in advancing manufacturing quality and sustainability. By implementing digital technologies, manufacturers can achieve significant improvements in process efficiency, product quality and environmental performance.

This study highlights the importance of a holistic and integrated approach to digitalization that aligns with lean and green manufacturing principles. Such an approach can enable manufacturers to optimize their operations, reduce waste and enhance customer value.

However, the successful implementation of digitalization requires addressing several challenges as mentioned throughout the study. A strategy must be analyzed and carried by steps starting in the top of management and passing it on through the chain of command by leaders to avoid downfalls, as employees are the key to success, and if they are resistant to change, downfall is inevitable.

Overall, this project provides practical implications for managers and stakeholders that seek to enhance manufacturing competitiveness and sustainability in the digital era.

7. *REFERENCES*

(s.f.). Obtained from Definition of Quality: https://www.twi-global.com/technical-knowledge/faqs/faq-what-is-lean-manufacturing

AICPA. (June de 2013). *AICPA & CIMA*. Obtained from de Together as the Association of International Certified Professional Accountants.

Ashrafian, A. (s.f.). Sketching the Landscape for Lean Digital Transformation. 8. Trondheim, Norway.

Bjorkdahl, J. (2020). Strategies for Digitalization in Manufacturing Firms. *California Management review*, 19.

CFI Team. (November de 2019). *Corporate Finance Institute*. Obtenido de https://corporatefinanceinstitute.com/resources/economics/standardization/

Deloitte. (s.f.).

Guasch, J. L. (2007). *Quality systems and standards for a competitive edge.* Washington, D.C. : World Bank.

ISO Organization. (13 de June de 2023). Obtained from ISO: https://www.iso.org/standards.html

John Lee, I. C. (2019). Improving process safety: What roles for Digitalization and Industry 4.0? *Process safety and environmental protection*, 14.

Kristine Nagle. (26 de May de 2022). *Evocon.* Obtained from What is Green Manufacturing, and Why Does it Matter?: https://evocon.com/articles/what-is-green-manufacturing-and-why-does-it-matter/

Kumar, P. (2018). *Quality, IT and Business Modeling and Optimization.* Singapore: Springer Singapore.

Last Name, F. M. (Year). Article Title. *Journal Title*, Pages From - To.

Last Name, F. M. (Year). *Book Title.* City Name: Publisher Name.

Manufacturing Studies Board Comission on Engineering and Technical Systems National Research Council. (1991). Reseach Priorities for US Manufacturing. Washington, United States of America.

Martin Boggess. (May de 2023). *Hitachi Solutions*. Obtained from 10 Trends That Will Dominate Manufacturing in 2023: https://global.hitachi-solutions.com/blog/top-manufacturing-trends/#

MC, K. (06 de 2018). Study on Digitalization in Industry: Requirements and Assessment. Stavanger, Norway: University of Stavanger.

NATO. (October de 1997). *Nato Logistics Handbook*. Obtenido de North Atlantich Treaty Organization: https://www.nato.int/docu/logi-en/1997/lo-1705.htm#:~:text=The%20levels%20of%20standardization%20are,%2C%20interoperability%2C%20interchangeability%20and%20commonality.

Peter Pearce. (3 de March de 2023). *Industry Today.* Obtained from Top trends in the Industrial Manufacturing Complex: https://industrytoday.com/top-trends-in-the-industrial-manufacturing-complex/

Porsche. (22 de 02 de 2018). *Porsche*. Obtained from Digital transformation at Porsche: https://newsroom.porsche.com/en/innovation/digital-deep-tech/porsche-digital-transformation-technology-tradition-blockchain-artificial-intelligence-virtual-augmented-reality-industry-automotive-sector-digitalization-connected-car-14903.html

Prasad, S. (2014). Lean and Green Manufacturing: Concept and its implementation in Operations Management. *International Journal of Advanced Mechanical Engineering*, 6.

Schneider Electric. (June de 2023). *Schneider Electric*. Obtained from Smart manufacturing solutions to accelerate your digital journey: https://www.se.com/ww/en/work/campaign/smart-factory/

Sele, R. K. (15 de 06 de 2018). Digitalization and Sensor Technology in an Industrial Context. Stavanger, Norway: University of Stavanger.

Stephen Laaper. (August de 2020). *Deloitte Insights*. Obtained from https://www2.deloitte.com/us/en/insights/focus/industry-4-0

Unilever. (June de 2023). *Unilever*. Obtained from Consumer-first approach accelerates digital transformation: https://developer.unilever.com/s/managed-content-news/unilever-consumer-first-approach-accelerates-digital-transformation-MC3HZVUBHEDNDW7LOHLXSYR6DITY

University, G. (19 de April de 2016). *ENEWS Goodwin University.* Obtained from https://www.goodwin.edu/enews/what-is-green-manufacturing/

Vorlet, O., Neutsch, L., Kronseder, C., & Kuhn, A. (2021). Digitalization in Processes. *Chimia*, 2.

Vries, H. d. (1998). The classification of Standards. *Nederlands Normalisatie-instituut, Delft, the Netherlands and Erasmus University Rotterdam*, 11.