Characterization of Key Processes for Production Systems Optimization

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Abstract. Several fields of knowledge have been invited to collaborate on production systems, in order to (a) answer to a growing system complexity, (b) offer organizations holistic solutions, and (c) obtain more resilient results to future changes. Examples of this are the collaborations between simulation, machine learning, and data engineering with multiple domains, for example production system – the focus of this research. Hence, this research aims to provide a holistic view of production systems, characterizing the key processes and concepts of production systems, to offer a clear and integrated understanding for newcomers into this field. The main processes are examined, such as: Production planning and control, Industrial processes, Logistics, Quality management, Maintenance, and Sustainability. The latter is structured around three core dimensions: environmental, social, and governance (ESG), representing an emerging differentiator among organisations. One notable example is green manufacturing, which focuses on minimising waste and promoting sustainable practices throughout the production process. Moreover, different production system models are reviewed, such as: Lean manufacturing, Just-in-time, and Mass production. At the end, a detailed analysis of each of these processes and models is provided, highlighting the relevance of a strategic and sustainable approach to success in contemporary production systems, promoting their optimization.

Keywords: Production system · Processes and models · Optimization

1 Introduction

Production systems are a framework within which production activities develop [1, 2]. A production system encompasses attributes – which may include people, machines, or tools – with the function of transforming raw materials into desired and forecasted goods and services. It is a quite complex concept, involving a series of activities and stakeholders, and thus must be treated with a certain level of seriousness.

Among the various types of production systems, Lean Manufacturing, Just-In-Time, and Mass Production stand out [3]. However, to gain a comprehensive understanding of these systems, it is essential to examine their core processes: production planning

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and control, production processes, logistics, quality management, maintenance, and sustainability.

Most of these concepts were defined many years ago, and their constructs are described in books. The objective is to condense this information into a single paper, so that newcomers in this area can develop a holistic view of the production system.

This research is, therefore, relevant not only because of the review and synthesis of already established concepts but also due to the opportunity to apply these concepts in the current context of organizations. By analysing the main processes and practices, the study aims to offer a clearer understanding of how these elements interconnect, with the goal of promoting more efficient management aligned with contemporary needs. Thus, this study seeks to provide a detailed view of production systems, as well as generate valuable insights for innovation and the advancement of production practices in organizations.

This research is structured into four sections. The first refers to the current subsection, where the opportunities of the developed research are explained, along with the research questions and objectives that prompted the development of the work, and the methodology used for its development. The second subsection provides a brief review of the various types of production systems and describes the main processes within the production system: Production Planning and Control, Production Process, Logistics, Quality Management, Maintenance, and Sustainability. The third subsection makes a brief discussion, and finally, the fourth subsection describes the main conclusions of the developed work, as well as suggestions for future research.

1.1 Research Questions and Objectives

Table 1. Research questions and objectives

Research Questions	Research Objectives	Research Strategy
1: What are the types of production systems?	RO2: Analyse the various types of production systems	Systematic Literature Review
2: What are the main processes inherent to production systems?	RO2: Investigate the main processes inherent to production system	Systematic Literature Review

This research aims to answer a set of research questions, from which a set of research objectives were derived. For each one, a research strategy was defined, and all are listed on Table 1.

1.2 Methodology

The strategy used to answer both RO1 and RO2 was a systematic literature review, developed to each of them separately. According to [4], systematic literature reviews should be rigorous and relevant, as they can foster scientific knowledge. Furthermore,

they should be reliable and repeatable [5] in order to enlighten the reader on what has been learned.

Based on the framework proposed by [6], the PRISMA was used to guide the article selection process. The complete details of the process can be accessed via the following link: https://tinyurl.com/yc8d5uu6. Initially, the selected databases were: Scopus, Google Scholar, and Web of Science (WoS). A filtering process was then applied to journal articles, conference papers, and books. The keywords used to obtain articles were previously defined, and are available at the following link: https://tinyurl.com/pafsyjh7. Subsequently, a filter for publication year was applied, from 2013 to 2025. An exception was made for studies identified through the snowballing technique, due to its relevance on the subject. The search results were ordered by relevance, and filtered by reading their abstracts.

The snowball technique was employed when a retrieved article, from the systematic review, cited another article, from which it was identified as the original source of the fundamental concepts for production system.

2 Production System and Its Models

The evolution of production systems reflects changes in technological advancements, market needs, and the growing ambition for efficiency in production. Mass production emerged in the early 20th century, as a response to the increasing demand, leading to the introduction of the assembly line, popularized by Henry Ford in the automotive industry. Mass production significantly reduced costs and increased output, becoming the dominant model for much of the 20th century [7], with a single goal: maximize production output [8].

As product diversity expanded and consumer demand increased, new production models began to gain prominence. Batch production, or mass customization, emerged as viable alternatives, allowing for a balance between mass production and a degree of customization. This model became common in industries such as semiconductors, automotive, and textiles; responding to the growing demand for customization without compromising efficiency [9, 10].

With the advent of the third Industrial Revolution, also known as the Digital Revolution, made-to-order production has been gaining ground, especially with the advancement of technologies such as CAD (computer-aided design), CAM (computer-aided manufacturing), and numerical control; which enabled the production of personalized goods in smaller batches, aiming at reducing that impact on production efficiency, therefore on the end-product's price. This model has allowed organizations to offer highly customized products tailored to the specific needs of each customer [11].

Despite these advantages, continuous production continues to be fundamental in some industries, such as petrochemical and metallurgical. These are characterized by an uninterrupted manufacturing process, making it particularly suitable for large-scale production of homogeneous products. This type of production offers great stability in product quality and operation efficiency, especially on complex production systems [12, 13].

After the 1973 oil crisis, demand decreased, and, consequently, economic growth slowed. As a response, mainly to induce demand, the need for product diversification arose. As such, the Just-In-Time (JIT) production system gained prominence as a recession-resistant model, due to its drastic reduction in Work-In-Process (WIP) and stock levels. JIT influences the production flow timing, where materials are delivered to the production system at the right moment, in the required quantities, to the production processes where they are needed. Materials need to arrive within minutes – not days or weeks – before being used on the production line. Hence, JIT reduces different types of waste, such as WIP, stock, overproduction, and delays in delivery times. The lead time will, in principle, be shorten. The JIT production system is market-oriented, entirely based on customer satisfaction [14, 15]. According to [16], JIT can also be understood as a production philosophy applied to production systems, with the goal of delivering a high-quality final product.

When discussing the JIT production system, the concept of Kanban immediately comes up, a component created by Toyota to enhance production efficiency. The term "Kanban" – which means "visual signal" or "card", in Japanese – is used to indicate the next stages in the production process. In a conventional Kanban system, whenever a material is used on the production line, a Kanban card is sent to the previous process to indicate the need for a replacement. This (a) facilitates inventory management and (b) ensures that materials are produced or moved only when necessary; therefore reducing waste and increasing flow efficiency [14].

The Lean Manufacturing production system originates from the Toyota Production System (TPS), based on the principles of JIT (Just-In-Time), meaning that materials should be requested when they are needed, the process should only initiate when needed, and the product should be manufactured when ordered, entirely based on consumer demand. Lean Manufacturing is grounded in the Kaizen philosophy of continuous process improvement, standardization of work procedures, and maintaining the improvements achieved. As a result, changes are expected, focusing on waste reduction, process enhancement, and increased value creation. Lean Manufacturing balances production speed according to demand [3].

The different production models mentioned above summarize the various approaches organizations have been adopting throughout the past decades, mainly to adapt to market demand, balancing factors such as production efficiency, flexibility, and customization. The choice of the adequate production system will depend on several factors, including the nature of the product, production volume, and consumer expectations.

2.1 Main Processes

A production line is a complex system, encompassing several concepts and elements, hence, it shall not be treated lightly. Characterizing the main processes of production systems is essential to better understand how organizations transform materials into products. Moreover, it is also relevant to understand the processes that indirectly influence the product and processes, e.g., maintenance. These (indirect) processes are crucial because, through them, we can promote better product quality. Arguably, it is an essential process in any production system, maintenance is often neglected.

This section focuses on the main processes of production systems, namely: production planning and control, industrial processes, logistics, quality management, maintenance, and sustainability.

Production Planning and Control

Production planning encompasses a multitude of elements, with a focus on the daily activities of the team, as well as meeting delivery deadlines. According to Henry Fayol, planning involves deciding the best strategy from a set of options [17].

When discussing production planning, aggregate production planning (APP), shall not be overlooked. APP consists of determining the optimal production levels and workforce for each period within the medium-term planning horizon. Its goal is to define the general production levels for each product family, to meet fluctuating demand in the near future. Among the existing APP models, stochastic models stand out. These models are typically based on the concept of randomness and probability theory, being limited in handling uncertainties through probability distributions [18]. Included in these models, stochastic simulation is becoming one of the main techniques applied to production systems, due to its capability of evaluating the performance of systems with random behaviours, which are mathematically intractable through a deterministic approach [19].

Regarding production control, according to Henry Fayol, it involves checking whether everything is running according to the adapted plans – the issued instructions, and the estimated principles. Its main objective is to identify deviations, to uncover weaknesses and errors, so they can be avoided or corrected in the future [17].

Production planning and control (PPC) encompasses a series of decisions aimed at defining what, how much, and when to produce, order, and deliver – to allow for operations to be carried out according to predefined schedules [17]. PPC activities are developed not only based on the restrictions and goals set by top management, but also on customer orders, demand forecasting, and stock [20]. According to [17], PPC should be tailored to the type and volume of production, developing simple techniques for organisations that manufacture high volumes of customised products, while balancing the level of control with associated costs. It is for this reason that each organisation has its own PPC technique, resulting from several insights from other organisations (e.g., Toyota and TPS), and continuous improvement.

The main PPC objectives include: minimising downtime (man vs. machine), reducing stock turnover time, maximising product quality and customer satisfaction, maintaining low inventory levels, ensuring short setup and lead times, preventing bottlenecks in the production flow, and planning material orders in advance. This last objective is achievable making use of the Bill of Materials (BOM), which details all components and consumables required to produce the final product.

A commonly used technique in PPC is (demand) forecasting, which involves using past demand patterns to forecast future demand. Typically, forecasting is more accurate in short-term planning. Demand forecasting is riskier upon increasing the planning horizon, due to the high scope of the current economical interdependency. Regardless, every forecasting should always include an error estimate [21].

Forecasting can be categorized from a period perspective: short-term, medium-term, and long-term forecasting. Short-term forecasting (up to 1 year) is necessary for personnel scaling, production, transportation, and demand forecasting. Medium-term forecasting (up to 5 years) is necessary to determine future requirements for material purchases, hiring personnel, or purchasing machinery and equipment. Long-term forecasting (over 5 years) is used in strategic planning, e.g., acquiring land, expanding facilities, establishing in a different country. The latter must take into account market opportunities, environmental factors, and internal resources [17].

MRP

Material Requirements Planning (MRP) is a key inventory management technique which allows to schedule materials, aligned with the Master Production Schedule (MPS). Its main objective is to ensure the right type and quantity of materials is available at the right time, avoiding both waiting times and WIP. MRP defines when to release and receive material orders, supporting the effective implementation of the MPS. In turn, the MPS guides production by coordinating inputs from different departments to determine what and when to produce, ensuring demand is met efficiently [22]. For each planning order, the MRP determines the materials based on the product BOM. When there is insufficient material stock, and no planned delivery, the MRP generates a replenishment proposal, alerting the need to order or produce said material [23, 24].

Due to the lot-sizing rule of the MRP technique, changes in higher-level schedules cause significant changes in lower-level schedules. For instance, a small change in the MPS may result in significant changes in the time or quantity of a given material at a production cell. The causes of MRP instability (or 'nervousness') include: changes in the MPS, fluctuations in supplier lead times, poor material quality, record errors, unplanned transactions, among others. Approaches to reduce MRP nervousness include: improving both customer and supplier relationships, as well as greater data processing efficiency [25].

MRP II

Manufacturing Resource Planning (MRP II) is an extension of the Material Requirements Planning (MRP). MRP II is an advancement which integrates various processes, such as: business and production planning, scheduling, and capacity management. It also supports execution, and links production data with financial planning – making it a broader extension of the closed-loop MRP system [24].

MRP II helps industrial engineers to plan all the resources needed for production, including: equipment, labour, production planning and control, costs, and more. MRP II provides industrial engineers with detailed information at the right time on what, how much, and when to produce; as well as generating new orders and reschedule previously planned orders. Hence, MRP II enables a more efficient response to volatile demand [17].

ERP

Enterprise Resource Planning (ERP) systems are intra-organization systems which support core business processes across various organizations. They include MRP II functionality for manufacturing organizations and general management features, e.g., accounting, financial planning, and human resources; applicable to all types of organizations. ERP systems serve as the backbone of business information processing, enabling integrated

management of major business processes and recording most business transactions [26]. ERP systems can significantly reduce operational costs while improving efficiency, productivity, and data quality – when implemented correctly. They contribute to internal integration, as well as supply chain integration [18, 27].

Digital Twin

Production planning and control (PPC) involves managing the processes necessary to produce goods and services [28]. As such processes are quite different among organizations, the PPC varies by organization. Despite this, the need to determine production schedules is universal [29].

Consumer, competition, and technology pressures are constantly evolving, requiring updates to processes, therefore, to the design of PPC systems. As a result, PPC systems must be responsive, supporting high-quality production, small lots, customization, customer commitment, and sustainable practices [20].

Research is being developed in Digital Twin technology for production systems to address PPC activities and modelling [30]. PPC is evolving with Industry 4.0 principles, focusing on self-managed, automated, and autonomous systems [20]. Industry 4.0 merges digital technologies, organizational concepts, and management principles to provide more economical, responsive, resilient, and sustainable operations [31].

Industrial Processes

A production process consists of a series of planned actions that cause physical or chemical changes in a material, with the purpose of adding value. Generally, a production process is carried out as a unit operation, i.e., it is a single step within a set of operations which are necessary to transform one or more materials into one or mode final products [32].

According to [33], a production process generally involves a sequence of fundamental steps, which form the material flow. This sequence can be divided into three main phases: (1) the first phase refers to processes that prepare the material by adjusting its geometry or properties, e.g., heating, melting, cutting, sawing; to make it suitable for the changes that will occur in the subsequent phases. (2) The second phase involves processes that modify the geometry or properties of the material, creating the desired shape for the component. (3) The third, and last, phase consists of processes that finish the component, bringing it to the final desired state, through actions, e.g., solidification, cooling, and deburring.

By contrast, [32] presents a more Boolean view of production processes, at a high-level. According to the author, production operations can be divided into two main types: (a) processing operations, and (b) assembly operations.

a) Processing Operations.

A processing operation uses energy to modify the shape, properties, or appearance of a material, adding value to the material. Energy sources include: mechanical, thermal, electrical, and chemical; applied by machines or tools. Human energy may also be required, typically for operating machines, supervising processes, or handling materials.

The general model of processing involves material entering the process, energy being applied to modify it, and the final piece exiting. Most operations generate waste or scrap, either as a by-product (e.g., material removal in machining) or defective pieces; and reducing waste is critical in these processing operations.

Usually, processing operations are applied to individual materials, but some can also be carried out on materials which have already been assembled (e.g., painting a vehicle body that has already been welded).

Typically, multiple operations are needed to transform the material into the final desired state, performed in a specific sequence, based on design requirements. Processing operations are classified into three categories: (i) shaping operations (e.g., casting, forging, machining), (ii) property improvement operations (e.g., tempering), and (iii) surface processing operations (e.g., galvanizing, painting).

b) Assembly Operations.

The assembly process occurs when two or more separate materials are joined to form a new, assembled, one. The materials of the resulting assembly can be joined permanently or semi-permanently. Permanent joining processes include welding, brazing, and gluing; which create a junction between components that cannot be easily separated. There are also mechanical assembly methods which allow two (or more) parts to be fixed in such a way that the assembly can be conveniently disassembled. The use of bolts, nuts, and other threaded fasteners are important traditional methods in these operations. Subassembly, the name can demonstrate the assembly process itself, e.g., a welded assembly is the result of a welding assembly operation.

Logistics

Transportation is an integral, and investable, part of the logistics system, as it is the physical link that connects materials, final products, customers, and suppliers [34]. Transportation can be grouped into two types: short-distance and long-distance transportation. Short-distance transportation refers to the movement between points relatively close to each other, within a specific area; while long-distance transportation involves the movement between distant points [35].

When discussing transportation, it is also important to consider the associated costs, making it crucial to distinguish between marginal costs and average costs. In this context, marginal cost refers to the additional expense incurred when transporting one extra unit, while average cost represents the total transportation cost divided by the number of units transported [36].

Inventory management is a critical component of logistics, allowing organizations to ensure customer service levels and support logistical and production activities, especially in situations where purchasing or producing items cannot immediately meet demand. Inability to respond to demand in a timely manner can occur, due to acquisition or production lead times, or the inability to supply the necessary quantities without pre-existing stock. The size of the logistics inventory is influenced, and often determined, by the chosen transportation methods and the resulting delivery lot size. Changing the delivery method can influence stock levels [37]. Furthermore, some materials might be perishable, i.e., tend to deteriorate over time, due to their characteristics. Hence, a proper inventory strategy might be required to ensure that those perishable materials are not wasted. E.g., FEFO (First-Expire, First-Out) prioritizes the retrieval of materials with the earliest expiration date.

Quality Management

For many, quality is seen as meeting pre-defined specifications. However, some argue

that quality is subjective and depends on each individual's perception [38]; in other words, quality has different meanings for different people. The definition of quality, in the context of production, processes and service industries is as follows [39]: meeting customer needs, suitability for use, compliance with requirements and degree of excellence at an acceptable price.

The International Organization for Standardization (ISO) defines quality as "the totality of characteristics of an entity that influences its ability to satisfy explicit or implicit needs", and provides an explanation of the various quality management principles, which are essential for facilitating the application of the ISO 9001:2015 standard [39].

Quality in a production system is achieved through a sequence of processes in which materials and labour are transformed to create the final product. The product is monitored throughout the system, by inspections and tests at different stages. If a product fails to meet the defined requirements, it is repaired, reworked, or discarded; and actions are taken to eliminate the root causes of the issue. For this, statistical process control methods are typically employed control the process, with the objective of reducing process variability and increase process efficiency [39].

Quality management is essential to ensure that objectives are achieved with the desired level of excellence, making the organization competitive in the market [39]. Over the past decade, quality management has promoted significant and valuable improvements in operations and supply chain systems [38].

The quality management principles are essential in the implementation of the ISO 9001:2015 standard. Albeit, they are not complete, nor do they have a clear theoretical or conceptual basis; being simply a list without prioritization and interconnections. Below are the seven principles contained in the ISO 9000:2015 Quality management systems - Fundamentals and vocabulary [40]:

- Customer Focus: Customer focus is seen as the central goal of quality management. The organization must understand customer expectations in order to respond to them and even exceed them, which will ultimately lead to higher customer satisfaction;
- Leadership: According to the Total Quality Management (TQM) philosophy, organization leaders should be role models in quality matters, engaging and empowering employees in quality improvement processes. Leadership is responsible for the implementation of quality management;
- Engagement of People: Employee engagement and qualification are directly related to leadership. Quality management requires skilled employees, who must be trained for the tasks they are assigned. Resources and tools, such as surveys, training, and internal communication programs, should be provided for this purpose;
- Process Approach: Quality management should analyse the organization's process flows. All processes must be coordinated and controlled, to avoid errors at different stages. This requires careful and systematic planning of individual processes;
- Improvement: The focus is on continuous improvement processes, which aim to optimize performance, processes, and products. These processes should be addressed systematically, using tools such as error analyses, quality circles, improvement suggestions, and feedback from market actors;

- Evidence-Based Decision Making: Professional quality management seeks to avoid excessive subjective evaluations of quality issues, such as causes, effects, and risks. Decision-making should be based on facts, provided by information, data, numbers, and evidence. Tools like key indicators, statistical surveys, and experiments are used;
- Relationship Management: For successful and long-term quality management, as many stakeholders as possible should be involved. The goal is not to achieve short-term advantages, but to build, maintain, and strengthen partnership relationships, also analysing the use of shared resources through cooperation with the appropriate market players.

The integration of business and production operations with quality practices and technological advancements can help achieve higher levels of maturity. As a result, it enables the optimization of production process performance and product quality, improves supply chain reliability, and promotes continuous and proactive improvement [41].

Maintenance

In the production context, maintenance plays a vital role across various sectors, including manufacturing and transportation. It both influences and is influenced by other organizational functions, such as: production, quality, inventory management, marketing, and human resources.

Although traditionally analysed in isolation, its integration with other departments – and the broader supply chain – has become increasingly essential. Within the production system, maintenance is one of the most complex processes, as it requires the reduction of costs, increase of asset value, and enhancement of product quality. Its impact on organizational success is undeniable, particularly in the manufacturing sector, where it has become a leading factor in advancing development in this sector [42].

Maintenance can be classified into three types:

- Corrective Maintenance: it is a maintenance task performed to identify and correct the causes of system failures. This type of maintenance occurs when equipment malfunctions and is unable to continue its intended operation, leading to unscheduled production downtimes [43, 44]. Corrective maintenance requires human involvement. When a system experiences downtime, the operator observes the system, analyses the failure (diagnostics), and takes corrective action to eliminate the cause of the failure. With the rise of technologies triggered by Industry 4.0, the complexity of production systems has increased, and, as a result, the occurrence of human errors during corrective maintenance has also risen [45]. Moreover, as it is human dependant, especially in terms of diagnosis, it benefits from training and experience.
- Preventive Maintenance: it is a programmed maintenance, consisting of activities initiated at predetermined intervals or based on prescribed criteria, aimed at reducing the likelihood and severity of failure [46, 47]. Preventive maintenance tasks can be performed during non-production periods, to avoid unexpected production downtimes [48]. According to [49], some researchers argue that preventive maintenance does not fully restore the system to an ideal state, but instead brings it to a state where it can perform its functions within what is possible.

- Predictive Maintenance: is a strategy that leverages real-time data to anticipate equipment failures before they occur, enabling scheduled interventions and preventing unexpected production downtimes. Unlike preventive maintenance, which operates on fixed intervals, predictive maintenance is based on the actual condition of the equipment, optimising resources and reducing operational costs [50]. This approach is particularly effective on specific equipment's, with predictable failure modes. For instance, predictive inspections may utilise existing equipment such as voltmeters and other measuring instruments [51], or new ones installed on older machinery. E.g., changes on a pump vibration patterns, caused by a failing bearing, can trigger a repair operation. It is relevant to note that such approach requires investment in infrastructure and technology, some of them linked to Industry 4.0 and the Digital Twin. The benefits are similar to Preventive Maintenance, adding the reduction in time and costs associated with excessive repair operations – as each repair operation is "predicted", based on data collected from the equipment itself. In cases of catastrophic system failures, predictive maintenance plays a crucial role in preventing significant damage to infrastructure or machinery, as well as mitigating potential risks to operators working on the system [52].

Sustainability

Sustainability defines the foundation of the human-nature relationship, encompassing issues such as equal access to resources, not only for present generations, but also for future generations [53]. It defines behaviours and attitudes that do not compromise the ability of future generations to meet their needs. Sustainable development intervenes in various areas, being highly dynamic and reactive, and interpreted in different ways, by different people, and in different contexts.

In this context, ESG (Environmental, Social, and Governance) emerges as a set of criteria that assess an organization's impact in three main areas: environmental, social, and governance, aiming to promote responsible and sustainable practices that ensure the preservation of natural resources, social well-being, and good corporate governance [6].

Sustainability is a concept that dates back to green manufacturing, which represents ecological sustainability. It encompasses various concerns, such as air, water, and soil pollution, waste recycling, as well as the use of more sustainable energy sources.

For some authors, green manufacturing is seen as a philosophy, not just a process; it is a production method that minimizes waste and pollution through product and process design. However, to achieve this, continuous improvement in production processes is necessary [54].

The goal of green manufacturing is to minimize the environmental impact caused by human activities. Several organizations have started adopting these initiatives in their operations due to rising energy costs and the growing demand for "green" products [55, 56]. Therefore, it is expected that manufacturing organizations will implement green manufacturing and increase product complexity at a competitive price [57].

Both governmental and non-governmental organizations are increasingly concerned with sustainability issues, such as: reducing the consumption of natural resources, using those resources sustainably, and utilizing renewable energy sources. This is possible

through technologies that enhance the generation of renewable energies, such as photovoltaic panels, wind turbines, bioreactors, biofiltration, bioremediation, and energy conservation [53, 56]. It is also important to highlight those socioeconomic issues, such as the creation of new jobs, are intrinsically linked to sustainability.

3 Discussion

It is widely recognized that organizations have to deal with an increasingly volatile marked, which will be reflected on their production system, through its processes, machinery, techniques, and technologies; which promotes the inclusion of new solutions [58].

Production planning and control should include the following activities: decomposition of all product tasks, product requirement analysis (technical and human resources), operation sequencing, and task progress real-time monitoring and control. It is a multi-departmental effort, meaning, it involves several expertise, e.g., product development, maintenance, customer service [59].

Therefore, the solutions employed on production systems – being machinery, technologies, or tools –must ensure both (a) interoperability among the multitude of digital assets already in place; and (b) attend to the different departmental requirements.

As a result, production systems are becoming increasingly complex and interoperable. In line, the need for maintenance on production systems is emphasized, to correct, but specially to prevent or predict failures; therefore, avoiding unscheduled production interruption.

This is mainly because the success of organizations is closely linked to the performance of their production systems, in terms of quantity, quality, and safety. This performance can only be achieved through a highly effective and efficient production system, capable of ensuring high manufacturing equipment availability, ensuring long-term reliability, and preserving asset value and human safety [42].

Quality management is an important part of the production processes, as it is closely linked to the organization credibility, in its processes, and products or services. Often, quality management is mandatory to be part of certain supply chains, e.g., automotive, aviation, food, medical. I.e., if organizational processes do not attend certain criteria, products do not meet certain specifications or attend the defined requirements; organization will not be eligible to supply parts (automotive and aviation) or even to operate (food and medical). Moreover, its credibility may be negatively impacted if a single aspect is not met. A plane crash, or a drug incident, may at minimum discourage consumers, or at maximum stop an organization from operating.

Many organizations are resorting to advanced technologies to ensure material and product quality, inventory optimization, production system availability, and supply chain integration [60]. These work to both increase organization efficiency, and also to avoid incidents.

Regarding logistics, it should be seen as a network in which all processes and organizational resources are interconnected, and communicate with each other [61]. Several initiatives are being researched to implement more sustainable and efficient solutions in terms of logistics transportation [60]. The use of AMRs (Autonomous Mobile Robots)

inside facilities, to reduce the amount of peripherals and deadlocks typically associated with AGVs (Automated Guided Vehicle) is an example, as well as self-driving semitrucks or hydrogen-powered airplanes.

Industrial organizations must adapt to changes, while consistently integrating sustainability principles into all their processes. In this context, Green manufacturing emerged, aiming to minimize waste and environmental impact throughout the production process [58, 60]. However, rather than relying solely on traditional frameworks, some authors argue that it is more effective to adopt the Environmental, Social, and Governance (ESG) criteria. ESG provides a structured framework for assessing and implementing sustainable practices, aligning with global initiatives, such as the SDG (Sustainable Development Goals, a United Nations Development Programme) and The European Green Deal (approved by the European Commission). This shift towards ESG ensures a more comprehensive and forward-looking approach to sustainability.

4 Conclusions and Future Work

Production systems involve a high level of complexity, making it vital to focus on their core processes to optimise performance. Different types of production systems exist to serve varying operational needs, and selecting the appropriate one depends on the strategic objectives of the organisation. To remain competitive, organizations must monitor broader economic shifts, stay attuned to evolving customer preferences, and continuously embrace innovation to ensure their products and services align with market demands.

In order to take full advantage of new technologies and tools which unlock greater integration and efficiency within and among organizations, all the stockholders should understand the core business. Indeed, the same is true regarding production system. Hence, this research provides a characterizing of the key processes and concepts of production systems, to offer a clear and integrated understanding for newcomers into this field. By doing so, we intend to promote an effective and efficient addition of specialists in different fields of knowledge, such as: simulation, machine learning and data engineering; in order to further advance production system optimization through collaboration efforts.

Through collaborative efforts, a set of advantages are unlocked, namely: (a) answer to a growing system complexity, (b) offer organizations holistic solutions, and (c) obtain more resilient results to future changes.

Moreover, the review of production systems allows for establishing a crucial connection for subsequent research on the fundamental building blocks structuring (source, server, combiner, separator, among others); which are essential for the construction of simulation models. This process eases the identification of critical production systems building blocks. The source, for example, can be applied in raw material input, adjusting times according to demand. The server, in turn, can be used to mimic the processing of raw materials. The combiner can be employed to replicate the assembly or palletization. By contrast, the separator can be used to separate components or to remove from a pallet. At last, there are elements which will link the previously mentioned building blocks, e.g., paths, conveyors.

Through this research, the main production processes and models were detailed, and the key building blocks were identified. This enables the collaboration among different fields of knowledge, promoting production system optimization. Particularly, regarding simulation, one of the authors' research topics, this effort is intended to feed future developments to promote the use of simulation as an optimization in decision-support systems (DSS).

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