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Digital Transformation in Human Resources and Operations Management

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ΒΛΑΣΤΑΡΙΔΟΥ ΑΝΑΣΤΑΣΙΑ

Α.Μ. : 2312016014

ΕΠΙΒΛΕΠΩΝ ΚΑΘΗΓΗΤΗΣ

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Abstract

The aim is to analyze the impact of technological applications in human resources and operations management. An extensive literature survey will be conducted in the fields of human resources management and operations management and the impact of the application of technology. The focus will be on the development of a maturity assessment framework for the assessment of initiatives like Industry 4 and Quality 4.

1.Introduction

Industry 4.0 (or I4.0) is understood as a new industrial stage in which there is integration between manufacturing operations systems and information and communication technologies (Glogovac et al. 2020). Industry 4.0 affects various aspects of our lives, such as employment, consumption, and trade and refers to the process of transforming an industrial facility into a modern one. Industry 4.0 can help improve a firm's financial performance and stock returns. It helps companies improve

their efficiency and profitability of manufacturing through increased product connectivity.

Industry has been constantly moving forward and quality concepts have gradually changed. Technology has played a vital role in the continuous improvement of organizations, helping them achieve higher levels of quality and performance. This improvement is succeeded with Digital Transformation (DT) process. Through the DT process, we can transform an organization and its various business models and operations, resulting new strategic objectives and enhances the organization's capabilities.

Technology has been used to create significant changes in society. The term *digital era* refers to the period when the changes were most significant. The recent discourses have focused on digital transformation which is defined as *the changes associated with the use of technology in various aspects of human society* (Van Veldhoven and Vanthienen 2021). Due to the increasing use of digital tools, the human resource management (HRM) function is affected by their effects on the organization's core values. One of the advantages of digitalization is the ability to gather and analyze vast amounts of data. This process enhances the knowledge acquired in the organization and increases the analytical capabilities of the collected data, by using algorithms and an increase in information flows.

The way people interact with information and data has changed as a result of the expansion of digital technologies. Human Resource processes, such as hiring and selection process, have become more digital as organizations look to improve the efficiency of their services.

Due to the rapid emergence of DT in the workplace, HRM has become more diverse, and people oriented. The various changes that are happening in the industry are some of the challenges that the profession faces. The rise of digital employees has required HR professionals to make operational and strategic changes in order to influence their behavior and attitudes (Fregnan et al. 2020).

Manufacturing organizations are not able to define their I4.0 maturity level. This is due to the lack of tools and definitions that can help them assess their digital transformation journey. Through the use of assessment frameworks and models, enterprises can help themselves in evaluating their progress and develop effective strategies and practices. An assessing digital transformation maturity model is needed to help companies define their digital transformation strategy.

The term maturity refers to a state of being completed, perfect, or ready for the next step in the development of a system. Maturing systems refer to the accumulation of capabilities that can be utilized for a desirable future state. A maturity model is a tool that measures and evaluates an organization's maturity. It can be performed in a continuous or discrete manner. Maturity can be labeled as readiness models.

The need for a relationship between technology and quality has become clear as we recognize the importance of quality in today's environment. Quality Management is a process utilized for optimizing the operations of organizations. This discipline can help improve the productivity and competitiveness of businesses in times of societal change. The goal is to help companies develop their capabilities in order to capitalize

on the opportunities presented by I4.0. This includes developing their innovation management capabilities and improving their skills in this area. Models for the Quality Management System (QMS) could play a role in supporting the development of skills and competencies in I4.0. As a result, there is a term of Quality 4.0 (Q4.0) signifying an integral part and extended concept of I4.0. The core culture and managerial approaches of quality managers are considered as factors that drive the success of Q4.0 concept. This argues that adopting a quality management system could help improve the profitability of the organization. Quality 4.0 is a shift that addresses the challenges of working with production systems that are constantly monitored and assessed in real-time.

While Quality 4.0 is mainly focused on the technical aspects of improving efficiency and effectiveness, it has a social side. This concept tackles issues such as the need for people to develop new skills and attitudes, as well as the establishment of a supportive culture. One of the key factors that the Q4.0 transition needs to consider is the development of skills in leadership. The new era of quality management requires a leader who combines the principles of quality with the demands of I4.0. This leader should have the necessary resources and the mindset to implement Q4.0 effectively.

Professionals in today's tech industry must learn how to adapt their skills to meet the demands of I4.0. This requires specific training that can help them develop transformational skills, social skills, critical thinking, and creativity. Leadership competencies are the most important aspect of a quality professional. They should be linked to communication skills and include the importance of teamwork and persuasion.

The transition to Q4.0 requires continuous learning and innovation. A quality-based knowledge is also necessary to support the development of effective and efficient processes and procedures, setting benchmarks for sharing digitalization-related practices. The goal of an agile approach is to enable cross-functional collaboration and the sharing of knowledge. This method facilitates the continuous improvement of processes and the dissemination of ideas and experiences, which leads to positive results.

An organization's philosophy of quality is a vital component to sustaining and developing a culture that encourages creativity and innovation. This philosophy plays a crucial role in the development of an organization's workforce. Quality integration within an organization is an integral part of the Q4.0 strategy. It supports the continuous improvement of processes and operations.

The next section defines operations management and discusses some of its applications in businesses. This paper's primary operations management features include performance, strategy, and sustainability.

Section 3 is concerned with the digital transformation in Human Resource Management. It examines Human Resource practices and models, as well as how digitization and new technology have impacted this department in the workplace. The concept of digital transformation is a key topic in this area. It is a required condition

for an organization, and its appearance has opened up numerous prospects in terms of business, resource growth, and business model.

The term Industry 4.0 is introduced in section 4. This revolution's innovations have resulted in substantial improvements in several aspects of a company, including operations management, human resources, and sustainability. A field literature review is conducted, and the term maturity models is highlighted for the first time.

Quality 4.0 is the foundation for section 5. The major aspects of quality are provided after a field literature review. The four perspectives in the context of Quality 4.0 maturity are an important part of the module. The last section presents and proposes the Glykas Quality Compass maturity assessment model.

Below in diagram is presented the thesis structure.

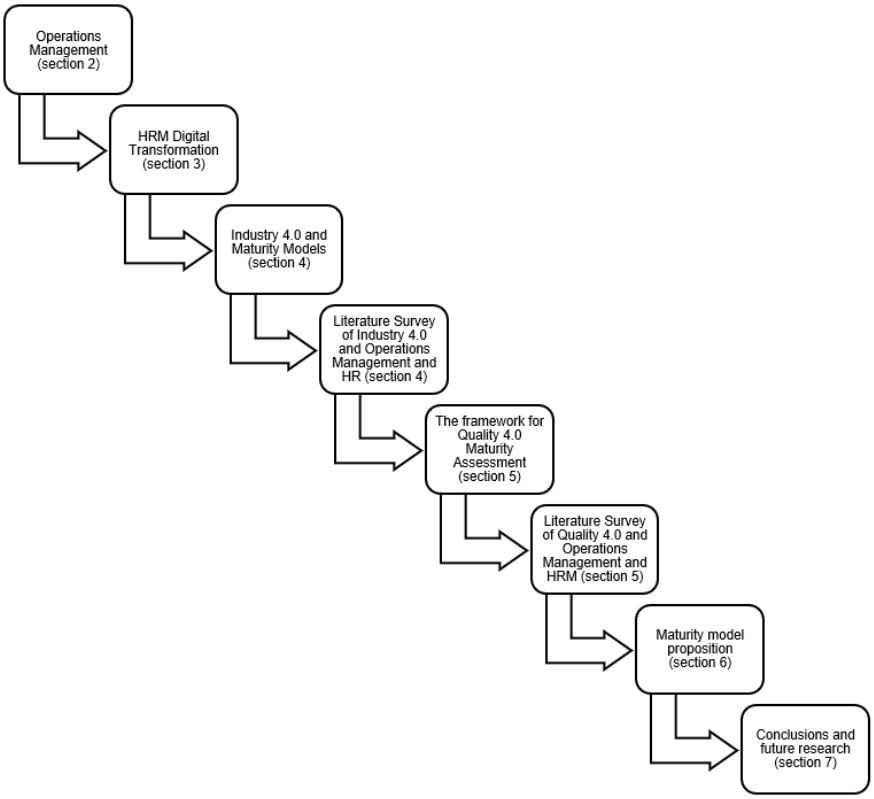

Figure 1 Research and presentation approach

2. Operations Management

The activity of managing the resources that produce and deliver products and services is known as operations management. This activity is managed by the operations function, which is part of the organization. Every company has an operations department because they all create goods and/or services. However, not all sorts of businesses will refer to the operations department as such. Operations managers are in charge of managing some or all of the resources that make up the operations function (Lohmer and Lasch 2020).

The operations function is important to the organization because it creates the commodities and services that allow it to function, but it is not the only function. It is one of any organization's three essential functions. These functions are the marketing (including sales) function, which is in charge of communicating the organization's products and services to its markets in order to generate customer service requests; the product/service development function, which is in charge of developing new and modified products and services in order to generate future customer service requests; and the operations function, which is in charge of fulfilling customer service requests through various channels (Lohmer and Lasch 2020).

There are also support functions that allow the core functions to perform efficiently. The accounting and finance function, for example, provides information to aid economic decision-making and controls the organization's financial resources; and the human resources function, which recruits and develops the organization's employees while also caring after their welfare (Lohmer and Lasch 2020).

All actions in the organization that contribute to the efficient production of products and services, fall within the purview of operations management. While the precise nature of the operations function's responsibilities varies depending on how the company defines the function's boundaries, there are some basic categories of activities that apply to all types of operations and are described below by Lohmer and Lasch (Lohmer and Lasch 2020).

- Understanding the strategic performance objectives of the enterprise: Any operations management team's first task is to figure out what it's trying to accomplish. This entails knowing how to assess the operation's performance at several levels, ranging from broad and strategic to more operational performance goals.

- Developing an operational strategy for the company: Because operations management entails hundreds of minute-by-minute decisions, a set of general principles that can guide decision-making toward the organization's long-term goals is essential.

- Product, service, and process design for the operation: The process of determining the physical form, shape, and content of products, services, and processes is known as design. It's an important aspect of what operations managers do.

- The operation's planning and control: The action of deciding what the operations resources should be doing and then ensuring that they are actually doing it is known as planning and control.

- Improving the operation's performance: All operations managers have the ongoing obligation of improving their operation's performance.

- Operations management's social responsibilities: Many organizations are increasingly recognizing that operations managers have a broader set of societal duties and concerns than their direct actions. Corporate social responsibility (CSR) is a broad phrase for these aspects of corporate responsibility. It should be of special importance to operations executives, as their actions can have a direct and major impact on society.

The operations manager's job is to plan and manage the operations department so that it can achieve its goals. Even the most basic operations usually necessitate a web of interconnected activities to function successfully. Without proper planning, the outcome will be chaotic. To be most effective, the operation should plan strategically, indicating what it plans to do in the medium and long run as well as the short term. However, planning alone is insufficient. Because of the dynamic nature of operations and the environments in which they operate, reporting on progress against plans is critical. This allows plans to be adjusted and the operation to be changed in some way to reflect the new reality. Control is the process of receiving feedback on performance and reacting to it. Control is vital in terms of the operation's daily performance. The operations manager must be aware of the operation's actual results in terms of quality, speed, cost, and dependability. With this information, he or she can adjust the operation's performance to correct flaws. As a result, planning and control play a significant part in operations management.

2.1 Operations Performance

There are stakeholders in every enterprise. People and organizations with a legitimate interest in the operation's actions are called stakeholders. Some stakeholders are internal, such as employees, while others are external, such as customers, society or community groups, and a company's shareholders. Some external stakeholders, such as suppliers and customers, have a direct business relationship with the company. The operations function in every organization is responsible for understanding the objectives of its stakeholders and setting goals appropriately.

The organization's top management has the most immediate impact on its success of all stakeholder groups. They represent the owners' interests and are the primary guardians of the organization's mission. They are in charge of putting the organization's general aims into more concrete terms. They expect all of their operations managers to contribute to the organization's success by properly utilizing its resources. It must be creative, imaginative, and energetic in upgrading its processes, goods, and services in order to achieve this. Effective operations

management can provide a business with five types of benefits. It is capable of lowering production costs and increasing efficiency. It can satisfy customers by providing good quality and service. It can lower the risk of operational failure since well-designed and well-run operations are less likely to fail, and if they do, they should recover faster and with less disturbance (this is called resilience) (Lohmer and Lasch 2020). By raising the effective capacity of the operation and being innovative in how it uses its physical resources, it can lower the amount of investment required to create the requisite type and quantity of products and services. It can provide the groundwork for future innovation by drawing on its experience running processes and establishing a solid foundation of operational skills, knowledge, and capability within the company.

The five core performance objectives are quality, speed, dependability, flexibility, and cost, and they apply to all sorts of operations (Lohmer and Lasch 2020).

Quality is defined as consistent compliance to customers' expectations, however the things that the operation must do properly vary depending on the type of activity. Quality is an aspect of the operation that a consumer finds reasonably simple to assess. It has a significant impact on customer satisfaction or discontent. Customer satisfaction and, as a result, the likelihood of the customer returning is increased when customers perceive high-quality products and services.

The time it takes for clients to request items or services and receive them is referred to as speed. The fundamental benefit of quick delivery of goods and services to the operation's external clients is that the faster they can get the product or service, the more likely they are to acquire it, pay more for it, or obtain more benefit.

Dependability relates to executing duties on schedule so that clients obtain their products or services when needed, or at least when is promised. Customers can only assess an operation's dependability after receiving the goods or service. Customers may not initially opt for the service as a result of this because they have already consumed it. Over time dependability may outweigh all other considerations.

Being able to adjust the operation in some way is what flexibility signifies. This could imply altering what the operation performs, how it does it, or when it does it. Customers demand that the business adapt in order to give product/service flexibility, mix of products and services flexibility, volume flexibility, and delivery flexibility.

Cost will clearly be the primary operational goal for organizations that compete directly on pricing. The lower their manufacturing costs, the lower the price they can charge their customers. Even companies who do not compete on price want to keep their costs low. The extent to which operations management can influence expenses is primarily determined on where the expenditures are incurred. The money will be used on personnel, facilities, technology, equipment, and materials.

At this point, quality might be described as completing the work to the needed standard with the resources available. Improving quality can help achieve all of other goals. The time it takes for an operation to deliver what is expected of it is referred to as its speed objective. The dependability goal addresses the organization's capacity to keep its promises to its customers. Flexibility refers to how rapidly a business can adapt to new needs. Changes in the volume of service or product delivered, the

balance of the current variety of services or products, or the sort of product or service delivered are all examples of new demands. The amount of money spent on the operation is referred to as the cost. Understanding what each of these generic objectives means in their own specific external settings is a critical responsibility for operations managers.

2.1.1 The measurement of operations performance

Quality-based measures of performance focus on factors like the amount of defects created and the cost of quality. The true cost of quality, according to Feigenbaum (1961), is a function of three categories of quality costs: prevention, evaluation, and failure costs (Neely 2007). These three forms of cost are defined as follows by Campanella and Corcoran (1983) (Neely 2007).

Expenses spent to prevent inconsistencies, such as quality planning, supplier quality surveys, and training programs, are examples of prevention costs. Inspection, test, and calibration control costs are examples of appraisal costs that are incurred in evaluating product quality and detecting inconsistencies. Failure costs are costs incurred as a result of discrepancies and are typically divided into two categories: internal failure costs are costs incurred prior to delivery of the product to the customer, such as rework, scrap, and material review; and external failure costs are costs incurred after delivery of the product to the customer, such as costs associated with the processing of customer complaints (Neely 2007).

Crosby's (1972) claim that quality is free is predicated on the assumption that an increase in preventive costs will be more than offset by a reduction in failure costs for most businesses (Neely 2007). Plunkett and Dale (1988) argue that, while conceptually appealing, the cost of quality model's academic rigor is questionable. Rather than data, it is based on assumptions and estimations, and like with the EOQ model, it's debatable if an optimal level of quality exists at all (Neely 2007).

According with speed and dependability, time has been defined as both a source of competitive advantage and the primary measure of operations performance. The just-in-time manufacturing philosophy is founded on the idea that producing or delivering things too early or too late wastes resources. Other factory planning strategies, such as optimized production technology, aim to reduce throughput times as much as possible. Understanding and managing profitability requires identifying resource restrictions (bottleneck processes) and ensuring that they are fully utilized. Of fact, identifying resource restrictions is challenging in practice, not least because they are affected by sales volume and variety at any one time.

In terms of cost, there is significant interest in product costing, in addition to the operations management community's focus on productivity. The developments in this area that the operations management community refers to are typically the outcome of accounting effort. Many managers, according to Miller and Vollmann (1985), focus on the obvious expenses, such as direct labor and material, but the majority of overheads are produced by unseen transaction costs (Neely 2007). These findings

are consistent with the assumptions behind activity-based costing, particularly the notion that cost is caused by activities rather than products.

The fifth operations performance objective, flexibility, is one of the most contentious areas of contention in the operations management field. Range, cost, and time are identified as dimensions of flexibility by Slack (1983), however he later alters this model to include simply range and reaction, where range refers to how far the production system can vary and response refers to how quickly and cheaply it can change (Neely 2007). According to Gerwin (1987), little is understood about the implications of flexibility for industrial management, and part of the difficulty stems from the lack of operational measurements of flexibility (Neely 2007). He offers the following measures after recognizing several degrees of flexibility.

Mix flexibility which is defined as the quantity of components that the equipment can handle. Changeover flexibility that is defined as the number of component substitutions made in a particular amount of time. Modification flexibility, it is the number of design modifications made to a component during a given period of time. When a machine breaks down, rerouting flexibility is quantified in terms of lost production. Volume flexibility which is defined as the capacity limit divided by the average volume fluctuations that can be handled during a specific time period. Material flexibility, it is defined as the ability of equipment to accommodate fluctuations in important dimensions and metallurgical qualities. Flexibility in sequencing, the amount of various sequences that the equipment can handle.

2.2 Operations strategy

The pattern of strategic decisions and actions that define the operation's role, objectives, and activities is known as operations strategy. Strategy is often thought of as the polar opposite of everyday activity. The resources used to develop products and services are referred to as operations. Both the operational and strategic sides of operations can be examined.

Four operational strategy perspectives have been developed. The top-down reflection of what the entire organization or business wants to do is operation strategy. Operations strategy is a bottom-up activity in which incremental improvements in operations lead to strategy. Translating market demands into operational decisions is the goal of operations strategy. Exploiting the capabilities of operations resources in targeted markets is part of operations strategy (Lohmer and Lasch 2020). None of these four viewpoints together provide a complete understanding of what operations strategy is. However, taken collectively, they give some insight into the pressures that influence the content of operations strategy.

An operations strategy is defined as the efficient application of operations capacity to meet business and corporate objectives. Strategies can be thought of as efforts aimed at achieving the firm's objectives by maximizing the use of many aspects in the manufacturing process. TQM, JIT, manufacturing cells, FMS, benchmarking, computer networking with suppliers, customers, and concurrent engineering are some examples of operations techniques (Bhattacharyya and Atre 2020).

TQM is an enterprise-wide strategy centered on continual improvement and customer satisfaction. The JIT strategy is founded on the premise of receiving the appropriate material at the appropriate time. Manufacturing cells try to organize the manufacturing process by integrating machines and equipment to manufacture a family of parts faster than a traditional job shop. FMS enable a company to respond to market demand by allowing its operations to be more flexible. Computer numerical control machinery, robotics, and automated materials handling devices are used to increase operational flexibility.

Benchmarking is a method for comparing an organization's present performance to that of its competitors. This information is then used to help plan for ongoing improvement. Computer networking with suppliers and customers is an important operational technique that should allow a company to be more responsive in decision making by allowing for better communication. Concurrent engineering combines product development and design with process design to ensure that the entire design process is completed correctly the first time around. This makes a company more competitive by lowering costs and shortening the time it takes to introduce a new product.

A resource-based view of strategy strengthens operations strategy. It is essential to challenge the long-term viability of competitive advantages derived from flexibility. Operations must support a larger resource preservation strategy. Operations managers take on the role of defenders, ensuring that critical sources of competitive advantage, such as new product development procedures, are updated on a regular basis to prevent competitors from copying them. The focus of operations strategy could then shift to resource management, assessing the long-term viability of the firm's competitive advantages (Cho and Linderman 2020).

The term operations strategy evolved from manufacturing strategy and has become a central theme in operations management. The word was coined to highlight how most economies are becoming increasingly service-centric, shifting their focus away from manufacturing and toward providing services (Matthias and Brown 2016). An operations strategy's goal is to provide a broader understanding of value and service delivery, as well as to build organizational expertise and enable planning to balance market demands and resources.

Brown et al. (2013) suggested that operations strategy is concerned with meeting existing market needs and exploiting opportunities for potential market segments, is about making the best use of resources and leveraging these resources either alone or with partners, is the responsibility of senior-level managers within the company, while recognizing the importance of a range of stakeholders in the process, be they internal or external, is about devising and implementing operations strategies, and is about devising and implementing operations strategies (Matthias and Brown 2016).

Sustainability, ethical issues, capacity management, location decisions – the range and locations of facilities, process management, managing technology, formation of strategic buyer-supplier relationships as part of the organization's extended enterprise, innovation – the introduction of new products or services, and human resources management are all part of the operations strategy (Matthias and Brown 2016).

Operations strategy is concerned not only with what it contains, but also with how it is developed and implemented. Thus, operations strategy, for example, can be considered as critical to the execution of a previously defined business strategy. The function of operations in this method is critical in providing strategic fit in focusing efforts and resources so that the operations plan is compatible with, and serves to support, the overall strategy that has previously been created. Operations strategy, on the other hand, can be employed in a more proactive manner. Operational capabilities are seen as part of an organization's fundamental capabilities and skills. The contribution of operations would thus be crucial to the planning stages of corporate strategy, rather than being limited to the execution of a previously created strategy.

2.3 Operations Management and Sustainability

Sustainable operations management and strategy refers to the procedures, processes, practices, and systems by which businesses, whether operating independently or as part of larger inter-organizational structures, initiate, create, and deliver outputs that are profitable from a business standpoint while also preserving or even improving the natural and/or social environment. This builds on the realization that organizations must consider sustainability challenges in order to succeed and survive in the long run.

Understanding and investigating strategy and how it relates to management can be done in a variety of ways. The actual or envisioned operations of a single organization are often the focal points of these designs, although they will almost always incorporate a larger network of business actors. Operational strategy, in essence, departs from operations and does not observe solid boundaries. As a result, operations management typically entails creating a vision and creating a collaborative network of actors capable of controlling a flow of resources and activities across many organizational boundaries to the end-user, and occasionally the other way around. This has a number of implications for strategic practice and, as a result, theory. A number of concerns emerge, indicating the possibility for a beneficial interaction between strategy and long-term operations management research. Strategic issues management, for example, is a strategy research stream that fits well with the issues and complexities of developing viable business strategies, while taking into account concepts like profit, people, and planet, creating strategic operational designs that support recycling, or lessening the environmental footprint (de Boer and Houman Andersen 2019). These and other difficulties provide distinct perspectives and beginning points for developing sustainable operations strategy goals.

According to Barney (1986), competitive strategy appears to reflect one of three theoretical approaches to strategic context: industrial organization, with Porter's strategy framework for strategic positioning vis-à-vis suppliers, buyers, new industry entrants, and substitutes providing an excellent example of how this perspective is applied in strategic theory; Chamberlinian economics, which begins with a focus on firms' unique resources and capabilities and how they are used; and Schumpeterian

strategies argue that strategic entrepreneurship, which entails ongoing change and disruption of incumbents' advantages, is the key to understanding and applying strategy (de Boer and Houman Andersen 2019).

The focus of sustainable operations management is on how to achieve the strategic goals in a resource-efficient and effective manner. Operations management is concerned with coordinating, integrating, and guiding activities and associated functions both inside and outside the organization's borders to offer a flow that meets the needs of users/consumers while taking into account the strategy's sustainability goals. Environmental management, closed-loop supply chains, and a comprehensive perspective on triple-bottom-line thinking, which integrates profit, people, and planet into a company's culture, strategy, and operations, are all included in the phrase (de Boer and Houman Andersen 2019).

Kleindorfer et al. define sustainable operations management as the set of skills and concepts that allow a company to structure and manage its business processes in order to obtain competitive returns on its capital assets without sacrificing the legitimate needs of internal and external stakeholders, and with due regard for the impact of its operations on people and the environment, bringing sustainability to the operations management field (Magon et al. 2018).

Sustainability concepts could be seen as operational methods analogous to agile manufacturing, lean production, and business process reengineering, according to Gunasekaran and Spalanzani. This assists a business not only improve its financial performance, but also meet social and environmental goals and standards (Magon et al. 2018).

Internal and external organizational management that integrates environmental, social, and economic considerations into operational activities, including the entire life cycle of a product, are examples of sustainable manufacturing techniques. The internal dimension refers to how a corporation implements sustainable manufacturing processes. It includes, among other things, sustainable new product development, procurement, production/manufacturing, and remanufacturing activities. External sustainability is defined as involving suppliers and consumers in joint projects linked to environmental and social management practices, as defined by external Green Supply Chain Management (GSCM) and Sustainable Supply Chain Management (SSCM) (Magon et al. 2018).

Sustainability has been studied as a determinant, mediator, moderator, or a performance component of the firm by operations management scholars using causal models to examine the relationship between sustainability and business performance. Antecedent or predictor variables are synonyms for determinants. Performance measures are dependent variables that are said to be the result of a determinant's activity. Multiple aspects, such as financial, market, and operational, usually through cost, quality, flexibility, and delivery dimensions, as well as environmental and sustainability factors, are traditionally included in business performance measures.

3. HRM Digital Transformation

3.1 HR Practices

Through the use of assessment frameworks and models, enterprises can help themselves in evaluating their progress and develop effective strategies and practices.

Human Resources Management (HRM) refers to a set of practices that organizations use to ensure that their workforce is well-equipped to meet their operational needs. HRM Practices are focused on the combination of administrative personnel functions with performance, employee relations and resource planning. They help organizations maximize their return on investment and minimize financial risk. HRM practices can affect various aspects of an organization's performance such as turnover, stress, and burnout etc., which in turn influences organization performance indicators like reputation, sales per employee, sales growth, return on investments etc. (Alam and Mukherjee 2014).

A particular definition of HRM, is the one defined HRM as those decisions and actions which concern the management of employees at all levels in the business and which are related to the implementation of strategies directed towards creating and sustaining competitive advantage(Syed and Bayeroju 2019). This definition of HRM states that the availability of HRM practices and standards, as well as strategies, can be linked together to improve the performance of an organization. This definition is applicable to organizations that have comprehensive HRM practices and procedures. However, it cannot claim that their performance will improve if they do not have performance strategies and standards in place.

HRM practices can improve and sustain an organization's performance. These practices are based on employee selection that fit with the company’s culture, on behavior, attitude, and necessary technical skills required by the job, compensation contingent on performance, and employee empowerment to foster teamwork. Seven HRM practices that improve organizational performance are employment security, selective hiring of new personnel, self-managed teams and decentralization of decision making as the basic principles of organizational design, comparatively high compensation contingent on organizational performance, extensive training, reduced status distinctions and barriers, including dress, language, office arrangements, and wage differences across levels, extensive sharing of financial and performance information throughout the organization(Pratibha et al. 2021).

The social exchange perspective can be used to understand the link between employee performance and HR practices. This concept argues that employees are more likely to respond to positive organizational investments if they feel valued by organizations and that they invest in them. Social exchange relationships are often formed by employees who voluntarily act with the expectation of a favor.

Due to social exchange perspective, various dimensions of HR practices can help employees align their work environment with the organization’s interests. Employees see these actions as HR practices for support and commitment from the organization

and they adopt positive attitudes toward its goals. Different dimensions of HR practices help employees feel valued by the organization. This can be evidenced by the number of employees who are satisfied with their work.

Employee personality and work environment effects on various aspects of performance are often measured through various happiness related constructs. Analyzing employee well-being is a vital step in determining the appropriate HR practices and employee outcomes. Employees use various dimensions of HR practices, the more they feel recognized, which leads to a higher psychological well-being. People generally feel an obligation to contribute to the company's overall performance. However, as HR practices become more sophisticated, they commit more time to their work. Working conditions are getting more stressful and they can lead to a reduction in employee well-being. This can create a negative work environment that can affect performance.

Due to digitalization the competition between workers has changed into competition between people and machines. Employees' careers depend on their skills in digital technologies, regardless of their qualifications. People take responsibility for their qualifications and skills and may be more or less willing to learn new technologies in any environment they want and be opened to change.

Technological, cognitive, social, and emotional are the skills that are in great demand. It is important for companies to offer continuous learning and training to their employees to acquire these skills. Education and continuing training to be effective must be based on the learning culture and HRM practices of organizations. Among the human resources practices that favor the success of training is the reward and promotion system of organizations that values continuous learning at the individual level and compensates employees accordingly for recently acquired skills. Creating a climate of continuous learning requires organizations to adopt characteristics such as openness, innovation, discipline, interactive collaboration and constructive confrontation(Zaitouni et al. 2020).

3.2 HRM Models

The new challenges brought about by digitalization have also required changes in HRM models. HRM models help to explain the role of HR in the business. Several HRM models have been identified as sources of inspiration for aspiring HRM professionals. These models provide a framework for linking HRM practices to key performance indicators. Three of these HRM models are the Harvard Business School HRM Model, the Michigan Business School HRM Model and the Best Practice HRM Model.

The Harvard Business School's HRM Model states that Line Managers are more responsible for ensuring that the policies and procedures they develop are aligned with the company's competitive strategy and personnel activities. This model of HRM focuses on the management of human resources, by seeing employees as resources. It encourages the organization to promote harmony and maximize output. The Harvard Business School Model stresses the human aspect of human resource

Management while the Michigan Business School is considered as instrumental in the implementation of organizational performance. The Harvard Business School Model is widely regarded as the academic lineage from the school of human relations. The Michigan Business School Model follows the line of the Scientific Management School and other approaches that are no related with culture and non-economic factors in the human resource management (Alam and Mukherjee 2014).

Universalism is the best practice tool for HRM. At this model regardless of internal factors the management of human resources can still lead to better results. The core concept of best practice tool of HRM is Universalism. The elements of best practices are employment security/Job security, sophisticated selection / selective hiring, team working and decentralization, high wages linked to organization performance, extensive training, narrow status differentials and communication and employee involvement(Pandey 2019).

3.3 Factors necessary for successful digitalization of HRM practices

Successful HRM digitalization involves clearly identifying of objectives, key figures, and digital tools for the digital transformation process. This helps the organization to understand how these tools and technologies can be utilized to enhance the overall operations and provide a better and more productive work environment. Identification of key players within the organization is related with the role played by HR managers. They need to develop digital awareness and adapt their strategy to take advantage of the opportunities presented by digitalization. Although digital tools are not substitutes for human resource processes, they can be utilized to improve them. In most cases, traditional HR processes must be modified to adapt to the latest technologies, to achieve the highest level of effectiveness and efficiency.

The factors propulsive the adoption of digital tools is a fundamental prerequisite for the success of HRM digitalization. These factors consecutively influence the results of HRM digitalization which determine the achievement of this process. The factors that determine the success of the digitalization of HRM practices are divided into three categories(Bondarouk et al. 2017) technological, organizational and people factors, as described in detail in Figure *2*.

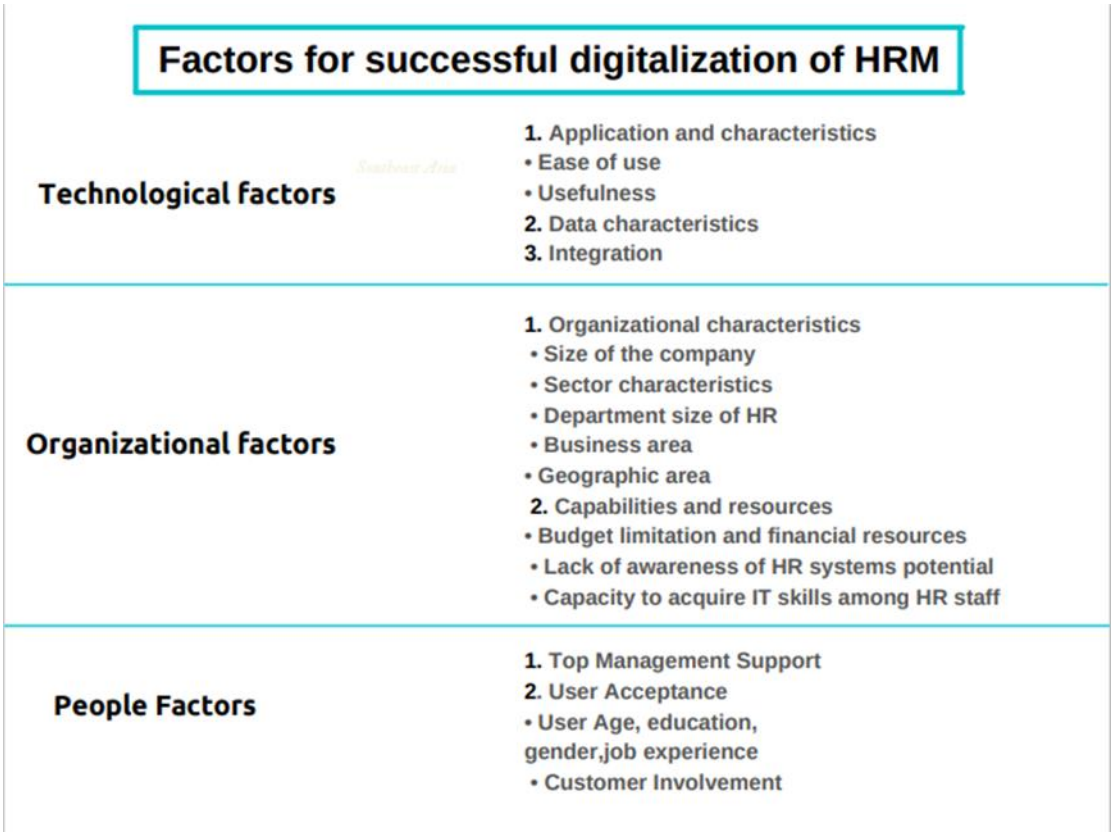

Figure 2 Factors for successful digitalization of HRM

About technological factors, it is important to consider application and characteristics, data characteristics and integration.

The various factors that influence the success of HR digital transformation can be divided into two main categories: organizational characteristics and, capabilities and resources. The size of organizations is positively correlated to digitalization. In fact, digital transformation is more widespread in medium and large organizations(Ketolainen 2018).

The second category of factors that prevent or slow down the digital transformation process include the lack of resources and capabilities. Most of these constraints are usually related to the procurement of digital tools and the lack of training on how to use them, or to tight budgets. People factors, in particular: Top management support and user acceptance, top management support is one of the most important factors in determining the success of the HRM digitalization process(Fenech et al. 2019).

Another factor that determines the success of the digitalization process because the use of digital tools, and especially of Artificial Intelligence (AI), allows to create a user-driven employee experience.

3.4 Consequences of HRM digitalization

Digitalization offers positive and negative consequences on HRM practices.

Advantages of HRM digitalization:	Disadvantages of HRM digitalization:
1. Cost Saving	1. Data Security
2. Efficiency Time Saving Productivity HR Efficiency Elimination of paperwork	2. Lacks suitable skills
3. Effectiveness Administrative Quality Flexibilities of HR Level of bureaucracy	3. Existing HR digital tools are not being exploited to their full potential
4. Employee Relationship Cooperation Communication Quality Employee get more informed about organizational issues Employee Motivation	4. Difficulty in using new technologies by employees
5. Digital HR enables new employment forms	

Figure 3 Advantages and Disadvantages of the digitalization of HRM

Cost saving is one of the most important advantages. Organizations can decrease their costs through the implementation of digital tools as they can speed up processes and information management. The efficiency of HRM practices can be improved through the use of digital technology. Digitalization of HRM saves time and helps in reducing errors and HRM processes are simplified and faster. This allows HR experts to better focus on activities that are meaningful to their function. About effectiveness the use of digital technology in HR practices can lead to an increase in productivity and flexibility, as well as lower administrative costs. The use of digital tools reduces the time taken to carry out low-level administrative tasks and HR employees can focus on activities with high added value.

Some relationship consequences of digitalization include employee engagement, better communication quality, and increased motivation. Technological tools help employees to be more motivated to try to improve their performance, to undertake new projects and to obtain recognition from superiors. Digitalization has led to the creation of new forms of employment(Fenech et al. 2019). HR managers are required to constantly adapt to new challenges. For instance, they may need to negotiate fixed-term contracts to avoid future uncertainty.

The most important disadvantages that caused by the digitalization of HRM practices are the problems relating to data security and to the management of sensitive employee information. The need to keep certain data confidential can limit the

digitalization of the HRM practices. Digital skills are necessary for utilization of digitalization and these skills to be acquired by HR managers.

3.5 A New Role of HR Practices

The appearance of technology-based working methods has changed the people's role at work.

In the labor market, change is a documentation of the significant changes that have occurred in the past decades. As a result of the combination of intrinsic and extrinsic factors, the working environment have redesigned by cultural, economic, and social conditions.

Organizations have been forced to change management models, reduce costs, and downsize to remain competitive, due to market globalization and the economic crisis. The rapid spread of technology consists of another relevant feature of the current labor market, as it has greatly influenced the way work is done, and it has created new demands on workers, such as through the introduction of smart ways of working. Technology has affected the redesigning of processes and tasks, which require new skills and abilities for workers and often substitute people with machines. The massive emergence and evolution of technology in the workplace has various implications. On the one hand, it has led to the elimination of workforce units, and on the other, it has produced demands for workers to adopt technology.

Digital transformation of businesses presents new challenges and opportunities for organizations. Companies and labor market are transforming by redesigning the way companies operate and re-thinking their practices and culture. It has imposed a revisitation of most organizational assets. One of these is finding ways to attract and retain talent. The changing dynamics of the labor market have caused many companies to reassess their employee engagement strategies. The rise of digital technology has changed the way people work. The shift to the digital application is making work easier, real-time, more productive, and more rewarding. With the ability to collect and manage vast amounts of data, HR can use this data to improve the way they manage the workforce. The rise of cognitive technology has given rise to new opportunities for people management practices and HR must exploit it (e.g., exploiting people analytics, big data, etc.).

The rapid emergence and evolution of technology has greatly changed the way people work and structures are designed. This has caused many organizations to rethink their human resources management strategies.

The evolution of HR has been widely documented through the adoption of cloud HR systems. This is transforming HR into intelligent platforms. People analytics are used to manage a wide range of business challenges: from recruiting to performance measurement, from compensation to workforce planning and retention (Manuti and de Palma 2018). People analytics is a practice used by executives and managers to make better decisions about how to manage and retain their employees. This process helps organizations improve and analyze their management and business

decisions, by applying technology, statistics, and expertise to various sets of data. Due to the increasing complexity of implementing digital technology in the enterprise, companies are changing their technical analytics to enable them to drive better business outcomes and digital solutions. These solutions developed internally or embedded in new digital solutions to deliver real-time analytics that enable organizations to run their business processes in the context of their existing digital platforms.

Human Resources leads this digital transformation of an organization by helping it design a working environment that enables productivity. It fosters change in three areas: digital workforce, digital workplace, and digital HR. HR function is changing as organizations move toward a digital transformation. This is where digital tools and apps are used to make decisions, to solve problems and innovate processes and practices.

3.6 Social Networks to HRM Practices and e- HRM in the Technology Era

The rise of social media has completely changed the way people connect. Social networks are tools that allow people to connect and share interests and activities, by developing online communities. Social networking tools allow organizations to create and maintain their own social networks without the need for extensive training or expertise. From an organizational point of view, by adopting social networking technologies companies could communicate with stakeholders inside and outside the organizational boundaries: they could be effective in creating and vehiculating their culture, in managing change, in stimulating collaboration, in increasing motivation, in empowering expertise and in sharing and building knowledge (Manuti and de Palma 2018).The term collaboration is an evolving process whereby two or more social entities actively and reciprocally engage in joint activities aimed at achieving at least one shared goal (Bedwell et al. 2012). The explosion of social media has highlighted the importance of collaboration in organizations. It has also called for a redefinition of what constitutes collaboration. The emergence and evolution of technologies within an organization's context have contributed to the creation of the so-called Enterprise 2.0, featured by an extended use of technology mainly addressed to four main working processes: communication, collaboration, cooperation, and connection (Manuti and de Palma 2018). People use various platforms to communicate with each other. These platforms allow people to interact with each other in various ways. They help people at work to their needs that related with operation and sociality. These platforms allow people to communicate with others through various ways, such as text, image, voice, or video, or a combination of these.

E-HRM (Electronic Human Resource Management) is the use of online technologies for the HRM services and practices within an organization. It is the first field of HRM to make use of web-based technology and it embraces e-recruitment and e-learning.

From this base e-HRM has expanded to embrace the virtual delivery of all HR policies and strategies. E-HRM is a tool that allows HR professionals to perform various HR activities such as planning and conduct appraisals, training, and

analyzing employee development programs, training, and evaluation labor costs. Employees can use e-HRM to plan their own development, apply for promotion, transfer, career development plans and access a range of information on HR policy and strategy. This system is in essence the devolution of HR functions to management and employees. They access these functions typically through web technology channels. E-HRM involves configuration of human resource, and it is a way of implementing human resource management in an organization. This implementing can be done through the application of strategies, policies, and practices. Improvement in the HR strategic orientation, improvement in client focusses and satisfaction and decrease in costs or increase in efficiency can be achieved by following a specific e-HRM direction. The companies are aware of the fact that human resources have changed more from a cost factor to a success factor. E-HRM is an automated and web-based tool that supports various HR processes. The three main tiers of e-HRM are operational, relational, and transformational. Operational e-HRM is concerned with administrative functions payroll and employee personal data. Relational e-HRM is concerned with supporting business processes by means of training, recruitment, performance management and so forth. Transformational e-HRM is concerned with strategic HR activities such as knowledge management, strategic re-orientation. An organization may choose to pursue e-HRM policies from any number of these tiers to achieve their HR goals(Prakash and Mores 2019).

Hiring is the process by which employers look for candidates to fill jobs in their business. The beginning of the process is the search for new recruits, and the end is the submission of applications. Through online application, managers have more efficient and effective ways of recruiting. Electronic recruitment is the implementation of this process through network technology. The websites used to fill the posts are about resume databases, marketing, search engines or social networking platforms.

Companies hire employees through many websites. E-recruitment channels are corporate websites, online recruiting platforms such as cv online, professional social media platforms such as linkedin.com and xing.com and social media platforms such as facebook.com and twitter.com. The services allow users to communicate with peers by voice using a microphone, video by using a webcam, video conferencing and instant messaging over the internet. Skype is a computer program that can be used to make free voice calls over the internet to anyone who is also using Skype. It is more useful for selecting the right candidate. E-recruitment offers wider access and geographical spread, larger audience, better chances of finding the right candidate, time and cost savings, better matching of staff with vacancies, efficiency, easy access to job seekers, reduction of unqualified candidates and more opportunities for smaller companies. Apart from these advantages, it also has several disadvantages such as checking the validity of CV skills, low internet penetration and lack of knowledge in many locations worldwide and the non-exclusive dependence of organizations on e-recruitment methods(Ltd 2019).

Through online recruitment job search costs are much lower, there are more opportunities for candidates to show their skills, there is no factor of geographical location, vacancies can be filled in less time, because through social media

networking answers are faster, young people have more job opportunities and positions can be viewed by more candidates.

E-learning technology is the utilization of the web technology to deliver learning. E-learning as an idea covers a scope of uses, learning techniques and procedures. E-learning allows the learners to watch different activities and listen to lessons repeatedly as required(Ghosh et al. 2021).

E-learning technology is in great demand worldwide. Organizations prefer e-learning because it reduces employee stress and increases their collaboration and satisfaction. The growing preference for e-learning is attributed to the motivation of the individual to interact with others, to exchange views, to receive feedback, to share knowledge, to improve communication and to facilitate the relationship that maintains learning agility.

E-learning technology can help employees maximize their performance by giving them the knowledge they need at the right time. E-learning(distance mode) technologies enable organizations to support the complete Human Value Cycle (HVC): recruit, assess, train, test, certify, and retain (Prakash and Mores 2019). E-learning is successful when the focus on everyone working is ensuring. By combining the right tools and methods of collaboration, knowledge and e-learning, employees can easily achieve higher performance. E-learning tools help identify and address a skills gap in one part of the solution, while helping collaborate on one outcome that can improve the performance of the workforce.

3.7 Digital Transformation

Digital transformation refers to the process of revamping an enterprise's operations through the use of digital technology. This process involves assessing the impact of digital technology on the enterprise and identifying ways to get services that are optimized for the digital world. Digital transformation enables businesses to speed up their activities and be more competent in a highly volatile environment. Digital transformation brings business transformation by boosting technology innovation and managing external factors. Provides various capabilities and opportunities that can be found in an organization's Human Resources (HR) department. This is particularly relevant for performance management, career management, compensation management.

The digital transformation of the industry is widely affecting the way businesses operate. It has created new opportunities for companies to gain competitive advantage and improve their operations through a variety of changes and modernization. The rise of digital transformation is being influenced by the explosion of software technologies. Most of these include the Internet of Things (IoT). Data analytics, cloud storage, and services are converging to create a new generation of technologies that enable a better understanding of complex systems. According to these are identified the various tools and methods that developers can use to enable secure and reliable distributed transactions.

An organization might embark on digitalization projects, which include the use of artificial intelligence and processes to improve efficiency. Unlike traditional projects, digital transformation is not a process that organizations can involve it as their project. Most digital transformation initiatives are typically focused on digitalization projects, increasing efficiency, or improving the customer experience. Digital transformation refers to the process of making changes in an organization's operations and processes. Doing so can be done in a way that is consistent with the organization's strategy and goals.

Digital Transformation initiatives take a diverse approach and aim for distinct objectives. These methods concentrate on how new technologies are transforming products, processes, and organizational features. Their scope is more expansive, expressly including digital activities at the customer interface or entirely on the customer's side, such as digital technology embedded in end-user products. This distinguishes Digital Transformation from process automation and optimization, because Digital Transformation initiatives encompass changes to and implications for products, services, and business models as a whole.

Certain aspects are present in all digital transformation initiatives. These initiatives can be classified into four categories: technology utilization, value creation changes, structural changes, and financial aspects (Landeta Echeberria 2020). The application of technologies refers to a company's attitude toward emerging technologies as well as its capacity to utilize them.

In terms of business, the adoption of new technology frequently entails changes in value production. These are about the impact of Digital Transformation plans on companies' value chains, or how much new digital activities diverge from the traditional and core business. Further deviations provide chances to expand and enrich the current product and service portfolio, but they are frequently accompanied by a greater demand for alternative technology and product-related competencies, as well as increased risks due to lack of experience in the new field.

If other markets or new client segments are addressed, digitalization of products or services can permit or demand various types of monetization, as well as alterations to companies' business scope. When multiple technologies and types of value generation are used, structural adjustments are frequently required to offer an appropriate foundation for new operations.

It is critical to tightly connect the four major dimensions: usage of technology, changes in value creation, structural changes, and financial factors, in order to ensure the effective deployment of a Digital Transformation strategy and fully utilize its intended effects.

3.7.1 Digitalization definition

Digitalization is introduced by accentuating the essential implications it has for society primarily and for organizations. However, there is no apparent conceptualization of this term. It can be considered either as the way people use

technology (Constantinide 2020), or the process of converting analogue signals or information in any form into a digital format that can be understood by computer systems or electronic devices (Bogoviz 2018). Several characteristics are important in defining digitalization, namely: fast moving and flexible processes, easy to use, customer-focused, data driven, collaborative process, strategically essential for the success of organizations. Digitalization involves the establishment of strategies and processes that enable the organization to continuously improve its operations and achieve long-term goals.

Digitalization is the most important technological trend that is changing society and business. Organizations are trying to apply digital technologies to their business models. The aim is to implement digitalization and create a proper relationship between products and services offered by companies, with the needs of customers.

Many areas have benefited from digitalization. For instance, cultural objects and assets can be digitalized and preserved for future generations and experiments can be digitalized, tested and replicated. A few examples of digitalization include smart homes (for entertainment, security, childcare, electrical, and heating), e-healthcare, smart mobility, and smart cities. The rapid emergence and evolution of digitalization affects everything from personal relationships augmented by social media and their services to other relationships such as how citizens interact with support services in e-government(Gray and Rumpe 2015). The focus of digitalization is on data. Information and knowledge can be gleaned from this data, with the collection of relevant and useful details. This collection is a digitalization model that can describe mechanisms, situations, and characteristics, helping experts and citizens to understand specific aspects of the world.

In the business sector, digitalization provides information on the process of buying, selling, advertising, and transporting products and services. Maintains contact with customer and helps them understand the product or service through digital format, virtual composition, and description.

Digitalization can help with the management of various aspects of transport, water, and energy supply, such as the physical distribution or location of things and people of interest, as well as the analysis of real-time data related to sustainability and scalability.

3.7.2 Digitalization and Digital Transformation

The term digital describes how companies manage their operations and businesses. More specifically, it concerns the creation of value at the new frontiers of the business world, the optimization of processes that have a direct impact on the customer experience and the creation of fundamental opportunities that maintain the whole business initiative.

Digitalization of organizations across all the industries includes new digital technologies like Big Data analytics, robots, Artificial Intelligence, IoT, Blockchain, AR and VR, cloud computing etc.(M. and Chattu 2021). Otherwise, a firm that doesn't

adapt to the changes brought about by the rapid emergence and evolution of digital technology can become weak and vulnerable to competing in the modern market. One of the main characteristics of digitalization is the speed of change, volatility and increasing level of connectedness physical, social, and digital environment. Thus, in the modern market it is important for the companies to be open to technological change, to critically analyze current business strategy and to become ready to undergo this change on time. As companies move towards digital transformation, they need to develop strategies and implement technologies that will help them achieve their goals. It is required companies experience socio-technical transformation that have a direct impact on firm's structure, business model, strategy, IT architecture etc. In order to be successful digitalization, the company's management should possess digital leadership and vision, open mindset, and a strong management strategy. To succeed in the digital age, organizations should re-evaluate their business models and develop a strategy that addresses the various challenges of the new environment. There are three key fields of action that companies must develop, to be digital enterprises (Stepantseva and Breitenecker 2020):

- *Digital Disruption*: Organizations are trying to improve the current business model by using technologies. The fact that various changes in the structures of industry, economy, market, etc., exert pressure to companies, they are forced to focus on the investigation and analysis of emerging and developing technologies. This is the main goal of digital disturbance. It is necessary to make a systematic analysis of technological possibilities and threats and to have recommendations for taking appropriate measures, while companies should develop their skills for the introduction of their processes and the effective use of digital technologies.

- *Digital Business*: Digital technology is activating new digital business models that businesses are being forced to design and implement. Organizations are moving from autonomous value propositions to holistic propositions with ecosystem potential, due to the merging of the digital and physical environments. As the creation and development of new business working models, companies are compelled to calculate the impact of digitalization at various levels: individual, organizational, competitive, and increasingly social.

- *Digital Transformation*: As soon as the company obtains changes in its business model, the need arises to transform the entire existing architecture of the organization. Considering the architecture from the business model to the business processes, companies must undergo organizational, technological and process transformation oriented towards the goal of achieving success in the digital age. In digital transformation, businesses need to know how to carry out business models, how business is affected by digitization and how it should be managed. Due to the rapid emergence and evolution of new business models and the changing demands of customers, companies need to thoroughly transform their infrastructure and processes,

data and application systems with new market conditions and new business models.

3.7.3 Digital Transformation of Business Model

Business models help companies to commercialize their new ideas and technologies. Technologies acquire economic value when they are commercialized. For the successful transformation it is necessary to analyze the interconnection of the organization's business model structure and the appropriateness of digital technology.

A business model is a conceptual framework that describes how a firm creates value for its customers. The following dimensions and elements can characterize a business model(Stepantseva and Breitenecker 2020):

- The benefit aspect involves provided values, products, services.
- The customer aspect includes the clients' segments, customer channels, and clients' relationships.
- The value-added aspect contains the resources, processes and skills involved.
- The financial aspect covers firms' revenues and expenses.
- The partner aspect involves partners, partner communication channels, and partner relationships.

The objective for companies is to combine and join as well as possible the elements of the business model and make it difficult for their competitors to copy or imitate it. Only then they will be able to succeed and grow. The market environment is constantly changing over the years. Organizations are considered successful only if they can invariably adapt to it. As companies evolve their organizational and human resource bases, they need to adapt to the changes brought about by the rapid emergence and evolution of new technologies. The ongoing transformation of economies and industries, the growing power and development of digital technologies in general, play the role of market engines and technology that has a direct impact on a business model. The achievement of these activities is done through the reshaping of the value chain of the company and the assurance of skills and technologies to gain a sustainable competitive advantage for the company. To be more successful organizations, need to consider different alternatives, understand, and know their customers' requirements and have a clear awareness of the company's value chain. This means that a company provides its customers their needs as much as possible cost-effective. Thus, the ability to adapt the business model to the environment is considered a dynamic ability.

Dynamic capability is the learning-driven approach of three main actions: *sensing, seizing*, and *reconfiguring*. With the help of these actions, companies can adapt to the changing environment and meet the requirements of their customers and the market, depending on their business strategy. The detection of technology and business model is the ability of the company to transfer technological capabilities to its new business model ideas, as well as the recognition of alternative business

models of strong competitors throughout the industry. The action of utilization, at the level of business models, is considered as the role of the company's focus on innovation activities through the process of recombining elements, including new technology, knowledge of the business model and market conditions. Restructuring is the process of selecting and procuring the relevant key resources and skills they need and the process of involving partners who could provide additional resources and capabilities to the business. Essentially, detection capabilities are required to identify opportunities and threats to the company's business model, exploitation capabilities to address and implement these new opportunities and capabilities in the existing business model, and, finally, reconfiguration capabilities are required to process and adapt organizational activities , processes, and structures, finding the necessary resources to enable the introduction of a new business model(Stepantseva and Breitenecker 2020).

Below is the set of concepts that surround the innovation of the business model, based on these digitization prospects and new fundamental changes in the business model.

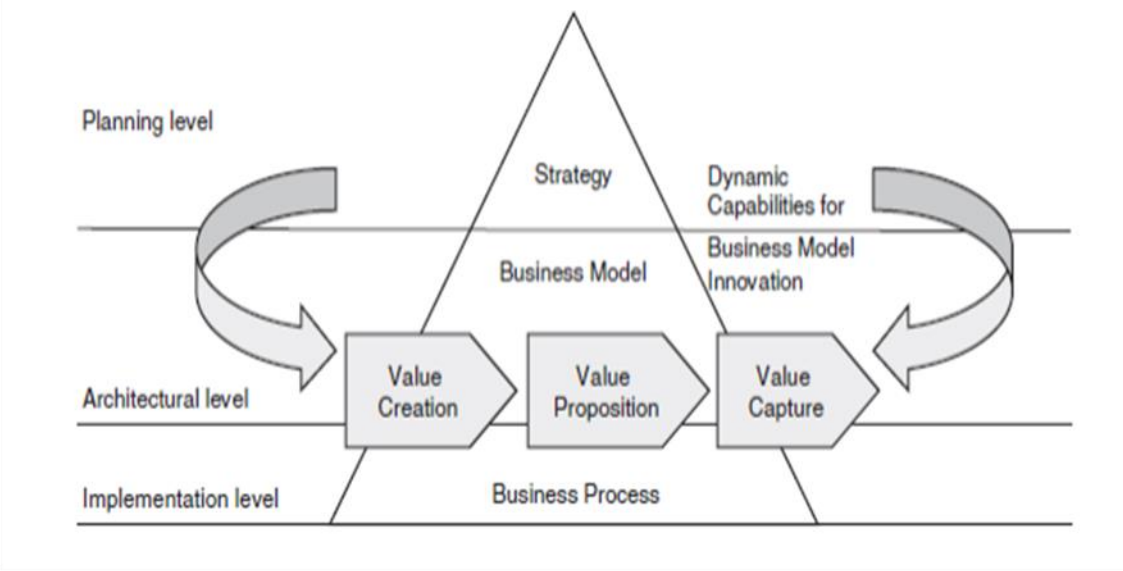

Figure 4 Conceptual setting(Rachinger et al. 2018)

This is the triangle of business logic, which captures business activities by dividing them into three levels. The highest level, from the top, is the level of design, which includes the company's strategy. The second level is the architectural level which the business model of the company takes place. The last level is the level of implementation with the business processes of the company. All three levels are affected by the changes brought about by digitization. The business model represents the reason for value creation and value capture in the organization, and this is what connects implementation and planning with the business model in the triangle of business logic.

Due to market changes and the entry of new competitors, current business models often become ineffective and lead organizations to replace them. Over the years,

many new technologies have appeared, such as social media and smartphones, which have led to the digital transformation of business models.

The Figure 5 below presents the structure of the digital transformation of business models and its main components. According to this the transformation of the business model can refer to 4 different objects. Time, e.g., with faster services deliveries and faster production, economy e.g., with cost savings and revenue increase, space e.g., with networking and automation and finally quality e.g., with product quality relationship quality and process quality. The next step is the process of transforming occurs such as sequence of tasks and decisions which are related to each other in a logical and temporal text, use of technologies to generate new applications or services, acquisitions and exchange of data including analysis and use for option calculations. The company then decides to what extent it intends to implement the digital transformation (degree of transformation): a slight, incremental degree of change or fundamental, radical change. The transformation of the company can be new for the customers, its own business, its competitors, the industry, and its partners, as reference units. Finally, a company should determine what is transformed. The individual elements like processes, customer relationships and products, the entire business model, the value chains, and value creation networks.

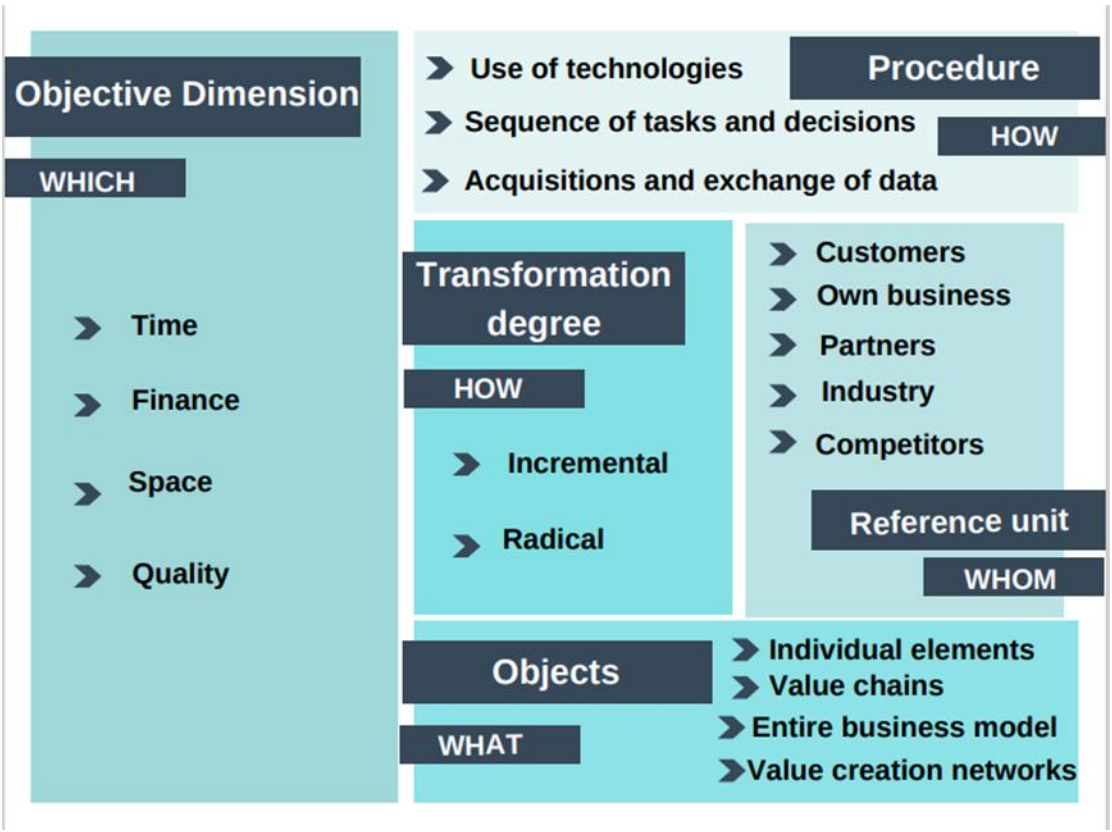

Figure 5 Digital Transformation of business model and its components

3.7.4 Business Opportunities and risks

Digital technologies can be incorporated into and support any part of the business. Such departments are those of production, marketing, customer service, logistics, financing, and human resource management. Using the right digital technologies in business processes can optimize resource utilization, reduce operating costs, and make business more efficient and productive. In addition, technological changes improve products or services in terms of flexibility, capability, and personalization. Digitalization offers businesses the opportunity to create new products or services and business models. By making these decisions, organizations can improve their value propositions, attract new customers, and form new relationships with existing ones, as well as create new ways of working with companies and customers. Digital technologies are important because they provide companies with quick access to a wide range of customer data and facilitate the collection, storage, and processing of this data. Analyzing and managing them is one of the most important competitive advantages, while enabling companies to have direct contact with customers and provide them with personalized offers.

There are two activities that lead companies to have a successful digital transformation: reshaping customer value proposition and transforming processes using digital technologies for greater customer engagement.

Companies have many benefits from digitalization but there are also many risks. Once technology permeates many business processes, computer systems become essential to the job. As computer systems have easy access to the Internet, issues of data security, systems destruction, viruses and starting a business are raised without the knowledge and permission of the company.

Information may now be shared globally with relatively little delays because to digitalization. Global events have a greater impact on competition. These advances further polarize the world and widen the chasms in various aspects, for example, countries and areas having a competitive advantage, particularly in new enabling technologies, enterprises embracing new digital technology vs. enterprises without competent human resources, economies adopting new technologies faster than others and employees with marketable new technological skills vs. those that lag behind (Rajnai and Kocsis 2017). The polarization of the labor market is represented in increased employment in the low- and high-income segments, as well as a decrease in the middle wage group. People who are difficult to replace earn a lot of money. Most people are capable of performing low-wage jobs.

3.7.5 New competences and skills

Companies, employees, and managers are not only confronted with completely new issues in their work and organizational processes as a result of digital transformation. To keep up with and adapt to these rapid changes, new skills and abilities are

required, such as capturing and filtering information. Whereas it used to be easy to cover one's entire working life with information gained through apprenticeships or studies, this is no longer the case. The half-life of expert knowledge has drastically diminished, and the task of lifelong learning has taken on a whole new meaning. No longer is it simply needed to learn to move ahead, but it is also needed to learn to stay up with the constant changes.

Expert knowledge must be continuously expanded and partially aligned in the workplace multiple times, to the point where there will be completely distinct job profiles every 10 years in the future. Recognizing, evaluating, and using relevant data is becoming increasingly critical. As a result, Markgraf's research has identified a number of new skills that will become increasingly important in the context of the fourth industrial revolution (Brauweiler et al. 2020). The respondents were asked to rate how essential things will be in the near future, from their perspective. The significance was graded on a scale of 1 to 7, with 7 indicating the highest level of significance. In total, more than 500 people took part in the assessment of future competency requirements. The following figure summarizes the findings.

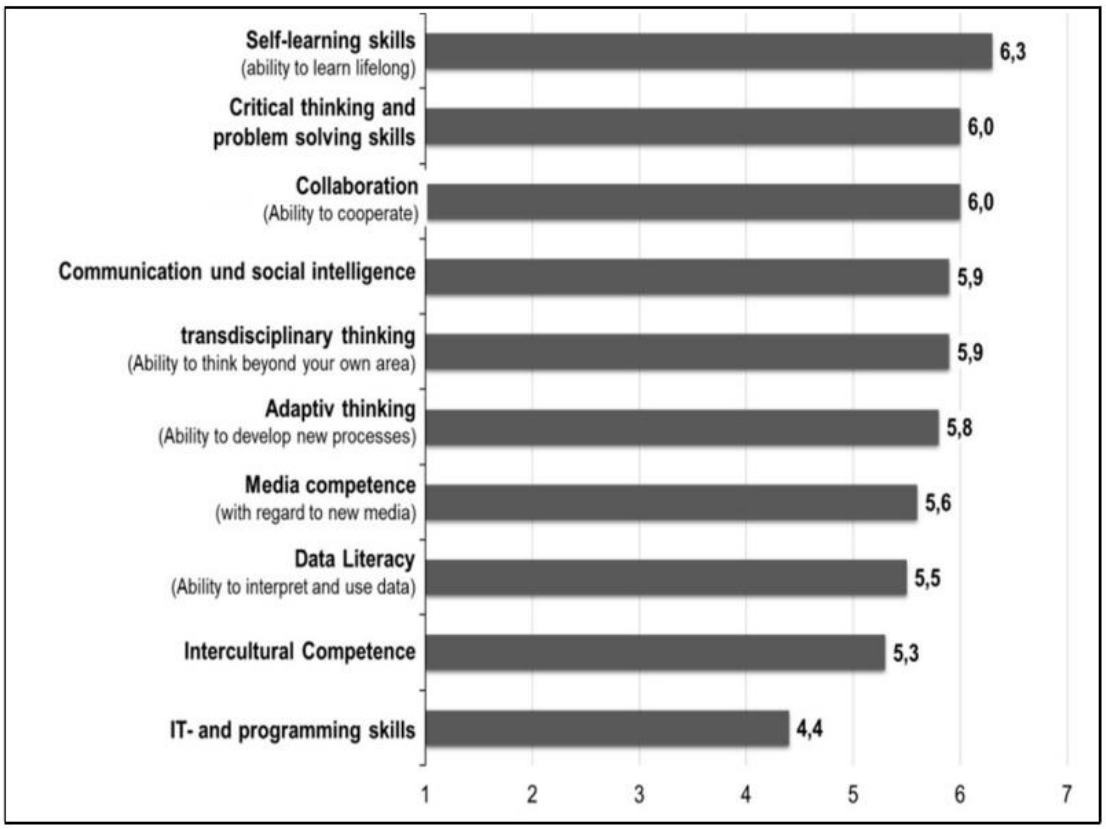

Figure 6 New competences and their importance in the near future (Brauweiler et al. 2020)

Participants were able to make their own additions to the given competencies in addition to rating them. This option was frequently used, but there was no clear idea of what additional skills would be necessary. The data included a wide range of themes related to teamwork and communication in many cases. Only self-

organization and ethical action or ethical moral responsibility can be identified as extra points.

Overall, it is clear that abilities connected to new problems, new situations, and communication and interaction are becoming increasingly important. The participants anticipate a constant metamorphosis and the opportunity to continuously train themselves.

3.7.6 The mean of Digital Technology

Technology is progressing and developing rapidly every day. Digital technologies have influenced the way people live, market and work. In addition, the business functions and the way companies are managed and organized have changed, while the ways of connection, cooperation, business conducting and relationships between people in companies have also been affected.

Organizations in practically all industry categories are implementing different programs to study and utilize the benefits of emerging digital technologies, such as social networks, mobile, big data, and so on. Companies must adopt management strategies to oversee these complex transitions, which usually entails transformations of critical company operations and impacts products and processes, as well as organizational structures. As a result of the maturing of digital technologies and their widespread penetration across all marketplaces, society as a whole is undergoing rapid and drastic transformation.

Digital technologies help companies reduce costs, improve work efficiency and productivity, improve customer satisfaction, and optimize the company's supply chain. These digital technologies have been defined as Artificial Intelligence (AI), Big Data, Cloud Computing, Internet of Things (IoT), Virtual and Augmented Reality (VR/AR), and cyber-physical systems, social media, analytics, mobile devices, or built-in devices. Features of digital technology are reprogramming, homogenization of data and self-referential character of digital technology.

Digital technologies have contributed to the ease of creating new forms of business ventures and digital start-ups, as technology is an element of business models. There are three elements that determine the form of entrepreneurship. Digital artefacts, digital tools or infrastructures, and digital platforms.

A digital artefact is a digital component, multimedia content, or application that composes a portion of a new product or service and provides value or specific functionality to the end user. Examples may be different applications running smartwatch (School of Information Technology, King Mongkut’s University of Technology Thonburi, Bangkok, Thailand et al. 2019), Amazon Dash Button (Sharma 2021), Google Pay(S.Poongodi et al. 2021), Face ID. Digital objects work either as standalone software or as a hardware component in a physical gadget or as part of a wider ecosystem running on a digital platform. A digital artefact makes natural products or services support innovation. For example, companies use social networking sites to create and grow social capital and find new business opportunities (Stepantseva and Breitenecker 2020).

Digital platform corresponds to the common sets of services and architectures used to promote product and service offerings. Examples are the Google Chrome browser that allows you to work with the Google search engine, and Apple's iOS platform that allows you to run different applications on your smartphone. Digital platforms have facilitated transformation of the industry, while creating new bases of innovation and positions.

Digital infrastructure or tools are the set of digital technology systems and tools that contribute to collaboration and communication. These tools support business and innovation. Examples of digital infrastructure include Microsoft Azure, the Google Cloud platform, or Stanford FabLearn and MIT Fab Central Labs used for digital prototypes and mock-ups.

Successful Digital Transformation necessitates the development of a diverse set of talents, the relevance of which will vary based on the business context and the specific demands of the organization. In order to be competitive, digital technology must become integral to how businesses run, and businesses must rethink and possibly re-invent their business models.

Because of their pervasiveness and economic effect, digital technologies spread quickly. They're referred to as general-purpose technology (GPTs) (Casalet and Stezano 2020). The phrase GPTs has been thrown around a lot in recent discussions of the role of technology in economic growth, and it usually refers to changes that affect both domestic life and corporate practices. For this reason, steam, electricity, internal combustion, and information technology (IT) are frequently characterized as GPTs. This transformation comes in the shape of once-in-a-lifetime opportunity to increase welfare and solve major social challenges ranging from health care to education to environmental protection. GPTs have four main characteristics: pervasiveness, which means they can be used in a wide range of industries; improvement, which means they should improve over time and thus improve quality; cost-cutting, which means they should continue to reduce costs for their users; and innovation spawning, which means they should make it easier to invent and produce new products or processes.

Interinstitutional and collaborative ties were increasingly important as Industry 4.0 took shape, helping to solve the digital ecosystem's execution and implementation issues. As social networks grew in size, decision-making became more important, opening up new avenues for thinking about highly specialized environments in collaborative settings.

3.7.7 Digital Technology trends

Value networks are reshaped by developing the digitalization of products and services. It is necessary for organizations to monitor technological changes in order to make improvements to the transform and business. These improvements can give organizations the competitive advantage. Digitalization of products and services requires application of new digital solutions.

There are many companies that monitor the trends in digitalization and its influence in the services and production sectors. The term digitalization is sometimes associated with industry 4.0. Industry 4.0 is defined as the integrated digitalization and connection of production processes, starting from the customer's order, through the creation of production processes, up to the next stage products (Wilkesmann and Wilkesmann 2018). In course of digitalization concept, it is important to apply to common technology trends in Industry 4.0. PWC company identified the following core digital technologies for the production: Mobile devices, IoT platforms, Location detection technologies, Advanced human-machine interfaces, Authentication & fraud detection, 3D printing, Smart sensors, big data analytics and advanced algorithms, Multilevel customer interaction and customer profiling, Augmented reality/wearables, and Cloud computing (Stepantseva and Breitenecker 2020).

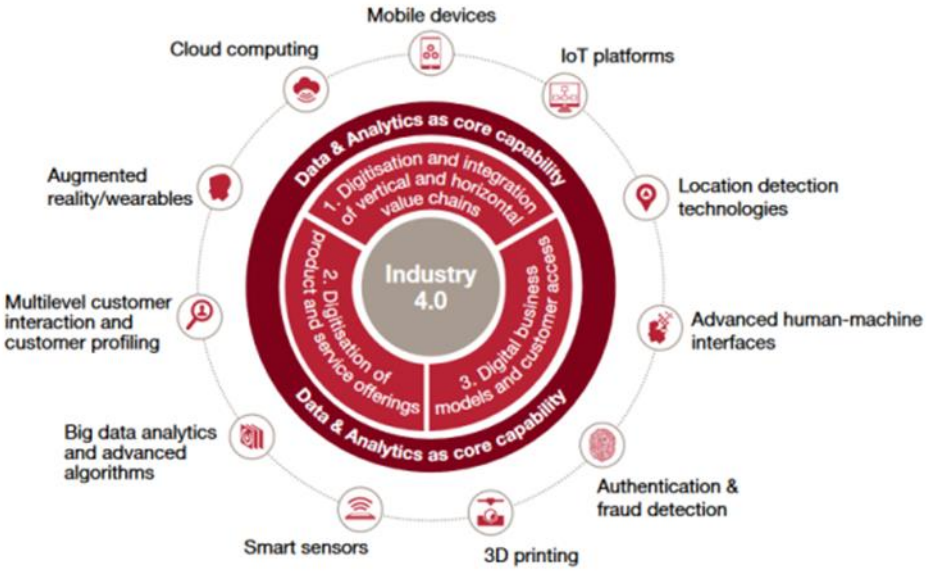

Figure 7 Key contributing digital technologies(Stepantseva and Breitenecker 2020)

There are several trends in digital technology that are important changes for society and business. With *analytics* organizations extract information about markets, customers, operations, and anything else related to their operations through big data. Since the amount of data is constantly increasing, companies use supporting infrastructures such as algorithms and analytics engines. The *cloud* is a tool that can differentiate a business from its competitors. It is used to expand the data center and shift the workload, while allowing access to artificial technology, digital reality, blockchain, quantum computing and for other more. The term *digital reality* refers to the way people interact with technologies and data. These are virtual reality (VR), augmented reality (AR), mixed reality (MR), the Internet of Things (IoT) and spatial technologies. Large companies implement *blockchain* solutions to manage different databases. It is expected that business process reengineering will enable companies

to realize massive transformation across various functions and locations. C*ognitive technologies* make decisions and activate business opportunities, towards people. Some examples are Robotic process automation (RPA), neural networks, bots, machine learning (ML), natural language processing (NLP), and the broader domain of artificial intelligence (AI) (Stepantseva and Breitenecker 2020).

Companies need to deal with strategic digital trends. *Automation* tools such as robots, autonomous vehicles, and drones, use artificial intelligence and perform automated functions that used to be done by humans. *Augmented Analytics* are a key feature of modern analytics, data preparation and management, data process mining, data science platforms and business process management. In order to create more artificial location solutions, developers can work independently using *AI-Driven Development*, advanced models delivered as a service. A *digital twin* is a digital representation of a system. Companies carry out digital representations in order to improve their ability to collect and display data and to apply the right analytics. *Empowered Edge and IoT* are endpoint devices. Edge computing outlines a computing topology where information processing, content collection and delivery, are located closer to these endpoints. *Digital reality* includes virtual (VR), augmented (AR) and mixed (MR) reality. It helps employees to understand digital world and be able to interact with it. Respectively offers a digital experience to customers. *Blockchain* ensures trust and reduces excessive interaction between business ecosystems. Reduces costs and time and increases cash flow (Stepantseva and Breitenecker 2020).

Artificial Intelligence (AI) is a tool that improves human well-being, increasing individual and social well-being and facilitating progress and innovation. It also contributes to achieving the goals of sustainable development by monitoring climate change, the proper utilization of natural resources, the improvement of human health and the business processes of companies.

Artificial health systems need to be human centered based on their commitment to service and human support. In addition to the opportunities offered by health, artificial intelligence also includes risks. It is important to ensure the trust of the machines and the introduction of reliable artificial energy in the products and services. Reliability is a prerequisite for people and societies to be able to implement artificial health systems. Mistake prevention is a great asset for the economy and society.

Trust in artificial energy systems concerns the internal characteristics of technology and quality assurance of socio-technical systems that provide the use of artificial energy. Similarly in systems related to food safety, aviation, and nuclear energy. The reliability of the system and the systemic approach must be applied to all parts and processes of the system, during its all-life cycle.

When reliability of AI applied throughout the life cycle of system should be legal, in line with human ethical values and principles, and technically and socially strong, in order not to damage the systems. These elements are necessary all together, but they are not enough alone to achieve reliability.

A reliable approach is driver for providing responsible competitiveness by enabling the base for all players they can trust that their development, expansion, and

application of AI systems are lawful, ethical, and robust. The requirements for reliable artificial intelligence are human agency and oversight, technical robustness and safety, privacy and data governance, transparency, diversity, non-discrimination and fairness, societal and environmental wellbeing and accountability (Stepantseva and Breitenecker 2020).

3.7.8 Digital Technology in practice

Connectivity and mobility are the key features of digital technology. These features are found in modern products and services and operate regardless of geographical location. The structure of the industry and the view of the company for its customers is changing due to technology. This means that in order to maintain their market position, organizations must interact with change.

Business transformation of companies is necessary to be part of their strategy. Organizations are now developing new digital divisions, shaping existing ones and hiring experts in digital transformation and technology. Companies that rely on digital technology, even if they are new to the market, are gaining a competitive edge. The reason is that they have not introduced changes at all or not changed promptly enough, or because these companies have not succeeded to adapt own business models to the competitive market conditions they meet from digital giant and major digital service providers, for example, as Amazon, Google, Facebook, Apple, Alibaba, Microsoft, Snap and eBay, Airbnb, Uber, Booking.com or Spotify. The music industry is one of illustrative examples of how rapidly the change can occur: ten years ago, Apple radically changed the industry launching iTunes. But up to the date, new streaming services (e.g., Spotify, the new Apple Music and Deezer) are turning the successful iTunes model inefficient. Thus, Apple has moved from a pioneer in its industry to an imitator (Stepantseva and Breitenecker 2020).

Artificial life and machine learning are new digital technologies that have been developed. For example, voice-user interfaces such as Google Assistant, Amazon Alexa, Apple Siri, Microsoft Cortana and Yandex Alice(Golenkov et al. 2020). These virtual assistants are based on voice recognition software and intelligent interfaces that enable collaboration between humans and computers. They can help you find information and follow some instructions. Recently, Amazon patented a new Alexa feature that it could understand based on speech and emotion when a user is sick and offering medication. All this enhances the customer experience and creates added value for the company's customers.

Digital transformation has affected society and business productivity. It gives companies the opportunity to operate globally and thus effects social sector in entrepreneurship and employment. The provision of public services is also influenced by the digital transformation, through the improvement of the provision of health and education, social protection systems and the way of cooperation of citizens with governments. In addition, individual behavior and human relationships are affected, because through new technologies communication, social inclusion and cooperation are encouraged. There is a possibility that digital transformation will have a negative

impact on society, resulting in a negative impact on human resource management, cybercrime, and business disappearances.

Digital technology became an important tool for organizations and new forms of work have emerged. Nevertheless, companies continue to use and enforce the old procedures and laws. An example is Uber, a company that provides digital taxi services. The government was against the company because it applied technology to open up and enhance access to taxi services for both providers and customers(Stepantseva and Breitenecker 2020)

New digital technologies are trying to encourage economic growth. They often have a negative effect. As people are being replaced by machines and technologies, jobs and practices are declining and tasks are being automated, increasing the possibility of mistakes. Results are labor market inequality and trend towards low-income manual labor. Potential negative effects can also occur on human resource management because new forms of production and services activated by digitalization require new highly cognitive skills.

New digital technologies require constant updating of employees' skills. Digital skills, use of innovation and ability to organize and make decisions are important for employees to be able to confront new technologies. Organizations that implement digital transformation are looking for candidates with critical thinking, entrepreneurship and problem solving, while providing opportunities for learning and adaptation to new transformational work environments. Necessary skill of an employee in a business is cooperation. Cooperation includes an ability to read and react to emotions, intentions and needs.

The value of manual labor is declining as global growth develops and new technologies, new robotics and learning algorithms emerge. Therefore, some jobs require more able workers and require skills to interact with other people. New technology, products, and the way they work need creativity as a key characteristic of employees.

Sectors with the least automation capabilities are telecommunications, insurance, and financial companies. In these industries, digital transformation was first implemented, doing them leaders in the adoption of digital technology. Healthcare, education, entertainment, and arts are sectors with a low level of digitization and do not face radical changes in automation. This means that areas with a low level of digitalization and major automation changes may be in greater demand for staff retraining.

Digital technology has affected job search in the labor market. Platforms have been created that allow finding employees, while also finding a job. Such platforms are LinkedIn and Facebook. LinkedIn and Facebook have become important tools for companies, for facilitating the recruitment processes and attracting candidates. Young people have the opportunity to connect with potential employers or start their own businesses. For recruiters, social networking platforms have become one of the key tools in finding potential employees(Marin and Nila 2021).

Digital technology has also become an integral part of banking system. Digital technologies have contributed too many changes in banking processes, in terms of

management, production and delivery. Digital transformation has affected banks in *new business models*, *operational efficiency, higher quality and faster service, personalization, transparency of operations and cybersecurity and largest investments.* Digital technologies were incorporated in the business processes of the banks and new business banking models were created, resulting in the development of digital banking. Banks improve their efficiency by transforming business models and automating business processes. In this way they save their workforce in simple functions that are not necessary and direct it to tasks related to strategic tasks. Financial technology allows improving the accessibility and speed of operational services and reduces errors and deviations in the work process. Banks offer targeted content thanks to a better understanding of lifestyle, interests, stage needs and social affiliation preferences. Financial technology helps prevent the risks associated with financial technologies. The artificial selection allows the problem to be solved. In order to apply digital technologies in the business processes of banks requires time and investment in the field of research and development. Digitalization process improves the customer experience by delivering better, faster, and more personalized banking services and products. Factors that create added value to customers for banking products and services are higher personalization, increased service speed, access to the service or product anytime and anywhere, better functionality and forecasting, better understanding customers' needs in advance and offering relevant products and services early.

4. Industry 4.0 and Maturity Models

4.1 Industry 4.0

Industry 4.0 (or I4.0) is a conceptual framework that focuses on the continuous evolution of the physical world. Its various components are cyber-physical systems, internet and future-oriented technologies, and smart systems. The increasing complexity of businesses' operations can be handled through the enhanced connectivity of these human–machine paradigms (Fonseca et al. 2021).

Before the 4th industrial revolution, the 3rd industrial revolution started with the introduction of robots and computers. The 3rd industrial revolution followed the 2nd with the development of mass production and electric vehicles and before was the 1st with mechanical production and steam-powered machines. Industry 4.0 is a framework for uniting the physical and virtual worlds. It features a variety of technologies such as artificial intelligence, 3D printing, big data and analytics and simulations, etc.

Industry 4.0 is a methodology for transforming manufacturing from a machine-dominated to a digital-dominated state. The Industry 4.0 standard must be thoroughly understood in order to achieve a successful transformation. It's critical to assess Industry 4.0 components and characteristics in order to determine the fundamental pillars of a concrete future manufacturing environment(Oztemel and Gursev 2020).

Industry 4.0 refers to the digital transformation of the entire industry, which involves the virtual representation of various business models and systems. It is a set of principles that aims to accelerate the evolution of organizational efficiency and adopt new business models that are designed to address the circular economy. Industry 4.0 uses a set of processes and products that are designed to support intelligent and efficient processes. It is supported by nine pillars: The industrial Internet of Things (IoT), Cloud computing, Big data, Simulation, Augmented reality (AR), Additive manufacturing, Horizontal and vertical system integration, Autonomous robots, and Cybersecurity (CS). The IoT is a concept that enables people and things to connect and interact with each other. Cloud computing provides a variety of advantages, such as reducing hardware complexity, improving system performance, and facilitating data sharing. Big data refers to the large volume of information that can be collected and analyzed quickly, with advanced techniques. Simulation is the process of developing digital twin models that can improve the productivity and maintenance performance. Augmented reality improves a person's performance by providing them with the information they need to complete a given task. Additive manufacturing (or 3D printing) is a technology used for the rapid creation of 3D models and prototypes. It can be used for the design and development of new products and business models. Horizontal and vertical system integration, with collaborative scenarios of system integration and real-time sharing. Autonomous robots with artificial intelligence and improved adaptation and flexibility can support different manufacturing processes and decrease production costs. Cybersecurity is related to a high level of information security and involves technology to protect, detect, and respond to attacks(Fonseca et al. 2021).

Artificial intelligence (AI) can help minimize waste and improve efficiency by developing new solutions that can solve real-world problems. Increased automation can improve processes and reduce human stress while reducing environmental impacts. Industry 4.0 can help companies reduce waste and improve the profitability of their product lifecycle by delivering real-time data to their decision makers. Some benefits of I4.0 that have identified are business processes integration across the entire value chain, the ability to improve productivity and efficiency, reduce costs and improve the customer's experience, support new business models that allow customers to create value through innovative products and services, improve the quality of products, and minimize the impact on the environment and focus on optimizing resource utilization and social sustainability.

The combination of I4.0 and methodologies can help improve employee morale, reduce lead times, improve product quality, and reduce waste. It is also identified that Industry 4.0's potential negative impacts on sustainability are considerable. These include increased labor-saving technologies and consumption rates, which could result in higher resource consumption and income inequality.

Due to the continuous evolution of industries, quality concepts have also undergone a major change. This has led to the emergence of digital transformation processes, which help organizations achieve better quality and performance. Through the Digital Transformation process, we can transform an organization and its various business models and operations. This process brings new strategic objectives and enhances the organization's capabilities. Digital transformation is driving businesses to create new jobs and improve their operations.

4.2 Literature Survey of Industry 4.0 and Operations Management and HR

The Google Scholar library was used to do research for this work on Industry 4.0. It all began with the fundamental premise of *Industry 4.0*. The investigation was split into two parts. *Industry 4.0 and Human Resources* was the first phase, while *Industry 4.0 and Operations Management* was the second.

The figures below show the roadmap of the literature survey, with the points being selected from the articles used and excluding those that did not meet the criteria, in order to be included in the paper.

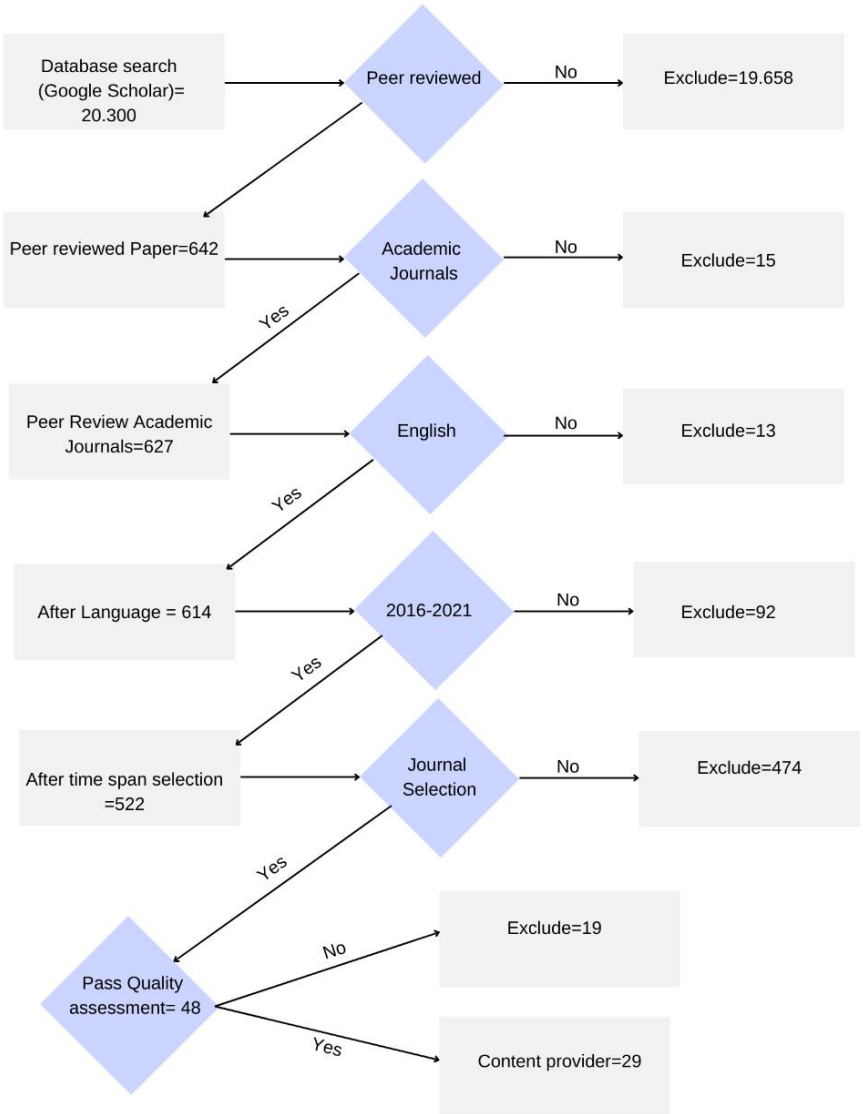

Figure 8 Research methodology with inclusions and exclusions of Industry 4.0 and Human Resources

The data collection started with the search of term industry 4.0 and human resources and a sufficient number of articles were identified. Peer reviewed, academic journals and English as the written language were used as criteria. According to these criteria, a large number of articles that did not meet them were excluded. Then another key criterion was added, the years of writing the articles. The period 2016 to 2021 was selected. The last criterion selected was the journals in which the articles are published.

In order to identify key concepts used in the literature, qualitative research was conducted in the study. This was followed by the evaluation of the research results according to the above criteria. The documents that met the criteria were selected and subjected to another quality evaluation, where their structure, methods and conclusions were analyzed. In this way some articles were chosen to be included and some others were excluded.

Qualitative research and qualitative evaluation resulted in the final selection of twenty nine articles that met all the criteria for this work.

Reference	Description	Method used	Sector	Country	Citescore
Shamim et al. 2016	This paper aims at offering a viewpoint on best suitable management practices which can promote the climate of innovation and learning in the organization, and hence facilitate the business to match the pace of industry 4.0.	Empirical and quantitative investigation on these management approaches in the context of industry 4.0.	Human resource management	UK	21.8
Ghobakhloo 2020	The present study contributes to the sustainability literature by systematically identifying the sustainability functions of Industry 4.0.	Interpretive structural modelling technique to model the contextual relationships among the Industry 4.0 sustainability functions and to MICMAC analysis.	Sustainability	Iran	13.1
Bag et al. 2021	This study aspires to develop a theoretical model linking key resources for Industry 4.0 adoption that are essential to drive technological progress; and its effect on sustainable production and circular economy capabilities.	A literature review to identify of resources that are essential for the adoption of Industry 4.0. Exploratory factor analysis and PLS-SEM technique.	industry 4.0	South Africa, India	13.1
Piwowar-Sulej 2021	The purpose of the article is to present the development of human potential in an organization against the background of other detailed sustainable HRM principles.	Survey method and representative data from Eurostat and Statistics Poland.	Human resources	Poland	13.1

Kamble et al. 2020	The study found that an Industry 4.0 enabled SMS offer more competitive benefits compared to a traditional manufacturing system.	A combination of exploratory and empirical research design.	Industry 4.0	France, USA, UK, India	12.2
Bai et al. 2020	In this study, we further examine Industry 4.0 technologies in terms of application and sustainability implications.	Development of a hybrid multi-situation decision method integrating hesitant fuzzy set, cumulative prospect theory and VIKOR.	Sustainability	China, Italy, USA, Finland	12.2
Neumann et al. 2021	This article discusses how failure to attend to HF in previous industrial system generations has had negative consequences for individual employees, production organisations, and for society as a whole.	Content analysis of earlier research on Industry 4.0. A conceptual framework that integrates several key concepts from the human factors engineering discipline.	Industry 4.0	Canada, Germany	12.2
Gunjan et al. 2020	This study aims to develop a framework to improve sustainability adoption across manufacturing organisations of developing nations using Industry 4.0 technologies.	The enablers that strongly influence sustainability adoption are identified through a literature review.	Sustainability	India, UK	12.0
De Pace et al. 2020	It is covered a wide range of I4.0 areas, there has been relatively little research devoted to the organisational side of implementing I4.0.	This systematic review paper used quantitative analysis by text-mining 97 articles from 2015 to 2021.	Industry 4.0	UK	10.8
Oztemel and Gursev 2020	It is intended to provide a clear idea for those wishing to generate a road map for digitizing the respective manufacturing suits.	Literature review to highlight the central aspects of Industry 4.0 to generate a common definition well accepted by both research and practical communities.	Industry 4.0	Turkey	10.6
Liboni et al. 2019	The purpose of this paper is to address the potential impacts of Industry 4.0 on human resource management (HRM).	A literature review to identify, classify and analyze current knowledge, flagging trends and proposing recommendations for future research in this area.	Human Resources Management 4.0	Brazil, France	9.3
Bajic et al. 2021	The purpose of the present article is to provide an overview of the reported Industry 4.0 implementation challenges in the relevant literature by conducting a systematic literature review.	Literature review performed by deriving an inductively coded Industry 4.0 technology framework.	Industry 4.0	Serbia, Italy	7.7
Scafà et al. 2020	The objective of this paper is to propose a new literature review focused on the analysis of common and different features between industrial symbiosis models and human–machine symbiosis.	A literature review about industrial symbiosis models and human symbiosis.	Industry 4.0	Italy	6.8

Hidayat et al. 2020	The arrangement of human resources is an important aspect that must be considered by the management to maintain and develop an organization in the era of Industry 4.0.	The Analytical Hierarchy Process Method is chosen as the base for determining the finest alternative strategy.	Human Resources Management	Indonesia	6.1
Muktiarni et al. 2019	This paper focuses on the challenges and opportunities of industry 4.0, the development of industry 4.0 is characterized by the development of big data and artificial intelligence.	Literature review by following the Web of Science database, followed by Scopus by including the keywords "trend digitalization" and "industry 4.0."	Digitalization	Indonesia	6.1
Sony and Naik 2019	The purpose of this paper is to identify the key ingredients for assessing Industry 4.0 readiness for organizations, the interrelationships that exist between these readiness factors and how future research should proceed given the research findings.	A systematic literature review (SLR) methodology to ensure the replicability and transparency of the review process.	Industry 4.0	Namibia, India	5.0
Souza et al. 2021	The purpose of this article is to explore the new concept of TQM 4.0 as a way of adapting quality management (QM) in Industry 4.0 (I4.0), guiding industries to this new phase, which has generated adaptations in numerous areas, one of which is QM and human resources.	A systematic review of the literature was carried out and methodi Ordinatio was applied to build the portfolio of articles with scientific relevance.	Total quality management 4.0	Brazil	4.3
Whysall et al. 2019	The transformational changes to business environments brought about by the fourth industrial revolution create a perfect storm for strategic HRM, prompting a need to explore the implications of this context for talent management theory and practice.	Interviews were conducted with HR directors and senior leaders.	Industry 4.0	UK	4.0
Fonseca et al. 2021	This research highlights the EFQM 2020 model's novelties and its relationships/implications with the Industry 4.0 paradigm, contributing to the Quality 4.0 body of knowledge.	A mixed inductive–deductive approach supports this research methodology.	Quality 4.0	Portugal	3.9
Scavarda et al. 2019	The global movement around themes like sustainability on its triple bottom line and industry 4.0 allows for the establishment of a ground of connection with corporate responsibility towards society.	A literature review involving HR and terms related to the concept of sustainability, industry 4.0, corporate social responsibility, and the youth generation.	Sustainable human resources	Brazil	3.9
Silva et al. 2020	This study proposes a field study, based on a literature review, about the applications and impacts of Industry 4.0 (I4.0) in the biopharmaceutical sector.	Literature review	Industry 4.0	Portugal	3.8

Pio et al. 2021	The present study aimed to evaluate how Brazilian companies from different sectors are developing human resources practices in the context of Industry 4.0 and which of these practices allows better differentiate of companies	Literature review to identify the most important HR practices in the context of Industry 4.0, and survey with HR professionals in Brazil.	Human resources and Industry 4.0	Brazil, Canada	3.0
Khalifa et al. 2019	In this paper, a proposal for an intelligent system for modeling skills and human resource management in the production system chain through the use of two artificial neural networks.	Neural networks, Input and output variables of neural network	Industry 4.0	Tunisia	2.8
Shaharudin et al. 2021	This study aims to evaluate and measure the Driver of Human Resources 4.0: Technology, Organization and Environment. It suggests the better Driver Human Resources 4.0 to increase at the company in future.	Literature review on how HRM can facilitate efficiency and quality enhancement through organisations' HRM activities.	Human Resources 4.0	Malaysia, lndonesia	2.4
Singh et al. 2021	The present study is an attempt of identifying the human capital skills and HR-related challenges faced by top management in the perspective of industry 4.0 in emerging economies.	For identifying the dimensions of human capital skills in the perspective of industry 4.0, an extensive review of literature was performed.	human capital 4.0	India	2.3
Wibowo et al. 2020	With a qualitative approach and descriptive analysis method, this study aims to analyze the opportunities that can and must be taken by stakeholders of defense to develop the competencies of their human resources.	A qualitative approach and descriptive analysis method, about the stakeholders opportunities to develop the competencies of their HR.	Industry 4.0	Indonesia	1.9
Ada et al. 2021	This paper aims to propose a framework identifying the skill set required for personnel selection in the era of Industry 4.0, and provide a roadmap for human resources managers by analyzing the importance of different skill categories.	Fuzzy Analytic Network Process (ANP) was used to compute the factors' weights.	Industry 4.0	Turkey	1.6
Mefi and Asoba 2021	The study considered the skills deficiencies arising from the transition to industry 4.0.	Electronic data collection methods based on a questionnaire with both qualitative and quantitative items was used to collect data.	Industry 4.0	South Africa	1.1
Sivathanu and Pillai 2018	This paper aims to highlight the importance of Smart Human Resources 4.0 (Smart HR 4.0) and its role as a catalyst in the disruption process in the human resource domain.	Smart HR 4.0 conceptual framework	Human resources	India	0.4

Table 1 Literature Survey Table of Industry 4.0 and Human Resources

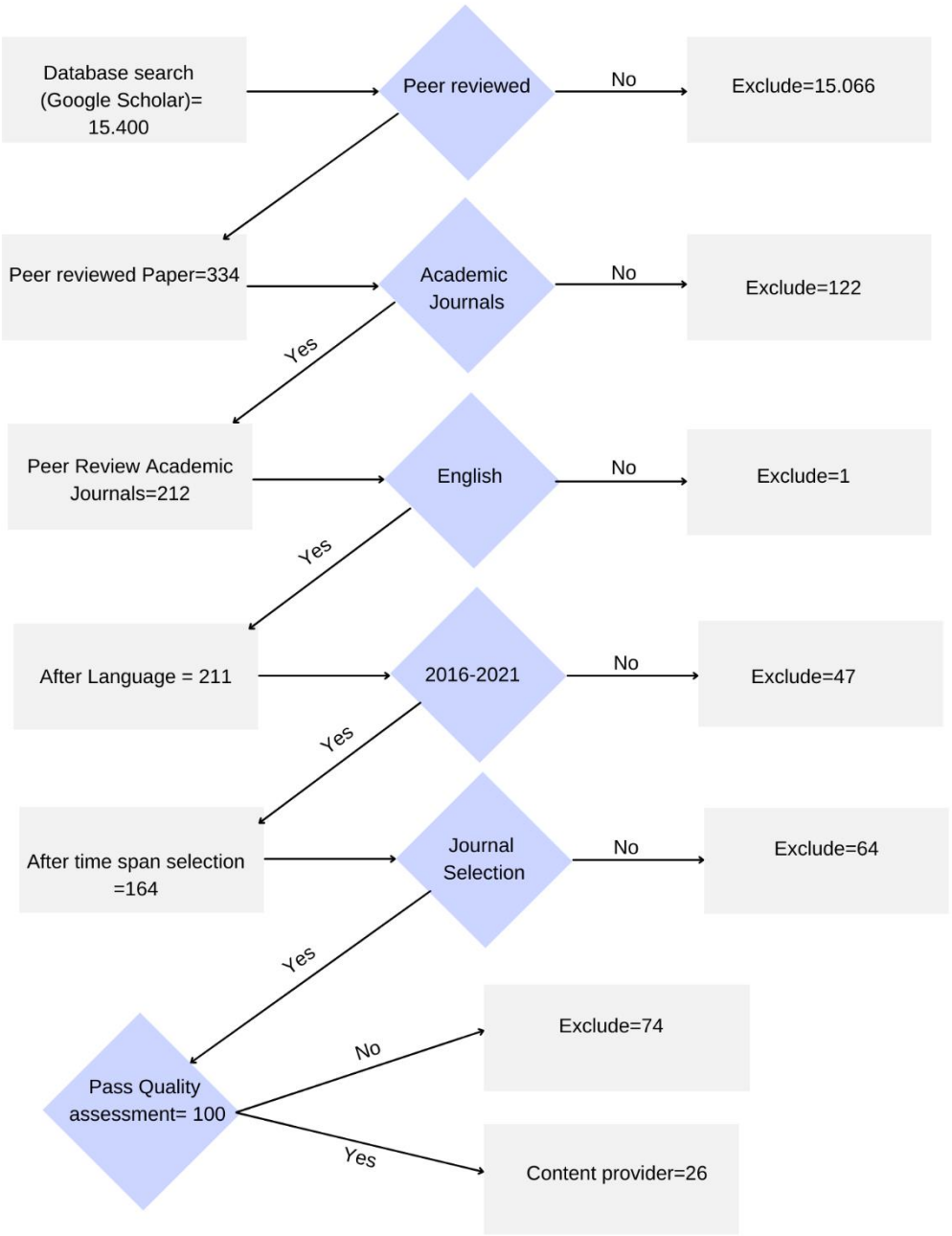

Figure 9 Research methodology with inclusions and exclusions of Industry 4.0 and Human Resources

The data collection continued with the search of term industry 4.0 and operations management and there were a sufficient amount of articles found.

It followed the same criteria as industry 4.0 and human resource management, namely peer reviewed, academic journals, English as the written language, period 2016 to 2021 and the journals in which the articles are published.

Qualitative research was employed in the study to identify major terms mentioned in the literature. Following that, the research findings were assessed using the criteria listed above. The documents that satisfied the requirements were chosen and subjected to a second quality assessment, which looked at their structure, techniques, and findings. As a result, certain items were picked for inclusion while others were left out.

Qualitative research and qualitative evaluation resulted in the final selection of twenty six articles that met all the criteria for this work.

Reference	Description	Method used	Sector	Country	Citescore
Lu 2017	This paper conducts a comprehensive review on Industry 4.0 and presents an overview of the content, scope, and findings of Industry 4.0.	Literature Review	Industry 4.0	USA, UK	22.1
Dalenogare et al. 2018	This work contributes by discussing the real expectations on the future performance of the industry when implementing new technologies, providing a background to advance in the research on real benefits of the Industry 4.0.	A large-scale survey and regression analysis	Industry 4.0 technologies	Brazil, France	12.2
Caiado et al. 2021	The paper proposes a set of OSCM indicators to measure the digitalization score in manufacturing organizations and their supply chains and a MM connected ith a self-assessment readiness-tool to support the transition towards I4.0 in the OSCM domain.	Comparison of existing I4.0 MMs, MM implementation, questionnaire and modeling of a set of fuzzy inferential systems, MM evaluation, maturity gap analysis and the proposal of action measures.	Industry 4.0 maturity model	Brazil, UK	12.2
Tortorella et al. 2021	This paper aims at examining the integration of I4.0 technologies into Total Productive Maintenance (TPM) practices in multiple large-sized manufacturing companies.	Case-based research	Industry 4.0	Australia, Argentina, Brazil, Uruguay	12.2

Li and Huang 2021	The field investigation highlights new challenges in the FAL - the mismatch between production (assembly) and intralogistics (material supply) leads to long waiting/idle time and workflow chaos, consequently lowers productivity and increases backorders.	A methodological research regarding utilizing real-time data to support production decisions under uncertainties.	Industry 4.0	China	12.2
Dmitry et al. 2021	Our intent is to understand the current state of research in Industry 4.0 in different disciplines and deduce insights and opportunities for future research in operations management.	A focused analysis to examine the state-of-the-art research in Industry 4.0.	Industry 4.0	Germany, USA, France, Italy	12.2
Osterrieder et al. 2020	Generation of further clarity and to consolidate the previous findings around smart factory.	Literature Review	Industry 4.0	Switzerland	12.2
Núñez-Merino et al. 2020	The purpose of this paper is to provide an overview of the current state of research and the key aspects and implications of the relationships between Information and Digital Technologies (IDT) of Industry 4.0 and Lean Supply Chain Management (LSCM).	A Systematic Literature Review methodology.	Industry 4.0	Spain	10.8
Rossini et al. 2021	This paper aims to test empirically the association of LA, in the form of integration of Lean practices and Industry 4.0 technologies, and operational performance.	Multi-stage empirical method and extensive survey.	Industry 4.0	Italy, Australia	10.8
Rossit et al. 2019	We introduce here a new decision-making schema, Smart Scheduling, intended to yield flexible and efficient production schedules on the fly.	Proposition of a smart approach to solving production scheduling problems.	Industry 4.0	Argentina	10.8
Koh et al. 2019	The purpose of this position paper is to summarize the major topics of recent research on industry 4.0.	Literature Review	Industry 4.0	UK, Italy	10.7

Belhadi et al. 2021	This paper aims to explore the distinct and combined effects of several approaches between I4.0 capabilities and sustainable performance.	Structural equation modeling and fuzzy set qualitative comparative analysis, development and test of a hypothetical model.	Digital business transformation	Morocco, France, USA	9.3
Szász et al. 2020	The purpose of this paper is to review the literature and offer a more generalizable empirical investigation on the performance impact of implementing Industry 4.0.	Literature Review	Industry 4.0	Romania, Hungary	8.4
Nascimento et al. 2018	The purpose of this paper is to explore how rising technologies from Industry 4.0 can be integrated with circular economy (CE) practices to establish a business model that reuses and recycles wasted material such as scrap metal or e-waste.	A qualitative research method that was deployed in three stages.	Industry 4.0 technologies	Brazil, UK, Mexico	8.4
Pagliosa et al. 2019	The purpose of this paper is to aim at identifying the relationships between Industry 4.0 (I4.0) technologies and Lean Manufacturing (LM) practices.	Literature Review	Industry 4.0	Brazil	8.4
Garay-Rondero et al. 2020	The purpose of this paper is to present a conceptual model that defines the essential components shaping the new Digital Supply Chains (DSCs) through the implementation and acceleration of Industry 4.0.	A conceptual approach and review of the key literature.	Industry 4.0	Mexico	8.4
Ghobakhloo and Fathi 2019	The purpose of this paper is to demonstrate how small manufacturing firms can leverage their IT resources to develop the lean-digitized manufacturing system that offers sustained competitiveness in the Industry 4.0 era.	A case study of a manufacturing firm.	Industry 4.0	Malaysia, Sweden	8.4
Olsen and Tomlin 2020	This article describes the technologies inherent in Industry 4.0 and the opportunities and challenges for research in this area.	Review and discussion of the technologies inherent in Industry 4.0	Industry 4.0	New Zealand, Hanover	8.0

Mittal et al. 2019	The purpose of this article is to collect and structure the various characteristics, technologies and enabling factors available in the current body of knowledge that are associated with smart manufacturing.	A literature review of characteristics, technologies and enabling factors .	Smart manufacturing	USA, Mexico	4.9
Arromba et al. 2020	The purpose of this study is to identify the benefits and difficulties of Industry 4.0 related to the PDP and its impact in marketing strategies and operations.	The methodology used to perform this research was a systematic literature review.	Industry 4.0	Brazil, Canada	4.4
Schumacher et al. 2016	In this paper we propose an empirically grounded novel model and its implementation to assess the Industry 4.0 maturity of industrial enterprises in the domain of discrete manufacturing.	A framework methodology. A multi-methodological development approach, including systematic literature research and review, expert interviews, conceptual modelling and validations and testing.	Maturity model for assessing Industry 4.0	Austria	3.3
Fettermann et al. 2018	This article aims to identify the contribution of the adoption of Industry 4.0 technologies for companies' operation management (OM).	A research method based on a multi-case study on successful implementations of Industry 4.0.	Industry 4.0	Brazil	2.8
Bag and Pretorius 2020	This paper aims to review the latest articles in the area of Industry 4.0, sustainable manufacturing and circular economy and further developed a research framework showing key paths.	Qualitative research performed in two stages.	Industry 4.0	South Africa	2.5
Naderi et al. 2019	In order to obtain a reliable prediction, of the operation of a Sustainable Manufacturing System (SMS) and its Social Return (SR), this paper develops a methodology and procedures that allow predicting the system performance as a whole.	Simulation	Sustainable Operations Management	Spain, Portugal	2.1
Rifqi et al. 2021	In our paper, we discuss the effect of Industry 4.0 on management and quality practices.	Literature Review	Industry 4.0	Morocco	1.1

Koleva and Andreev 2018	The present paper discusses the requirements concerning education and training in the field of Operations Management, particularly with a view on ensuring efficient management of the production system with respect to an Industry 4.0 environment.	Literature Review	Operations Management	Bulgaria	0.6

Table 2 Literature Survey Table of Industry 4.0 and Operations Management

4.3 Industry 4.0 and Sustainability

Since the Industrial Revolution, the world has been facing the challenge of increasing the amount of goods produced from limited natural resources. Industry 4.0 is a way of doing so that can contribute to the environment's sustainable development. Sustainability is a broad concept that addresses various aspects of the human world. It also involves the preservation of natural resources and economic growth.

Industry 4.0 and sustainability are two newer technology and organizational trends that are driven or impacted by increasing productivity and ensuring long-term sustainability. Global competitiveness, fluctuating markets and demand, more personalization through communication, information, and intelligence, and shorter innovation and product life cycles are key difficulties that Industry 4.0 technologies aim to address(Bai et al. 2020). The potentials of Industry 4.0 technologies include significant contributions or limitations to organizational and social sustainable development. Reduced set-up times, shorter lead times, lower labor and material costs, increased production flexibility, higher productivity, and enhanced customization are all available from an economic standpoint.

Due to its significant concepts and solutions, sustainability has received worldwide attention, notably in the environment and climate change. Economic, environmental, and social sustainability are three layers of the word. Economic sustainability emphasizes a variety of productivity and profit-on-investment criteria for the company. The introduction of Industry 4.0 technologies lowers manufacturing costs by making better use of resources. Economic sustainability entails a business plan that encourages revenue generation to help the company succeed.

The term environmental sustainability refers to the use of natural resources in a manner that does not affect or destroy the environment (Bai et al. 2020). Environmental sustainability includes the effective use of resources, the reduction of greenhouse gas emissions, and the minimization of ecological impact. The term social sustainability refers to an organization's ethical business practices, as well as its workplace equity, human capital development, and community involvement. The connection between society and business that deals with social involvement,

employer-employee relationships, fair compensation, and health-care services is referred to as social sustainability (Gunjan et al. 2020).

Environmentally, Industry 4.0 technologies can reduce energy and resource consumption by detecting and analyzing data across production and supply chain processes. Through data-driven and traceable carbon footprint analyses, they can lead to waste or CO2-emission reductions. Products can be disassembled into individual components for reuse, recycling, or remanufacturing (Bai et al. 2020).

Smart and autonomous production systems can support employee health and safety by taking over monotonous and repetitive tasks, resulting in increased employee satisfaction and motivation. However, Industry 4.0 technologies bring with them a slew of new challenges and constraints for society. Reduced employment, information security issues, data complexity, electronic waste, and poor quality are just a few examples.

In the Industry 4.0 environment, intelligent machines and interconnected computers communicate with each other. They make decisions without requiring humans to be involved. The digital connectedness and sharing of information may have conflicting impacts on sustainability. Digitalizing manufacturing and improving processes can offer numerous advantages, such as reduced waste and resource efficiency. An increase in production due to automation would have negative effects on the environment and energy consumption. The rise of digital transformation and the restructuring of industries are expected to severely affect the labor market. Digitalization and the emergence of new technologies such as artificial intelligence and robots eliminate many lower-skilled jobs. Digitalization also creates numerous job opportunities in various industries, such as automation engineering, control system design, machine learning, and software engineering.

Industry 4.0 is a conceptual framework that aims to digital transform the entire value chain of industries. The principles of I4.0 have changed the way businesses deliver products and services. Industry 4.0 is associated with the widespread application of new business models such as Crowd-Sourced Innovation (CSI) and Manufacturing as a Service (MaaS), that can provide significant social and economic sustainability benefits (Ghobakhloo 2020).

With smart devices and equipment integration, Industry 4.0 enables digital manufacturing and business operations. Product customization, manufacturing efficiency, resource conservation, waste reduction, and workplace safety are all aided by this technology integration. Industry 4.0 technologies, as demonstrated by de Sousa Jabbour et al. (2018), enable businesses to reduce resource consumption, demand, and supply-related data exchange, gathering, and optimization from many sources (Gunjan et al. 2020). The authors also demonstrated how extended circularity of energy and materials, as well as interactions between businesses, suppliers, and consumers, might help to improve long-term operations management systems.

According to reports, industrial emission is responsible for greenhouse gas emissions. The 4th industrial revolution can help reduce the carbon footprint. The potential of I4.0 can help create new business models that can improve the efficiency and

profitability of mass production, while also contributing to the environment and social sustainability.

Despite the potential impact of I4.0 on low-skilled jobs, it still creates numerous opportunities for people with digital expertise. Operations management sustainability is an integral part of the digital economy. Since Industry 4.0 technology has wide-ranging implications for various industries and consumer markets, its spread has the potential to create sustainable economic development.

Digital transformation is a process that enables sustainable energy and resource management. Industry 4.0 has changed the way people consume and produce goods. Its widespread application has led to the development of new energy-related technologies. Smart grids are an example of how technology can help integrate various forms of distributed energy sources into the electrical grid. The sustainability implications of I4.0 are not limited to energy sustainability. The emergence of digital manufacturing technologies such as additive manufacturing and intelligent robots has led to the significant reduction in material costs and production efficiencies.

Industry 4.0 includes various potentials that can contribute to the development of sustainable development strategies. According to economic dimension the production time has been reduced, just as lead times and labor and material costs. As for the ecological point I4.0 technology can help minimize energy consumption and resource consumption through the use of sensors and data analysis. It can help reduce waste and greenhouse gas emissions through data-based carbon footprint analyses. According to sustainability from social part, smart production systems can help minimize manual work and provide better employee satisfaction. Although Industry 4.0 has many advantages, it also brings many challenges and limitations. Some of these include reduced employment opportunities and increased data complexity.

The scientific community has recognized opportunities for the deployment of sustainable manufacturing strategies. Some of the identified opportunities include ways to leverage data for use in sustainable business models and a framework for product life cycle including feedback loop. The identified prospects, however, did not translate into tangible benefits, necessitating further research. Although it is recognized that Industry 4.0 can assist in the development of long-term business models, it is yet unclear how this can be accomplished.

Data can be gathered from a variety of sources, including customers and raw materials. The idea of value creation, however, cannot be completely realized until and until the obtained data is used.

Gap continues to exist in the establishment of mechanisms that can aid in the use of data acquired throughout the product's life cycle in order to obtain sustainable products. Although the deployment of an Industry 4.0 environment results in improved service in terms of higher quality products, mass customization, and faster and more efficient manufacturing methods, Industry 4.0 has failed to directly address the manufacturers' sustainability concerns. When the benefits of sustainable innovation provide economic rewards, sustainability is typically addressed implicitly. For example, if a company's revenue from product sales remains constant but

revenue from services increases, this does not necessarily indicate that the company has grown more sustainable.

4.4 Industry 4.0 and Human Resource Development

The rise of digital transformation and Industry 4.0 has fundamentally changed the way people work. It can help improve the efficiency of human resource processes. Data analytics and artificial intelligence tools can help human resource professionals create effective and personalized learning programs based on the patterns in an employee's data. Using artificial intelligence and predictive analytics, organizations can identify the most qualified candidates based on their past work history. Human resource development initiatives can help improve sustainability by increasing employee productivity and overall corporate efficiency.

According to industrial reports, the rise of Industry 4.0 has affected the recruitment industry. Industry 4.0 environment and its technologies are transforming various industries such as quality control, manufacturing, and distribution. As Industry 4.0 continues to evolve, many low to medium-skilled positions are lost in, but the resulting job opportunities are in the areas of informatics, process engineering and system integration. The social and environmental impacts of Industry 4.0 are not only limited to the creation of new jobs related with digitalization. They also contribute to the creation of green and sustainable job opportunities. The organization must analyze the new skills that are necessary as well as the demand for skilled workers in order to successfully transition to Industry 4.0. The company's biggest difficulty is training staff and attracting new talent.

Human resources procedures have been altered by digital technologies, particularly in terms of how information about job seekers and current employees is collected, stored, used, and disseminated. They've also altered the nature of work, corporate connections, and control. Employees have been able to work from home or engage with team members across geographic borders thanks to the development of digital technology and applications such as web-based applications, virtual teams, and remote work. This circumstance has diminished the impact of organizational distance. It has allowed firms to recruit people with certain abilities, such as software developers, from all around the world. Digital technologies have advanced, organizational processes and the nature and meaning of work have continued to evolve. Work has evolved into a more modular, granular, networked, and decontextualized form that is more flexible, ad hoc, and part-time, according to Connelly et al. (2020) (Aybas 2021).

Employee learning is accelerated by technology like virtual and augmented reality, which reduces work pressure and boosts morale.

The employees are the ones who are most affected by the changes that are happening in the industry due to Industry 4.0. They not only have to adapt to the changes, but also understand the potential of these changes, as they are directly working with new technologies. As human resource professionals are usually

experienced in working with various departments and more developed, should be expected higher maturity levels should be achieved.

Industry 4.0 success hinges on an organization's ability to innovate, whether it's through cyber-physical systems (CPS) (embedded actuators, sensors, and computer networks), product reengineering, distinctiveness, or supply chain difficulties. If a business wants to be smart, it needs clever personnel and a learning and innovation-friendly environment, which necessitates appropriate management techniques. Management for Industry 4.0 is an extremely significant topic. Because of globalization, there is a need to create capabilities to successfully manage business models and product portfolios, gain access to future markets and customers, improve value chain processes and systems, risk management and legal matters, and cultural management.

Human resources practices are regarded as one of the most important ways for organizations to mold their employees' skills, competencies, behaviors, and attitudes in order to achieve organizational goals. Managers can improve employee innovation, knowledge management capability, and learning by tailoring human resources approaches to their needs. In a knowledge-based economy, human resources practices are important for competitive advantage. Training, staffing, performance appraisal, remuneration, and job design are all human resources processes that must be planned with innovation and learning in mind. Managers in industry 4.0 must design these human resources practices with the goal of encouraging innovation and learning within the company.

Industry 4.0 organizations must build their training programs in such a way that they may improve their innovative capability and learning. Organizations should provide several types of training to employees in order to enable them to multitask. These trainings do not have to be directly related to the employee's profession, but they should broaden their skill set. These training sessions should continue indefinitely. Trainings should also emphasize team building and collaboration skills, and managers should mentor new employees on a regular basis. There should also be training sessions to improve the employees' problem-solving abilities.

Hiring in Industry 4.0 should be based on a diversity of skills and diverse knowledge, which should be tested throughout the screening process before the candidate is chosen. Organizations should devote a significant amount of time and effort to finding the best candidate for each job through a thorough recruitment and selection process. For example, in order to hire innovative people, recruiters should concentrate on finding the characteristics that are required for innovative behavior, such as openness to experience, which may be assessed by psychometric testing throughout the selection process. Active imagination, inner feeling attentiveness, various preferences, intellectual curiosity, inventiveness, and flexible thinking are all characteristics of openness to new experiences. People who are open to new experiences have a more positive outlook on learning. Organizations should evaluate the candidate's goal orientation, which might be learning orientation or performance orientation, during the recruitment and selection process. Recruiters should prioritize individuals with a strong learning orientation in order to foster creativity and learning in the workplace. Employees that have a learning goal orientation prefer to work on

difficult tasks, are keen to improve themselves, are willing to learn new abilities, and are more likely to reach mastery. The importance of focusing on the candidate's future potential during the recruitment process cannot be overstated.

Employee contribution to the company should be reflected in the compensation structure in Industry 4.0. Employees should be compensated based on their individual, group, and organizational accomplishments. There should be a link between performance and compensation, such as profit sharing and bonus pay. A remuneration structure like this has the ability to improve the organization's climate of innovation and learning.

Employee development, a result-based approach, and a behavior-based approach should all be emphasized in a performance appraisal system that can accommodate Industry 4.0, as these approaches can help with learning and innovation. Establishing performance standards, conveying expectations, assessing actual performance, comparing actual performance to standards, discussing the appraisal with the employee, and taking corrective action if necessary are all part of an ideal appraisal process.

Job design refers to how a position and its activities are organized, including how and when tasks are executed, as well as any other aspects that affect the work, such as the order in which tasks are completed and the conditions under which they are completed(Shamim et al. 2016). Job rotation, flexible assignments in many areas, and substantial delegation of duties and responsibilities to employees should all be features of job design that encourage an atmosphere of creativity in learning. Job design should encourage teamwork and collaboration while also needing a diverse set of talents. Such a job design can assist the company in adapting to the business climate in the industry 4.0 environment, which is defined by change and innovation.

Emerging technologies like the Internet of Things are allowing physical objects to link to the digital world, resulting in a tremendous amount of real-time organizational data, which is supported by massive scalable storage capacity provided by cloud technology (Sivathanu and Pillai 2018). With the help of breakthroughs in Big Data and AI technologies, computing power has also expanded rapidly, maintaining its trend, enabling automation and faster analysis of an organization's data.

Companies throughout the world must innovate in terms of goods, processes, and management systems in order to become competitive in the Industry 4.0 context and ensure the long-term viability of their businesses. These measures necessitate the introduction of smart technologies and systems that considerably increase the flexibility of business activities while also improving market awareness (Pio et al. 2021).

Employees joining businesses in the age of the internet, social media, and smartphones have various expectations from their employers, including anytime and anywhere collaboration, rapid feedback, an open culture, and data-driven decisions.

Big Data and AI enable to automate candidate resume and job description matching, allowing only those profiles with a high probability of satisfying the job requirement to be considered for interviews (Sivathanu and Pillai 2018). This would save a tremendous amount of time and effort in the present resume screening process.

Instead of generic testing, automated and personalized testing can be used in interviews to predict better future on-the-job performance. Remote video-based interview discussions in real time are now possible thanks to faster data network connections (4G/5G), which will significantly shorten the total recruitment cycle (Sivathanu and Pillai 2018). AI chatbots can assist in real-time interpretation and validation of candidate responses, eliminating interviewer bias. Following selection, rather than a one-size-fits-all approach, new joiner induction programs can be tailored to the person. New hires would be guided through various office processes and layouts using augmented reality/virtual reality (AR/ VR), ensuring that they are productive right away.

Leadership training is one technique to conduct competency development to improve individual and organizational performance. Because human resources in the defense apparatus rely on an effective command system that is in sync with the organization, leadership is critical because it can foster a positive organizational culture, strong work motivation, a clear mission, and organizational goals, as well as guide the organization toward more productive and high-performance outcomes (Wibowo et al. 2020).

In creating leadership, a competent leader for governance is required in Industry 4.0. For all organizations, there are five executive core qualifications to develop: leading change, leading people, results-driven, business acumen, and establishing coalitions or communication (Wibowo et al. 2020).

Human Resources management is referred to as a transition agent in the organization, and it is expected to assist employees in accepting unavoidable changes and utilizing potential ways to generate value for their companies (Shaharudin et al. 2021).

4.5 Industry 4.0 and Operations Management

Industry 4.0 has been defined as technology advancements, organizational re-designs, operations management developments, and market revolutions in fields such as engineering, management, control, and data science. Industry 4.0, according to Piccarozzi, Aquilani, and Gatti (2018), is the integration of Internet of Things technologies into industrial value creation, allowing manufacturers to harness completely digitized, connected, smart, and decentralized value chains capable of delivering greater flexibility and robustness to firm competitiveness and enabling them to build flexible and adaptable business structures with the permanent ability for internal evolution (Dmitry et al. 2021).

There are only a few studies on industry 4.0 in the operations management research field. Recent studies have revealed that, in the context of industry 4.0, operations management research has mostly focused on industrial applications of technologies including additive manufacturing, the Internet of Things, blockchain, advanced robots, and artificial intelligence (Dmitry et al. 2021). From the perspective of operations management, Industry 4.0 refers to the consistency of technologies, organizational concepts, and management principles that underpin a cost-effective, responsive,

resilient, and sustainable network that is data-driven and dynamically and structurally adaptable to changes in demand and supply by rapidly rearrangement and reallocating its components and capabilities.

Researchers have provided several overviews of the changes in organization, technology, and management that have culminated in industry 4.0 during the last four decades. At the 1980s and 1990s saw a shift from stable markets served by mass production to increasingly volatile variety and volume market environments that necessitated adaptable, small-lot manufacturing using technologies like flexible manufacturing systems (FMS) and reconfigurable manufacturing systems (RMS) (Dmitry et al. 2021). Advances in manufacturing and information technology enable and support the development of computer integrated manufacturing (CIM) and automated manufacturing processes, which are enabled and supported by novel systems such as enterprise resource planning (ERP) and modular and fractal factories. The key management and organizational principles of these periods were flexibility and integration.

To serve the increasingly unpredictable new market models, the evolution between 2000 and 2010 was marked by the development of management principles such as coordination, collaboration, decentralization, and agility. Advances in information and manufacturing technologies, such as multi-agent systems, complex adaptive systems, RFID, and APS (advanced planning systems), enabled the adoption of these new organizational principles (Dmitry et al. 2021). The virtual enterprise framework, as well as vendor-managed inventory (VMI) and collaborative planning, forecasting, and replenishment (CPFR) principles, were developed around the same time. In virtual firms, supply chain dynamics included so-called competence cells or agents networking. Collaborative control theory is another contribution that can be considered a watershed moment in the development of industrial enterprise systems. Collaborative control is based on the idea of combining decentralized agent-oriented control with bio-inspired coordination and control, adaptation, and learning.

The constituent components of a nascent Industry 4.0 (e.g. collaborative robots, sensors, agents, modular factories, Internet-of-Things (IoT), etc.) were familiar to some in the industry in the early 2010s, but their relative utility and utilization contexts and requirements were not evident (Dmitry et al. 2021). Attempts to connect these local solutions frequently failed. Following significant advancements in data processing and robotics technologies, this became practical later. Industry 4.0 is producing major consequences such as digital supply chains, smart manufacturing, and cloud manufacturing. Sensors, autonomous guided vehicles (AGVs), blockchain, additive manufacturing, augmented reality, big data analytics, track&trace systems (T&T), and mobile robots are all helping to construct cyber-physical systems (CPS) in production and supply chains.

New disruptive manufacturing and supply chain business models have emerged, in which supply chains are no longer thought of as inflexible physical systems with fixed and static allocation of specific processes to specific enterprises. Separate physical firms provide supply, production, logistics, and sales services at different periods, resulting in dynamic process allocation and supply chain topologies. Electronic merchants, for example, are leveraging their massive transactional and behavioral

customer data to provide customers with new options to try, experience, and purchase their products (e.g., Amazon with Alexa). Logistics and supply chain control with real-time data, dynamic resource allocation in Industry 4.0 customized assembly systems, improving forecasting models using Big Data, and combining optimization, machine learning algorithms, and agent-based modeling for supply chain resilience are all examples of digitalized supply chain and operations (Dmitry et al. 2021).

Intelligent logistics solutions, such as the IoT-based Omni-Channel Logistics Service, can help manufacturers, retailers, and logistics providers exploit synergies and facilitate real-time self-optimization. Supplier relationship management is also determined by integrated information systems and enhanced forecasting methods (SRM) (Caiado et al. 2021). Blockchain technologies can help with real-time information sharing from the supply chain to numerous parties for increased transparency, allowing suppliers and buyers in virtual markets to employ intermediate manufacturing resources and services.

Industry 4.0 is drastically transformed operational Operations Management tasks and decision-support systems, particularly in manufacturing and logistics. Manufacturing is the primary application of Industry 4.0 engineering technology and infrastructure. The majority of data processing technologies are used in the decision-making domains of planning and sourcing. The communication component of Industry 4.0 dominates the logistics space.

One of the key features of Industry 4.0 is an individual approach to customers, which is why concepts for customer involvement/integration in the value creation process (Customer Order Decoupling Point, Co-Creation, Co-Development, and so on) are becoming increasingly important for manufacturing operations management (Koleva and Andreev 2018).

The advantages that are expected to accompany Industry 4.0 appear to be numerous. Automation improves product quality while also increasing the efficiency of industrial processes. This is especially relevant when considering the transformation that many businesses are going through as a result of Industry 4.0. Lower product processing time, manufacturing cost reduction, improved value chain coordination, enhanced process flexibility, better customer service, and higher product customization are a few of the benefits that Industry 4.0 technologies can provide in the management of operations. Because many of these benefits are centered on process automation, they can provide outputs for a variety of areas within operations management, particularly in technology management. Additionally, automated processes have the ability to improve all actions carried out in a company, resulting in improvements in all areas of operations management.

Industry 4.0 technology can still transform a company's core competences, and it's been highlighted as an enabler of several operations management concepts, such as agile manufacturing and mass customization. Lean manufacturing is a commonly utilized method that strives to reduce waste while increasing productivity and quality in accordance with customer needs (Schumacher et al. 2016). The application of the lean strategy is based on a human-centered approach to numerous management ideas and practices. This technique is frequently cited in contrast to the consequence of implementing Industry 4.0 technologies, which tends to reduce human involvement.

4.6 Industry 4.0 in manufacturing

The importance of Industry 4.0 in manufacturing cannot be overstated. The manufacturing ecosystem is transformed by the industrial revolution, which give rise to new capabilities and increase productivity. Industry 4.0 is defined by the integration of industrial assets, which allows for improved connectivity, data transmission, and analytics-driven decision-making capabilities, resulting in considerable improvements in overall performance. The system becomes more autonomous, cognitive, and intelligent as a result of Industry 4.0's expanded data-driven and decision-making capabilities. It is considered *smart* to develop these capabilities within a manufacturing system, thus, the systems are usually referred to as smart manufacturing systems (Mittal et al. 2019). The application of developing technologies and their interaction with the manufacturing environment are conceived as Industry 4.0 deployment. The Internet of Things (IoT), big data analytics (including AI and machine learning), Cyber-Physical Systems (CPS), cloud computing, Additive Manufacturing (AM), Augmented Reality (AR), digital twin, cloud computing, and autonomous robots are all technologies connected with Industry 4.0. The enablers for implementing Industry 4.0 are often referred to as technologies.

In comparison to a typical manufacturing environment, Industry 4.0 technologies can make the overall manufacturing system more nimble, robust, and resilient. AR, for example, improves the virtualization capabilities of industrial systems and can provide greater assistance to workers assembling parts. As a result, the total system becomes more robust and resilient to quality-related hazards. The use of digital twins and CPS allows real-time processes to be visualized on a cyber interface or in a virtual world. The embedded IoT on production equipment makes it easier to collect real-time data from digital twins, which improves monitoring and control efficiency. IoT implementation leads to a deeper integration of various assets across production systems. Horizontal and vertical integration are examples of this type of integration, and they are a major enabler for Industry 4.0. Vertical integration tries to integrate across hierarchies, whereas horizontal integration aims to integrate across the value chain. The smooth interaction and communication among the industrial assets are enabled by the integration across the various layers. The assets' seamless connectivity allows for continuous data communication amongst industrial resources with low latency and jitter. Continuous connectivity increases the likelihood of cyber-attacks. Effective cybersecurity measures must be implemented to prevent industrial espionage and data leakage from cyber-attacks. Complex-shaped geometries of components, which are generally difficult to make using standard manufacturing procedures, can be manufactured using AM systems. AM machines expand the number of potential variants that production systems can offer, as well as the degree of customization that the manufacturing process can achieve.

Deployment of autonomous machines, robots, and cobots improves smart manufacturing systems' localized decision-making capability, allowing for decentralization. Robots in traditional production systems are designed to perform dangerous and difficult tasks. Industry 4.0, includes a new generation of cognition-

enabled robots, often known as cobots, that improve human-robot collaboration (De Pace et al. 2020). Autonomous systems have the ability to make cognitive decisions and the intelligence to self-adjust and self-configure to meet the needs of the product. Such capabilities improve the decentralization of production systems by allowing localized resource decision-making. Machine learning techniques, for example, are used to train autonomous systems based on past data. Machine learning systems provide autonomous systems with the training they need to respond to conditions.

The collective action of Industry 4.0 technologies has resulted in the creation of smart capabilities such as cognitive decision making, virtualization of processes, real-time monitoring, resilient operations, and seamless communication of industrial systems. The production system becomes more agile, intelligent, autonomous, and responsive as a result of these characteristics. Incorporating Industry 4.0 into a manufacturing organization would result in significant technological advancements, increasing human skills for computational thinking and a creative attitude. As a result, human resources play an important role in adopting Industry 4.0. Lack of operational and process improvements, lack of training and skill development, and supplier cooperation are all hurdles in implementing Industry 4.0. Industry 4.0 adoption is influenced by a number of factors, both internal and external. Internal variables such as human skill development, technological infrastructure development, software capabilities, and external factors such as supplier coordination and customer requirements all play a part in the implementation of Industry 4.0.

Organization-based determinants, such as having a good attitude toward innovation and designing organizational strategies, have a role in the adoption of Industry 4.0. Because Industry 4.0 is a technology-driven development, technology-related variables become crucial conditions for adoption. As a result, the deployment of emerging technologies such as IoT, big data, and additive manufacturing is anticipated to be a key driver for effective Industry 4.0 adoption. Another important feature of embracing Industry 4.0 is the reliance on financial variables like as current infrastructure investment, financing of supplier development activities, and the engagement of stakeholders.

Industrial sensors, controllers, and networks are costly, and it's difficult to upgrade current facilities. Cost reductions in sensors, controllers, and communications have been driven by high-volume semiconductor manufacturing, such as smart gadgets, as consumer use of the IoT has grown. Standard industrial equipment is limited by an enormous installed base of legacy equipment and standards. To turn basic materials into value-added products and components, capital, energy, human resources, information, and raw materials are acquired, transferred, and consumed. Networking, adaptability, and dynamic, well-organized manufacturing lines for configurable goods are advantages of manufacturing under the label of Industry 4.0, Digital Manufacturing, or smart factory. This goes hand in hand with the trend of moving from stationary to mobile, universal human-machine interfaces based on modern information and communication technologies that are emerging from the consumer market in the manufacturing world, such as mobile operator panels and wireless technologies, and will be one of the key factors in the future development of manufacturing automation.

Technologies developed in the manufacturing industry during the Industry 4.0 era that allowed for the production of tiny quantities in real time at high quality but at a manageable cost. Manufacturers can profitably service changing markets and worldwide trends by delivering a wide range of versions or small series, as well as meet individual customer needs on demand. Intelligent data analysis in smart manufacturing and the use and service of smart products, which leads to smart data from which new or enhanced products and services can be extracted, is a unique property. Cyber-physical systems and the Internet of Things will be critical characteristics of the smart factory of the future, allowing for agility, adaptability, and multiadaptive.

4.7 Industry 4.0: Challenges and Opportunities

In the current setting, global industries are confronted with significant economic issues as a result of the rapid rate of societal and technical development, such as declining natural resource availability, rising energy prices, an ageing workforce, and market globalization. Customer demands for enhanced product-service innovation, product diversity, quality standards, support services, and immediate gratification are also on the rise.

In order to meet these difficulties, industrial businesses must be able to manage their entire value chain in a flexible and responsive manner. Companies require virtual and physical frameworks that enable close collaboration and rapid adaptation across the whole lifecycle, from product development to distribution.

Industry 4.0 is a set of pull applications and push technologies that enable the high level of sustainability required in future factories (Landeta Echeberria 2020). According to, Industry 4.0 addresses today's resource and energy efficiency concerns, as well as urban production and population change, by enabling ongoing resource productivity and efficiency.

Internet-based and Internet of Services are two of the most widely pushed technologies, with fresh improvements in computational capacity favoring cloud computing and services. These technologies have the potential to usher in a new generation of service-based industrial systems with on-device and cloud-based features. Talented employees, a robust IT infrastructure, economic power, and forward-thinking manufacturers are required to develop these technologies and applications successfully.

An Industry 4.0 factory has the potential to predict future products and respond to increased variety and complexity at low cost and with minimal environmental effect.

Management challenges in adopting Industry 4.0 are challenges that pertain to managerial issues in implementing Industry 4.0. These difficulties can include, for example, a lack of financial resources, a lack of personnel resources, security concerns, and so on. These issues can arise as a result of either the overall deployment of the Industry 4.0 concept or the implementation of a specific Industry 4.0 technology category.

Technology implementation challenges in Industry 4.0 relate to specific technological issues that arise during the deployment of Industry 4.0. Device incompatibility, data analysis, algorithm development, and other issues are examples of these problems. Technological obstacles are associated with the execution of a given technology category.

Industrial artificial intelligence is constrained by the physical nature of the systems and processes it manages, which other types of artificial intelligence are not. Retrieving industrial data in sufficient quantity and diversity to train industrial or defense artificial intelligence is extremely difficult. Industries are hesitant to divulge data that could reveal product manufacturing processes. The demand for competence has increased. Industrial artificial intelligence models are more difficult to create, train, and test, and the costs of failure are higher.

Industrial artificial intelligent systems frequently rely on data gathered via sensors that attempt to digitally represent the real environment, as opposed to *born digital* data captured, for example, from web interaction logs (Fuller et al. 2020). This method can produce datasets that are intrinsically noisy. Sensor data might be quite large. Obtaining this information and keeping it for analysis might be a difficult task. Simulation is frequently utilized due to the high expense of acquiring training data under a wide range of scenarios. High-fidelity simulations, often known as *digital twins*, can be very effective, but they can be difficult to design and maintain, as well as computationally costly to run (Fuller et al. 2020). At training issues, the success of *deep learning* has fueled a lot of the recent buzz regarding artificial intelligent. The majority of these achievements are based on supervised learning issues, in which deep neural networks are trained with labelled training data. Testing artificial intelligent systems on live production lines, industrial equipment, warehouses, and other industrial systems is both costly and disruptive due to testing expenses and complexity. As a result, simulation is frequently used to train and evaluate industrial artificial intelligent systems, which has its own set of issues. Modern industrial systems are exceedingly complicated at huge state spaces, with tens or hundreds of inputs that machine learning algorithms can optimize. This may necessitate the employment of advanced approaches to reduce the problem and ensure convergence to a solution, resulting in more complex development and training routines, both in terms of time and expense.

Industry 4.0 is a vision for the future because it encompasses a wide range of topics and challenges, including scientific, technological, economic, social, and political issues.

A factory using Industry 4.0 technologies is smarter than any other factory, requiring greater intervention from artificial devices, including robots, and minimizing employee engagement. Different factories, on the other hand, require different smart device configurations, and smart device development takes a long time and a lot of money before it can be used in an Industry 4.0 facility.

4.8 Digital transformation and Industry 4.0

The Fourth Industrial Revolution was originally assumed to be a digital revolution sweeping the manufacturing industry. Industry 4.0 is now defined as the digital transformation of all industrial value chains (Ghobakhloo and Iranmanesh 2021). Implementing specific digital technologies and adopting valuable design concepts are hallmarks of Industry 4.0's digital revolution.

Low or high tier modern digital breakthroughs or advanced manufacturing technologies that enable the digital industrial revolution are Industry 4.0 technological developments. Low tier Industry 4.0 technology developments include smart sensors, industrial robots, smart wearables, and machine controllers, which can be procured and installed as discrete digitalization initiatives inside the industrial environment. Industry 4.0's higher tier technology trends, such as the industrial Internet of Things (IoT), Cyber-physical Production Systems (CPPS), and digital twins, are built on the integration of a variety of lower tier digital and operations technologies, such as networking infrastructure, sensors, machinery, and even connected human components.

Industry 4.0 design principles, as a building block of digital transformation, are required conditions for industrial value chain members to reap the benefits promised by the Industry 4.0 transition. Previous researches has shown a wide range of Industry 4.0 design principles (Ghobakhloo and Iranmanesh 2021). Horizontal and vertical integration, real-time capability, and client focus are some of the most commonly acknowledged Industry 4.0 design ideas. Scholars have been very interested in discussing the benefits and problems of Industry 4.0 for social medias. Another common research topic is evaluating social medias' behavior in integrating Industry 4.0 technology trends. The most popular research streams have been strategic management of digital transformation, company value generation strategies for competitiveness, and digitalization maturity evaluation.

Industry 4.0 was defined by Kagermann and Wahlster (2013) as a smart factory, a manufacturing unit with horizontal and vertically integrated operations (Schumacher et al. 2016). In order to produce smart products and services, the smart factory relies on a high level of connectivity that enables for end-to-end digital integration across the value chain. The particular manufacturing unit is part of a network that shares information and knowledge with other units, suppliers, and customers. Automated and digital technologies work in a completely connected environment with entire information transparency, as data from processes is always available. Following research focused on framing Industry 4.0 by outlining the capabilities of linked technology and data applications. AM, augmented reality, CPS, big data, CC (CPS), and IoT are some of the technologies usually linked with Industry 4.0.

Internal communication, managerial support, and the availability of expertise are all key variables in ensuring the company's efficacy. The network effect of vertical and horizontal integration necessitates an understanding of the ecosystem in which the organization operates in order to disseminate knowledge and innovate. New technologies and the possibilities given by data utilization open up new revenue streams, but businesses react to the possibility of business model innovation in different ways.

Implementing Industry 4.0 has a significant organizational impact that is directly linked to the digital transformation process. Adoption of technologies such as IoT and CPS, as well as the ability to treat data and integrate processes inside internal departments and with external partners, encourages innovation and changes in business models. New technology may allow for alternate production methods and/or the creation of new value propositions. In any event, data derived from manufacturing processes or interactions with suppliers or consumers is a valuable resource. Data can be utilized to give useful information for predictive or corrective reasons, to increase process efficiency, or to develop new revenue streams in situations where services add value. The relationship between the supplier and the customer in a collaborative process can be used to produce value through services. As a result, the offer becomes more complex, and the value proposition may comprise customized products and services resulting from value co-creation between the supplier and the client. The integration of the value proposition with distribution through digital platforms generates a new sort of customer connection downstream in the value chain, where the digital, physical, and social components interact to create a customer experience that ensures long term engagement.

While the potential of Industry 4.0 for the service of manufacturing is extensively documented, some authors acknowledge its relevance to service-providing activities that are not directly tied to manufacturing processes. Along the supply chain, integration of processes and data generation allows for inventory tracking, information exchange, and collaborative ordering, while smart labeling may deliver interactive content to the final consumer. Similarly, supply chain 4.0 and the incorporation of building information modeling may aid the construction industry.

Products, devices, and services become smarter as a result of the integration of microprocessors with AI techniques, possessing not just processing, communication, and control capabilities, but also autonomy and sociality. Adaptive and flexible robots, in combination with artificial intelligence, make it easier to manufacture various items by recognizing the lower segments of each part. This segmentation proposes lower manufacturing costs, shorter production times, and shorter wait times in operations. In manufacturing systems, adaptive robots are particularly beneficial throughout the design, manufacture, and assembly phases. As an example, allocated tasks are broken down into smaller subproblems, which are then assembled into a series of modules to address each subproblem. Integration of the modules is required at the end of each subtask to arrive at an optimal solution. Co-evolutionary robots, which are energetically independent and have a scenario-based thinking and reaction-focused operating principle, are one of the sub technologies underlying adaptive robots.

Embedded systems, also known as Cyber-Physical Networks (CPS), are a type of technology that helps to organize and coordinate networking systems between physical infrastructure and computing capabilities (Ustundag and Cevikcan 2018).In order to achieve decentralized actions, physical and digital tools should be merged and connected with other devices. Embedded systems are systems that combine physical reality with novel features such as computation and communication infrastructure.

An embedded system must meet two main functional requirements, advanced networking to provide real-time data processing from the physical infrastructure as well as information feedback from the digital structure, and intelligent data processing, decision-making, and computational capability to support the physical infrastructure (Ustundag and Cevikcan 2018). RTLS technologies, sensors, actuators, controllers, and a networked system that transforms and transfers data or information from every device are used in embedded systems for this purpose. In terms of using computational intelligence supported by learning methodologies such as case-based reasoning, information acquisition can be obtained from data processing and data gathering.

Additive manufacturing is a group of new technologies that uses an additive method to create three-dimensional objects directly from digital models, primarily by storing and combining the products with appropriate polymers, ceramics, or metals (Ustundag and Cevikcan 2018). Additive manufacturing begins with the creation of computer-aided design and modeling, which organizes a collection of digital features for a product and sends descriptions of the products to industrial machinery. By adding material layers, the machines use the sent descriptions as blueprints to create the item. The layers, which are measured in microns, are repeatedly added until a three-dimensional object is formed. Plastics, other polymers, metals, and ceramics are common raw materials. They might be in the form of a liquid, powder, or sheet. In this regard, additive manufacturing is divided into two parts, software for creating 3D objects and material procurement.

Although there are hurdles to present technologies, particularly in production processes, 3D printers and additive manufacturing have unequaled properties. For example, for some products, additive manufacturing procedures outperform traditional manufacturing mechanisms, such as molding previously inconceivable geometries like pyramidal lattice truss systems (Ustundag and Cevikcan 2018). The printing technique reduces waste by just using the resources that are required. A networked system that includes ordering and injection molding selection is also required to monitor process variables and parameters on a specific interface. Customer needs are included in the manufacturing design, and the necessary components for the manufacture of these plastic parts are obtained ahead of time. The metal blades are encased in the injection molding machine, and the design features information system combines the individual design process phases with correct additive manufacturing system operations. In addition, a laser-marking phase is used in the manufacturing process.

Another important topic for the contribution of networked system integration in the Industry 4.0 revolution is cloud-based operation. Cloud computing and cloud-based manufacturing and design are both included in the term cloud (Ustundag and Cevikcan 2018). Cloud manufacturing refers to the coordinated and networked production that makes products accessible on demand. Demand-based manufacturing creates and operates reconfigurable cyber-physical manufacturing processes by bringing together a collection of distributed manufacturing resources. The primary goal is to improve efficiency by lowering product lifecycle costs and enabling optimal resource utilization by dealing with fluctuating demand customer-focused projects. Cloud-based design and manufacturing operations suggest

integrated and collaborative product development models based on open innovation through social networking and crowd-sourcing platforms (Ustundag and Cevikcan 2018).

Virtualization technologies are based on augmented reality (AR) and virtual reality (VR) tools, which are defined as the integration of a computer-supported reflection of a real-world environment with additional and useful data (Ustundag and Cevikcan 2018). Virtual information can be included into real-world presentations with the goal of enhancing human perceptions of reality through the use of augmented items and features. Existing VR and AR applications do this by associating graphical interfaces with the user's current environment view. Users can directly influence visual representations of elements by performing instructions on the screen and interacting with these menus referenced by ad hoc feedbacks, which is the primary job of graphical user interfaces.

Visualization technologies must meet four functional requirements, scene capture, scene identification, scene processing, and scene visualization (Ustundag and Cevikcan 2018). For implementation, handheld devices, stationary visualization systems, spatial visualization systems, head mounted displays, smart glasses, and smart lenses are used. Key issues for the adaption of visualization scenarios, on the other hand, include providing a realistic environment for a better user experience, adding important information via meta graphics, and enriching users' perception through color saturation and contrast. Approaches for visualization technologies' displays are based on three foci, video-based adaptation, which uses the camera to aid enhanced information, optical adaptation, in which the user provides information by wearing a specific display, and projection of mentioned items (Ustundag and Cevikcan 2018).

Various types of simulation, such as discrete event and 3D motion simulation, can be used to improve product or process planning in a variety of situations. For instance, simulation can be used in product development, testing, and optimization, as well as in the development and optimization of manufacturing processes and facility design and improvement (Ustundag and Cevikcan 2018). In the context of Industry 4.0, simulation can be viewed as a useful tool for tracking the effects of various parameter changes and facilitating visualization in decision-making. Simulation tools can be utilized in conjunction with other Industry 4.0 basic technologies.

As a result of manufacturing organizations using modern information and knowledge technologies to streamline their information flow, a massive amount of real-time manufacturing data is gathered from many sources. The amount of data collected during research and development, manufacturing, operations, and maintenance processes is growing at an exponential rate. Data integration and processing, in particular, are used in Industry 4.0 to improve an easy and highly scalable adaption for dataflow-based performance measurement of networked equipment and processes. Data comes in vast quantities, needs to be processed fast, and necessitates the integration of multiple data sources in a variety of formats. When data is collected from numerous sensors, for example, data mining techniques must be applied. As observed in smart factories, this information aids in the evaluation of the current state and configuration of various machines, as well as environmental

and other concomitant factors that can effect output. Companies may gain a major competitive edge by analyzing all of this data and being able to meaningfully evaluate the entire process.

Communication and networking can be characterized as a link between individually defined physical and dispersed systems (Ustundag and Cevikcan 2018). Machines can interact via communication tools and devices to achieve predetermined goals, with a focus on embedding intelligent sensors in real-world settings and processes. Distributed computing and parallel computing for data processing, Internet Protocol (IP), communication technology, embedded devices such as RFID tags or Wireless Sensor Networks (WSN), and application are the major needs for communication and networking (Ustundag and Cevikcan 2018).

Industry 4.0 transformation necessitates extensive data collection and processing. As a result, the security of data storage and transfer protocols is a critical issue for businesses. Regarding data exportation technologies' security, privacy regulations and standardization of communication protocols, personal authorization level for information sharing, and detection and reaction to unexpected changes and unauthorized access by standardized algorithms, security should be provided in both cloud technologies, machines, robots, and automated systems (Ustundag and Cevikcan 2018).

4.9 Industry 4.0 and Maturity Models

A maturity model or framework is a structured approach designed to support companies moving towards Industry 4.0 by providing comprehensive guidance on how to initiate a roadmap. The term maturity is used to define, evaluate, and form guidelines and a basis for evaluating an organization's progress. The purpose of a maturity model is to describe the level of perfectness of an entity, such as a new business model or newly developed software. The main idea of a maturity model is to identify maturity levels associated with different aspects of an organization's progress in achieving performance.

According to Suh et al. (2017), an organization's maturity, which indicates its ability to plan, use, and control information systems internally, is considered an important consulting factor for business success(Bandara et al. 2019). They proposed a maturity framework to assess the maturity level of information systems. The framework consists of three main dimensions, such as information system quality success, information system utilization success, and information system utilization success. The first dimension, information systems quality success, is weighted by system quality, information quality, and service quality. The second dimension, success in using information systems, is weighted based on usage and user satisfaction. The third dimension, the effectiveness of information systems, is measured in terms of operational excellence and strategic positioning(Bandara et al. 2019).

An assessing digital transformation maturity model is needed to help companies define their digital transformation strategy. A maturity model is a tool used to measure and evaluate an organization's maturity. It can be used to identify

processes and procedures that are ready to be executed. Readiness models as synonyms are intended to capture the starting point and allow to start the development process. This distinction between readiness and maturity pertains to the various stages of a maturing process. Readiness assessment takes place before engaging in the maturing process whereas maturity assessment aims for capturing the as-it-is state whilst the maturing process. In the production domain recent readiness and maturity models have been proposed for example in energy and utility management, in eco design manufacturing. Bellow following models and tools for assessing readiness or maturity. (Schumacher et al. 2016).

Model Name	Assessment Approach
IMPULS – Industrie 4.0 Readiness (2015)	Assessment in 6 dimension including 18 items to indicate readiness in 5 levels, barriers for progressing to the next stage are defined as well as advice how to overcome them.
Empowered and Implementation Strategy for Industry 4.0 (2016)	Assessment of Industry 4.0 maturity as a quick check and part of a process model for realization, gap-analyses and toolbox for overcoming maturity-barriers are intended, no details about items and development process offered.
Industry 4.0 / Digital Operations Self Assessment (2016)	Online-self assessment in 6 dimensions, focus on digital maturity in 4 levels, application as consulting tool as fee for assessment is required in 3 of the 6 dimensions, no details about items and development process offered.
The Connected Enterprise Maturity Model (2014)	Maturity model as part of a five-stage approach to realize Industry 4.0, technology focused assessment in 4 dimensions, no details about items and development process offered.
I 4.0 Reifegradmodell (2015)	Assessment of maturity in 3 dimensions including 13 items for maturity indication, maturity is assessed in 10 levels, no details about items and development process offered (development process not finished).

Figure 10 Existing Industry 4.0 readiness and maturity models.

The concept of the *IMPULS – Industry 4.0 Readiness Model* is based on a comprehensive data set and offers details of various dimensions and items. The model is well-documented, and its results are explained in transparent manners. Other approaches listed in Figure 10 provide only a limited overview of the development process and do not provide a base for comparison. Industry 4.0 Maturity Model aims for an extension of existing models and tools through its strong focus on organizational aspects (Schumacher et al. 2016). Schumacher et al. (2016) proposes a model with the purpose of gaining solid data about the current state of the manufacturing companies in order to understand industry 4.0 strategies to extract potential success factors. This model presents a set of 62 key maturity items that are grouped into nine main company dimensions. The objective is to provide a conceptual framework for analyzing the various dimensions of Industry 4.0. It helps assess an organization's Industry 4.0 maturity and reflects the suitability of its current strategy. The model consists of nine dimensions, four of which serve as basic drivers and the rest as organizational drivers. The nine dimensions are product, customer, operations, technology, strategy, leadership, governance, culture, and people. These dimensions are weighted according to six factors including use of the Industry 4.0 roadmap, availability of resources, communication and documentation of Industry 4.0 activities, suitability of the business model, digital transformation strategy, and

alignment of Industry 4.0 with the corporate vision. Maturity for each dimension is calculated using a weighted average so that the overall maturity level of the organization is represented in a radar chart(Schumacher et al. 2016).

Dimension	Exemplary maturity item
Strategy	Implementation I40 roadmap, Available resources for realization, Adaption of business models, …
Leadership	Willingness of leaders, Management competences and methods, Existence of central coordination for I40, …
Customers	Utilization of customer data, Digitalization of sales/services, Costumer's Digital media competence, …
Products	Individualization of products, Digitalization of products, Product integration into other systems, …
Operations	Decentralization of processes, Modelling and simulation, Interdisciplinary, interdepartmental collaboration, …
Culture	Knowledge sharing, Open-innovation and cross company collaboration, Value of ICT in company, …
People	ICT competences of employees, openness of employees to new technology, autonomy of employees, …
Governance	Labour regulations for I40, Suitability of technological standards, Protection of intellectual property, …
Technology	Existence of modern ICT, Utilization of mobile devices, Utilization of machine-to-machine communication, …

Table 3 Dimensions and maturity items of Industry 4.0 Maturity Model (Schumacher et al. 2016)

To the evolution path each item undergoes five maturity levels. The first level involves description the lack of attributes that support the concepts of Industry 4.0 and level 5 represents the state-of-the-art of required attributes. Measuring, determining, and representing the enterprise's maturity follows a three-step procedure: measurement of maturing items in enterprise via questionnaire, input of calculation of maturity level in nine dimensions software supported and output of representation and visualization of maturity via maturity report and radar charts.

The evaluation of maturity is carried out using a standardized questionnaire that consists of one closed-ended question per item. The answer type is Likert-scale, reaching from 1 *not distinct* to 5 *very distinct*. The objective is to find out respondents that have a basic knowledge regarding Industry 4.0. The answers to the questions serve as data input to the model and determine the maturity level.

Several models have been developed to assess an organization's maturity in industry 4.0, with the majority of the models focusing on the manufacturing sector. As a result,

the maturity models' application to the service sector is quite limited. Table 4 provides a detailed overview of existing maturity models.

Maturity Model	Number of Maturity Levels	Number of Dimensions	Maturity Definition	Assessment method described	Continuous Assessment	Focussed field of study	Practicality
IS Maturity Model [Suh et al., 2017]	3	3	Yes	Yes	-	IT Maturity of a firm	General recommendations
I4 Maturity Model [Schumacher et al., 2016]	5	9	No	Yes	Yes	Manufacturing firms' maturity of I4	General recommendations
Roadmap I4 [Pessl et al, 2017]	5	6	Yes	No	-	Manufacturing firms' maturity of I4	General recommendations
E-governance maturity model [Kim and Grant, 2010]	5	2	Yes	No	Yes	E-governance maturity	Specific improvement Activities
I4 Readiness Model [Lichtblau et al., 2015]	6	6	Yes	No	Yes	Manufacturing firms' maturity of I4	Specific improvement Activities
SIMMI 4.0 [Leyh et al., 2016]	5	4	Yes	No	-	IT landscape maturity	General recommendations
Maturity of a factory [Koska et al., 2017]	-	-	-	No	No	Manufacturing firm maturity	-
Smart i4.0 Navigator [Kermer-Meyer, 2017]	4	6	No	No	No	Enterprise maturity of I4	-
SPICE extention [Gokalp et al., 2017]	6	5	Yes	No	Yes	Enterprise maturity of I4	General recommendations
Digital Readiness Assessment [Carolis et al., 2017]	5	5	Yes	No	Yes	Manufacturing Firms I4 maturity	General recommendations
Connected Enterprise Maturity Model [Bradley, 2014]	5	-	Yes	No	Yes	Enterprise maturity of I4	General recommendations
I4 Readiness Assessment Model [Agca et al., 2017]	4	6	Yes	No	Yes	Manufacturing Firms I4 maturity	General recommendations

Table 4 Analysis of Existing Maturity Models(Bandara et al. 2019)

Despite the fact that there are numerous maturity models, there is still room for improvement in order to best fit the chosen business. A maturity model, also known as a framework, is a structured method that was created to help organizations navigate the industry 4.0 journey by giving thorough assistance. The term maturity is used to define, measure, and create a framework for analyzing a company's progress. A maturity model consists of major characteristics that must be evaluated in order to measure an organization's maturity in the adoption of a new business model or software system. As a result, it has a variety of maturity levels.

The majority of models have numerous maturity stages, but most of them do not focus on the features that must be addressed at each level in order for the organization to continue to improve. To comprehend the maturity level of industry 4.0 and increase performance to the next maturity level, it is necessary to analyze how an organization operates under each facet of the maturity assessment model.

Even if organizations compromise advanced technologies to redesign their operations in order to benchmark with world-class performance, sustainability is important. Because Industry 4.0 is still at its development, it's critical to outline the structure and technique of implementation guidelines explicitly. As a result, there is a need to advise enterprises that are transitioning to smarter operations in order to improve their capabilities.

5. The framework for Quality 4.0 Maturity Assessment

Quality 4.0 framework can be developed and defined in a variety of ways. It can be based on a variety of factors, including a move from products to services, value creation in markets, and the quality of business models, among others. Zairi (2017) proposes such a response to the quality profession's crisis. He proposes that the quality profession requires a new quality DNA by changing how quality is understood as a concept and the notion of customer satisfaction, by employing disruptive thinking to keep up with business evolutions, particularly the digital revolution, for proactive pursuit of excellence and quality leadership, and by changing the meaning of strategy in the role of quality to reflect the need for agility and flexibility and to focus on a customer-centric approach (Zonnenshain and Kenett 2020).

For the new quality revolution, which Zairi refers to as Quality Mark II, he proposes the following framework: The discovery as the propelling force; the value creation generator which includes: personalization, perfection, partnership, prediction and delivery; the business renewal rocket which includes: experience, engagement, experimentation, enlightenment, disruption and distinction (Zonnenshain and Kenett 2020).

The Quality 4.0 system's goal is to help companies attain maturity in their Industry 4.0 capabilities. Real-time data management, interoperability, virtualization, decentralization, agility, service orientation, and integrated business processes are all Industry 4.0 design principles (Ranjith et al. 2021). These design concepts are relevant for developing the framework since they are organizational capabilities for both Industry 4.0 and Quality 4.0. In addition, achieving Sustainability is a vital competence for enterprises in the Industry 4.0 age. The core goal of Quality 4.0 strategy and implementation is to achieve maturity in these eight skills.

5.1 Quality 4.0

Aldag and Eker defined Quality 4.0 (or Q4.0) as the blending of traditional quality management practices and techniques with new technologies such as machine learning, cloud technologies, Big-Data, connectivity devices, Internet of Things, and Artificial Intelligence(Sader et al. 2021). Through the integration of various functions, such as supply chain and customer relationship management, the management of these activities were brought to a more collaborative environment. Jacob defined Quality 4.0 as the leverage of traditional quality management techniques which was gained by modern technologies in order to reach a new level of excellence at the functional and operational levels(Sader et al. 2021). He noted that adopting Q4.0 enabled manufacturers to improve their efficiency and effectiveness, which in turn boosted their market share and enhanced brand recognition.

In 2018, Allcock explained how Q4.0 refers to the shift from manual measurement to fully automated manufacturing. This process involves the use of sensors and

software to automate the manufacturing process. Schnreiter defined Q4.0 as the process of integrating and managing data related to manufacturing activities and processes(Sader et al. 2021). Quality 4.0 required an analysis system that can monitor and control the entire value chain.

Quality 4.0 combines quality management with digitalization and technology, which provides a management and process dimension to the digital transformation technology driver(Fonseca et al. 2021). Industry 4.0 requires product and process quality, in order to support flexibility, productivity, planning and implementation of the new processes. Quality 4.0 can improve Industry 4.0's quality and results.

Quality management is related to the four elements of a business analysis, namely the organizational structure, jobs, processes, and management systems, and the six business resources that are buildings, equipment, human resources, stocks, technologies, and capital. More specifically with quality management the organization can detect defects in products or processes, track back its processes, identify the cause of the defect in the resources or analysis data and perform actions to correct the defects and ensure that they do not reappear. The four processes that describe quality management are *total quality management*, *quality methodologies*, *quality standards* and *excellence awards*. Total quality management focuses on human resources, and it is desirable to transfer to employee level. Quality methodologies install the four quality elements, quality organizational structure, quality jobs, quality control procedures and quality management systems. The goal is continuous improvement with various methodologies, such as Six Sigma. There is a continuous improvement in the quality standards with the difference that it needs certification and renewal every year (e.g., ISO, IEEE, ANSI). According to excellence awards, there is a list of indicators that evaluate the organization in terms of quality management, which are divided into two categories, people enablers and people result (e.g., EFQM model).

The concept of digital transformation is often interconnected with the concept of I4.0 and Q4.0. This concept proposes that the goals of digital transformation are aligned with the goals of quality, and that the use of digital tools and methods can achieve these goals. The main driver for I4.0 is technology and Artificial Intelligence (AI) while Q4.0 focuses on customer-centric approach. Quality 4.0 refers to the capacity of a product to meet the needs of its customers at any stage of its life cycle. It can be seen as a way to improve the efficiency of the entire value chain. It can be used to measure and improve the quality of production through digital tools.

Quality 4.0 is often referred to as a major transformation that affect all levels of an organization. The new era technologies can help people and businesses achieve their goals and needs. They should be used to improve processes and efficiency. The evolution of human capabilities and the fusion of various Quality Control disciplines enable organizations to achieve an agile Q4.0 transition. This can be achieved through development of the TQM 4.0 environment consisting of the convergence of Industry 4.0, Total Quality Management (TQM), and Quality Control (QC)(Dias et al. 2021).

5.2 Literature Survey of Quality 4.0 and Operations Management and HRM

This study on Quality 4.0 was researched using the Google Scholar library. The terms were searched was *Quality 4.0 and Operation Management* and *Quality 4.0 and Human Resources Management.*

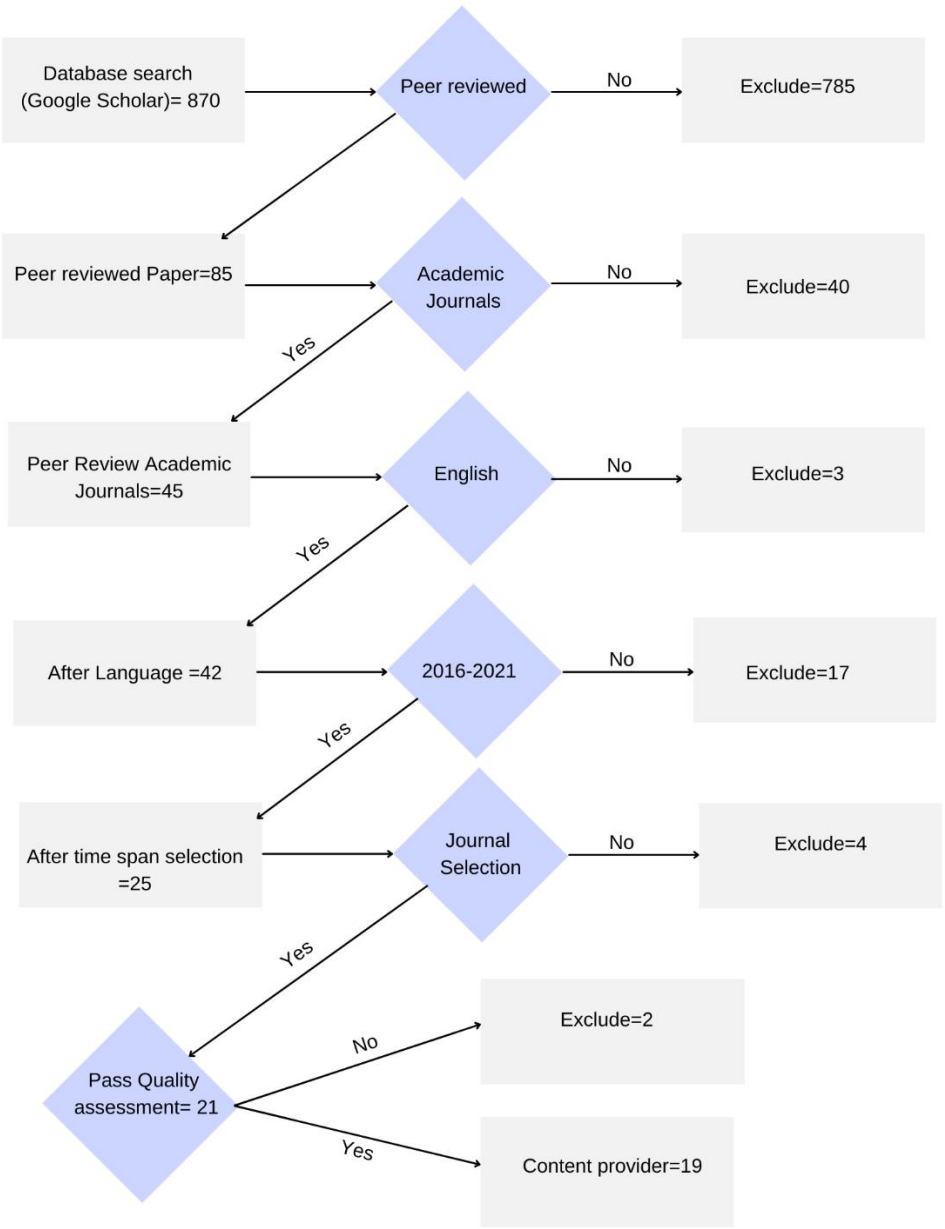

Figure 11 Research methodology with inclusions and exclusions of Quality 4.0 and Operations Management

Figure 11 depicts the roadmap of the Quality 4.0 and Operations Management literature survey, with points selected from the articles used and those that did not fulfill the requirements being excluded from the report. Criteria included peer review, academic journals, and English as a written language. A huge number of items were excluded because they did not match these criteria. The years spent authoring the articles were then added as another important factor. The years 2016 to 2021 were chosen. The journals in which the articles are published were the final criterion chosen.

Qualitative research was employed in the study to identify major terms mentioned in the literature. Following that, the research findings were assessed using the criteria listed above. The documents that satisfied the requirements were chosen and subjected to a second quality assessment, which looked at their structure, techniques, and findings. As a result, certain items were picked for inclusion while others were left out.

Qualitative research and qualitative evaluation resulted in the final selection of nineteen articles that met all the criteria for this work.

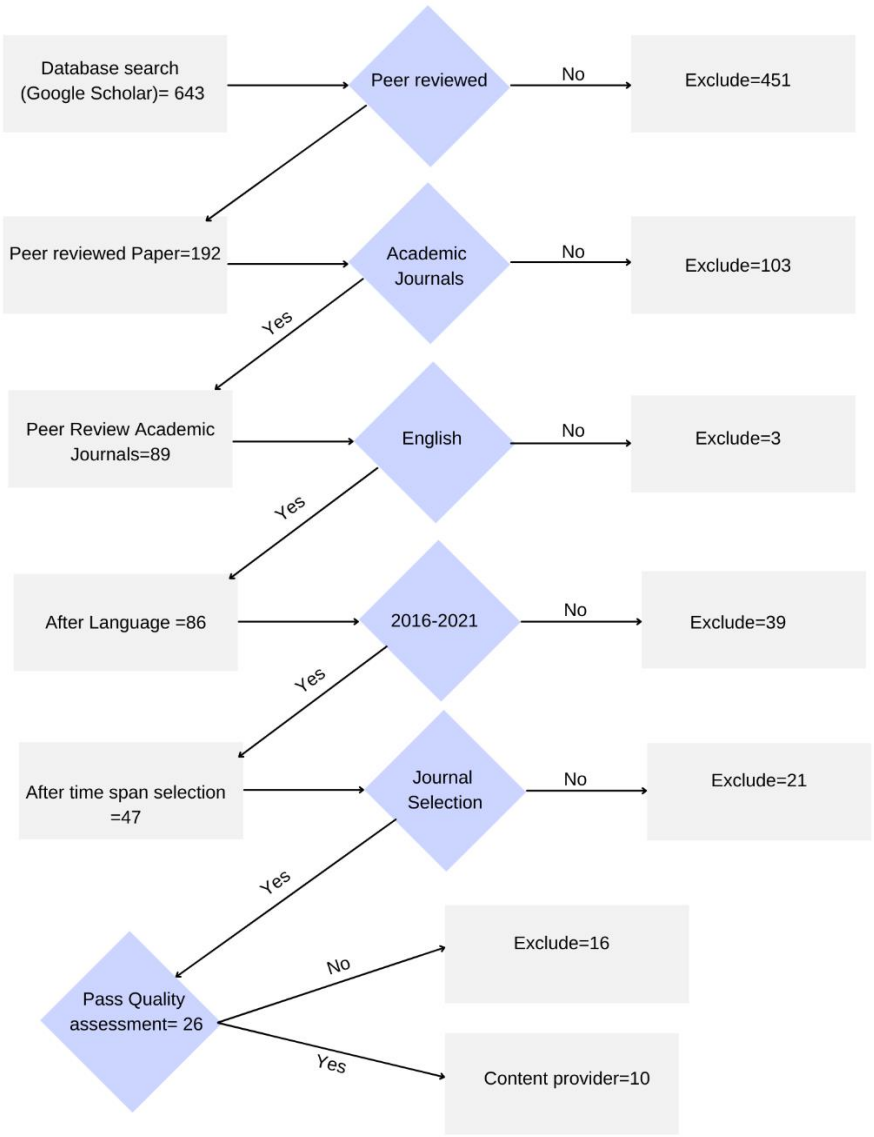

Figure 12 Research methodology with inclusions and exclusions of Quality 4.0 and Human Resources Management

Figure 12 shows the roadmap of the literature survey of Quality 4.0 and Human Resources Management, with the points being selected from the articles used and excluding those that did not meet the criteria, in order to be included in the paper. Peer reviewed, academic journals and English as the written language were used as criteria. According to these criteria, a large number of articles that did not meet them were excluded. Then another key criterion was added, the years of writing the

articles. The period 2016 to 2021 was selected. The last criterion selected was the journals in which the articles are published.

In order to identify key concepts used in the literature, qualitative research was conducted in the study. This was followed by the evaluation of the research results according to the above criteria. The documents that met the criteria were selected and subjected to another quality evaluation, where their structure, methods and conclusions were analyzed. In this way some articles were chosen to be included and some others were excluded.

Qualitative research and qualitative evaluation resulted in the final selection of ten articles that met all the criteria for this work.

Reference	Description	Method used	Sector	Country	Citescore
Gunasekaran et al. 2019	The aim of this special issue to explore the developments in quality management in the era of Industry 4.0.	Literature review	Quality management	USA, United Kingdom, China	12.2
Xu et al. 2020	The current research provides insights for expanding quality management theory using evidence from a meta-analysis that examines the correlations presented in prior empirical studies.	Meta-analysis with a sample of 28 empirical studies spanning a twenty-year period from 1995 to 2015.	Quality management	USA	12.2
Flores et al. 2020	The purpose of this paper is to raise and address an important change for the human capital in the future of Industry 4.0, and to propose a human-focused perspective for companies underneath the new Industrial Revolution.	Literature review	Human Capital 4.0	New Zealand	8.4
Bibby and Dehe 2018	In this study, an assessment model is developed to measure the level of implementation of Industry 4.0 technologies, around three dimensions: 'Factory of the Future', 'People and Culture', and 'Strategy'.	Literature Review and a combination of data collection methods.	Industry 4.0 maturity	UK	8.2
Bakotić and Rogošić 2017	The framework of this research consists of eight quality management (QM) principles according to the ISO 9001 standard.	literature review and empirical research.	Quality management	Croatia	6.2
Sader et al. 2021	This paper suggested a comprehensive, hybrid and balanced definition for Quality 4.0. and identified Quality 4.0 features, technologies, and applications.	Literature Review	Quality 4.0	Hungary	6.2

Para-González et al. 2021	This research empirically examines whether EFQM improves learning ambidexterity as well as promotes incremental and radical innovations.	Literature Review	EFQM	Spain	6.2
Dahlgaard et al. 2019	This study is an extension of the 2013 study, where we extend the previous study on TQM publications to 2017.	Literature review	Total Quality Management	Sweden, China	6.2
Carnerud and Bäckström 2019	The purpose of this paper is to identify and depict the key areas around which research on quality has orbited during the past 37 years.	Data- and text modelling methodology.	Quality management	Sweden	6.2
Lekan et al. 2021	This study was centered on application of intelligent manufacturing in industrial productivity and cost/time wastage.	Literature review	Quality control	Nigeria, South Africa	4.7
Yadav et al. 2020	This paper compares impact of Industry 4.0 on 22 organisational performance indicators under nine combinations of Lean Six Sigma (LSS) and quality management systems (QMS).	Literature survey	Industry 4.0	India	4.3
Antony et al. 2021	The purpose of this study is to examine Quality 4.0, benefits, motivating factors, critical success factors and the skills required by quality professionals in the successful implementation of Quality 4.0.	Qualitative interview approach	Quality 4.0	United Arab Emirates, Ireland, Namibia	4.3
Sony et al. 2020	The purpose of this paper is to investigate the key ingredients for the effective implementation of Quality 4.0.	Literature review	Quality 4.0	Namibia, UK	4.3
Itam and Swetha 2021	The purpose of the study is to examine the structural relationships of employee branding (EB), total quality human resource management (TQHRM) and sustainable employability outcome variables (employee performance, satisfaction and loyalty).	Hypotheses and the structural equation modelling	Total quality human resource management	India	4.3
Balouei Jamkhaneh et al. 2021	This study aims to identify the drivers of human resource empowerment in understanding the new concept of Quality 4.0 in the digital era.	Literature review	Human resources	Iran, France	4.3
Sony et al. 2021	The purpose of this paper is to investigate what are the motivations, barriers and readiness factors for Quality 4.0 implementation.	Literature survey	Quality 4.0	India, UK, Ireland	4.3

Antony et al. 2021	The main purpose of this study is to revisit Dr. Ishikawa's statement: “95% of problems in processes can be accomplished using the seven quality control (QC) tools” from his book “What is Quality Control?”.	Literature review	Quality control	UK, Ireland, Namibia, Brazil	4.3
Dias et al. 2021	While the concept of Quality 4.0 has resulted from these changes, there is still limited understanding and unclear definitions in this new era of Quality Management.	A bibliometric analysis and descriptive/mapping literature review	Quality 4.0	Portugal	4.2
Ranjith et al. 2021	The current study attempts to address the knowledge gap through a literature review and subsequently provide a conceptual framework for quality in the digital transformation context.	Literature review	Quality 4.0	India	4.2
Aquilani et al. 2016	The paper is based on a review of the literature and bridges sustainability, value co-creation, TQM, EM and IMS literature for the first time, proposing a new model of value co-creation processes, which considers it a never ending cycle.	Literature Review and proposition of model based on CSFs to foster sustainability.	Sustainability	Italy	3.9
Fonseca et al. 2021	This research highlights the EFQM 2020 model’s novelties and its relationships/implications with the Industry 4.0 paradigm, contributing to the Quality 4.0 body of knowledge.	A mixed inductive–deductive approach	Quality 4.0	Portugal	3.9
Jankalová and Jankal 2020	The aim of the paper is to identify the Business Excellence dimensions, on the grounds of comparative analysis of selected national quality award models.	Literature review	Business Excellence	Slovakia	3.9
Yadav et al. 2021	This study aims to validates CSF already identified for LSS under conventional technologies.	Empirical research using the questionnaire method	Quality 4.0	India	3.7
Batalden and Foster 2021	The invitation to improve health-care service quality has taken many different forms. In this paper we present three phases of this work.	Literature review	Quality of health-care service	USA,Sweden	3.4
Zonnenshain and Kenett 2020	In this paper, we present a framework for a quality discipline supporting the fourth industrial revolution.	Framework for the quality discipline supporting the fourth Industrial Revolution.	Quality 4.0	Israel	2.8

Ganzarain and Errasti 2016	In this paper we suggest a stage process model to guide and train companies to identify new opportunities for diversification within Industry 4.0.	Collaborative diversification methodology	Industry 4.0	Barcelona	2.5
Negron 2020	This study will evaluate the relationship of the Key QM practices proposed by Ebrahimi and Sadeghi (2013) and will assess the impact of the maturity level in a general way.	Literature survey and use of questionnaire.	Quality management	Peru	2.3
Nenadál 2020	The paper offers a set of original information based on critical analysis of description two last versions of excellence models presented by the European Organisation for Quality Management (EFQM).	Comparative analysis	EFQM Model		2.1
Glykas 2019	The purpose of this paper is to examine the application of quality management systems in the health care sector in the UAE.	Case study	Quality Management	Greece	0.9

Table 5 Literature Survey Table of Quality 4.0 and Operations Management and Human Resources Management

5.3 Critical Success Factors in Quality 4.0 Maturity frameworks

Quality 4.0 is still a relatively recent trend. The restrictions for implementing Quality 4.0 fall into three categories: human resources, organizational, technology and managerial problems. These three categories, while challenging, can also be considered success factors because they combine qualified human resources, good organizational performance during the transition, and the organization's technological readiness to lead to a successful transition from traditional to a Quality 4.0 management system.

Quality 4.0 applications result in higher performance efficiencies due to the automation of quality inspection and analysis activities. High-quality apps necessitate more sophisticated abilities, as well as greater certifications and competencies, in order to comprehend new technology opportunities and how to put them to use. It's also crucial to define what kinds of talents are needed and where they can be found.

Although Quality 4.0 enhances enterprise efficiency, performance, and innovation, many quality teams are still relying on traditional quality management approaches and extremely local problem-solving techniques, rather than Quality 4.0. Quality 4.0 projects have thus far been more IT-led activities than quality-led activities, with a concentration on machines rather than labor. Despite the availability of Big-Data analytics, Internet of Things, Connectivity, and low-cost data collection tools for

acquiring large amounts of data regarding machine performance, there is still a need to measure labor performance (Sader et al. 2021).

In order to make a successful transition from traditional quality management to quality 4.0, the quality team, particularly quality managers, should be fully aware of technologies and their impact on quality, be involved in technological advancement within Industry 4.0, and play a leadership role in the transition. Quality 4.0 cannot be achieved without solid and mature traditional quality management foundations; hence, Quality 4.0 is not a replacement for common quality management concepts, but a capitalization on them.

The technological challenges for Quality 4.0 can be summarized as the company's readiness to begin the transition to Quality 4.0 from both a managerial and technical standpoint, including infrastructure, technology selection, and the type of data gathered and how it can be analyzed and related to one another. Traditional quality procedures, according to Schönreiter (2017), should be examined to see if they are ready for the Quality 4.0 transition and what benefits can be expected (Sader et al. 2021). Successful Quality 4.0 implementation necessitates dependable data sources and powerful analytical tools capable of gathering accurate information, such as customer brand-related social media comments, and imposing the appropriate measures based on such factual data.

Quality 4.0 is impacted by Industry 4.0 core difficulties such as IT security due to increasing networking and a lack of security awareness, network and device reliability, as well as social, technological, scientific, and political challenges.

To overcome such obstacles, businesses must first believe in the promise and benefits of Quality 4.0 for their operations, and then devise a strategy for transitioning from traditional quality management to Quality 4.0 (Sader et al. 2021). This strategy should cover all types of risks and problems, as well as measures for dealing with them. Quality 4.0 technology, such as analytics, data, and networking strategies, have been shown to help organizations achieve increased competitiveness and unique services and products. Companies who overcome the hurdles of Quality 4.0 transformation can gain a competitive advantage, improve customer happiness, and increase overall business performance.

Organizational culture, among other things, is critical to the success of Industry 4.0 deployment. Gender diversity, as well as an inclusive, multi-cultural, multi-racial, collaborative work culture, must improve the quality of the workplace. Furthermore, with a big number of millennials entering the industry, all employees' wants and goals must be met in order to foster a healthy workplace (Ranjith et al. 2021). According to the Quality 4.0 framework, businesses must devote time and effort to cultivating a culture that prioritizes learning, quality, safety, and ethics, among other things.

Organizational processes must be integrated to attain process maturity in the Industry 4.0 and Quality 4.0 contexts. The core of Industry 4.0 is the integration of systems across the enterprise. Vertical, horizontal, and end-to-end integration are the types of integration required, and the integration could be accomplished via Cyber-Physical Systems or Cyber Security Systems.

In contrast to the old centralized decision-making structure, integration enhances Quality 4.0 implementation by moving toward data centralization and decision de-centralization. The quality of integration, in terms of how well it combines multiple data sources, the ability to recognize problems systematically, and the ability to attribute non-conformance causality across functions and systems, is therefore critical to Quality 4.0. End-to-end integration, for example, makes it simple to track problematic materials. Real-time information exchange and rapid responses to changes in product specifications and distribution channels to satisfy customer or market requirements would be enabled by such integration, resulting in improved operational and organizational performance (Ranjith et al. 2021).

Customer focus philosophy, one of the critical success factors of quality, has gotten a lot of attention because of its detrimental impact on innovation. Customer focus principles may trap businesses in captive markets where they are solely focused on serving the requirements of existing clients and hence only see their business through the eyes of those consumers. Change management is a factor witch is connected with customers. It is the process of continuously updating an organization's direction, structure, and capabilities in order to meet the ever-changing needs of external and internal customers.

Information knowledge management has become a phenomenon with far-reaching ramifications for organizational innovation and competitiveness. It's looked at from a variety of angles, including strategy, human resources management, information technology, overall quality management, and marketing. Implementing information knowledge management allows for formulation of relevant performance metrics.

Quality management systems provide a framework for executing corporate social responsibility strategy at all levels of management, laying the groundwork for the creation of sustainable development policies and actions. The combination of focusing on quality at the process level and following the demands of stakeholders is critical for organizational excellence, resulting in a beneficial contribution to society's well-being (Frolova and Lapina 2014).

5.3.1 Quality 4.0 and Technology

Quality management has been greatly benefited by the use of digital technologies. Some examples include the transformation of records into electronic files and databases, the transition to electronic work orders, and documents generated and stored online. The majority of products and services can be controlled through an automated process across the value chain. This can be done by establishing collaborations and communicating with smart factories and machines, in order to take immediate measures to prevent defects, and avoid production and product failures.

The rapid emergence and increasing popularity of information technologies led to the improvement of processes and products quality. Various technologies are supporting these changes, and they are grouped into four main themes: cybernetics (digitization and automation), connectivity, data, and simulation technologies(Dias et al. 2021).

Cybernetics is a topic that concerns systems and their regulation. As the industry increasingly relies on cyber-physical systems, the use of automation and sensors has become a critical part of Q4.0. Cyber-physical systems are considered as vital tools for Q4.0, as they allow the continuous monitoring and analysis of defects in products at any stage of production. The information helps in identifying potential issues and provide a dynamic workplace environment. Improvement of processes can be achieved through the use of process monitoring tools. For instance, robotic process automation (RPA) can help minimize risk and improve the quality of processes. Automating routine processes can reduce operational risk and cost and improve the quality of processes. A comprehensive monitoring system that collects real-time data on a manufacturing process allows for effective and efficient inspection and correction of defects. This eliminates the need for manual work and helps minimize costs.

Quality 4.0 is about *connectivity*. This concept allows organizations to improve their performance through collective decision-making and collaborative problem solving. Connectivity allows superior agility to adapt in a fast way to market trends, to support the reduction of failures and rework, to increase productivity, to optimize the reliability of the devices and to drive innovation. It leads to a network technology that enables users to connect and communicate in various ways. The quality planning and control processes can be linked and share information across the organization's functional areas. This can be done through the transfer of data diagnosis from the shop floor to the decision-makers. The concept of the closed loop manufacturing (CLM) process is a great example of how technology can support improved integration. This process allows manufacturers to continuously collect and share quality data during the manufacturing process. This process allows collecting and sharing quality data during the manufacturing process, while also reducing variability and mitigating risk. New technologies are helping improve the way businesses interact with their customers. This is another example of how new practices can enhance existing ones. For example, through Virtual Customer Integration (VCI), customers can provide their insights on new product design. This process helps minimize the risks involved in the launch of a new product, as it helps customer needs to be recognized more precisely. With increased connectivity, it is possible to improve the quality of products and services through continuous monitoring and feedback. Each step of the order process is redesigned to guarantee a closer relationship with the customer. This is achieved through the use of real-time monitoring and tracking. Continuous monitoring of the customer's involvement in the manufacturing process is key to the continuous improvement of Q4.0. The reinforcement of quality and customer service are key factors that businesses can rely on to improve their efficiency and profitability. In order to meet the expectations of the new Quality era, an organization must increase the speed of its production and development processes. This requires the use of data collected and analyzed in order to achieve this goal.

Quality 4.0 is about how technology allows *data* to be used in new and insightful ways, to help organizations improve processes and support quality operations while reducing time. The true benefit of data is the ability to continuously ensure superior performance in an organization. The discussion about data in Q4.0 is focused on two main issues: the quality of data and the ability to extract value from it, and the use of data to enhance traditional quality tools and methods(Dias et al. 2021). Data

management is an integral part of any organization's operations, and it is done with the proper diligence and attention to avoid unwanted consequences, based on the analysis of personal data. Organizations must build a data management strategy to address the various pain points across various functions and to maximize the quality of their data and to involve the proper analysis and collection of analytical methods. Data quality methods are becoming more important as the volume of data they handle increases. As an example, Bossert suggests that Six Sigma methodologies should be integrated with new technologies must support the use of Big Data and expanded with the use of predictive analysis and multivariate analysis(Dias et al. 2021). The combination of high-quality data and traditional quality techniques has the potential to provide advanced analytical capabilities. There are four types of data analysis: descriptive, diagnostic, predictive, and prescriptive. The former uses data to outline what happened or is already happening, while the latter uses data to identify causal relationships and root causes. Predictive analysis techniques are used to predict and understand the future and prescriptive techniques help in making decisions based on past performance. Quality 4.0 allows for the integration of various analytical techniques. An example of a descriptive, predictive, and prescriptive analytics application is the Digital Lean Manufacturing (DLM). The DLM system uses advanced data acquisition and processing capabilities to detect and prevent quality issues.

A *simulation* program is a tool used to assess the performance of various design products and processes. Simulation models provide clear opportunities for improvement in quality and performance. They can be used to check the quality of work throughout the entire process. The models help organizations minimize the time between the design and production of products. Digital twins are virtual systems that are synchronized to a real physical system and constitute an example of simulation capabilities that are brought forth by technological solutions(Dias et al. 2021). Digital twins allow organizations to experiment with virtual reality through the influence of various external and internal inputs. It helps organizations achieve better decision making, maximum efficiency and reduce costs. It also reduces unproductive working times and lower-quality products and services.

5.3.2 Quality 4.0 and People

The most crucial feature of Quality 4.0 is the human element. Although some clerical or repetitive human jobs can be automated, not all functions can. The goal of the first Industrial Revolution was to mechanize intensive human labor in order to increase productivity. Humans were not designed to be replaced by mechanization technology, but rather to be aided by them. The emerging technologies that define Industry 4.0 share this goal, as well as other features like large-scale automation and sustainability.

Human factors account for five of the eight key criteria for Quality 4.0 achievement. The best predictors of organizational effectiveness are people and leadership behaviors. This emphasizes the significance of the human element in Quality 4.0. People are mostly responsible for quality procedures and judgments. Certain quality

functions and judgments may be semi-automated or totally automated in the future, depending on data availability. Quality 4.0 becomes particularly relevant in this interactional framework. Leadership, Culture, and Competency have been highlighted as critical characteristics that connect People and Quality 4.0 (Ranjith et al. 2021).

As for leadership, senior management commitment has always been a vital success factor for implementing any quality practice, and Quality 4.0 is no exception. Digital transformation of the company is the path to Industry 4.0 and Quality 4.0. The ability to anticipate the transformation and guide the organization through it becomes critical in this situation. While managers are expected to lead, the topic of this discussion is not immediately related to process management, but it is vital in bringing about change for digital transformation.

Organizational and external situational restrictions influence leadership style. Both transformative and transactional leadership are needed at different levels and coexist. Transactional leadership, for example, assures compliance while transformational leadership encourages involvement, nonetheless, a blend of the two approaches is best for fostering an innovative culture (Ranjith et al. 2021). Traditional leadership is still important, but the dynamic nature of change necessitates more abilities and behaviors for leaders at all levels of the business, and Industry 4.0 necessitates more than transformational leadership.

Because of their ability to lead organizational learning, quality professionals are well-suited to lead digital transformation. Quality managers can play a key role in enabling change and transformation by aligning the organization's vision and ensuring that the dimensions of people, process, and technology all work together to achieve that common goal, based on a thorough understanding of the technologies and their capabilities, as well as the requisite competencies, risk landscape, and customer requirements (Ranjith et al. 2021).

Conducive leadership fosters a desire to adopt a high-quality culture. Culture and leadership are inextricably intertwined, with good leadership nurturing a strong culture and this culture developing good leaders.

Leadership has a significant impact on culture, and culture has a significant impact on leadership. Bass and Avolio's (1994) study demonstrates how different mixtures of transformational and transactional leadership lead to distinct sorts of organizational cultures (Ranjith et al. 2021). The role of culture in the effective adoption of Quality 4.0 has received a lot of attention. Quality management outcomes are influenced by national cultures as well. Much Industry 4.0 research has concentrated on the technological rather than the human aspects.

Acceptance and transparency are two key characteristics of culture that are required for Quality 4.0 maturity (Ranjith et al. 2021). As for acceptance the reality of Cyber-Physical Systems is machine–human interaction, and the stronger the synergy, the better the outcome. It is critical that individuals in the organization see technology and change as allies rather than enemies in accomplishing corporate goals. The Quality 4.0 acceptance and the innovations that result are critical to the successful implementation of Quality 4.0. Acceptance of new industry by users’ operators' use of

4.0 technologies is a critical component of job quality and well-being. Although older staff may struggle to adapt to new technology and systems, they are given ways to manage the cultural impact and user approval.

The increase in the amount of data across all processes, according to transparency, can be scary at times, but the necessity of this must be explained to all stakeholders. Improving openness and trust contributes to the development of an innovative culture, which is critical for a Quality 4.0 firm. Governance is aided by transparency, as well as training and learning. For fear of being penalized, errors or non-conformances are frequently not recorded. The quality of data gathering and, as a result, the quality of processes can only be improved if the culture does not penalize a person for non-conformance and transparency is fostered.

Skill refers to the knowledge or ability to accomplish a task that has been acquired via education or experience. Competency refers to the knowledge, abilities, skills, and behaviors required for job success. The entrance of Industry 4.0 has also resulted in a shift in the talent hiring market. Organizations look for people with certain skillsets and abilities in addition to qualifications.

Organizations may confront technological and/or behavioral hurdles in aligning with Quality 4.0 objectives. While employees may be familiar with the organization's processes, the introduction of new technology and process integration necessitates the acquisition of new skills. Although companies may hire for specific skills and abilities, they must also be trained and educated on key business processes. People can be trained at a variety of levels to ensure that everyone understands the business, processes, and technology. There are proposed strategies to address this problem by providing generic and specialized training at several levels. In addition to having a varied workforce, establishing organizational flexibility entails upskilling, reskilling, and multi-skilling (Ranjith et al. 2021).

5.4 Four perspectives in Quality 4.0 maturity frameworks

5.4.1 Total Quality Management

Total Quality Management (TQM) is a collective system of quality practices that are linked to organizational performance (Jehangiri 2017). Total quality management is a process that can help managers improve their organizations' performance and their client’s satisfaction. This concept has become widely accepted in the workplace. The TQM system consists of four practices of management that are focused on assessing the quality of processes and human resources. Management of process quality, human resources management, strategic quality planning, and information and analysis. An integrated TQM combines seven facets in order to be composite. These include top management commitment, quality measurement and benchmarking, process management, product design, employee training and empowerment, supplier quality management and customer involvement and satisfaction. (Xu et al. 2020).

Total Quality Management has commonly been discussed due to its reasons of implementation failures. Successful implementation of TQM is achieved through identified *critical success factors* (CSFs). There are several CSFs such as human resources, process management, leadership, process management, customer focus, information analysis, strategic planning, culture, social responsibility and supplier partnership (Hietschold et al. 2014). Continuous improvement and performance measurement are two key CSFs that highlight the need for change management and should be managed throughout the entire process of TQM (Aquilani et al. 2016).

Employees should participate in the company according to training and education, in order to maximize TQM success (Dahlgaard et al. 2019). The need for continuous adjustment of the Quality Management (QM) maturity frameworks is highlighted to approach QM with better techniques. Quality Management and organizational resources should have more links because of indications of a disconnection between the three levels of management (strategic, tactical, and operational).

The implementation of TQM requires a major transformation in an organization's culture, processes, and strategic priorities. Critical success factors and the above elements are influenced by processes such as employment continuity, management leadership for quality, teamwork, education, and training.

In a study conducted in 2021, the authors identified the CSFs of Six Sigma QM methodology implementation (the DMAIC and DMADV methodologies) (Yadav et al. 2021). They highlight that availability of resources is the second most important CSF for lean six sigma implementation, the importance of software applications of resources and the use of any experience that is necessary to successfully implement change management programs and projects, such as ISO Standards.

Implementation of ISO 9001 standard has two fundamental categories of CSFs, infrastructure, and core. There have been identified four infrastructure practices: customer, leadership, employee, supplier relationships and four core practices: process, system approach, continual improvement, factual decision making. (Bakotić and Rogošić 2017).

In 2021, Para-Gonzalez et al. have developed a model for the European Foundation for Quality Management (EFQM) that helps organizations improve their QM maturity practices (Para-González et al. 2021).They have identified nine practices, namely: Leadership, Strategy, Personnel, Alliances, Processes, People, Customers, Society, Key Performance.

5.4.2 Lean Six Sigma in Quality 4.0 Continuous Improvement

Six Sigma is identified as a process improvement strategy that is used for raising a company's profits. It eliminates waste for lowers costs and improves the efficiency of all its processes in order to achieve higher customer satisfaction(Jehangiri 2017).

Six Sigma is the use of many statistical data analysis tools to reduce and control variation in a process so that the process can consistently meet its target (Yadav et al. 2021a). Sigma (or standard deviation) is a measure of variability of a particular

characteristic that requires control. The properties of Normal distribution indicate that a Six Sigma level process help in controlling the variation within the allowed limits. It can help in improving the quality of the product or service, reducing the cost of poor quality, and increasing the stakeholder value.

Six Sigma is a framework for implementing quality management in organizations. It started as a measure of defects where the higher the number of defects the greater the sigma number. DMADV (Define Measure Analyze Design Verify) and DMAIC (Define Measure Analyze Improve Control) are two methodologies used in Six Sigma. The first three phases (Definition, Measurement, Analysis) are common and there is a difference in the last two phases due to implementation. At the end of the DMAIC phase there is an implementation plan for the full development application that is provided during the improvement phase. During the DMAIC control phase the alignment between the implementation plan and the actual implementation is examined. During the last two phases of DMADV in the design phase, a test implementation is designed in a small-scale project that is verified during the verification phase. This cycle (planning, verification) continues several times until there is certainty that the end result is satisfactory. The Design and Verification cycle is then used for full-scale implementation.

Define refers to the process of defining the project's objectives. This step's goal is to define the business problem, goal, potential resources, project scope, and high-level project timeline. The goal is to ensure that customer demand and the organization's strategic goals are in sync. Typically, businesses create a roadmap to achieve the organization's targets and goals. The aim of measure is to launch improvement baselines and initiatives objectively. For evaluating business performance, performance measurement and management techniques are used. Analyzing purpose is to identify, validate, and select root causes for elimination. This phase is critical for determining any inconsistencies that may exist between business goals and organizational performance. Analysis techniques are used to identify bottlenecks, cycle time issues, process or output defects, and so on. The goal of improve is to find, test, and implement improvement projects. Brainstorming and approaches such as *Six Thinking Hats* and *Random Word* may aid in the identification of creative ideas to eliminate the primary root causes of process difficulties. Various implementation activities are planned and managed through project planning and management. The project plans created in the preceding phase are implemented in a synchronous manner at control phase. To ensure long-term success, improvements are tracked and controlled. During this step, it is be building a control plan to ensure that update papers, business processes, and training records are properly versioned (Glykas 2019).

Lean six sigma (LSS) is a combination of Six Sigma and lean. According to Figure 13 techniques and objectives of Lean Management and Six Sigma are common.

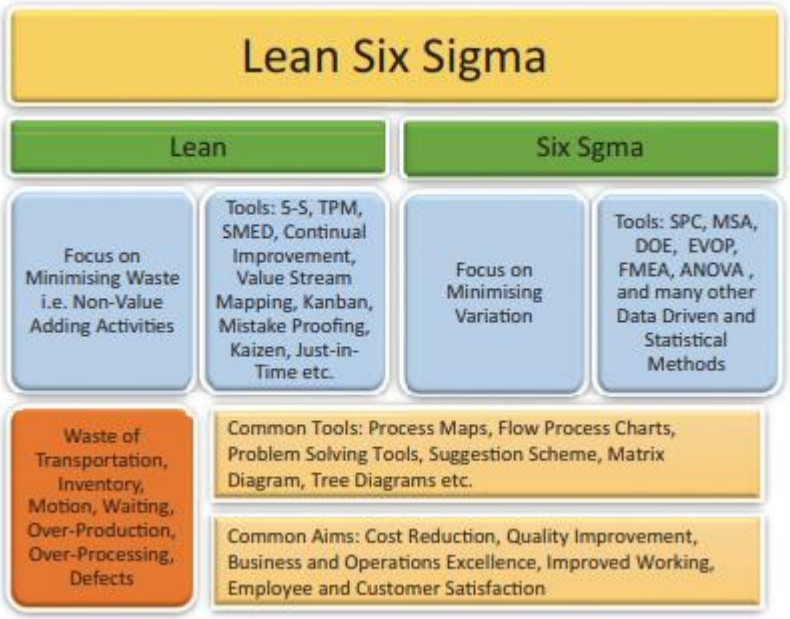

Figure 13 Lean Six Sigma (Yadav et al. 2021b)

Lean management focuses on methodologies that eliminating non-value-adding activities. According to the term Lean, wastes that not needed are not keeping. Figure 13 shows important tools used for this process. Due to their common objectives these concepts are used togethers as LSS. Its implementation is not easy and often requires the involvement of various levels of expertise.

Lean six sigma is an extension of DMAIC and DMADV and its definition strives to minimize waste and idle time in the service provision, production, and supply chain while offering perfect goods and services. Transportation, inventory, motion, waiting, overproduction, overprocessing, and defects are the *seven wastes* that must be eliminated in order for an organization to achieve Lean Six Sigma(Glykas 2019).

The concept of Quality 4.0 emerged from the combination of Industry 4.0 and traditional quality practices. Today's operations rely on various technologies such as automation and data processing to improve their quality control and overall operations. The quality interface of technology and operations is dependent on many factors such as an organization's culture, external service providers' role, and the requirements of the customers. The concept of Q4.0 is still evolving, but the influence of it on LSS is widely known. Data management tools such as Big-Data and Cloud Computing can help implement the various requirements of LSS.

The potential of Lean Manufacturing to integrate into I4.0 has been debated. LSS various applications have been studied to see how they can be utilized to extract valuable insights from Big Data. The Industrial Revolution is a process that has undergone a major change due to the emergence of new technologies. One of these is the use of sensors. This revolution allows for the collection of vast amounts of data and enables businesses to develop more sophisticated analytics. Every LSS project follows DMAIC. It is used to identify and solve any kind of problem that can be reinforced through the use of Industry 4.0 tools.

I4.0 enables faster, better, and more accurate planning of production plans, while also allowing the use of self-optimizing strategies. LSS has the latest features and intelligent algorithms that make it stand out. Advanced analytics allows to improve the performance of LSS projects by analyzing the data collected during the course of the project. It allows to identify the root causes of the process deviations and to remove them from the system. I4.0 helps in accelerating the collection of data and in removing human error. It also helps in improving the efficiency of the operations by implementing LSS processes. LSS offers some *quantitative* tools (Hypothesis Tests, Correlation Matrix, Regression Models) and some *qualitative* tools (5Whys, Fishbone) are able to describe in depth the process(Yadav et al. 2020).

5.4.3 The EFQM 2020 Model

According to Fonseca and Amaral the concept of excellence has been alive within the business and academic world, and business excellence models (BEMs) have been proposed as assessment frameworks for organizational excellence (Fonseca et al. 2021). The adoption of BEM can help improve various aspects of an organization, such as employee satisfaction, operational improvement, and profitability.

From the several available BEMs, the Malcolm Baldrige National Quality Award (MBNQA) from the USA, first granted in 1989, and the European Foundation for Quality Management (EFQM) Excellence Award, awarded for the first time in 1992, have been recognized worldwide has the most influential ones(Fonseca et al. 2021).

The EFQM model was first introduced in 1991 to help organizations improve their performance and achieve business sustainability. It is frequently updated to reflect the latest business environment trends and dynamics. EFQM 2013 model is presented in Figure 14.

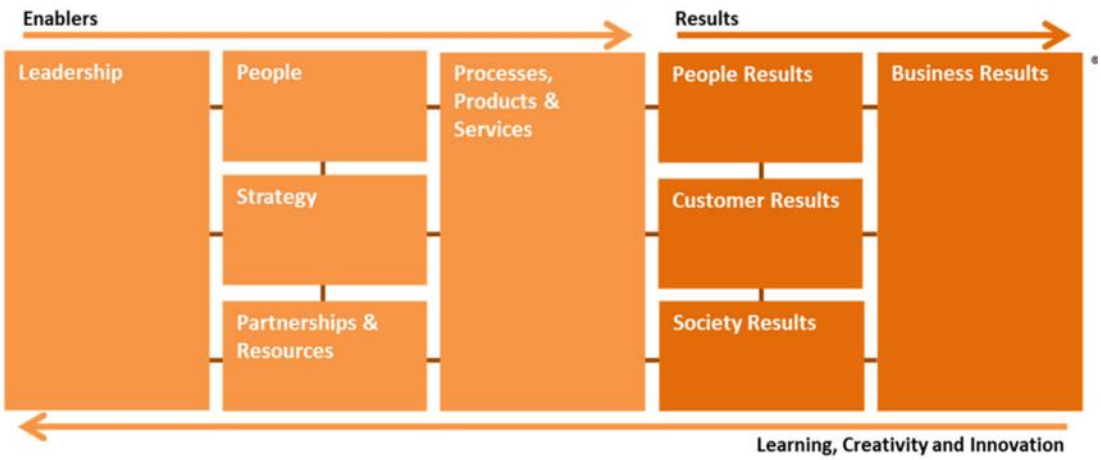

Figure 14 The European Foundation for Quality Management (EFQM) 2013 model (EFQM, 2012)(Fonseca et al. 2021).

The EFQM Excellence Award is a set of performance criteria that fall into two broad categories: performance and results. In results category, the organizational performance is examined from the point of view of the final production results. For example, people are examined the achievements of employees in terms of sales, percentages of defects, etc. In performance category is examined the existence of the necessary organizational elements that will allow employees to perform well. For example, at HRM the experience of performance measurement systems, training and education, rewards and motivations and career paths.

The concept of the novel EFQM 2020 model was conceptualized during the EFQM 2019 co-creation process. EFQM 2019 was included a wide range of EFQM stakeholders, from business and academia. The literature review of the 2020 edition of the EFQM model revealed a scarcity of papers on the novel model. This prompted the analysis of the papers covering the previous editions of the model.

Figure 15 The EFQM 2020 model (EFQM, 2020)(Fonseca et al. 2021).

The EFQM 2020 model calls for a new approach to manage change and operations that can improve both the agility and performance of organizations. It also framed in the United Nations Sustainable Development Goals (SDGs) and European business ethics values.

The EFQM 2020 model presents a conceptual framework that consists of three dimensions: direction (why), execution (how), and results (what). It has seven criteria (and twenty-three criterion parts, plus two results Criteria) and a robust assessment tool called the RADAR (Result, Approach, Deploy, Assess, and Refine).

The EFQM 2013 and 2020 models were compared based on their sub-criteria and the keywords used in their descriptions. Both the 2013 and 2020 models have specific guidance points that support their sub-criteria. For 2013 model total of 119 guidance points and for 2020 model total of 112 guidance points. The results of the analysis reveal that the core criteria that make up the EFQM 2020 model are more influential than those derived from the 2013 model. Those are Leadership, Strategy, Product Process and Services, and Business Results. The criteria from the EFQM 2020 model that have a stronger adoption of guidance points from the EFQM 2013 model are Purpose, Vision and Strategy, and Organizational Culture and Leadership.

	EFQM 2020	EFQM 2013
Criterion	1. Purpose, Vision & Strategy	1. Leadership
		2. Strategy
	2. Organisational Culture & Leadership	2. Strategy
	3. Engaging Stakeholders	3. People
		4. Partnerships & Resources
	4. Creating Sustainable Value	5. Processes, Products and Services
	5. Driving Performance & Transformation	4. Partnerships & Resources
	6. Stakeholder Perceptions	6. Customer Results
		7. People Results
		8. Society Results
	7. Strategic & Operational Performance	9. Business Results
Criterion parts	23 Criterion Parts and 2 Results Criterion	32 Criterion parts
Criteria weightings	600 points for Direction and Execution and 400 points for Results	500 points for Enablers and 500 points for Results

Table 6 EFQM 2020 and EFQM 2013 comparison (Fonseca et al. 2021).

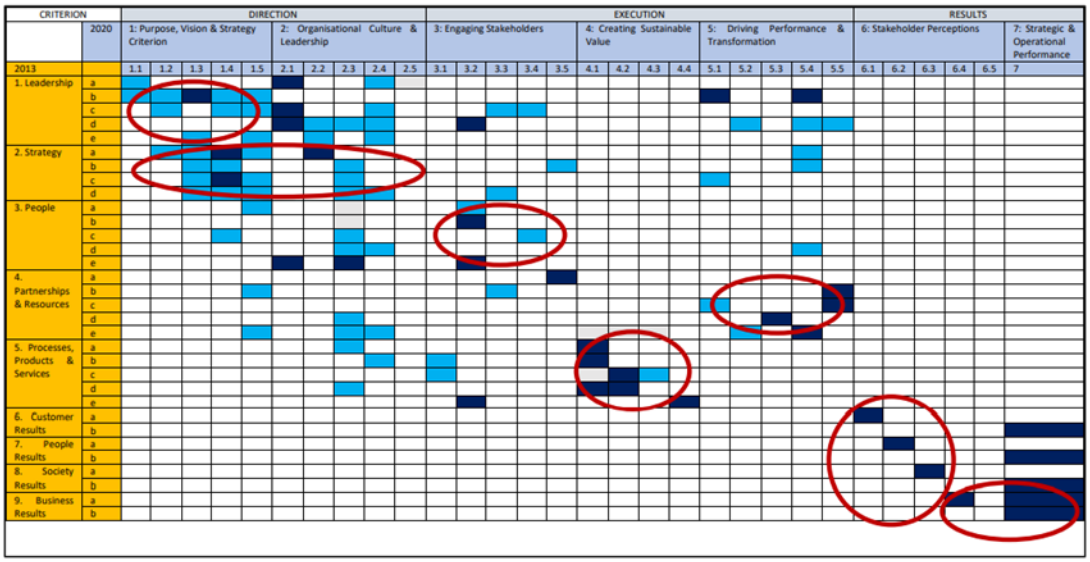

Figure 16 EFQM 2013 versus EFQM 2020(Fonseca et al. 2021)

	High Correlation between Sub-Criteria
	Medium correlation between sub-criteria
	No correlation between sub-criteria

Table 7 Legend for Figure 8 (Fonseca et al. 2021)

According to Figure 16 the content analysis of the EFQM 2013 and EFQM 2020 criterion 1a. describes the role that leaders develop, being role models, about the mission, vision, values, and ethics. Guidance points 2 states that leaders in excellent organizations are role models for ethical behavior and integrity, to enhance the organization's reputation. One of the criteria mentioned in the 2020 edition of EFQM is *2.1 Steer the Organization's Culture & Nurture Values*. This refers to the organization's commitment to its values, which are translated into desired norms and behaviors and identifies, promotes, and recognizes other role models.

The 2020 EFQM model is positioned to organizations that are focused on sustainable value creation. The model considers five key concepts: Culture, Leadership, Transformation & Performance, Flexibility & Adaptation, and Focus on the Future. Performance and risk assessments should be performed regularly to identify opportunities and formulate strategies that can prepare for the future. The model construct of the EFQM 2020 has been changed from its previous of 2013, from nine criteria to seven. The model now has 25 sub-criteria, which are more flexible and with less bureaucracy.

Figure 16 highlights that 2020 model criteria are affected significantly from strategy and business results 2013 model criteria. At 2013 model the People criterion (3) is not related to the 2020 model criterion and is widely used across various criteria of the EFQM 2020 model. Criteria have people as the critical organizational stakeholder: criterion 1.1 (Purpose and Vision should inspire all the organization decisions and its People), criterion 1.2 (Identification & Understanding of Stakeholder needs, including

People), criterion 2.1–2.4 (creation of the desired work environment for People), criterion 3.2 (People—Attract, Involve, Develop and Retain), criterion 6 (Perception of Stakeholders, including People) and criterion 7(Measure other aspects of performance in people management)(Fonseca et al. 2021). There is a lack of standard guidelines for people management. This is mainly related to developing people's skills and abilities, as well as motivating them to reach their potential.

Although process management is not explicitly mentioned in the EFQM 2020 model, the following criteria are often used to describe processes: 1.4 (Develop Strategy), 1.5 (Design and Implement a Governance and Performance Management System), and 5.1 (Drive Performance and Manage Risk).

Harnessing Creativity & Innovation at model 2013 was covered in 1.e (flexibility and change management), 2d (Guidance point to set clear goals for innovation), 3.c (guidance point on innovation scope and creativity and innovation culture), and 4.e (guidance point on managing learning and collaboration networks). Creativity and innovation are specifically addressed in criteria 2.3 (Enable Creativity and Innovation, with six guidance points) and 5.3 (Drive Innovation & Utilize Technology, with five guidance points), emphasizing these two critical success factors(Fonseca et al. 2021).

According to Jankalová and Jankal 2020 excellence has a relationship with sustainability (Jankalová and Jankal 2020). The EFQM 2013 model highlighted the importance of integrating the concepts of sustainable development into the core strategy, value chain, and process design. The concept of People, Planet and Profit is considered a reference and assumes that an organization will follow the guidelines of the UN Global Compact. Sustainability is at the core of the EFQM 2020 model. This framework links the organization's purpose and strategy to its alignment with the United Nations Sustainable Development Goals (SDGs). The SDGs aim to achieve balanced and sustainable development. The SDGs are incorporated into criteria 1.3 (Understand the Ecosystem, Own Capabilities & Major Challenges) and 6 (Stakeholder Perceptions). Furthermore, sustainable levels of performance, a sustainable future, and sustainable value are further addressed in criteria 1.1, 2.1, 3.1, 3.5, 4.3, 5.1, 5.2, 5.4, 5.5, 6, and 7 (Fonseca et al. 2021). The concept of the EFQM 2020, with the incorporation of the SDGs, is to deliver continuous improvement and transformation while simultaneously addressing the needs of the organization's stakeholders.

Business models are defined as the activities that an organization does to execute its strategy. While the new EFQM 2020 model emphasizes the importance of having a strategy and communicating it to the various stakeholder groups, it doesn’t cover the various critical dimensions of a business model e.g., how to link strategy for operationalization; how to communicate the strategy; how to prioritize and manage different stakeholders’ expectations; and how to manage competency and skills development which will be critical towards ensuring a smooth transition throughout the business’s digital transformation (Fonseca et al. 2021).

5.4.4 ISO 9004 maturity model for quality in industry 4.0

A standard is a document that provides requirements, specifications, guidelines, or characteristics that can be used consistently to ensure that materials, products, processes, and services are fit for their purpose (Piergiovanni et al. 2021). International Standards bring technological, economic, and societal benefits. They help to streamline the process of international trade and provide consumers with assurance that their products are safe and technical efficient.

Although Industry 4.0 is widely believed to improve processes and innovation, most companies are not aware of their current maturity level. Since many considerations, related with quality management system, are involved in achieving successfulness in Industry 4.0, this paper considers the importance of ISO 9004:2018 maintaining a sustained success in maturity level assessment of quality. ISO 9000 family principles are customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, actual approach to decision making and mutually beneficial supplier relationships. ISO 9004 focuses on how to make a quality management system more efficient and effective.

The ISO 9004:2018 standard provides a roadmap for an organization's long-term performance in a complex, demanding, and ever-changing environment. A company's long-term success is dependent on its capacity to meet the demands and expectations of customers and other interested parties in a balanced and long-term manner. ISO 9004 was not created for certification reasons, although it does provide a self-assessment tool that can be used to determine the level of maturity of a company's quality management system, as well as identify and prioritize areas for improvement. If effectively executed, it should ease the transition to a full Total Quality Management (TQM) program, which necessitates significant organizational transformation as well as a culture of strong, committed, and supportive leadership and management.

Before implementing Industry 4.0 strategies, companies should first understand their current digital transformation maturity. In line with this, De Carolis et al. (2017) propose a model as a ground for the companies' digital maturity investigation, based on the principles of the CMMI (Capability Maturity Model Integration). They determined 5 areas of key processes: design and engineering, production management, quality management, maintenance management and logistics management (Glogovac et al. 2020). In 2016, Ganzarain and Errasti suggested a three-stage process model to identify opportunities in the area of Industry 4.0 (Ganzarain and Errasti 2016). For their study, Dehe and Bibby developed a model and assessed the level of Industry 4.0 implementation in three dimensions: factory of the future, people and culture, and strategy(Bibby and Dehe 2018). According to them, Industry 4.0 is the process of digitally transforming manufacturing. Schumacher et al. (2016) identify a strategy, leadership, customers, products, operations, culture, people, governance and technology as determinants of the maturity of the Industry 4.0 concepts within organizations (Schumacher et al. 2016). According to the above it seems that many elements of Quality Management System (QMS) are included to Industry 4.0 successfulness elements.

The standard recommends developing an organization measurement process as a tool for evaluating the degree of achievement of targeted results and performance at all levels of the organization. In ISO 9004:2018, the theme of improvement is articulated and affects both tangible and intangible aspects of the organization. The standard, in fact, applies not only to products and processes, but also to organizational structure, management system, human and cultural aspects, infrastructures, the environment, and stakeholder relations.

According to the standard, it is preferable for the logic of continuous improvement to become ingrained in the organization's culture, and for a genuine improvement-oriented process to be created, actively including all employees. People should be appreciated, encouraged to participate in improvement activities, and to propose ideas in a *mature* organization, in this sense, the standard emphasizes learning as the foundation for effective and efficient improvement and innovation processes(Bravi and Murmura 2021).

The concepts and elements of the QMS that are covered by the ISO 9004:2018 model could be used to evaluate the level of quality maturity within Industry 4.0. Consideration of various elements of Industry 4.0 is used as a way for conversations about the maturity of Quality 4.0, instead of just focusing on the QMS.

The elements of QMS that are covered by the standard ISO 9004:2018 are used as a basis for assessing the level of quality maturity in Industry 4.0. They were used by be putting into the context of Industry 4.0, in order to demonstrate that standard is the model for assessing the maturity level of Quality 4.0. Most companies do not have the necessary expertise or the capability to assess their Industry 4.0 maturity level, so it is necessary to have affirmed guidance on evaluating it. Even though ISO 9004 focuses on management, there is a lack of research on it. A maturity assessment model is a framework that can be used for a sustainability system development in Quality 4.0. ISO 9004:2018 is a set of requirements that were developed for quality management, and it represents a maturity model of QMS. It is structured according to a globally used model, ISO 9001:2015.

Standard ISO 9004:2018 provides a framework for assessing the quality management system's maturity. It gives organizations guidance to achieve sustained success and provides them a simple maturity evaluation tool. Many companies that have applied for ISO 9004 have noticed the various advantages it brings. It helps them identify and implement best practices in their operations and achieve sustainability. This international standard aims at continuously improving the profitability of organizations regardless of size, type, and activity.

This standard focuses on analyzing the maturity of the organization's processes as a whole in terms of attaining long-term success and includes instruments for assessing process maturity. Six primary (top-level) organizational maturity elements are assumed in the standard. These characteristics include an organization, leadership, process management, resource management, analysis and evaluation of an organization’s performance, improvement, learning and innovation(Dorrer 2019).

5.5 The Need for an Integrated-Holistic Framework

Carnerud and Bäckström at 2019 to their study revealed seven main topics: 1. service quality and customer satisfaction; 2. process design and control; 3. (International Organization for Standardization) ISO certification and standards; 4. TQM implementation, performance, and culture; 5. QM practices and performance; 6. reliability, costs, failure, and problems; and 7. excellence, quality awards (Carnerud and Bäckström 2019).

Quality Management is classifying in four different perspectives. The implementation of Total Quality Management which is focused on company's organizational performance and culture. It is related with the topic 4, TQM implementation, performance, and culture. Quality Management methodologies according to the principles of process design and control. Methodologies are based on QM implementation practices and performance and related with topics 2,5 and 6, process design and control, QM practices and performance, reliability, costs, failure, and problems. Quality Management standards, based on topic 3 ISO certification and standards. Quality Management excellence awards related with topic 7, excellence, quality awards. A study conducted in 2019 by Gunasekaran et al. focused on two perspectives, TQM and Methodologies. It pointed the lack of empirical research on the role of HR and new technologies in QM (Gunasekaran et al. 2019).

A survey was conducted in 2020 by Negron for all the identified projects and efforts related to QM implementation maturity assessment. He provided and highlighted two important distinctions of CSFs-practices. Infrastructure Practices which are strategy, human resources, leadership and supplier quality and core practices which are process, information analysis and customer. Those two practices contribute to achieving operational performance. Negron noted that an integrated approach to QM maturity should involve multiple phases and multiple QM perspectives, such as TQM, Six Sigma, Standards and Excellence Awards (Negron 2020).

6. Maturity model proposition

The importance of assessing a company's maturity in Quality Management has been advocated a lot. There have been proposed five categories of analyzing an organization's QM maturity (Negron 2020). The five categories are management understanding, management attitude, quality organization status, problem handling, cost of quality as percentage Maturity Grid (QMMG). They are connecting with six measurement categories, uncertainty, awakening, enlightenment, wisdom, certainty of sales, improvement actions and company quality posture.

6.1 A Proposal for a Holistic-Integrated QM Maturity Assessment Framework

The Glykas Quality Compass (GQC) is a maturity analysis model and its enablers are identified based on the results and findings conducted from Carnerud and Bäckström 2019, Gunasekaran et al. 2019 and Metaxas and Koulouriotis 2019. According to the surveys a comprehensive QM Maturity Assessment should encompass four distinct categories: Total Quality Management Philosophies, Quality Methodologies, Quality Standards and Excellence awards (Glykas 2019).

The definition of philosophy is *the academic discipline concerned with making explicit the nature and significance of ordinary and scientific beliefs and investigating the intelligibility of concepts through rational argument concerning their presuppositions, implications, and interrelationships*(Glykas 2019). It is related with the rational investigation of the nature and structure of reality (metaphysics), the resources and limits of knowledge (epistemology), the principles and import of moralism (ethics), and the relationship between language and reality (semantics). For decades, most organizations have placed a premium on leadership and management.

Methodology is an *actual or mental structure designed to serve as a support or guide for the building, or anything that develops the structure into something useful*(Glykas 2019). PDCA cycle, EFQM model, and Six Sigma are GQC quality management approaches or frameworks for quality management improvement. The Plan – Do – Check – Act (PDCA) cycle is the most well-known methodology for continuous quality improvement and is used in quality management with its variations: DMAIC and DMADV used in Six Sigma. The EFQM Excellence Model is identified as a framework, for Quality Management that can be operated as a diagnostic tool in order to attain excellence in a business (Fonseca et al. 2021). Six Sigma was created with a focus to reduce or eliminate the causes of defects and deficiencies in manufacturing and service processes(Glykas 2019).

According to the GQC Category of quality standards, a standard is a document that offers rules, specifications, guidelines, or characteristics that may be used regularly to verify that materials, products, processes, and services are fit for their purpose (Glykas 2019). The International Organization for Standardization (ISO) is the most well-known quality standard. It establishes quality requirements that a company must satisfy in order to be certified as meeting international quality standards.

Excellence awards are given to companies who have demonstrated exceptional performance in quality management by achieving excellence in internal processes and systems, as well as offering high-quality products and services. The award may also be given to a firm for its remarkable contribution to environmental sustainability initiatives. MalcomBaldrige National Quality Award, The Deming Prize, European Quality Award (EFQM), and Canadian Award for Business Excellence are some of the world's most prestigious excellence awards(Glykas 2019).

The concept of GQC incorporates ten CSFs that belong to three different categories. Those are five core concepts, three intra-core concepts and two auxiliary concepts. (Glykas 2019). The five core CSFs are classified to customer, human resource management, leadership, process, strategic. The three intra-core CSFs are performance measurement, change management, continuous improvement. The auxiliary CSFs are classified to information-Knowledge management, partnership, Social Responsibility and Stakeholders' value.

According with the Negron 2020 guidelines, there are also relationships among the ten core CSFs. The three intra-core CSFs are focused on the five identified core CSFs. The three intra-core CSFs (performance measurement, change management and continuous improvement) are applicable to each one of the five identified core CSFs (Negron 2020). For instance, performance measurement and continuous improvement intra-core CSFs in the strategy focus are evaluated along with the success of implementing the core CSFs. There is success of the auxiliary CSF partnerships, social responsibility, and stakeholders' value in the five core CSFs: customer, strategic, process, leadership, and human resources.

The link between QM maturity assessment CSFs and core management principles has been the subject of various studies. In order to achieve the goals of the ten CSFs, the four management principles are regarded as necessary at GQC.

In this context, researchers often advocate the existence of various organizational resources in order to enable the achievement of certain identified CSFs. GQC identify as key organizational resources Land and Buildings, Equipment, Human Resources, Material and Inventories, Capital, and Technology-Information Systems. These resources are based on the principles of operations and accounting management theory. They are commonly used for developing activity-based costing models. The same resources mentioned in the chart of accounts, and they are the assets in the balance sheets. All these six resources and the aforementioned four managerial principles constitute the ten enablers of GQC.

According to the Critical Success Factors Quality Management implementation, Figure 17 presents a ten-by-ten table which is GQC maturity model. The maturity assessment framework is combined with CSFs and their enablers in the four distinct QM categories: total quality management philosophies, methodologies, standards, and excellence awards.

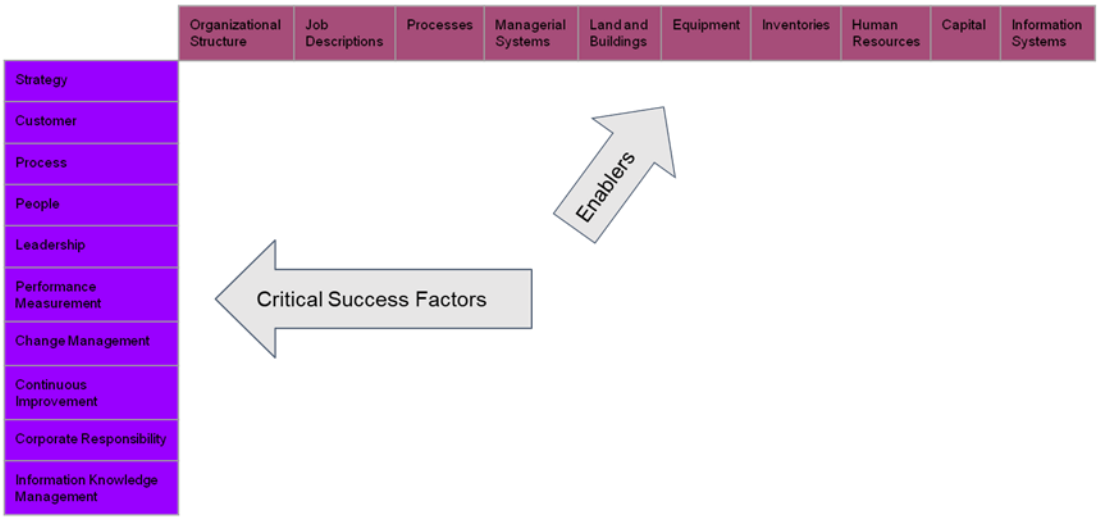

Figure 17 GQC Critical Success Factors and Enablers

7. Conclusions and future research

Digital transformation is the process of using digital technologies to redesign an organization operations. Digital transformation had a significant impact on human resources and operations management. Digital technology was the main driver for changes, situational factors that favor digital transformation, social impact and customer value as the consequences. The goal of the thesis was to show how digital transformation affects several parts of a business.

The aim was to analyze the impact of technological applications on human resource and operations management. The thesis defined operations management and examined some of its business applications.

Industry 4.0 had an impact on employment, consumption, and trade, among other things. It was demonstrated how Industry 4.0 can benefit a company's financial performance and stock returns. Increased product connectivity helps organizations enhance their manufacturing efficiency and profitability.

This thesis argued that the human resource management function was influenced by the effects of digital tools on the organization's basic values. The ability to collect and analyze large amounts of data is one of the benefits of digitalization. Using algorithms and increasing information flows, this process improves the organization's knowledge and boosts the analytical capabilities of the obtained data.

Manufacturing organizations are unable to determine their Industry 4.0 maturity level, according to the findings of the thesis. This is due to a lack of tools and terminology that can assist them in evaluating their digital transformation efforts. Enterprises can assist themselves evaluate their success and build effective strategies and practices by using evaluation frameworks and models. To assist companies in defining their digital transformation strategy, it is required a digital transformation maturity model.

Extensive literature surveys concentrating on Industry 4.0 and Quality 4.0 were presented, revealing the research's primary features, human resource management, and operations management. As the general outcome of this thesis, the final thesis framework was elaborated based on these literature reviews.

This paper does a descriptive review on Quality 4.0 and provides an overview of the important topics and directions for quality management in the digital transformation. In addition, Quality 4.0 related topics such as technology, business management, and a human-centered approach are frequently discussed.

The goal is to assist businesses in developing their capabilities so that they can take advantage of the opportunities given by Industry 4.0.

The Glykas Quality Compass framework was established in order to demonstrate the relevance of maturity for organizations supporting Industry 4.0 technologies and their quality. A ten-by-ten matrix based on the ten most significant critical success factors identified in existing maturity assessment frameworks and the ten most important enablers reported in the literature for Quality Management maturity evaluation.

The results of this thesis have theoretical and practical implications. They contribute to the digitalization and quality literature. This study discovered that motivation-boosting Human Resource practices improve psychological employee well-being, which leads to increased employee inventive job performance. Employee well-being is improved as a result of skill and opportunity enhancing Human Resource practices, which improves employee in-role work performance. As a result, when companies want to enhance their employees' health and relationships with their coworkers, they should focus more on measures like training and development and including employees in cooperation.

The most common subjects on Quality 4.0, according to the thesis, are technology and its consequences for quality, business management and strategy models, systems, and human factors. The use of technology for quality management is documented in a variety of sources, and it appears to be the most direct link between quality and technology. The bulk of products, services, and operations may now be controlled in an automated manner across the value chain thanks to intelligent machines and augmented reality enabled operators. The quick advancement of disruptive technology enables rapid advancements in company models and, as a result, management practices. As a result of the good connectivity between the technological and social sides of the digital transformation, quality management systems have adapted to the changing way of thinking and judging quality.

Organizations must assess the maturity of industry 4.0 in order to identify present capabilities as well as prospects for possible continual improvements. As a result, developing a maturity model for the optimal fit is critical.

Further research and studies in the subject of maturity and Quality 4.0 can benefit from the Glykas Quality Compass concept. It is a new methodology for evaluating Quality Management maturity that separates the assessment into four categories: Total Quality Management, Quality Management methodologies, standards, and excellence awards. Because their means (methods, techniques, etc.) and ends are distinct and should not be confounded, each of these perspectives' maturity should be assessed separately.

There was limitations elaborated for this thesis, which open the opportunities for future researches in this field.

Except for the supply chain sector, operations management was a topic that lacked considerable literature on its primary features. During the study of quality's four viewpoints, a similar issue arose. There are a lot of articles about Total Quality Management, but there aren't as many about the other perspectives. During the literature survey process of Quality 4.0 and Human Resources Management, it was discovered that there was a paucity of information.

Future work proposals are connected to the absence of information mentioned above. Operations Management necessitates an investigation into the major components and sectors of a business, such as procedures, models, and strategies. A number of operations strategies have been found to have a significant and beneficial impact on organizational performance. The appropriateness of an individual strategy or a mix of methods that may benefit a given industry is one of the areas of future research. It is

advised that a study of digital transformation's influences and applications in industry operations management be conducted.

Further study can include primary data obtained through interviews and questionnaires about the prospects provided by digital technology in various domains such as supply chain, banking, and industry, etc.

More research and case studies are needed on quality procedures, standards, and excellence awards. Human Resources Management is a field that need further investigation. There is a scarcity of data on the impact of quality 4.0 and paradigm shifts.

The aim of future efforts could be to create Glykas Quality Compass generic matrices for the perspectives Total Quality Management, Quality Management standards, Quality Management methodologies and excellence awards.

References

Alam, Dr. A. and Mukherjee, U., 2014. HRM- A Literature Survey. *IOSR Journal of Business and Management*, 16, 31–38.

Aquilani, B., Silvestri, C. and Ruggieri, A., 2016. Sustainability, TQM and Value Co-Creation Processes: The Role of Critical Success Factors. *Sustainability*, 8 (10), 995.

Aybas, M., 2021. THE BEHAVIORAL DIMENSIONS OF HUMAN RESOURCES MANAGEMENT IN THE AGE OF DIGITALIZATION AND INDUSTRY 4.0. *In*: . 127–144.

Bai, C., Dallasega, P., Orzes, G. and Sarkis, J., 2020. Industry 4.0 technologies assessment: A sustainability perspective. *International Journal of Production Economics*, 229, 107776.

Bakotić, D. and Rogošić, A., 2017. Employee involvement as a key determinant of core quality management practices. *Total Quality Management & Business Excellence*, 28 (11–12), 1209–1226.

Bandara, O., Vidanagamachchi, K. and Wickramarachchi, R., 2019. *A Model for Assessing Maturity of Industry 4.0 in the Banking Sector*.

Bedwell, W. L., Wildman, J. L., DiazGranados, D., Salazar, M., Kramer, W. S. and Salas, E., 2012. Collaboration at work: An integrative multilevel conceptualization. *Human Resource Management Review*, 22 (2), 128–145.

Bhattacharyya, S. S. and Atre, S., 2020. Additive Manufacturing Technology: Realities and Strategic Perspectives From India. *International Journal of Asian Business and Information Management (IJABIM)*, 11 (1), 1–20.

Bibby, L. and Dehe, B., 2018. Defining and assessing industry 4.0 maturity levels – case of the defence sector. *Production Planning & Control*, 29 (12), 1030–1043.

de Boer, L. and Houman Andersen, P., eds. 2019. *Operations Management and Sustainability: New Research Perspectives* [online]. Cham: Springer International Publishing. Available from: http://link.springer.com/10.1007/978-3-319-93212-5 [Accessed 11 May 2022].

Bogoviz, A. V., 2018. DIGITALIZATION OF THE RUSSIAN EDUCATION SYSTEM: OPPORTUNITIES AND PERSPECTIVES, 19, 6.

Bondarouk, T., Parry, E. and Furtmueller, E., 2017. Electronic HRM: four decades of research on adoption and consequences. *The International Journal of Human Resource Management*, 28 (1), 98–131.

Brauweiler, H.-C., Kurchenkov, V. V., Abilov, S. and Zirkler, B., eds. 2020. *Digitalization and Industry 4.0: Economic and Societal Development: An International and Interdisciplinary Exchange of Views and Ideas* [online]. Wiesbaden: Springer Fachmedien Wiesbaden. Available from: http://link.springer.com/10.1007/978-3-658-27110-7 [Accessed 27 Apr 2022].

Bravi, L. and Murmura, F., 2021. Evidences about ISO 9001:2015 and ISO 9004:2018 implementation in different-size organisations. *Total Quality Management & Business Excellence*, 1–21.

Caiado, R. G. G., Scavarda, L. F., Gavião, L. O., Ivson, P., Nascimento, D. L. de M. and Garza-Reyes, J. A., 2021. A fuzzy rule-based industry 4.0 maturity model for operations and supply chain management. *International Journal of Production Economics*, 231, 107883.

Carnerud, D. and Bäckström, I., 2019. Four decades of research on quality: summarising, Trendspotting and looking ahead. *Total Quality Management & Business Excellence*, 32 (9–10), 1023–1045.

Casalet, M. and Stezano, F., 2020. Risks and opportunities for the progress of digitalization in Mexico. *Economics of Innovation and New Technology*, 29 (7), 689–704.

Cho, Y. S. and Linderman, K., 2020. Resource-Based Product and Process Innovation Model: Theory Development and Empirical Validation. *Sustainability*, 12 (3), 913.

Constantinide, A. U., 2020. Are managers ready for HRM 4.0?: the potential role of blockchain technology in HRM. [online]. Available from: https://repositorio.iscte-iul.pt/handle/10071/21426 [Accessed 28 Apr 2021].

Dahlgaard, J. J., Reyes, L., Chen, C.-K. and Dahlgaard-Park, S. M., 2019. Evolution and future of total quality management: management control and organisational learning. *Total Quality Management & Business Excellence*, 30 (sup1), S1–S16.

De Pace, F., Manuri, F., Sanna, A. and Fornaro, C., 2020. A systematic review of Augmented Reality interfaces for collaborative industrial robots. *Computers & Industrial Engineering*, 149, 106806.

Dias, A., Carvalho, A. M. and Sampaio, P., 2021. Quality 4.0: literature review analysis, definition and impacts of the digital transformation process on quality. *International Journal of Quality & Reliability Management*, ahead-of-print.

Dmitry, I., Christopher, S. T., Alexandre, D., Daria, B. and Ajay, D., 2021. *Researchers' perspectives on Industry 4.0: multi-disciplinary analysis and opportunities for operations management* [online]. Available from: https://www.tandfonline.com/doi/epub/10.1080/00207543.2020.1798035?needAccess=true [Accessed 14 Apr 2022].

Dorrer, M., 2019. Parametric identification of the organizational maturity management system. [online]. Available from: https://elib.sfu-kras.ru/handle/2311/128460 [Accessed 5 Apr 2022].

Ebert, C. and Duarte, C. H., 2018. Digital Transformation. *IEEE Software*, 35, 16–21.

Fenech, R., Baguant, P. and Ivanov, D., 2019. *THE CHANGING ROLE OF HUMAN RESOURCE MANAGEMENT IN AN ERA OF DIGITAL TRANSFORMATION - ProQuest* [online]. Available from: https://search.proquest.com/openview/683dd7c5bc7a3658475b0fce99e160d9/1?cbl=38743&pq-origsite=gscholar [Accessed 5 May 2021].

Fettig, K., Gačić, T., Köskal, A., Kühn, A. and Stuber, F., 2018. Impact of Industry 4.0 on Organizational Structures. *In*: *2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*. Presented at the 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), 1–8.

Fonseca, L., Amaral, A. and Oliveira, J., 2021. Quality 4.0: The EFQM 2020 Model and Industry 4.0 Relationships and Implications. *Sustainability*, 13, 1.

Fregnan, E., Ivaldi, S. and Scaratti, G., 2020. HRM 4.0 and New Managerial Competences Profile: The COMAU Case. *Frontiers in Psychology* [online], 11. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7714775/ [Accessed 27 Apr 2021].

Frolova, I. and Lapina, I., 2014. Corporate Social Responsibility in the Framework of Quality Management. *Procedia - Social and Behavioral Sciences*, 156, 178–182.

Fuller, A., Fan, Z., Day, C. and Barlow, C., 2020. Digital Twin: Enabling Technologies, Challenges and Open Research. *IEEE Access*, 8, 108952–108971.

Ganzarain, J. and Errasti, N., 2016. Three stage maturity model in SME's toward industry 4.0. *Journal of Industrial Engineering and Management*, 9 (5), 1119–1128.

Ghobakhloo, M., 2020. Industry 4.0, digitization, and opportunities for sustainability. *Journal of Cleaner Production*, 252, 119869.

Ghobakhloo, M. and Iranmanesh, M., 2021. Digital transformation success under Industry 4.0: a strategic guideline for manufacturing SMEs. *Journal of Manufacturing Technology Management*, 32 (8), 1533–1556.

Ghosh, S., Muduli, A. and Pingle, S., 2021. Role of e-learning technology and culture on learning agility: An empirical evidence. *Human Systems Management*, 40 (2), 235–248.

Glogovac, M., Ruso, J. and Maricic, M., 2020. ISO 9004 maturity model for quality in industry 4.0. *Total Quality Management & Business Excellence*, 0 (0), 1–19.

Glykas, M., 2019. Quality Management Review, 6 (12), 20.

Golenkov, V., Krasnoproshin, V., Golovko, V. and Azarov, E., eds. 2020. *Open Semantic Technologies for Intelligent System: 10th International Conference, OSTIS 2020, Minsk, Belarus, February 19–22, 2020, Revised Selected Papers* [online]. Cham: Springer International Publishing. Available from: http://link.springer.com/10.1007/978-3-030-60447-9 [Accessed 31 Oct 2021].

Gray, J. and Rumpe, B., 2015. Models for digitalization. *Software & Systems Modeling*, 14 (4), 1319–1320.

Gunasekaran, A., Nachiappan, S. and Wai Ting Eric, N., 2019. *Quality management in the 21st century enterprises: Research pathway towards Industry 4.0 - ScienceDirect* [online]. Available from: https://www.sciencedirect.com/science/article/pii/S092552731830375X [Accessed 10 Jan 2022].

Gunjan, Y., Anil, K., Sunil, L., Jose Arturo, J. A. G.-R., Vikas, K. and Luciano, B., 2020. *A framework to achieve sustainability in manufacturing organisations of developing economies using industry 4.0 technologies enablers | Elsevier Enhanced Reader* [online]. Available from: https://reader.elsevier.com/reader/sd/pii/S0166361520305145?token=68A698E2E047DE81676D02FD632D4939584C5353D329997FC58F1F00F475012429969484DD545255AE0C199440517CF2&originRegion=eu-west-1&originCreation=20220414095156 [Accessed 14 Apr 2022].

Hietschold, N., Reinhardt, R. and Gurtner, S., 2014. *Full article: Measuring critical success factors of TQM implementation successfully – a systematic literature review* [online]. Available from: https://www.tandfonline.com/doi/full/10.1080/00207543.2014.918288?casa_token=C70kMc1zi78AAAAA%3AK6BA-Y_1uxg3C8VZrniQFjD6nZlum6hHFsjipLUMg5nIyQXC5ithWndB63EvxIepL-Hho0huRAnjjA [Accessed 10 Jan 2022].

Jankalová, M. and Jankal, R., 2020. How to Characterize Business Excellence and Determine the Relation between Business Excellence and Sustainability. *Sustainability*, 12 (15), 6198.

Jehangiri, R., 2017. Identification of Critical Success Factors for Total Quality Management Implementation in Organizations. *International Journal of Economics & Management Sciences*, 06.

Ketolainen, N., 2018. *Digitalization of Human Resources – the transformation journey into automated and data-driven service organization* [online]. Available from: http://www.theseus.fi/handle/10024/149759 [Accessed 5 May 2021].

Khoreva, V. and Wechtler, H., 2018. HR practices and employee performance: the mediating role of well-being. *Employee Relations*, 40 (2), 227–243.

Koleva, N. and Andreev, O., 2018. Aspects of Training in the Field of Operations Management with Respect to Industry 4.0. *In*: *2018 International Conference on High Technology for Sustainable Development (HiTech)*. Presented at the 2018 International Conference on High Technology for Sustainable Development (HiTech), 1–3.

Landeta Echeberria, A., 2020. *A Digital Framework for Industry 4.0: Managing Strategy* [online]. Cham: Springer International Publishing. Available from: http://link.springer.com/10.1007/978-3-030-60049-5 [Accessed 19 Apr 2022].

Lohmer, J. and Lasch, R., 2020. *Blockchain in operations management and manufacturing: Potential and barriers | Elsevier Enhanced Reader* [online]. Available from: https://reader.elsevier.com/reader/sd/pii/S0360835220304988?token=B8EB902D592B83E54C7DF9AEBAA5459FCAF5E070F6F6B1BEF57A5A1DDFE485FCDCCC702DD01728C00BF03BA9E97D5446&originRegion=eu-west-1&originCreation=20220509073208 [Accessed 9 May 2022].

Ltd, I.-I. B., 2019. EDITORIAL. *VADYBA*, 34 (1), 5–6.

M., S. and Chattu, V. K., 2021. A Review of Artificial Intelligence, Big Data, and Blockchain Technology Applications in Medicine and Global Health. *Big Data and Cognitive Computing*, 5 (3), 41.

Magon, R. B., Thomé, A. M. T., Ferrer, A. L. C. and Scavarda, L. F., 2018. Sustainability and performance in operations management research. *Journal of Cleaner Production*, 190, 104–117.

Manuti, A. and de Palma, P. D., 2018. The Cognitive Technology Revolution: A New Role of HR Practices? *In*: Manuti, A. and de Palma, P. D., eds. *Digital HR: A Critical Management Approach to the Digitilization of Organizations* [online]. Cham: Springer International Publishing, 39–53. Available from: https://doi.org/10.1007/978-3-319-60210-3_3 [Accessed 6 Jul 2021].

Marin, G. D. and Nila, C., 2021. *Branding in social media. Using LinkedIn in personal brand communication: A study on communications/marketing and recruitment/human resources specialists perception | Elsevier Enhanced Reader* [online]. Available from: https://reader.elsevier.com/reader/sd/pii/S259029112100070X?token=57DF3E51A8255BBD80485A57B25DA1021E8ED9F10CD55D3788C626C264D74D8725B5CAEC2B06E5AF5280E17BC5EBEC33&originRegion=eu-west-1&originCreation=20211031172503 [Accessed 31 Oct 2021].

Matthias, O. and Brown, S., 2016. Implementing operations strategy through Lean processes within health care: The example of NHS in the UK. *International Journal of Operations & Production Management*, 36 (11), 1435–1457.

Metaxas, I. and Koulouriotis, D., 2019. *Full article: Business excellence measurement: a literature analysis (1990–2016)* [online]. Available from:

https://www.tandfonline.com/doi/full/10.1080/14783363.2017.1356201 [Accessed 10 Jan 2022].
Mittal, S., Khan, M. A., Romero, D. and Wuest, T., 2019. Smart manufacturing: Characteristics, technologies and enabling factors. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 233 (5), 1342–1361.
Neely, A., 2007. Business Performance Measurement: Unifying theories and integrating practice, Second edition, 529.
Negron, L. A., 2020. *Relationship between quality management practices, performance and maturity quality management, a contingency approach: Quality Management Journal: Vol 27, No 4* [online]. Available from: https://www.tandfonline.com/doi/abs/10.1080/10686967.2020.1809582 [Accessed 10 Jan 2022].
Oztemel, E. and Gursev, S., 2020. Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*, 31 (1), 127–182.
Pandey, D., 2019. The Impact of Human Resource Management on Employee Commitment: A Study of the Nepalese Banking Sector. *International Journal of Management Studies*, VI, 12.
Para-González, L., Jiménez-Jiménez, D. and Martínez-Lorente, Á.-R., 2021. Does EFQM enhance learning and innovation? *Total Quality Management & Business Excellence*, 0 (0), 1–25.
Piergiovanni, M., Cangar, O., Leite, S. B., Mian, L., Jenet, A., Corvi, R., Whelan, M., Taucer, F. and Ganesh, A., 2021. Putting Science into Standards workshop on standards for organ-on-chip. *Stem Cell Reports*, 16 (9), 2076–2077.
Pio, P. C., Rampasso, I. S., Cazeri, G. T., Santa-Eulalia, L. A., Pavan, S. M. and Anholon, R., 2021. Human resources and Industry 4.0: an exploratory study in the Brazilian business context. *Kybernetes* [online], ahead-of-print (ahead-of-print). Available from: https://doi.org/10.1108/K-04-2021-0253 [Accessed 10 May 2022].
Prakash, N. B. and Mores, G. S., 2019. Digitalization of HRM Practice in the Present Scenario, 5.
Pratibha, Shiva, A. and Arora, R., 2021. Impact of HRM practices on organisational commitment: evidence from school educators' in Indian context. *World Review of Entrepreneurship, Management and Sustainable Development*, 17 (2–3), 186–205.
Rachinger, M., Rauter, R., Müller, C., Vorraber, W. and Schirgi, E., 2018. Digitalization and its influence on business model innovation. *Journal of Manufacturing Technology Management*, 30 (8), 1143–1160.
Rajnai, Z. and Kocsis, I., 2017. Labor market risks of industry 4.0, digitization, robots and AI. *In*: *2017 IEEE 15th International Symposium on Intelligent Systems and Informatics (SISY)*. Presented at the 2017 IEEE 15th International Symposium on Intelligent Systems and Informatics (SISY), 000343–000346.
Ranjith, K. R., Ganesh, L. S. and Rajendran, C., 2021. Quality 4.0 – a review of and framework for quality management in the digital era. *International Journal of Quality & Reliability Management* [online], ahead-of-print (ahead-of-print). Available from: https://doi.org/10.1108/IJQRM-05-2021-0150 [Accessed 4 May 2022].
Sader, S., Husti, I. and Daroczi, M., 2021. A review of quality 4.0: definitions, features, technologies, applications, and challenges. *Total Quality Management & Business Excellence*, 0 (0), 1–19.

School of Information Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand, Sukreep, S., Elgazzar, K., Chu, H., Mongkolnam, P. and Nukoolkit, C., 2019. iWatch: A Fall and Activity Recognition System Using Smart Devices. *International Journal of Computer and Communication Engineering*, 8 (1), 18–31.

Schumacher, A., Erol, S. and Sihn, W., 2016. A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. *Procedia CIRP*, 52, 161–166.

Shaharudin, M. S., Zulkifli, W. N., Gui, A. and Fernando, Y., 2021. Drivers Human Resources 4.0: Technological, Organisational & Environmental of Human Resources 4.0 at Malaysian Private Companies. *International Journal of Industrial Management*, 12 (1), 306–318.

Shamim, S., Cang, S., Yu, H. and Li, Y., 2016. Management approaches for Industry 4.0: A human resource management perspective. *In*: *2016 IEEE Congress on Evolutionary Computation (CEC)*. Presented at the 2016 IEEE Congress on Evolutionary Computation (CEC), 5309–5316.

Sharma, P., 2021. Internet of Things and Blockchain. *In*: *Blockchain for Business* [online]. John Wiley & Sons, Ltd, 296–336. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119711063.ch13 [Accessed 31 Oct 2021].

Sivathanu, B. and Pillai, R., 2018. Smart HR 4.0 – how industry 4.0 is disrupting HR. *Human Resource Management International Digest*, 26 (4), 7–11.

S.Poongodi, D., P.Jayanthi, D. and R.Ramya, M., 2021. Users Perception towards Google Pay. *PalArch's Journal of Archaeology of Egypt / Egyptology*, 18 (1), 4821–4825.

Stepantseva, A. and Breitenecker, R., 2020. Digital Transformation of Business Models in the banking sector: a multiple case study. [online]. Linz. Available from: https://resolver.obvsg.at/urn:nbn:at:at-ubl:1-38982 [Accessed 10 Oct 2021].

Syed, J. and Bayeroju, O., 2019. HRM and business performance. *In*: *5TH BIENNIAL CONFERENCE - Nigeria 2020* [online]. Presented at the 5TH BIENNIAL CONFERENCE - Nigeria 2020. Available from: https://www.africaacademyofmanagement.org/conferences/index.php/afambc/bc2020/paper/view/158 [Accessed 6 May 2021].

Ustundag, A. and Cevikcan, E., 2018. *Industry 4.0: Managing The Digital Transformation* [online]. Cham: Springer International Publishing. Available from: http://link.springer.com/10.1007/978-3-319-57870-5 [Accessed 15 Apr 2022].

Van Veldhoven, Z. and Vanthienen, J., 2021. Digital transformation as an interaction-driven perspective between business, society, and technology. *Electronic Markets* [online]. Available from: https://doi.org/10.1007/s12525-021-00464-5 [Accessed 27 Apr 2021].

Wibowo, E., Legionosuko, T., Mahroza, J. and Jaya, Y., 2020. Industry 4.0: Challenges and Opportunities in Competency Development for Defense Apparatus' Human Resources. *Applied Science and Engineering Progress*, Vol. 29 No. 7, 45–60.

Wilkesmann, M. and Wilkesmann, U., 2018. Industry 4.0 – organizing routines or innovations? *VINE Journal of Information and Knowledge Management Systems*, 48 (2), 238–254.

Xu, L., Peng, X., Pavur, R. and Prybutok, V., 2020. Quality management theory development via meta-analysis. *International Journal of Production Economics*, 229, 107759.

Yadav, N., Shankar, R. and Singh, S. P., 2020. Impact of Industry4.0/ICTs, Lean Six Sigma and quality management systems on organisational performance. *The TQM Journal*, 32 (4), 815–835.

Yadav, N., Shankar, R. and Singh, S. P., 2021a. Critical success factors for lean six sigma in quality 4.0. *International Journal of Quality and Service Sciences*, 13 (1), 123–156.

Yadav, N., Shankar, R. and Singh, S. P., 2021b. Critical success factors for lean six sigma in quality 4.0. *International Journal of Quality and Service Sciences*, 13 (1), 123–156.

Zaitouni, M., Harraf, A. and Kisswani, A. M., 2020. Resources for development: the relationship of HRM practices and continuous learning culture with training success, 18.

Zonnenshain, A. and Kenett, R. S., 2020. Quality 4.0—the challenging future of quality engineering. *Quality Engineering*, 32 (4), 614–626.