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Industry 4.0 Process-Operations Management Maturity Assessment: A Literature Survey

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Abstract: *The aim is to demonstrate the necessity of evaluating industry 4.0 maturity in order to discover capabilities and opportunities for potential ongoing improvements to company operation management. There will be a thorough review of the literature in the areas of operations management and Industry 4.0. Because there aren't enough tools and terms to help firms assess their attempts to undergo digital transformation, the paper's findings show that they are unable to establish their Industry 4.0 maturity level. It is critical to assess their effectiveness and develop strategies and practices that work by employing evaluation frameworks and models. A digital transformation maturity model is necessary. There is no prior research that offers a comprehensive examination.*

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.

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 complete, 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 continuously or discretely. Maturity can be labeled as readiness models.

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2. INDUSTRY 4.0 AND MATURITY MODELS

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 business 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 & 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 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 been 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.

3. 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 et al. (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 rapid 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. 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 the 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 & 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 can 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 following 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. 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 aging 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 flexibly and responsively. 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). 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 technical 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 intrinsically noisy datasets. 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 intelligence. 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.

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.

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 & 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 research has shown a wide range of Industry 4.0 design principles (Ghobakhloo & 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 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. The 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.

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 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 & 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 & 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 & 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 & 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 & 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 & 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 & 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 & Cevikcan, 2018).

Various types of simulation, such as discrete events 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.

Communication and networking can be characterized as a link between individually defined physical and dispersed systems (Ustundag & 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 & 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 & Cevikcan, 2018).

5. INDUSTRY 4.0 MATURITY MODELS

A maturity model or framework is a structured approach designed to support companies moving toward 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 the 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 of 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. Below are the following models and tools for assessing readiness or maturity (Schumacher et al., 2016).

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 transparently. 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) propose a model to gain solid data about the current state of 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).

To the evolution path, each item undergoes five maturity levels. The first level involves a description of 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 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.

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 in 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.

6. CONCLUSION AND FUTURE RESEARCH

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.

Manufacturing organizations are unable to determine their Industry 4.0 maturity level, according to the findings of this paper. 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.

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

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

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.

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 to conduct a study on the impact of digital transformation and its application in industrial operations management.

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