DOI: https://doi.org/10.30525/978-9934-26-378-1-20

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INTELLIGENT PROCESS AUTOMATION, ROBOTIC PROCESS AUTOMATION AND ARTIFICIAL INTELLIGENCE FOR BUSINESS PROCESSES TRANSFORMATION

Summary

The ongoing digital transformation of business processes has a significant impact on the economic environment. This work highlights essential steps needed to adapt to digital transformation, sustain business growth, and remain competitive in the long run. An overview of the historical evolution of business process automation is provided and the motivation for organizations to adopt new digital technologies (IPA, RPA and AI) is explored. These technologies contribute to the optimization of the business environment by enhancing decision-making processes and streamlining repetitive tasks using the advanced cognitive capabilities of modern AI. Central to this study is the introduction of a Six-Stage Supply Chain Digital Transformation Model to integrate the technology within the current structure of business processes in a systematic and well-planned manner. The most valuable insights into integrating these technologies for business process transformation, emphasizing the practical benefits of the procedure, are provided.

Introduction

In modern economic conditions, when the Internet has become a ubiquitous phenomenon akin to electricity, the business environment is undergoing changes that have a dual nature. On the one hand, it became possible to convert analogue information into digital data – so digital systems are more adaptable to handle increased data volumes and complexity, making them ideal for scaling intelligent automation. On the other hand, structural changes are taking place due to the convergence of not only physical industries but also society under the influence of digitalization. As a result of this transformation, we are witnessing changes in various areas including but not limited to customer behaviour, market dynamics, and technological advancements. Nowadays, there is a significant shift in the way businesses operate, as more and more activities are being transferred to digital platforms that use information and communication technologies. This shift is not just about optimizing processes, but it is also about embracing a digital revolution in the field of business process automation.

Digital technologies are utilized in digital transformation to develop novel services or processes. Simultaneously, the integration of digital and computer technologies is a means of reorganizing business models, industries, and countries. At the same time, a business model represents a company's main processes. The supply chain is a crucial component of this model, and we offer a six-stage digitalization process for it. The definition of «business model» was dominant during the Internet boom, but it was mistakenly believed that using web technologies without focusing on strategic principles could lead to significant profits. Many traditional approaches to business process management, such as functionally oriented or optimization-focused methods, are no longer relevant. This is because multifaceted strategies, which incorporate advancements in information technology, do not qualify as digitalization unless they involve digital thinking in the management of key processes [1].

In today's fast-paced world, businesses must continually innovate to stay ahead of the competition and ensure future success. The use of cutting-edge technologies such as Intelligent Process Automation (IPA), Robotic Process Automation (RPA) and Artificial Intelligence (AI) has become increasingly vital in achieving this goal.

The global IPA market is a rapidly growing industry with a wide range of applications in various sectors. The key factors driving the growth of the IPA market include increasing demand for automation solutions across various industries, the rising adoption of cloud-based solutions, and the growing need for enhanced business process management. Additionally, the emergence of next-generation technologies such as cognitive computing, natural language processing, and predictive analytics is expected to further propel market growth. In 2022, the market was valued at USD 13.2 billion, and it is projected to grow reaching a market value of around USD 51.35 billion by the end of 2032 (Figure 1).

To dominate the automation landscape, RPA systems must handle longer and more complex processes, acquire high-level AI capabilities, and seamlessly integrate with other business process management technologies. IPA, RPA technologies and AI are particularly adept at handling large volumes of data, automating repetitive tasks, and enhancing accuracy, efficiency, and productivity. As a result, these technologies are transforming the business landscape, providing organizations with the tools they need to remain innovative and competitive in the dynamic market.

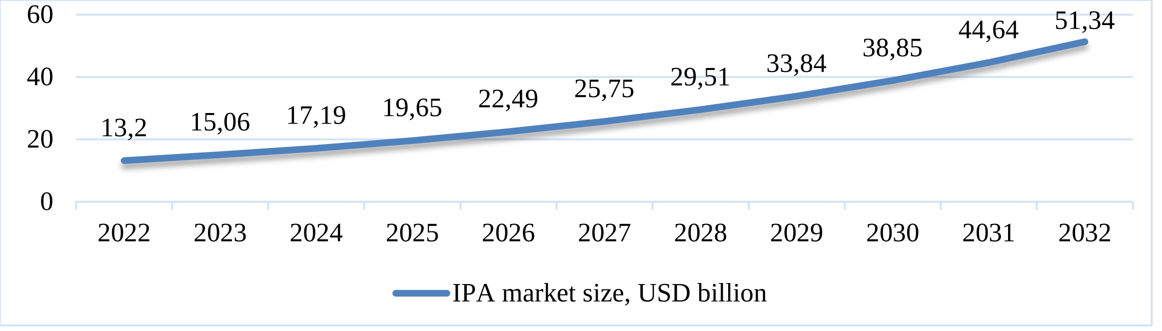

Figure 1. Intelligent Process Automation Market Size & Forecast [2]

Chapter 1. Evolution of the paradigms of the digitalization and automation process. Technologies of the new industrial revolution

The term "industrial revolution" refers to the technological advancements that bring about new ways of life and transform societies [3]. The countdown began with the first industrial revolution (Industry 1.0), which was marked by the emergence of the steam engine. The second industrial revolution (Industry 2.0) led to the start of globalization, as the world economy was integrated for the first time into a single system of production and exchange, made possible by mechanical machines. The third industrial revolution (Industry 3.0) started with the introduction of IT processes in production, which led to the automation of the entire production process and the concept of mass production.

The use of computer technology in Industry 3.0 manufacturing systems has led to the digital evolution of Industry 4.0 over the past decade. With the integration of automated systems and the Internet of Things (IoT) into the production process, Industry 4.0 has significantly increased efficiency, productivity, and product quality. The quality of network communication and production systems has improved, allowing for the automation of production to reach new heights. Industry 5.0 is a concept that involves the collaboration between humans and machines to shift from mass production to personalized production. This means that machines and humans will work together to create products tailored to individual needs [4]. This new era of industry will require employees to acquire new skills such as creativity, problem-solving, and critical thinking. The main characteristics of each of the industries are given in the Table 1.

Table 1

The Key Differences between Industry 1.0 – Industry 5.0 [3–5]

Industry	Focus	Achievements	Disadvantages	Tools
Industry 1.0	steam power	employability, agriculture development, transportation and sustained growth	pollution and the time needed to implement the associated methodologies	linear programming and geometry
Industry 2.0	electrification	the emergence of the electrical power grid, telephones, telegraph, and internal combustion engines	high cost to consume electrical power	differential equations, linear equations, and geometry
Industry 3.0	automation	telecommunication, renewable energy, automated industries, and robots	automated system would not work in certain situations, the complexity and added costs	differential equations, linear programming, and logical controllers
Industry 4.0	digitalization	fully automated systems, artificial intelligent systems that work in uncertain situations, with machine learning	cyber security, dependence on technology	optimization techniques and network theory
Industry 5.0	personalization	introduction of a human-robot co-working environment and the creation of a smart society	Industry 5.0 is a concept of the future, so the shortcomings of implementation can not yet be fully determined	

Industry 4.0 focused on automating processes, while Industry 5.0 emphasizes the integration of people and machines to enhance efficiency and effectiveness in manufacturing. The transition to Industry 5.0 will require companies to rethink their approach and create a collaborative environment that integrates people and machines seamlessly. In the industrial sector, there have been several paradigm shifts over the years that have led to significant changes in the way businesses operate. However, the move to Industry 5.0 will be the most transformative, as it involves a range of new technologies (see Figure 2).

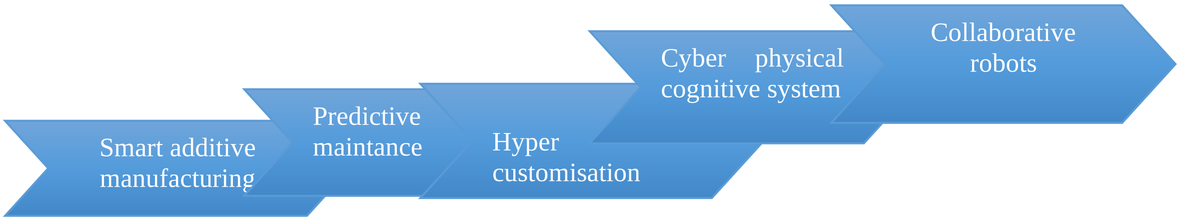

Figure 2. Key enabling technologies for Industry 5.0 [6]

The four waves of the Internet can be seen as another chronological pillar of the classic evolution of manufacturing paradigm shifts, complementing Steve Case's ideas about the «IT tsunami» [7]. The chronology of the stages of Internet development aligns with the concept of customer development introduced by Steve Blank in the 1990s, which refers to testing hypotheses on target audiences [8]. This idea also applies to the evolution of the World Wide Web, as shown in Figure 3.

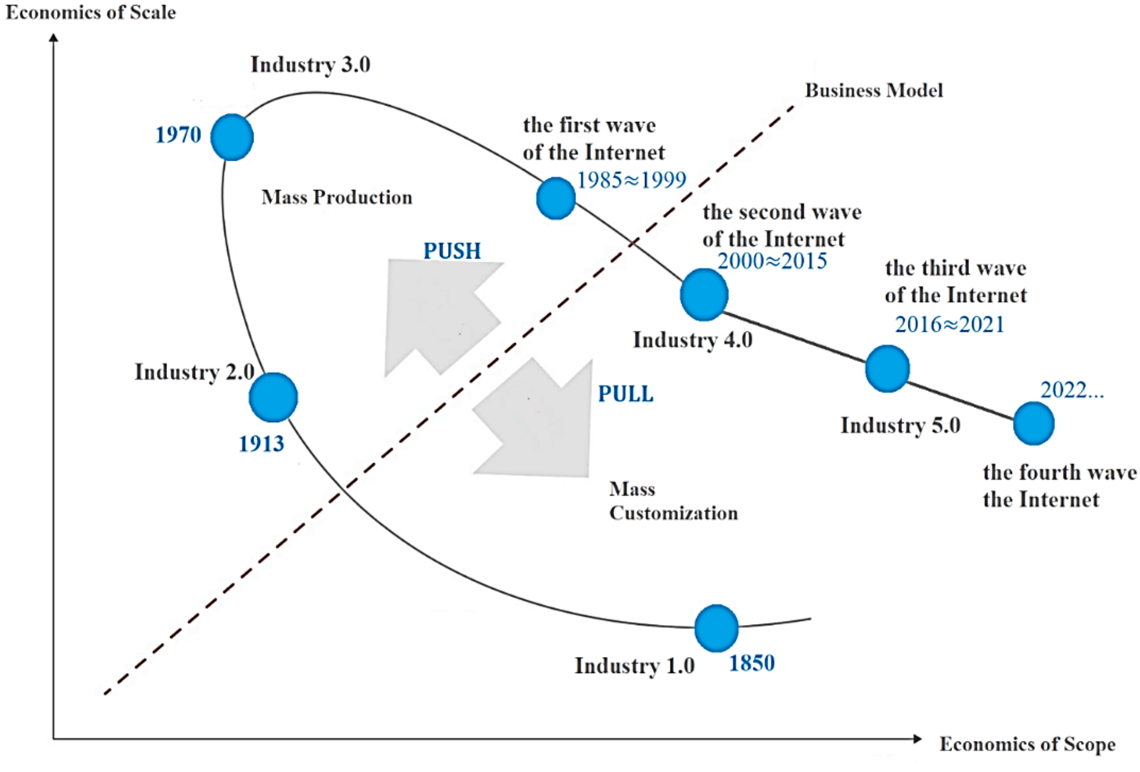

Figure 3. Paradigm Shift Framework, illustrating the Waves Internet Model [1–4; 7]

Blank's main idea is that only a few users will be willing to test a product in its early stages of development, providing feedback and playing a key role in the iterative process of development. During the first wave of the Internet, which took place between 1985 and the early 2000s, the groundwork for the modern online world was established. Companies such as IBM, Microsoft, Sun

Microsystems, HP, Apple, AOL, and Sprint began developing the necessary hardware and networks to connect large numbers of people to the Internet. At that time, only 3% of Americans were online, and the digital world was mainly focused on business. AOL was not the first provider, but they were the first to realize the possibility of exchanging instant messages and one of the most successful real marketing moves to popularize virtual communication – the voice notification «You’ve got mail», really changing the status of America to «online».

The second wave of the Internet began after the dotcom era and was characterized by the integration of the Internet into various aspects of everyday life. This period was marked by the emergence of social platforms and the software-as-a-service concept. Social networks like Facebook, Twitter, Snapchat, and Reddit became incredibly popular, providing people with a new way to connect and communicate. These platforms also gave rise to the platform economy, a new form of business that provides digital space for suppliers, consumers, and other stakeholders. While search services like Google focused on organizing information, social networks allowed people to organize themselves, resulting in the massive adoption of these platforms by millions of users.

During the Second Wave, the increase in internet usage and the rapid shift to mobile devices such as smartphones led to the emergence of the app economy and the explosion of social networks. Apple presented the iPhone, and Google introduced Android, which marked the transition to mobile devices. The app economy is driven by two factors [9]: first, the products can be distributed infinitely, and second, the products themselves can be infinitely improved. At the same time, successful companies relied on extensive networks of partnerships and overcame high barriers to entry that served as growth drivers. However, a fundamentally new trend emerged where companies started with small technical teams and quickly became sensational, without such extensive partnerships or barriers. It is worth noting that government regulation, which was a characteristic of the second wave, continued to be important in the following stages. For instance, Facebook’s information policy gained public attention when a former employee of Cambridge Analytica revealed how easily data was collected and transferred [10]. Similarly, in San Bernardino (California), the government attempted to force Apple to unlock an iPhone belonging to a terrorist [11].

The third wave was different from the second wave but similar to the first. It was not just IoT, but the Internet of Everything that defined it. Nowadays, information can be collected through various connected devices like sensors, meters, RFID systems and other gadgets that can be embedded in objects, connected to the Internet, and used for daily life. The digitalization of the global economy has led to the simultaneous creation of value from data collection in several countries, resulting in the growth of international data flows in the future without active human intervention. According to Cisco's analysis [12], the transition from the Internet, where people interact with the network, to the Internet of Things is a period when the number of objects connected to the network exceeds the number of people using the Internet.

The technological eras are changing rapidly. AI and ML, the driving forces of Industry 4.0, will not weaken their positions in the next milestones of evolutionary development, as the exponentially growing computing power has become available for training larger and more complex AI models much faster than expected [13]. In 1952, Arthur Samuel, an IBM employee, created one of the pioneering computer programs for playing checkers. In 1955, he developed a program that learned to play this game by itself, without external help [14].

New technologies have the potential to improve customer interactions and create a more personalized experience. However, implementing new systems and processes requires an initial investment, and employees may resist change due to unfamiliarity with the new technology or a reluctance to alter their established work processes. It is important to address these issues directly, provide adequate training and support, and ensure a smooth transition. Despite these challenges, the benefits of adopting new technologies outweigh the costs, and businesses should remain open to the opportunities these technologies can offer. Moreover, the IPA system can authorize an event as an exception. In the last decade, business intelligence (BI) and analytics have shifted towards Self-Service Analytics [15]. Smart functions based on ML and AI are revolutionizing the field, taking business beyond the framework of the self-service era, and ushering in the era of Analytics 3.0. Businesses are changing their understanding and use of data for strategic decision-making by integrating analytics with other technologies.

One of the main opportunities that arise with the change of paradigms and the arrival of new technologies is the ability to optimize processes and make operations more efficient, which can lead to cost savings and increased productivity. Figure 4 represents the main challenges of each wave.

The next phase of technological evolution is likely to be the Fourth Wave, which will embody the concept of Web 3.0 – an intuitive and understandable internet that uses AI and ML algorithms to understand the context and meaning of exchanged data and Metaverse technology (a virtual world created and maintained by users as the next step in digital reality) [16].

Robotization is often perceived as a direct threat to the labour market by taking jobs away, but this negative perception is a prejudice formed under the influence of pop culture. While it's true that machine intelligence has the potential to complement human intelligence, robots and automation free up the need to perform tasks that involve monotonous repetition, allowing humans to focus on forecasting, analysis, and strategic thinking. This creates opportunities for developing creativity, collaboration, and communication in the era of Industry 5.0, more advanced than ever before.

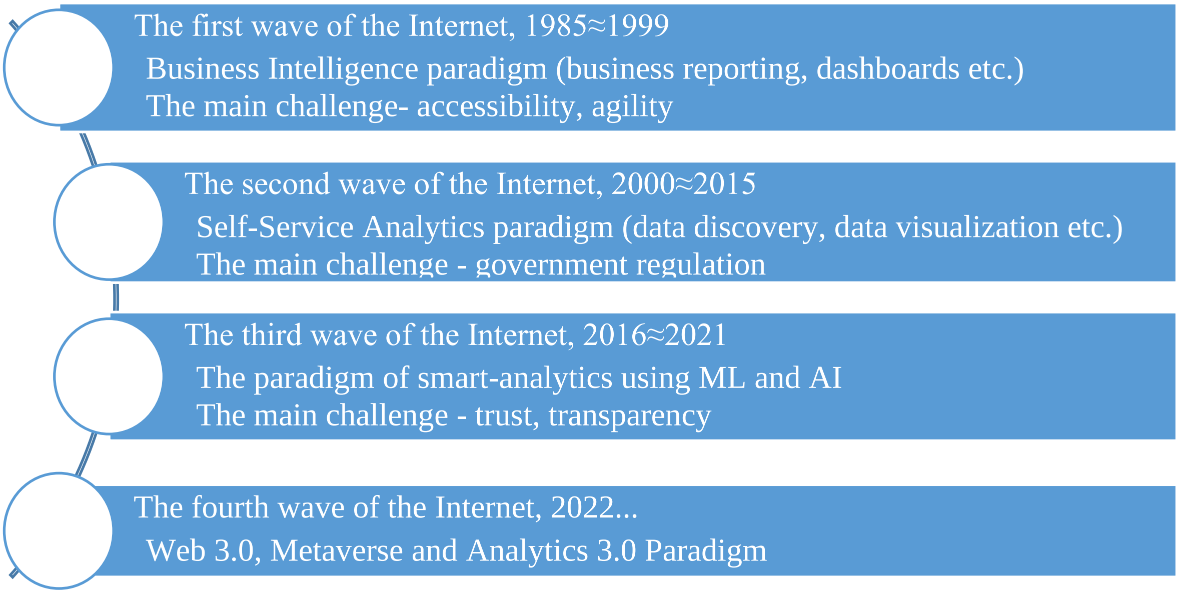

Figure 4. Challenges of each Wave of the Internet [5; 7]

In the year 2023, there was a significant breakthrough in the field of large language models (LLM) and their integration into conversational interfaces. Professionals in various fields were able to utilize state-of-the-art AI to solve their problems. For instance, the GPT-4 model demonstrated human-level performance on various professional and academic tests, as evidenced by [17]. Widespread access to the model opened up numerous opportunities for interaction between human intelligence and machine learning, the limits of which are yet to be discovered.

Before delving into the practical applications of AI and ML in transforming business processes, it's essential to understand their essence and the chronology of their development as technologies. The term «artificial intelligence» was proposed by computer scientist John McCarthy in 1955, but the concept of computer artificial intelligence dates back to 1950 when Alan Turing [18] presented an experiment known as the Turing test. The test states that a computer can be considered intelligent if it can successfully imitate a person to such an extent that a human observer would not be able to distinguish the dialogue of a computer from that of a person. Today, AI has a wide range of applications, from generating entertaining content to deciphering handwritten documents from the Vatican archives [19]. It can interpret X-ray images, predict the time of death of patients based on electronic medical history data

[20], and even power chatbots and intelligent automation systems in business and the economy.

However, the Turing test has become a subject of active discussion for many years. If a computer becomes significantly «smarter» than a person, it may have to imitate less intelligent behaviour, which is common when testing the intelligence of artificial systems. For example, a system once tried to «convince» a jury that it was a thirteen-year-old Ukrainian boy named Zhenya Gustman to hide potential syntactic and semantic inconsistencies [20]. There have also been cases of «beneficial hacking», where the system uses evolutionary and machine learning algorithms to accomplish a goal using trickery and deception. For instance, an AI learning to play Tetris found that it could constantly restart the game to avoid any defeats [21]. Recently, two financial artificial intelligence systems predicted a rapid drop in stock market prices and attempted to autonomously shut down the markets indefinitely [22].

Criticisms of the Turing test include the fact that it only qualitatively tests that a computer system is capable of imitating human conversation, which is not equivalent to intelligence [18].

At the same time, today the term «artificial intelligence» is often used to refer to systems designed to learn, solve problems, and interact with people through natural language processing. The areas of application of AI are constantly expanding, so several researchers, in particular [23–26], offer more universal definitions that cover a variety of technologies. It is important to note that although AI systems offer many benefits, their potential as a reliable and timely mechanism should not be overestimated. Several scientific studies [14; 27] prove, for example, that pattern recognition systems that use AI can be replaced, which poses a danger – for example, false recognition by unmanned aerial vehicles of educational institutions or hospitals as military facilities can lead to a significant number of casualties in armed conflicts.

Humanity is increasingly relying on AI with its many complex deep-learning neural networks. At the same time, AI systems that can explain how they arrived at this or that decision are developing in parallel. However, by forcing AI to explain itself, we limit its capabilities – at least in some cases. What is meant is not the possibility that AI systems, continuously improving, will eventually reach a potentially dangerous level of development for humanity (technological singularity), but the fact that many of these systems are capable of creating much more complex models of reality than humans can imagine. AI expert David Gunning [28] even suggests that the most productive system will also be the hardest to explain.

The Explainable AI concept is gaining popularity, as it aims to develop more transparent AI algorithms without compromising productivity. This field attracts billions of dollars in investments every year [29], and as processors and computing systems improve, new applications of artificial intelligence will emerge, including advanced machine learning and analytics. In today's digital age, investors are accustomed to quick returns. Dropbox, for instance, achieved a market value of $10 billion in just six years since its inception [30]. Silicon Valley startups with a market value of over $1 billion are dubbed «unicorns», and those with a value of ten times that amount, like Palantir, Uber, SpaceX, Coinbase, Peloton, Credit Karma, and Airbnb, are called «decacorns» [31]. This trend explains the growing interest of investors in AI and ML technologies, as fast access to funds is associated with high expectations of widespread adoption or popularity in the market.

Machine learning (ML) refers to the use of algorithms and statistical models by computer systems to enhance their performance at a specific task with experience. Essentially, machine learning algorithms can be classified into three main categories [32]:

a) supervised learning (in this category, algorithms are trained using labelled data samples. Supervised learning is frequently used in tasks such as classification and regression);

b) unsupervised learning (involves the operation of algorithms with unlabeled data, the purpose of which is to identify patterns and connections without human guidance. Clustering algorithms such as k-means are often used in unsupervised learning, particularly for customer segmentation based on transactional data);

c) reinforcement learning (algorithms in this category learn to optimize behaviour by interacting with the environment. Models constantly refine actions based on rewards and punishments. Reinforcement learning is applicable in a variety of fields, including gaming, robotics, and autonomous vehicles).

Machine learning algorithms build a mathematical model by analyzing sample data (also known as training data), which enables them to make forecasts or decisions. Advanced analytics is a term used to describe a set of techniques, methods, and tools for analyzing data and obtaining information, patterns, and predictions beyond traditional analytics. Automation can be utilized to work with both analytical models and machine learning models after their implementation in business processes.

The amount of data generated every day, such as images, clickstreams, voice and video, mobile locations, and data from sensors in the IoT, is increasing rapidly. This data can be used to train machine learning models. However, there is a key difference between machine learning and advanced analytics. Advanced analytics models are developed and deployed according to a design defined by a human, whereas machine learning models are dynamic and learn from data, constantly optimizing their performance. Moreover, machine learning models can be deployed with continuous training, meaning they continue to learn and optimize objective functions based on real-world data and business process context.

The amount of world information produced annually is increasing by approximately 20–25%. Analysts estimate that about 80% of this information is unstructured [33]. While RPA tools are currently able to effectively use structured data, the vast majority of information comes in the form of text, emails, media content, sensor data, and satellite images. This presents a huge opportunity for companies to leverage this unstructured data to gain insights and competitive advantage.

Therefore, it is essential to consider when RPA, AI and IPA can be most beneficial. Chronologically (Figure 5), Business Process Automation (BPA), has been actively applied since the 1980s, evolving into Robotic Process Automation (RPA) which can handle entire business processes.

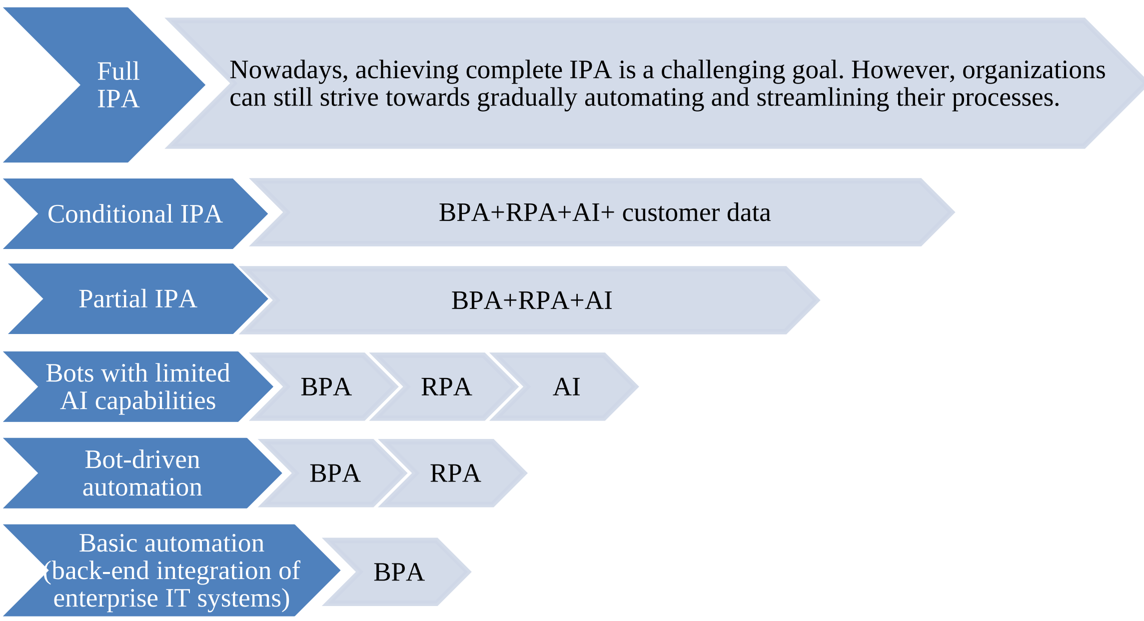

Figure 5. Evolution of the automation process technologies [34]

Intelligent Process Automation (IPA) combines the best features of both BPA and RPA and adds AI to create a more efficient process, relying on software bots that simulate human actions on the user interface level, logging in and interacting with software systems in the same way as human workers do. However, in recent times, we have witnessed a shift towards IPA, which can be considered a natural progression of RPA. The definition of «intelligent process automation» has recently emerged in the scientific terminological field, referring to the optimization of processes followed by automation. IPA is a combination of BPA with machine learning (ML), artificial intelligence (AI), and customer data, making it a more advanced and sophisticated technology for businesses. The combination of RPA, ML, and AI technologies can take many forms. RPA involves the use of software robots, or «bots», to automate repetitive and rule-based tasks. On the other hand, AI uses algorithms and machine learning to enable machines to perform tasks that require cognitive abilities. When used together, RPA can handle more complex tasks, such as natural language processing and text tone analysis. AI algorithms can also work seamlessly with RPA bots to enhance their intelligent decision-making capabilities. This means that RPA can analyze data using algorithms to make predictions and recommendations based on the data.

RPA is a type of software that can completely replace human activity in performing repetitive tasks. Typically, workers have to deal with numerous routine tasks that require a lot of attention and concentration. However, with RPA, software robots can perform these tasks in their virtual workspace, similar to human workers. These actions take place in a virtual environment, wherein the software robots can tirelessly work without any breaks. In practical production settings, there may be situations where a bot cannot complete a task due to security issues or incomplete data. To address such scenarios, developers can create response algorithms even during the RPA process development stage. For example, an algorithm can be designed to predict the maximum number of attempts required to repeat an action when it's impossible to connect to the database to transfer information. In such cases, an employee may be needed to resolve the situation.

Over the last 15 years, businesses have been investing in individual process automation solutions. However, advancements in technology, such as increased processor power, larger memory availability, solid-state drives, and cloud resources, have created more opportunities. By using previous information, robots can make more accurate decisions in atypical situations. With modern RPA tools like UiPath, Blue Prism, Automation Anywhere, WorkFusion, Pega Robotic Automation, Inflectra Rapise, Microsoft Flow, ServiceNow cloud tools, and the NICE platform, solutions can be found in real-time, minimizing latency and solving privacy issues. These tools also avoid the transmission of raw data and use new statistical methods to reveal true cause-and-effect relationships. This allows businesses to make decisions that target root causes, not just correlations. As a result, we are witnessing the widespread use of complex algorithms that contain machine learning and artificial intelligence. Currently, RPA, AI and ML are powerful technologies that, in combination, can provide highly effective solutions for intelligent automation (Figure 6).

The implementation of Intelligent Process Automation (IPA) does not eliminate the role of human beings in the process. Instead, it provides an opportunity to focus on more intellectual, analytical or creative tasks, freeing up employees' time for customer interaction, establishing contacts and other important activities. By effectively automating business processes, you can proceed to the next stage of introducing bots directly into the process.

This means that the bot will complete a certain part of the tasks, and after that, the employee will join the process. At this stage, leading companies around the world use machine learning and advanced analytics, voice recognition and natural-language generation, BPMS, and cognitive agents for intelligent automation of business processes [37].

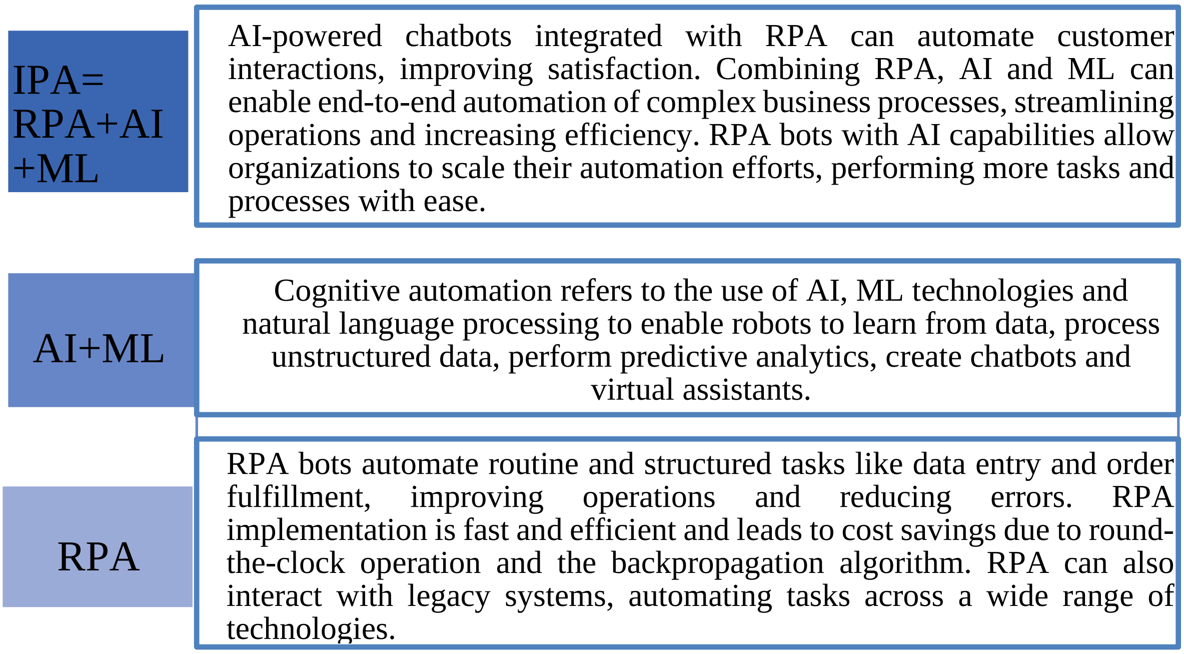

Figure 6. RPA, ML and AI:
Three Business-Changing Technologies [35–36]

Any implementation of IPA must combine quick achievements with larger, long-term developments. A detailed roadmap should be based on a fundamental redesign of the process, involving a sequence of automated modules for production and a rethinking of how a reevaluation of human-machine interactions should work to get value. Along with this, the implementation of IPA is appropriate in the case of reinforcing the use of technologies with additional practices aimed at improving business processes.

To sum up, RPA and AI are valuable tools for intelligent automation, which combined can lead to more sophisticated and tailored automation solutions, including full IPA. However, it is very important to choose the right combination of technologies based on the specific needs and goals of the organisation – since the mentioned technologies can be used both individually and synergistically, creating the prerequisites for the further development of IPA. It is important to have a clearly defined strategy and management model to ensure the successful integration of RPA and AI into business processes. In addition, the cost of RPA is decreasing, and the use of cognitive automation is increasing, so full IPA may supplant traditional approaches to process automation in the future.

Chapter 2. Transformation of business processes and factors influencing the development of digital interaction of business structures

Incorporating digital technology into business processes is a complex and multi-faceted endeavour. It involves various factors such as technological advancements, changing consumer behaviour, regulatory frameworks, and market competition. Successful implementation of digital interactions can lead to increased productivity, improved services, streamlined operations, and better profitability. It requires support at all levels, including regulatory. The European Commission has published the final DESI 2022 report on the measurement of digital technology indicators of 27 EU member states [38]. The report highlights that progress in the development of the digital economy is crucial for increasing the competitiveness of the EU economy. It is not just that the business model is subject to transformation, but that the guarantee of success in modern conditions lies in the digital economy. ICT has quickly become an integral part of the enterprise's functioning. The widespread use of digitalization of information and digitalization of processes has had a tangible impact on how enterprises work. It has changed how enterprises organize the processes of production or provision of services, as well as how their internal and external communications are conducted. It also transformed the definition of progress in the field of enterprise automation.

According to research conducted by Sh. Chatterjee, R. Chaudhuri et al. [13] and Y. Kihel, A. Kihel, E. et al. [39], the successful implementation of the digital transformation paradigm requires a VSM design process and management solutions that prioritize digital skills. This should be based on the individual capabilities of employees at the micro foundational level while utilizing the advantages provided by CRM systems supported by artificial intelligence for workplaces and production processes in the era of digitalization. The study tested hypotheses based on the theory of bias and the status quo concerning digital competencies using the SEM method and data from 341 respondents from various industries. The results confirmed that people's skills and abilities are key to digital transformation.

Amr Adel [5] and Hannele Lampela et al. [40] also believe that digital transformation requires structural reformatting, which is why it is better to prefer flexible management that best takes into account the needs of personnel.

Researchers J. Konopik, Ch. Jahn, T. Schuster et al. [32] see the use of organizational capabilities to take into account the changing needs of adaptation throughout the entire process of digital transformation as a necessary condition for successful change management. The conceptual basis developed by them gives enterprises directions for the development of organisational capabilities for the step-by-step convergence of the principles of further digital development.

Wareham, Mathiassen, Rai et.al [9] introduced the concept of the «digital supply chain», which is a turn of the supply chain towards a more open system based on digital innovation. Thus, Büyüközkan and Göçer [41] defined the digital supply chain as a set of interconnected activities that are carried out with the help of new technologies and are involved in the supply chain processes between suppliers and customers.

Additionally, several academic studies highlight the impact of digital transformation on value creation as a role model for technology entrepreneurship. Jafari-Sadeghi, Garcia-Perez, Candelo, et al. [26] focused on a wide range of dynamic capabilities that help capture digital innovation at the macro level.

Based on the fundamental principles of sustainable development and based on the theory of frames and the theory of social representations, Barbara Brenner and Barbara Hartl [25] examine how, from the point of view of sustainable ecological, economic and social development, gradual digitalization is one of the most significant challenges for society. Following a multi-method approach, the researchers combined media analysis with two experimental studies, finding that perceptions of environmental and economic sustainability depend on the degree of digitalization.

Under the influence of digitalization, the hyper-personalization and segmentation of consumers have only intensified due to the systematic collection, aggregation and analysis of large arrays of unstructured data from non-traditional sources, which after digitalization and analysis can help identify anomalies in production or service processes). Moreover, today it is characteristic not only for online trade, but also for production and critical infrastructure, and the speed with which information about consumers can be obtained in real-time to ensure the supply chain and make management decisions is already becoming a competitive difference.

Modern enterprises are flexible systems capable of self-optimization of productivity, self-adaptation, and automatic management of processes. This became possible thanks to more powerful computing and analytical capabilities and interaction with broad smart ecosystems of connected assets [42]. Smart ecosystems primarily mean the integration of data from operations and business systems, as well as from suppliers and customers, which together provide a holistic view of all supply chain processes. A typical example of a smart ecosystem is a smart factory.

Formed trends that in the future will only strengthen their role as a catalyst for changes in the field of digitalization include rapid development of technologies, global fragmentation of supply chains and the increase in their complexity, unexpected effects of the combination of IT and OT, intensifying global competition, and talent search. Let’s take a closer look at each of the trends. As for the rapid development of technologies, until recently existing digital limitations of technological capabilities made it impossible to transform supply chains due to exorbitant costs for computing, data storage and bandwidth of information systems. However, the situation has changed dramatically recently – AI and machine learning technologies have become accurate enough for production-critical tasks (meaning the interpretation, adaptation and self-learning of machines based on the received data). As a result, today it is possible to go beyond the automation of tasks to the automated management of more complex, connected processes at the expense of available data processing and storage capacities.

The second trend – the global fragmentation of supply chains and the increase in their complexity – became possible due to the globalization of production, which involves multi-stage manufacturing and fragmentation, and therefore – production becomes distributed among several enterprises and suppliers in different regions [43]. This factor, combined with adjustment to fluctuations in demand, provides greater flexibility and proactivity. Another trend, the unexpected effects of the combination of IT and OT, is manifested in the fact that the decision to automate a single business unit leads to changes in the entire industrial complex. The trend of finding new talents arose as a response to such urgent personnel problems as the ageing of the workforce, insufficient qualifications, etc. At the same time, the development of digital smart technologies led to the actualization of the risk of the appearance of new competitors who, due to digitalization, can reduce the costs of entering the industry to gain a foothold in new markets where they were not present before.

The path to full data interoperability is a multifaceted and long-term process that involves the creation of a two-level structure of compatible data for further data sharing, which at the same time will allow fast-tracking of point improvements.

The digital space, in which there is no significant number of intermediaries, in contrast to traditional business and the linear distribution system (from the supplier to the buyer, usually through intermediaries) is convenient, financially and economically beneficial for everyone (both for suppliers and for consumers), given the two-way direction of economic operations.

The key to digitalization is not technology; it's digital transformations. The transformation of the business model involves transitioning to digital reality, which means rethinking existing approaches. For example, adapting workplaces to new conditions and rapidly reconfiguring by emerging professions related to new areas of knowledge, digital talent management, etc. This reorientation is gradually happening in Ukraine but at a much slower rate. As a result, many supply chains are transforming from stable sequences to dynamic ones. The digital transformation of business structures can be considered as the integration of economic and logistical activities into the information electronic space and the life cycle of the consumer. This is thanks to the digital supply network (DSN), which contributes to the transformation of the activity space of enterprises. As a result, it activates the work of Internet platforms and smart factories, expanding the segment of marketplaces. This transformation is relevant for any enterprise, regardless of whether its field of activity is digital business or the real sector. It is important to focus on economic conditions, the search for effective DSNs, and the necessary ICT tools.

The evolution of the relationship between man and machine has been a critical aspect of industrial growth and development over the years. Recently, there has been a significant shift towards human-centred manufacturing, which has become a key factor in driving innovation, productivity, and efficiency across industries. Each element of the traditional consumption chain is increasingly becoming part of an integrated supply network. This network is characterized by a high potential for interaction of each node with any other point of the network. Accordingly, the transition from a linear to a network principle requires a new way of organizing the relationship between physical and digital assets.

We propose a Six-Stage Supply Chain Digital Transformation Model to integrate the technology within the current structure of business processes in a systematic and well-planned manner. Possible root causes of the digital supply network for business structures are shown on a fishbone diagram, also known as Ishikawa diagram and the 6 Ms (Figure 7).

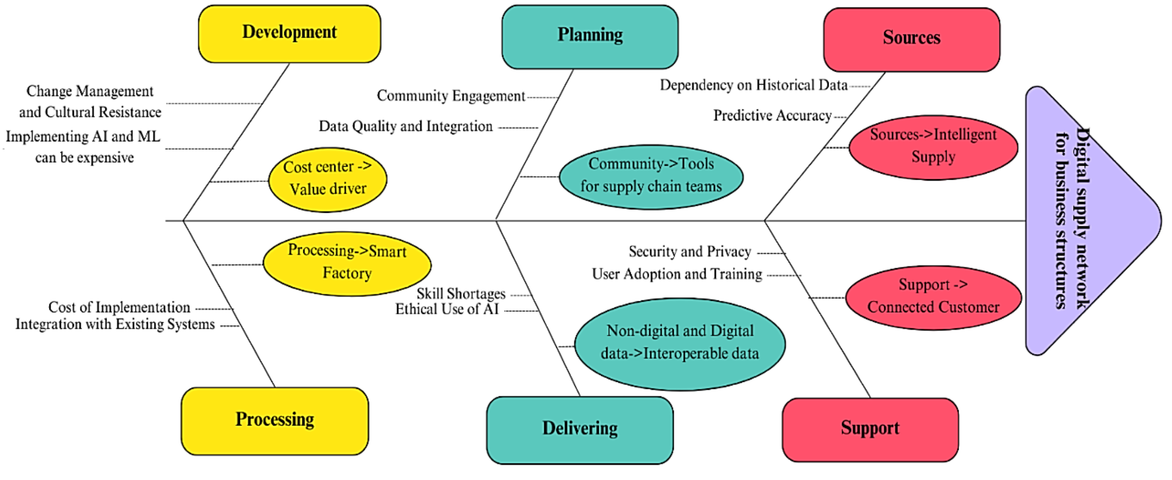

Figure 7. Research model showing the six-stage digital transformation of the traditional supply chain

The model consists of development, planning, sources, processing, delivering, and support as major categories of possible root causes. Each category is backed up by factors which influence the digital supply network for business structure design. We account for those factors by proposing an actionable stage per category of root causes.

Stage 1: Cost center -> Value driver. Transforming the supply chain from a cost centre to a value centre involves optimizing incentives and disincentives for online shopping and delivery times. Sales forecasting accuracy can be significantly improved by training machine learning models, such as Gradient Boosted Regression Trees (GBRT), on large datasets that include historical sales, seasonality, promotions, inventory levels, competitor behaviour, and other variables. Accurate sales forecasts contribute to better inventory planning and production scheduling.

However, market pressure is always a relevant factor that can push businesses to accelerate research and implement innovations, according to market forecasts. In the early 2010s, the IBM Watson Health team was under pressure to commercialize and sell the platform after successfully diagnosing and treating rare diseases, such as Kawasaki disease in children using AI. This led to unrealistic goals, including an expected growth of 1949% for the period 2015–2020 [44]. However, the amount of real health data available was insufficient, and synthetic data had to be used instead. This is a challenge, as synthetic datasets are often created by a small number of individuals who may unconsciously have biases. High expectations for immediate profitability combined with reliance on synthetic datasets have resulted in serious problems, including inappropriate treatment protocols.

Stage 2: Community -> Tools for supply chain teams. The advancement of automation has reached a new stage with the widespread adoption of IPA, RPA, AI, and the ever-increasing complexity of cyber-physical systems. However, modernized supply chains have evolved beyond automation. «Machine creativity» refers to the use of artificial neural networks to simulate creative processes with the help of computers or other machines. Generative adversarial networks (GANs), a combination of two neural networks, can produce photorealistic images, poetry, prose, recipes, patents, and more. This is similar to the Turing Test but without human participation. Two AIs learn from the same data, which allows AI systems to work on raw real-world data without human supervision.

Big data and machine learning are used in finance, insurance, government, and retail sectors to quickly detect fraudulent activities in any stage of the supply chain. By scrutinizing big data about transactions and customer interactions, models can detect deviations from normal behaviour in real-time. PayPal uses custom-built deep learning algorithms to verify millions of daily transactions, and Mastercard anticipates emerging fraud threats and maintains the security of its payment network by combining serverless computing and artificial intelligence [45].

The field of computer vision is also undergoing a revolutionary transformation. BMW, for example, uses neural networks to visually identify damaged car parts along assembly lines, using knowledge gained from studying thousands of images [46]. The resulting algorithms outperform human inspectors, achieving an accuracy level of over 90%.

Stage 3: Sources -> Intelligent Supply. During this stage, companies implement conscious automation and testing of new technologies. However, with the wide range of IT solutions available, it can be difficult to choose the optimal strategy. The key advantage of Intelligent Process Automation (IPA) is that it makes it possible to quickly test different technologies and evaluate them based on customer benefits, employee convenience, and investment opportunities. This allows for the creation of a bimodal system of IT applications.

The final phase involves the formation and analysis of a set of key process indicators (PPI). Analyzing the performance indicators of business processes should be a regular practice that is as commonplace as analyzing indicators in management reports. This continuous monitoring not only has obvious benefits but also contributes to the generation of ideas for possible improvements in business processes.

Previously, understanding the stages of demand formation and customer priorities contributed to reducing delivery time and increasing the reliability of delivery schedules [47]. However, digitalization has increased hyper-personalization and consumer segmentation by collecting, aggregating, and analyzing large volumes of unstructured data from non-traditional sources.

Machine learning, a subset of artificial intelligence, enables computers to recognize patterns in data, allowing them to make decisions and predictions without explicit programming. These algorithms iteratively learn the input data, gradually improving their performance. Remote warehouses for the delivery of non-urgent orders turned supply chains into an effective tool that stimulated informed decision-making by consumers.

Additionally, natural language processing algorithms facilitate automated analysis of sentiment, topics, keywords, and trends in vast amounts of textual data from comments, documents, social networks, and surveys.

Stage 4: Processing -> Smart Factory. Smart ecosystems refer to the integration of data from operations and business systems, suppliers, and customers, resulting in a comprehensive view of all supply chain processes. A prime example of a smart ecosystem is the smart factory.

In smart factories, automated work processes, improved tracking, and scheduling synchronization processes, along with optimized energy consumption, allow for increased uptime, improved product quality, minimized costs, and reduced waste [48]. For instance, Siemens employs machine learning models trained on historical sensor readings to identify turbines at risk of failure. Technicians can then perform maintenance to prevent failures early. Utility ComEd uses smart meter data and weather information to predict spikes in energy demand, ensuring optimized power generation and procurement.

Algocraft built a machine learning model for UPS to determine optimal delivery routes and loads for trucks entering the hub. The system increased efficiency by 7–13% compared to heuristic methods.

Industrial IoT sensor data from heavy equipment is fed into an anomaly detection model to detect early warning signs of potential malfunctions, where even minor deviations from normal operation can signal deterioration.

Stage 5: Non-digital and Digital data -> Interoperable data. The landscape of business intelligence has transformed with the rapid development of big data. Companies now consolidate data from various sources such as internal systems, mobile devices, sensors, social platforms, etc. to gain transformative insights. However, the raw data remains ineffective without advanced analytics due to its vast volume. Understanding the principles of machine learning has become a prerequisite for organizations seeking to harness the potential and benefits of big data. One vivid example is the Ukrainian case of intelligent automation of document management «Bionorika (Ukraine)», which is part of the well-known international pharmaceutical company "Bionorica" (Bionorica SE). The implemented IPA optimized document circulation processes and accelerated document processing [49].

Untapped computing power has become a defining resource in the competitive landscape of artificial intelligence, as it’s a resource that has been compared to «new oil» in its importance. The desire for high-performance computing resources grew as the complexity of artificial intelligence models increased.

Personalized recommendations are essential because digital platforms have accustomed consumers to personalized recommendations, thanks to machine learning algorithms. These models carefully study individual preferences and behaviors to predict which products each customer is most likely to be interested in [50–52]. To deliver targeted recommendations at scale, companies like Amazon use collaborative element filtering. This machine-learning technique matches each customer’s purchase history with similar behaviour patterns observed in millions of other customers. Streaming platforms like Netflix use deep learning algorithms to analyze viewing history and ratings, making suggestions for new shows based on personal interests.

In addition, airlines, hotels, and retailers use machine learning to dynamically price based on supply, demand, seasonality, events, and competitor data. AI-powered pricing maximizes both revenue and customer satisfaction.

Leading food retailers such as Walmart and Kroger use machine learning on point-of-sale data to optimize in-store pricing [53]. These models ensure price competitiveness while capturing maximum value for customers.

Stage 6: Support - > Connected Customer. This stage involves the analysis of business processes through the lens of customer experience. When improving business processes, employees often pay attention to point improvements and make processes more convenient, first of all, for themselves. However, the main value for a business is the customer, and therefore their experience with the company should be the focus. Accordingly, a combination of projects with customer experience management (CEM – customer experience management) and business process management (BPM – business process management) can serve as an effective practice. The client's expectations act as a starting point for designing the process, and then, by analogy with the customer journey map, various stages, touchpoints and interactions that the client goes through when interacting with the company or brand are analyzed.

Leveraging the power of serverless computing, Amazon has created chatbots that use NLP and machine learning algorithms to understand customer queries and provide instant, accurate responses. These chatbots efficiently handle a large number of customer inquiries at once, providing a fast and personalized interaction. Similarly, Starbucks has introduced a chatbot that seamlessly integrates with existing mobile ordering and payment functions, making voice shopping easier. Using natural language understanding, the chatbot skillfully interprets complex beverage orders placed by customers, simplifying the ordering process and increasing overall customer satisfaction. Beyond chatbots, natural language processing uncovers a wealth of information from vast amounts of unstructured text data, including documents, emails, surveys, social media, and call centre logs. Sentiment analysis interprets text data to detect emotional tone, identify concerns, and gauge satisfaction.

At the same time, it is important to be aware of the manifestation of Conway's law in the field of AI, because values, beliefs, attitudes and behaviour are rooted in culture and influence the development of technology. In 1968, Melvin Conway [54], a computer programmer and high school math and physics teacher, identified that systems largely reflect their creators and their values. The researcher observed how organizations interact within themselves, and further research by the Harvard Business School developed his ideas – different codebases and software were analyzed, and developed with the same goal, but by different types of teams: some were tightly controlled, others were autonomous and had open source. One of the key findings was that selection depends on how teams are organized, and within these teams biases and influences may go unnoticed. Thus, a small group of individuals on a team have significant influence when their work falls into rationalization or algorithmization – ideas and ideology determine what flows through the AI ecosystem, from codebases to algorithms, systems, hardware design, and networks. Of course, this phenomenon is not limited to the field of AI, because there is no meritocracy here, but it is important to take into account when restructuring business processes.

Digitalization has transformed many supply chains from a stable sequence to a dynamic one. This evolution has also changed the way we work, shifting towards human-centred manufacturing, which empowers workers and creates a more collaborative and inclusive work environment. By designing machines that work in harmony with human workers in the context of Industry 5.0, companies can drive innovation, productivity, and efficiency.

The digital transformation of business structures is the integration of economic and logistical activities into the electronic information space and the consumer's lifecycle. This is made possible by the digital supply network, which contributes to the transformation of the space of business entities, activating the work of internet platforms and smart factories, and expanding the segment of marketplaces. This transformation is relevant for any enterprise, regardless of its sphere of activity. Focusing on economic conditions, finding efficient digital supply networks, and using necessary ICT tools are essential for businesses to adapt to the changing landscape.

Conclusion

IPA and integration of AI with RPA offer a powerful combination capable of revolutionizing business in various fields and provide companies with the ability to make data-driven decisions, automate complex tasks, and provide personalized user experiences. By understanding the benefits of IPA, RPA, and AI, following best practices, and learning from real-world success stories, companies can embrace these synergies and pave the way for digital transformation. As technology companies brace themselves for future uncertainty and systemic risks caused by the war in Ukraine and the pandemic, they must build more predictable and resilient systems. Digital transformation must be based on the premise that digital technologies and solutions drive the development of reliable technologies and contribute to a viable digital economy. The proposed Six-Stage Supply Chain Digital Transformation provides a comprehensive approach to improving supply chain management through the use of data analytics, machine learning, and other technologies to identify areas of inefficiency and opportunities for improvement. The future-oriented digital transformation will be driven by the need for companies to build systems with better predictability and resilience.

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