Towards Intelligent Supply Chain Automation

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Abstract: Shop floor automation has been leveraged in the industry for a long time. Recently, however, technological advancements in digital technologies such as Internet of Things (IoT), Artificial Intelligence (AI) and Big Data Analytics (BDA) have increasingly focused on automating tasks commonly done by white-collar workers. In supply chain planning and management, for example, the level of automation has reached unprecedented levels, so we believe it is essential to introduce the concept of Supply Chain Automation (SCA). While similar concepts, such as Business Process Automation, have been widely discussed in academia, SCA still lacks conceptualisation. However, conceptualising an emerging field is an important endeavour, as it supports aligning and orchestrating efforts in academia and industry. To fill this gap, a systematic literature review was performed to identify different types of automation (Robotic Process Automation (RPA), AI-assisted or AI-driven RPA, and Hyperautomation), as well as the motivations and benefits of automation adoption, and to derive a framework that highlights the sequence of different automation levels according to supply chain processes and technological complexity. This research allowed us to propose a definition of Supply Chain Automation concept based on analysed contributions, characterise each type of automation from the technological perspective, highlighting the possible benefits. Supported by recent technological evolution, SCA can be regarded as the new paradigm in supply chain planning.

Keywords: Supply Chain Automation, Intelligent Automation, Hyperautomation, Artificial Intelligence

1.Introduction

Supply chains are becoming more complex, costly, and uncertain. Almost half the activities people are paid almost $16 trillion in wages to do in the global economy have the potential to be automated by adapting currently demonstrated technology, according to an analysis by McKinsey research of more than 2,000 work activities across 800 occupations. At the same time, technology and information advancements open up many new possibilities in the scope of digital transformation of the supply chain (Vu et al., 2023). The increasing complexity, cost, and uncertainty of modern supply chains have boosted growing interest in automation (Xu et al., 2023). Automation is shifting from an option to a necessity to increase productivity and minimise time to market to stay competitive (Abid Haleem, 2021).

According to the analysis of SnapLogic, 90% of employees are being burdened with boring and repetitive tasks, which could be easily automated (SnapLogic, 2017). Such tasks include searching for data, data entry, processing and analysis, and combining data from multiple sources. On average, they are costing businesses around 19 working days per year per employee. These monotonous and repetitive tasks imply huge quantities of disconnected data that negatively impact productivity. Digital transformation, however, offers an increasing number of solutions to such data gaps.

Digital technologies such as robotic process automation (RPA) with the Internet of Things (IoT), Artificial Intelligence (AI) and Big Data Analytics (BDA) open broad possibilities to achieve the digital transformation of entire supply chains and exploit new levels of business process automation (Santos et al., 2020). Digital technologies integration to automation can allow workers to make higher-level cognitive decisions, acquiring more human capabilities, such as deductive analysis and quick judgement (Ng et al., 2021), thus increasing automation potential from simple activities to processes or entire systems. Thus, a more "intelligent" automation can handle more complex processes, systems or supply chains. These allow one to overcome current challenges and release new potentials to enhance supply chain performances and completely redesign the way supply chains are managed and run.

Supply Chain Automation (SCA) concept encompasses physical and digital automation of information and business processes at a large scale (Xu et al., 2023). So far, the concept of SCA received more attention from practitioners and vendors than researchers. The academic literature is more focused on digital supply chains and the application of single digital technologies or RPA as a specific automation capability rather than on the comprehensive view that should characterise SCA (Vu et al., 2023). Given its potential value in applications and the growing attention of automation solution providers, it is fundamental to conceptualise "supply chain automation" to build the roadmap towards automation.

The objective of this paper is to analyse state-of-the-art academic literature on Supply Chain Automation and systematise existing knowledge on the topic, and propose an evolutionary path towards Supply Chain Automation. Hence, our research question is "How Supply Chain Automation can be conceptualised?" By exploring SCA state-of-the-art, we investigate the SCA technological readiness, in other words, "How far we are from the fully automated supply chain?"

Given the complexity of SCA from a technological perspective, in particular because of the heterogeneity of processes that could be automated, a comprehensive analysis of the concept is required, with focus on technological readiness for integration toward a fully automated SC.

2.Background

While physical automation is, per se, not a new topic, the scope of automation nowadays is much broader (Vu et al., 2023). Current work automation efforts commonly focus on automation in a digital manner, targeting tasks related to the interaction between humans and computers. The so-called informational automation distinguishes itself from physical automation as it represents one of the most significant recent developments in planning and controlling supply chains at the strategic, tactical, and operational levels (Nitsche, 2021). At the same time, automation represents a high source of complexity since it involves aligning and integrating multiple partners, data, and systems in complex global networks.

Automation typically integrates supply chains for two interrelated reasons: (i) to improve people productivity, which is referred to by Anywhere (2023) as the primary driver of SCA effort, and (ii) to reduce operational costs (Ng et al., 2021). Another relevant benefit is increased resilience against disruption due to higher visibility, responsiveness, proactivity, and intelligent decision-making support.

Nevertheless, SCA presents several challenges, such as a lack of IT readiness and skills, integration problems among technologies and systems, availability and quality of data, lack of a clear vision and a common mindset toward automation in line with the company strategy, employee resistance to change and high costs, are the most relevant ones (Ng et al., 2021).

Different technologies have different impacts on automation and, therefore, on how they reshape the management of supply chains. Moreover, automation potential does not result from one single technology but rather from a range of technologies, tools and techniques that must work in concert with one another. Building an automated supply chain that can perform the entire end-to-end flow, from procurement over transportation, inventory and production to delivery and demand management, could be an essential endeavour for many companies. Data, decision-making, and execution would be completely automated and integrated across all stages, thus optimising the entire supply chain ecosystem. However, such configuration is linked to many challenges and barriers, such as the lack of IT infrastructures, relevant skills, in addition to high costs and complexity of implementation and management (Watson et al., 2020).

3.Methodology

A systematic literature review was performed by using the Scopus database. The query was structured as follows: TITLE-ABS-KEY ("robotic process automation" AND ("business process automation" OR "orchestration" OR "business process management" OR "supply chain") OR "supply chain automation" OR "autonomous supply chain" OR "intelligent automation"). The search process generated 217 papers that were screened through filters related to the subject area, document type, availability, and alignment with the research scope (Figure 1) distributed by year, as shown on Figure 2.

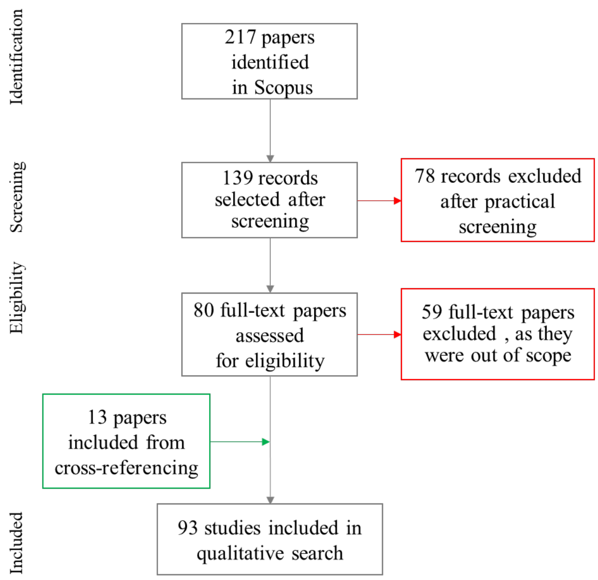

Figure 1: Systematic literature review funnel

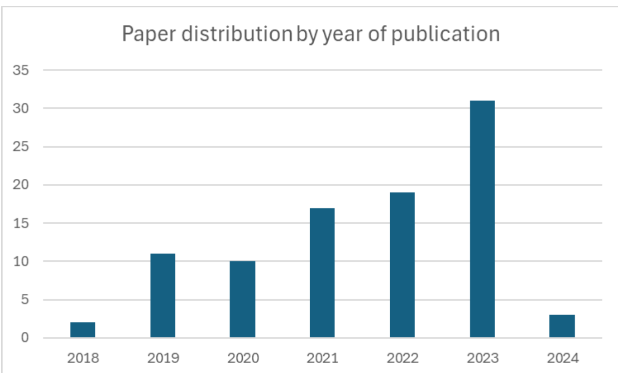

Figure 2: Distribution of selected papers by year of publication

Figure 2 highlights the novelty of the topic, as more than half most relevant contributions were published in the recent 2 years.

Through the snowballing approach, five further scientific papers were included, and additionally, eight papers were found in the grey literature published by leading vendors of supply chain business process automation solutions or consultancy companies active in the field. This process resulted in a total sample of 93 papers to be reviewed.

The literature review allowed us to identify different types of automation, the motivations and benefits of automation adoption, and to draw a framework that highlights the sequence of different automation levels according to process and technological complexity.

4.Findings

There is still no widely accepted definition of the concept of supply chain automation. Only two papers mention a specific definition of SCA, while seven others acknowledge the need for more research in this area. SCA has been defined as the partial or full replacement of a human-performed physical or informational process by a machine. This includes tasks to plan, control or execute the physical flow of goods as well as the corresponding informational and financial flows within the focal firm and its supply chain partners. It involves integrating disruptive digital and operations technologies that reduce the dependencies of SC operations on human interventions (Ghobakhloo et al., 2023; Nitsche, 2021).

Adopting digital technologies to automate supply chain processes represents a shift in how organisations create value. Information technologies such as IoT, AI and BDA, can bring RPA to the next level, enabling so-called AI-Assisted RPA or intelligent automation. The highest level of automation involves a system of processes in the entire supply chain. It can be seen as a system of systems and may be defined as Hyperautomation. The following section presents these concepts.

4.1 RPA

RPA denotes a software system that imitates the steps humans perform in routine, repetitive, and predictable tasks to efficiently accelerate the task execution (Vu et al., 2023; Ng et al., 2021). It uses business rules and predefined activity choreography to automate the execution of a combination of business processes, activities, transactions and tasks that use one or more unrelated software systems to deliver a result or service, with human exception management. RPA is often the companies' first step toward automation due to its relatively easy and fast implementation process (Hartley and Sawaya, 2019; UiPath, 2021). As supply chain management and execution contain many repetitive tasks, RPA can take over these tasks, requiring limited human supervision (Hartley and Sawaya, 2019). A study on SCA run by Deloitte illustrates RPA as the most widespread technology, with 78% of 441 interviewed companies already implementing it and 16% planning to use it in the next three years. The primary reasons behind RPA adoption are manifold. First, it works "on top" of existing software and information systems and through the existing user interface without changing the underlying software architecture (Viale and Zouari, 2020; Radke et al., 2020). Second, it is easy to introduce in companies due to limited training and required coding skills, as well as the high availability of providers in the market (Hartley and Sawaya, 2019). Third, it is easy to add or remove capacity and to scale up or down bots depending on business needs (Hartley and Sawaya, 2019). Fourth, it can be applied to single tasks in a process without having to redesign and re-engineer the end-to-end process (Viale and Zouari, 2020).

Generally, processes suitable for RPA automation are routine tasks that are repetitive, mature and rule-based, with a high level of predictability and frequency and minimal requirements for exception handling. Typical applications include data entry automation, transfers and extraction from documents and ERP systems, simple calculations, and form completion. Such robots can navigate systems, identify data and perform well-define actions faster and more consistently than people (UiPath, 2021). RPA shows clear benefits in terms of productivity increase, processing time reduction and compliance, and quality levels improvements. An increase in productivity comes from freeing up employees from nonproductive tasks, so they can focus on higher value-added activities and those that are more tactical and strategic (van Hoek et al., 2022; Radke et al., 2020). Processing time reduction can be achieved thanks to robots' ability to work 24 hours a day, which improves efficiency (Radke et al., 2020). Compliance levels also improve because RPA eliminates human errors, improves data quality and enhances process accuracy (Viale and Zouari, 2020; Ng et al., 2021) while lowering compliance risk (Radke et al., 2020). RPA technology not only gives organisations an opportunity to automate their processes but also helps them to simplify and rapidly streamline them (Viale and Zouari, 2020), leading to an increase in agility and transparency between different actors of the supply chain.

4.2 AI-assisted RPA

The integration of RPA with other digital technologies, such as IoT, AI and BDA, enables the automation of even more complex activities and processes. RPA enhanced with these technologies integrates multiple automation capabilities in a single automation suite, creating a new level of automation, so-called intelligent automation (Vu et al., 2023; Ng et al., 2021).

IoT is composed of physical devices (e.g. sensors) that collect data, and a communication network that transmits the collected data for the purpose of identification, tracking, and monitoring (Tadejko, 2015). Thus, IoT improves data accuracy and integration, while enhancing end-to-end transparency and visibility, especially considering that, at present, the majority of IoT applications are developed in the Cloud. The data collected by means of these technologies enable a more complex automation. IoT enabled data collection and monitoring, and Cloud implementation, constitute first steps towards SCA, enhancing SC visibility and creating ground for the use of AI- algorithms. IoT implementation may involve significant costs, given the large volume and range of sensors to be used. Its introduction in SC can start from more relevant processes and then gradually expand.

AI is a technology that enables a computer system to understand relationships, learn from data, and use those learnings to achieve specific goals and tasks through flexible adaptation. Big Data Analytics (BDA) is a technology that treats ways to analyse and systematically extract information from large data sets (Ramirez-Asis et al., 2022; Watson et al., 2020).

Within the scope of SCA, AI and BDA are dealt with jointly. By merging them, a new level of automation of business processes and systems can be reached. RPA seems to not lose its importance, leading to the emergence of AI-assisted or AI-driven RPA. Thus, when human-like intelligence and cognitive capabilities are required, such as processing unstructured data, recognition of patterns and categories, and problem-solving, such systems will be used to automate planning, optimisation, and prediction processes. Automated recommendation systems that aim to identify the best answers to problems in the supply chain constitute another relevant field of application for AI.

AI and BDA enable companies to automate processes with characteristics that would have been impossible to automate with RPA alone, thus expanding automation capabilities and accelerating decision-making (UiPath, 2021). For example, AI helps robots perform cognitive tasks, navigate uncertainty and resolve inconsistencies. The more robots can think and understand on their own, the more and faster they can do tasks and the more significant the impact they can make. This arises from the cognitive capabilities enabled by AI and BDA, including 1) recognising known and novel patterns and categories, 2) logical reasoning and problem-solving that uses contextual information and complex input variables, 3) optimising and planning to achieve specific objectives given constraints, 4) creating diverse and novel ideas, 5) searching and retrieving information from an extensive range of sources and 6) articulating and presenting output (Manyika, 2017).

AI, the most discussed and challenging technology for SCA, is relevant to be implemented to provide active monitoring and recommendation, prediction, and planning automation. Automation requires IT readiness, a skilled workforce, and data. Its implementation could start with "easier" algorithms and then evolve to more complex applications that require specific skills and competencies.

4.3 Hyperautomation

By its nature, RPA cannot automate complex processes and systems. Scaling up RPA programmes also constitutes a big challenge, and many enterprise automation initiatives cannot scale because of the lack of a clear automation strategy. Most organisations, even those that have implemented some RPA projects, do not have a Centre of Excellence (CoE), which is required to draw the guidelines and make the automation strategy uniform.

Implementing a wider range of technologies and business process redesign allows organisations to find more space for automation and move towards a so-called Hyperautomation. It is a paradigm according to which everything that can be automated should be automated (UiPath, 2021).

Gartner coined the term "Hyperautomation" in 2019, formally defining it in 2020 as a business-driven, disciplined approach that organisations use to rapidly identify, vet and automate as many business and IT processes as possible. Hyperautomation involves the orchestrated use of multiple technologies, tools or platforms, including IoT, AI, RPA, business process management, low-code or no-code tools and other types of decision, process and task automation tools.

Under a technological dimension, the Hyperautomation toolbox leverages many digital tools with the ambitious goal of mimicking human capabilities to automate cognitive processes that humans currently perform. RPA plays a fundamental role in this, but its features can be fully exploited if combined with the capabilities of AI and other digital technologies.

Automating all activities and processes that can be automated will make organisations closer to self-governing systems bult upon intelligence and automation, which are capable of autonomous decision-making with no human intervention. This type of automation may characterise exactly the autonomous supply chains (Xu et al., 2023) or SCA.

4.4 Path to Intelligent SCA: a conceptualisation

Starting from this evidence, it is possible to conceptualise a feasible path to intelligent SCA, which encompasses both the technological and the managerial aspects.

At the very beginning, companies will start with simple automation technologies, such as RPA, applied to well-structured tasks like the ones described above, to catch the immediate benefits of efficiency and velocity. Subsequently, more complex process tasks will be tackled, enhancing RPA with AI and BDA, resulting in AI-assisted RPA. This could encompass less structured tasks such as finding patterns, analysing documents, interacting for task completion and data collection, thus enlarging the scope of SCA initiatives.

After that, to further progress in SCA, companies would need to tackle very unstructured tasks, also affected by uncertainty and variance. This will likely lead to a bifurcation, as some automation initiatives may address process redesign to contain the level of complexity, and therefore limit the technology complexity level. This could lead to a concept of process automation which is similar to the concept of "autonomation" as introduced in blue collar processes in the '80s by the lean paradigm (Jana and Tiwari, 2021). Conversely, other tasks, if full automation is still sought for, will require a big step in machine intelligence and, eventually, technology complexity. This will require the best of hyper-automation capabilities (Gartner, 2019), with the related investments and capabilities. This conceptualisation is illustrated in Figure 3.

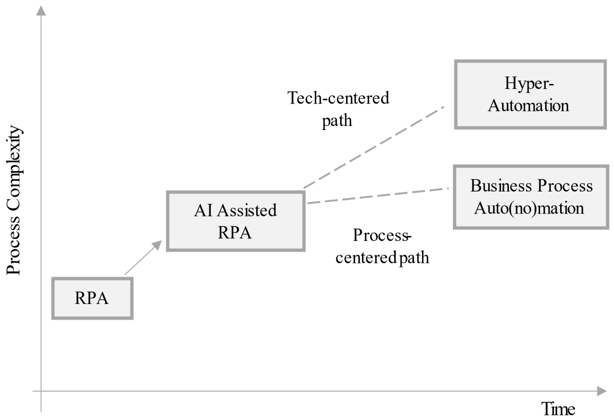

Figure 3: Path to intelligent SCA

5.Discussion: SCA implementation roadmap

SCA goes beyond the single process to orchestrate and integrate several processes. This enlarges the automation scope and potential, as well as the impact on the supply chain. The ultimate objective is to create an automated supply chain where the entire end-to-end process where execution and decisions are integrated and synchronised across all stages and actors.

Literature review results highlight that the journey toward building an automated supply chain is still long and that technology readiness is not sufficient yet. Barriers for the implementation of this integrated automation are mainly integration problems among technologies and systems that need to work together, and organisational readiness issues such as the lack of a clear strategy and roadmap for implementation, as well as leadership support to manage the change. Lack of IT readiness, skills, and knowledge to implement, manage and exploit technologies for automation, and barriers of data requirements, are other relevant challenges.

Given the complexity and heterogeneity of SCA and underlying technologies, several managerial insights may be relevant for companies to be analysed, to assess the best way to approach automation. The development of a common strategic mindset toward automation and a clear direction to follow, shared across the organisation, is a pre-requisite.

6.Conclusions

The paper defines Supply Chain Automation and provides a better understanding of its benefits and implementation challenges, focusing on enabling technologies and a generalized implementation path.

The paper sketches the evolution of supply chain automation, illustrating that RPA is the starting point of SC automation endeavors, and AI-assisted RPA is the next natural step to increase SC automation levels, thus dealing with higher levels of process complexities. RPA and AI-assisted RPA are state-of-the-art-SCA and address only a limited number of activities or tasks within SC processes. The path to intelligent SCI outlines two possible evolution scenarios in the future, one is rather process-centered, and the other is tech-centered. The process-oriented approach will place process redesign at the core of automation endeavors and will capitalize on existing technologies such as RPA and AI-assisted RPA to increase automation levels. This transition will occur with less technological development and can be sufficient for certain companies due to the nature of their operations (e.g., low-tech industries). The hyper automation approach is fully different, as it places technology (and less the process) in the center of endeavors and aims at integrating existing and new technologies to automate supply chain decision making, thus achieving an even greater step toward autonomously managed supply chains.

These contributions aim to fill the literature gap related to the diversified and fragmented vision that characterises research on SCA, where a technological overview for its implementation is lacking, as well as a general assessment of technology readiness and managerial implication in the journey towards a fully automated SC. RPA is the most widely used technology to automate supply chain processes, but it is no longer sufficient to address the full complexity of the supply chain. Recent technological developments, especially AI open up broad possibilities for the implementation of SCA.

Trough the literature review, the paper offers a framework that illustrates different levels of automation, and how companies my evolve in their supply chain automation journey.

Of course, the proposed conceptualisation provides just a starting point to examine SC Automation. Future studies are needed to develop a supply chain automation maturity model that enables the comparison between different automation levels in companies; moreover, a toroughful analysis of pre-requisites in terms of IT infrastructure and data quality is needed, to provide some normative insights into the SC automation strategy. Best practices from companies that have achieved successful SCA should be collected and analysed, among others with the objective of confirming the path to intelligent SCA. Last but not least, understanding the impact on SC workers, on their jobs and the impact on short-term and mid-term managerial skills is important as well. All these areas will represent directions for future research.

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