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Unlocking the Potential of Robotic Process Automation for Digital Transformation in Logistics and Supply Chain Management

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ABSTRACT

Digital transformation (DT) and automation technologies have significantly impacted logistics and supply chain management (LSCM), enhancing business performance. Efforts to automate processes alongside machine and robotic automation aim to improve reliability, consistency, efficiency, and cost-effectiveness. While existing research has explored specific aspects of DT and robotic process automation (RPA), the deployment and implementation of RPA as a service (RPAaaS) in LSCM are under-explored. This study focuses on RPA in LSCM and aims to improve organisational processes associated with DT. A systematic review identifies five knowledge clusters regarding RPA deployment for DT in LSCM. Real-life RPA implementation cases in a third-party logistics company highlight challenges and opportunities related to RPA deployment. Insights on the timing and choice of the RPAaaS platform to facilitate DT in enterprises are discussed. This paper provides extensive theoretical insights into RPA for DT in LSCM and offers practical guidance for streamlined implementation.

KEYWORDS

Robotic Process Automation, Digital Transformation, Logistics, Supply Chain Management, Innovation Resistance Theory

UNLOCKING THE POTENTIAL OF ROBOTIC PROCESS AUTOMATION FOR DIGITAL TRANSFORMATION IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT

Today, the global logistics service provider (LSP) market is experiencing rapid growth. While major international players attempt to capture significant market share, LSPs must adapt to changing internal and external environments such as innovation, the ongoing US–China trade war, and deglobalization (Jintana et al., 2021). The continual development of global trade in recent years has necessitated substantial changes in logistic processes (Saoud & Bellabdaoui, 2023; Law et al., 2021). In recent years, digital transformation (DT) and automation technologies have had a powerful

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impact on logistics and supply chain management (LSCM) around the world, with a positive effect on business performance (Boyle et al., 2022; Li et al., 2023). Such technologies include autonomous mobile robots and automated guided vehicles. According to Anthony (2021), digital transformation involves applying digital technologies to some areas of an enterprise, which leads to important changes in enterprises' activities and the way value is created for stakeholders. Sadangharn (2022) reports that robotic automation confers numerous benefits, such as improved customer service, enhanced productivity, and competitive advantages.

In addition to machine and robotic automation, recent research and development efforts on automation have extended to business processes. These efforts aim to optimize, implement, and automate selected organizational and business processes with enhanced reliability, consistency, efficiency, and cost-effectiveness (Wewerka & Reichert, 2021; Sharma et al., 2024). According to Statista (2021), the worldwide market revenue for intelligent process automation is expected to reach US$30 billion in 2024, an increase of more than 30% from 2022. In view of this growing trend and the huge economic potential of process automation in numerous industries, it is worth synthesizing the recent development of robotics process automation (RPA) in LSCM. This review aims to pave the way for DT, allowing enterprises to automate repetitive human processes.

The motivations for exploring the values of RPA in LSCM can be summarized into two facets. First, although RPA has been regarded as a trendy technology on the market, resources for high-level deployment and implementation from RPA as a service (RPAaaS) remain underexplored. In the case of LSCM-focused enterprises, developing intelligent process automation from scratch requires extensive talent and equipment, which may hinder on-the-ground system implementation and customization. Therefore, the possibilities for applying RPAaaS in LSCM scenarios should be explored.

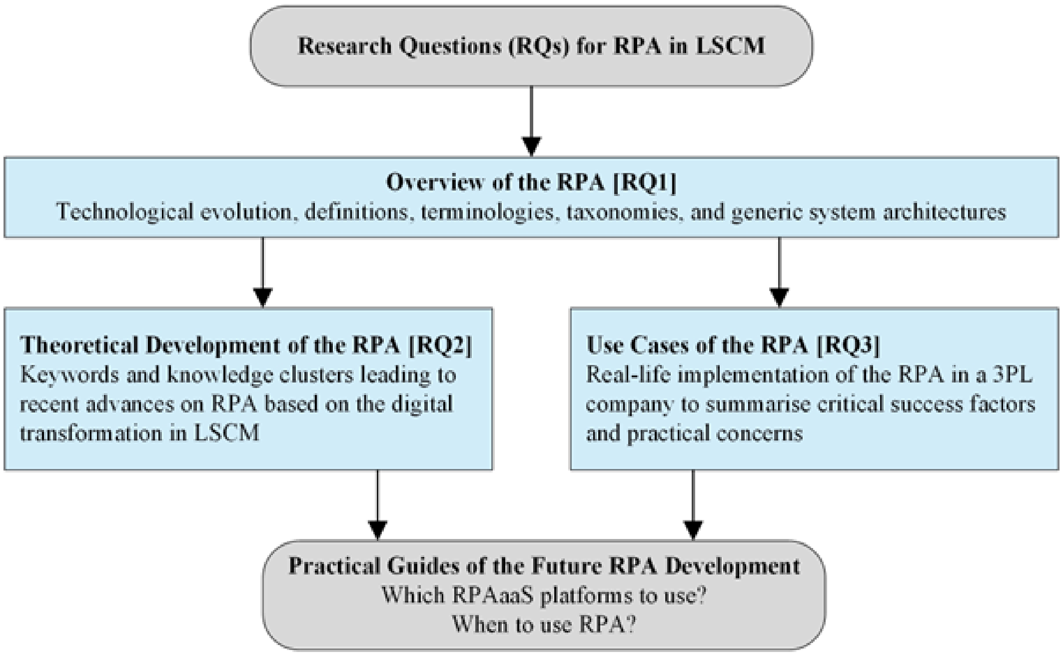
Second, implementing RPA in business scenarios allows businesses to shift their focus away from repetitive and error-prone tasks and toward advanced knowledge-intensive and value-adding activities. According to Deloitte (2017), 400 companies worldwide have started on their RPA journey, and 25% have a solid execution plan to implement RPA solutions in the coming years. These companies also report that the payback periods of RPA implementation are around a year on average, with expectations of improving cost-effectiveness, accuracy, timeliness, flexibility, and compliance. Forrester Research, Inc. (2017) estimated that over 4 million software robots would be automating repeatable tasks by 2021. Also, the focus is expected to move toward integrating RPA with other technologies to build analytics capabilities in business operations (Chakraborti et al., 2020).

Nevertheless, there is a lack of formal review analyses related to the RPA deployment in logistics and supply chain management. Since the corresponding theoretical and practical knowledge has not yet been systematically summarized, it is challenging for industrial practitioners to embrace other advanced concepts, such as intelligent process automation, hyper-automation, and even DT. In this context, three research questions (RQs) were developed for this research on the LSCM scenarios:

RQ1: What is RPA?
RQ2: What is the theoretical development of RPA in LSCM in the era of DT?
RQ3: How can RPA effectively facilitate DT in real-life LSCM scenarios?

A mixed-method research design is employed to address these RQs. First, a rapid review is conducted to explore the technological evolution, definitions, classifications, and system architectures of RPA, primarily addressing RQ1 and laying the groundwork for RQ2. Subsequently, a systematic review incorporating co-occurrence analysis and bibliographic coupling is performed to analyze the theoretical development and future deployment possibilities of RPA in the context of LSCM, directly addressing RQ2. This bibliometric approach identifies key themes, concepts, and research clusters in the RPA-LSCM-DT nexus. Multiple case studies of RPA implementation are conducted in a logistics service provider (LSP) in Hong Kong to bridge the gap between theory and practice

Figure 1. Research framework of this study



and address RQ3. This analysis aimed to diagnose the challenges and opportunities associated with RPA deployment in real-life LSCM scenarios.

The integration of findings enables a comprehensive exploration of RPA in LSCM, offering valuable insights to guide future research and development in this field. Fig. 1 depicts the research framework of this study, illustrating the interconnections between the research questions and methodological approaches.

OVERVIEW OF RPA

Technological Evolution

Although automation technologies have a relatively long history, the term “robotic process automation” first appeared in the early 2000s (Taulli, 2020). As a developing technology, RPA initially relied on screen capture, workflow automation, and other artificial intelligence (AI) engines (Zhou et al., 2022a, 2022b). Rather than depending on coding and programming, most RPAaaS solutions can create software robots (i.e., bots) to automate and manage workflows through drag-and-drop features. These tools eliminated the technical barriers to RPA's development and implementation, particularly for nontechnical users. In its emerging state in the early 2000s, RPA could only streamline repetitive and rule-based tasks; bots could not handle exceptional cases, and only simple programmed decisions could be made. Subsequently, optical character recognition (OCR) was implemented as a feature of RPA to enhance its data acquisition capabilities, allowing the technology to adapt to different types of content without human intervention (Taulli, 2020; Ostdick, 2016). Moreover, the integration of AI and RPA began to unleash more complex capabilities of RPA software, allowing it to recognize patterns and adapt to new situations and business cases. As a result, solutions created on RPAaaS platforms, such as those provided by UiPath, Kofax, and Automation Anywhere, became more flexible and responsive in the global business market.

Once RPA started reengineering more complex business processes in the mid-2000s, industrial practitioners attempted to exploit RPA solutions on a larger scale. Specifically, business process outsourcers began to perceive RPA as a driver for improving business efficiency (Gould, 2018). Indeed, implementing RPA provides numerous benefits to companies, including huge cost reductions [around 50% less costly than offshore information technology (IT) outsourcing], improved efficiency (nonstop operations without human errors), and better customer satisfaction and retention (high responsiveness and transparency with clients).

Since 2010, major RPA efforts have focused on discovering novel business applications, such as LSCM, health care, and finance (Gould, 2018). Companies in these industries have obtained significant benefits by applying RPA to handle manual and repetitive activities. They are eager to transform their businesses to digitally succeed in the smart era. In the past 20 years, RPA has proven its effectiveness in data entry, extraction, aggregation, and analysis. However, the bots in these applications could not understand the meaning of the information they were handling so effectively. Because of this concern, cognitive document automation is now developing rapidly. This technique involves a collaboration of AI with RPA to deal with unstructured data in business documents and emails (Automation Anywhere, 2022). It aims to allow bots to comprehend such information to provide AI-driven decision support, such as predictive data analytics, machine learning, and natural language processing, in various business circumstances. Furthermore, RPA is expected to work with other advanced technologies, such as OCR and business process management tools, to establish a human-like digital workforce and intelligent automation.

Definitions and Terminology

RPA enables users to automate manual, rule-based, and repetitive human tasks for standardized business operations (Aguirre & Rodríguez, 2017; Javatpoint, n.d.). Software bots interact with various application systems and data files as a human would. The significant difference is that such bots perform tasks more efficiently and consistently. In addition, these bots can work in a nonstop and standardized manner and can independently collaborate with in-house systems and interfaces. Most RPAaaS providers offer code-free RPA development platforms, and bots can interact with various applications based on operating systems, web pages, mainframe applications, or even applications written in outdated programming languages (Peluso, 2022). In short, RPA can be defined as the design and development of software bots integrated with advanced data acquisition technologies to perform human-like actions in standardized business operations.

A list of essential terminology is provided below to fully understand RPA's technological design and development (McDaniel, 2019; CiGen, 2018).

- Software bot: an automated entity programmed to carry out high-volume, repetitive tasks that emulate human interactions with digital systems. Bots follow algorithmic rules to execute tasks, reducing human workload and allowing personnel to engage in more complex, value-added activities.
- Standardized business processes: refers to regimented business processes that are methodically designed to be consistent and repeatable. These processes are usually documented as standard operating procedures, ensuring tasks are performed uniformly and efficiently across different instances and by different users.
- Attended automation: a type of RPA where user actions trigger bots and they work in tandem with humans on the same workstation, typically for front-office tasks.
- Unattended automation: bots in this category operate independently of human interaction, typically for back-office processing, and are scheduled to run at specific times or triggered by predefined events.

Table 1. Summary of the RPA taxonomy

	Rule-Based	Cognitive
Attended (Human–bot collaboration)	Bots operate on an individual's workstation and are invoked by the user to perform predefined, structured tasks based on specific rules.	Bots work alongside human users and support decision-making processes by interpreting unstructured data, understanding language, and making recommendations, such as customer services.
Unattended (End-to-end automation)	Bots are scheduled to execute highly repetitive and rule-based tasks, such as data entry, batch processing, or system integrations.	Bots incorporate AI components to handle complex tasks that require understanding unstructured data, pattern recognition, and adaptive decision-making.

Taxonomy

Regarding the current RPA development, two typical classifications, namely traditional versus cognitive RPA and attended versus unattended RPA, are organized for comparing different types of RPA solutions as follows (IBM, 2024; Martins et al., 2020).

Rule-Based and Cognitive RPA

Traditional RPA supports automation based on structured data and standardized processes, executing mostly simple tasks without a need for decision-making or cognitive activities. Such RPA solutions operate in a rule-based manner, with rules constructed using antecedents and consequents that articulate the underlying business logic. However, traditional RPA solutions are very limited in understanding collected data, particularly unstructured data such as human speech and handwriting. Therefore, cognitive RPA has been developed to enhance the bots' intelligence.

Cognitive RPA enables companies to automate complicated processes with unstructured datasets. In this approach, business logic and rules are mined rather than predefined. Examples of unstructured data sources include scanned documents, voice recordings, and images; cognitive RPA can recognize and understand such data to provide real-time decision support to business operations. Contrary to traditional RPA, cognitive RPA is designed to handle unexpected tasks without human intervention, and machine learning components are embedded in the design of the software bots to adapt to the environment effectively. Rather than rule-based reasoning, cognitive RPA can thus perform intelligent decision-making processes.

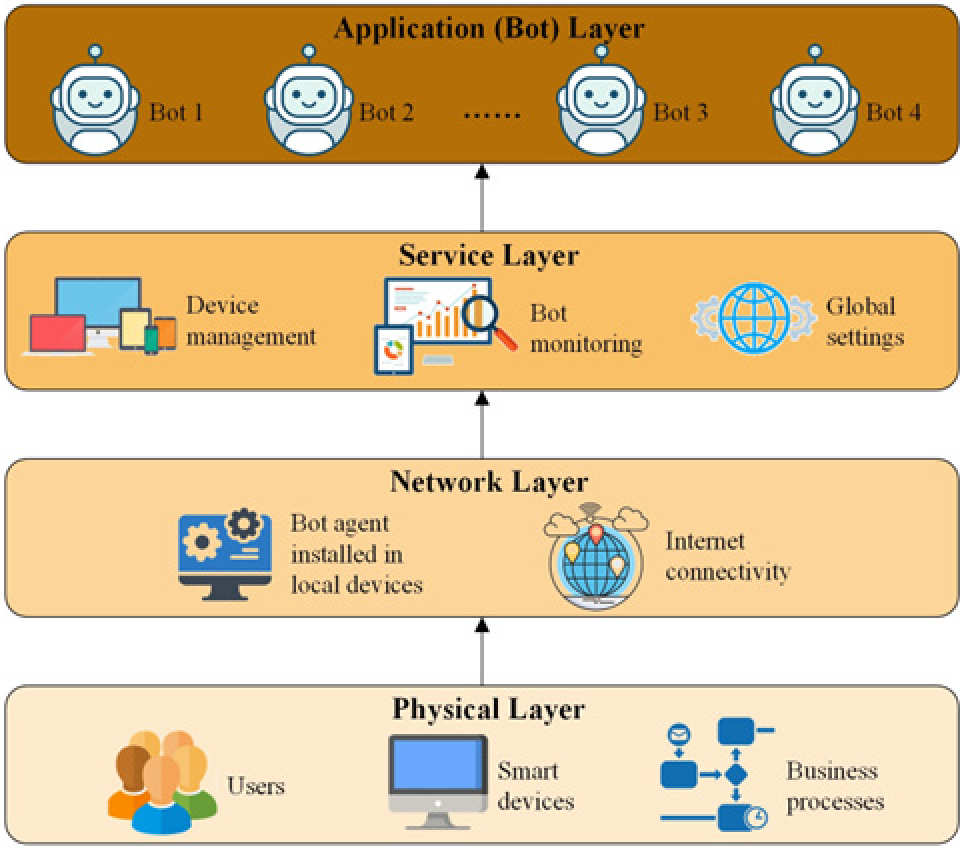
Attended and Unattended RPA

The design of software bots can also be classified into two types: attended and unattended RPA. Attended bots refer to establishing a human–bot collaboration, whereas unattended bots work independently. Table 1 shows a summary of the RPA taxonomy.

Attended bots are constructed to assist an organization's employees with routine tasks to improve their productivity, acting as personal virtual assistants. This type of process automation is particularly useful when handling certain repetitive and non-value-added tasks in front-office operations (e.g., marketing, sales, and customer service). Since users must collaborate with attended bots for process automation, some flexibility and dynamicity in business processes can be considered to adjust the attended bots for better customer values.

Unattended bots execute tasks without human supervision or interaction, which is called end-to-end automation. As such, bots can complete entire processes independently. Ideally, this method aims to automate back-office processes at a larger scale and create bots that work independently to enhance business performance. A task completion procedure is often started by a preset schedule or a logical trigger in the process workflow.

Figure 2. Layered architecture of the RPA solutions



Layered Architecture of the RPA

Typically, a layered architecture of the RPA consists of four major layers: physical layer, network layer, service layer, and application layer (Fig. 2).

In the physical layer, the essential elements of the physical business processes are clearly defined, including users, equipment, and process flow. Using equipment such as computers, users can access RPAaaS platforms for bot design and development to convert process flows obtained from standard operating procedures into business rules and logic. In the network layer, bot agents are installed in smart devices to connect bot agent services and develop attended and unattended bots before building software bots for business operations. Local devices connect to RPAaaS following typical communication protocols such as WebSocket. The service layer includes bot creation, bot management, services monitoring, and connections to local devices. Specifically, bot packages, credentials, and global values can be set in the global environment, while bot operations can be monitored to optimize resource allocation. Users can design and develop their own software bots in the application layer according to specific business rules and logic to perform customized business operations between various application systems, including Microsoft Office, SAP, and G Suite apps. Consequently, standardized business processes can be automated to support routine operations and business users can effectively concentrate on value-added tasks for enhanced customer values and operational effectiveness.

Table 2. Review protocol for the systematic literature review

Protocol Item	Description
Research database	Web of Science Core Collection
Keywords	[Topic: (“robotic process automation”) OR (“digital transformation”)] AND [Topic: (logistic*) OR (supply chain) OR (warehouse*) OR (transport*)]
Publication type	Article
Publication date	From 2003 to April 5, 2024
Suitability criterion	Content of the article is closely related to the use of RPA or DT in the fields of logistics and/or supply chain management

THEORETICAL DEVELOPMENT OF RPA AND DT IN LSCM

Review Protocol and Methodology

This review aims to identify state-of-the-art RPA research and examine how RPA deployment can guide the prospective DT for LSCM. In addition to investigating RPA technology, we consider the DT initiative. With the latter, we aim to address the huge research gap on how the high-level deployment and implementation of RPAaaS can guide the DT process in LSCM research. DT is a trendy concept that describes how digital technologies create innovative business strategies and models with new business management methods to provide customers with improved products, services, and user experiences (Vial, 2019). RPA can be regarded as one of the technologies enabling DT in this era. To organize the review, Table 2 shows the review protocol, including the scientific databases, keywords, and selection criteria employed. The Web of Science Core Collection was chosen due to its comprehensive, multidisciplinary coverage of high-quality, peer-reviewed publications. It is widely recognized for its rigorous selection criteria, ensuring the inclusion of leading scholarly journals and enhancing our literature review's reliability and validity.

To generate insights into the logistics industry's digitalization and create knowledge clusters, we conducted two types of bibliometric analyses using VOSviewer to visualize connections among research articles (Chen et al., 2023). VOSviewer is a software tool specifically designed to construct and visualize bibliometric networks. It was selected for its user-friendly interface and ability to handle large bibliometric datasets, enabling the creation of detailed maps of scientific fields based on citation, bibliographic coupling, co-citation, and co-authorship data (Kim & Han, 2023; Zhao et al., 2023). Also, it offers intuitive insights into the structure and dynamics of the literature, making it an indispensable tool for identifying and interpreting the core themes and knowledge clusters within the RPA domain. First, we performed a co-occurrence analysis to ensure that all authors' keywords are highly relevant to the topic of consideration, ensuring a proper discussion of potential RPA deployments. Next, bibliographic coupling analysis was selected to develop knowledge clusters concerning the digitalization of LSCM.

Descriptive Statistics

As a result of the search following the review methodology, a total of 842 scientific articles were identified. After applying the suitability criteria described above, only 114 out of 842 articles were selected as appropriate for conducting the co-occurrence and bibliometric coupling analyses. Fig. 3 shows the publication trend of the selected 114 articles over the years; research on RPA and other DT technologies developed rapidly beginning in 2019 and continuing until now.

In addition, Table 3 summarizes the top 10 journals (in terms of generated citations) publishing relevant research articles. Under the current Supply Chain 4.0 paradigm, more and more technology-driven research is cultivated. Meanwhile, the number of relevant papers is rapidly increasing. RPA and DT can be considered enablers in contemporary technology-driven LSCM

Figure 3. Number of selected publications over the years

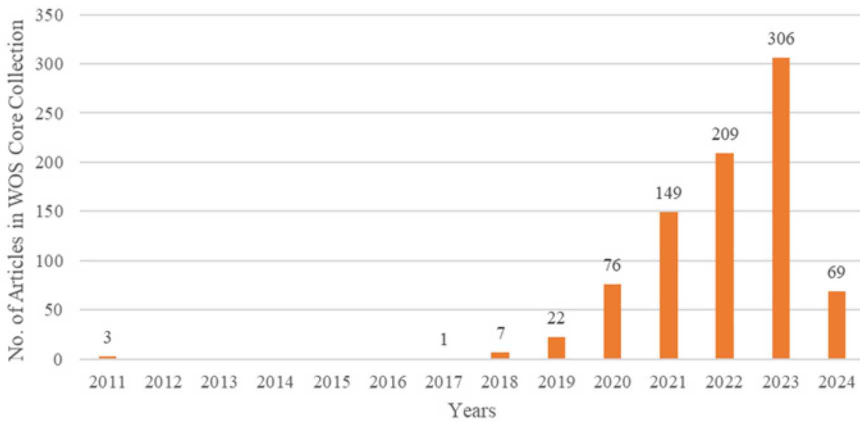


Table 3. Top 10 journals for RPA and DT in LSCM

Journal	Number of Articles	Citations
Sustainability	94	1,412
Technological Forecasting and Social Change	18	1,221
IEEE Transactions on Engineering Management	16	108
International Journal of Production Economics	15	1,686
Journal of Cleaner Production	14	206
IEEE Access	11	70
Production Planning & Control	11	313
Journal of Enterprise Information Management	10	82
Applied Sciences-Basel	9	135
Business Process Management Journal	9	341

research. Moreover, Fig. 4 demonstrates the descriptive information of the pool of the relevant articles in terms of the top 10 authors, countries/regions, and affiliations, respectively.

Co-occurrence Analysis

The co-occurrence analysis is important in ensuring that all the keywords of selected articles are highly relevant to the topic of automation in LSCM, which guarantees the generation of a proper discussion for potential RPA deployment in the era of DT. Following Pareto's 80/20 rule, the minimum number of keyword co-occurrences was selected as two; this resulted in 124 keywords, the closest to 20% of all 708 keywords identified (Fig. 5). In other words, these 124 keywords occur at least twice in the 107 articles selected. The co-occurrence analysis facilitates the identification of thematic patterns and prevailing trends within the corpus of literature by examining the frequency with which key terms appear together. Also, it can illuminate the interdisciplinary nature of RPA research, revealing how diverse fields converge within the literature and the extent to which RPA principles permeate various domains.

Figure 4. Descriptive summary of the top 10 authors, countries/regions, and affiliations

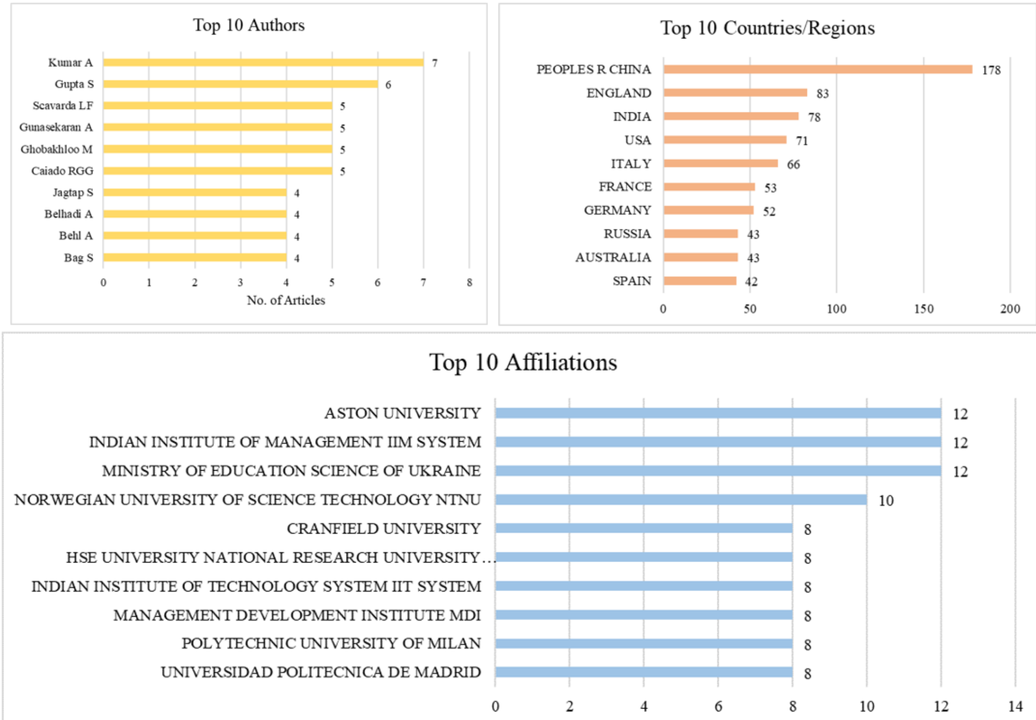


Figure 5. Result of the co-occurrence analysis

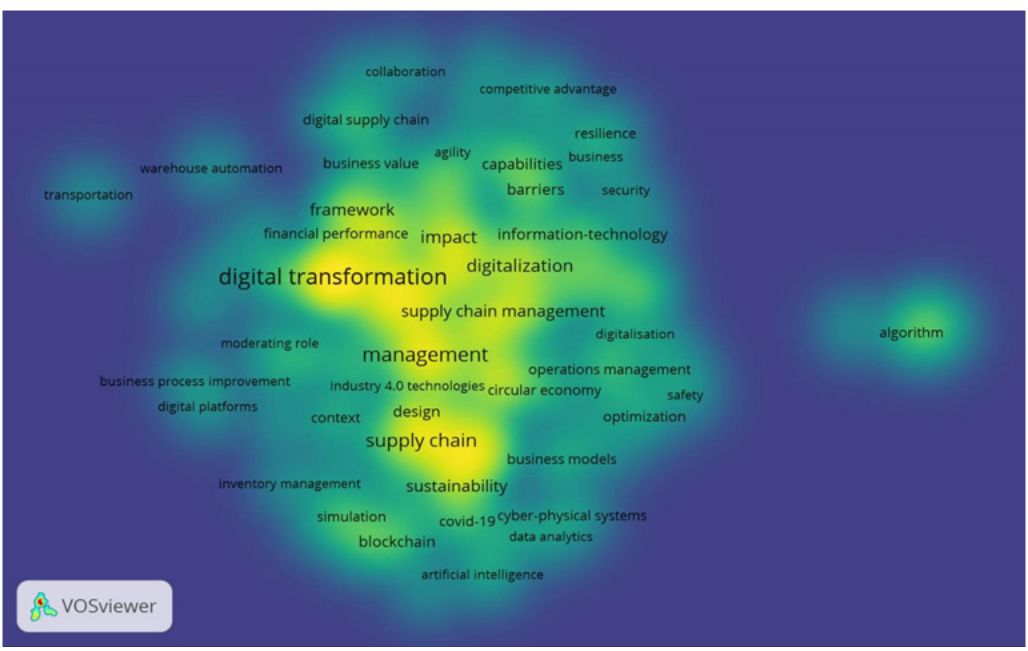
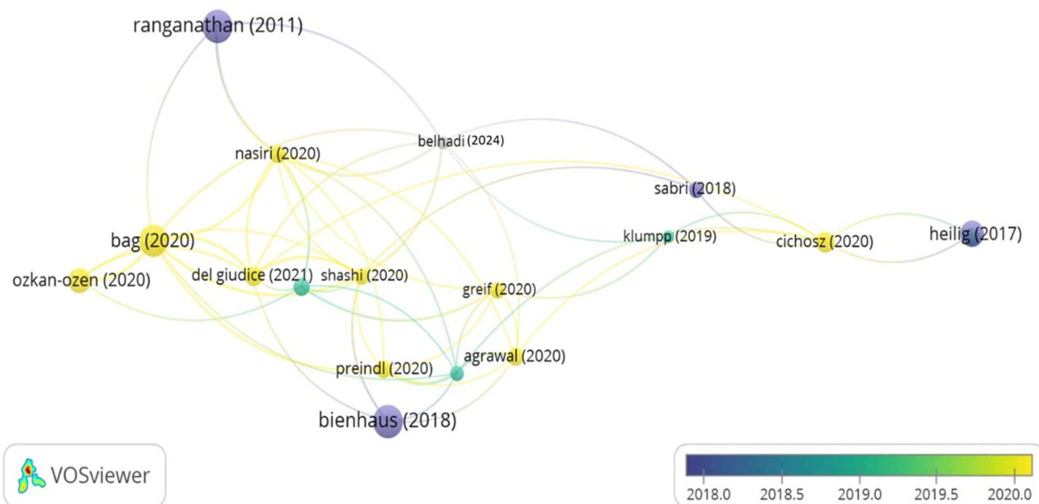


Figure 6. Result of the bibliographic coupling analysis



Bibliographic Coupling Analysis

This section presents the results of the bibliographic coupling analysis conducted for the selected 107 articles to visualize the connections among the articles (Fig. 6). This analysis is essential in developing knowledge clusters on RPA that guide the DT of the LSCM sector. The citation threshold was set to 11, and the resulting top 18 articles (regarding the number of citations) were further investigated to build the knowledge clusters. Bibliographic coupling is incorporated as an analytical tool to uncover the extent of shared references among publications, thereby indicating their thematic proximity. By aggregating works that cite similar foundational studies, bibliographic coupling provides a substantive indication of the research fronts and the coherence of scientific efforts within the realm of RPA. This method is instrumental in understanding the field's evolution, as it highlights clusters of research that collectively contribute to the advancement of knowledge on RPA, signposting seminal works that have influenced subsequent research trajectories.

Knowledge Clusters for RPA and DT Research

It was found that the entire research domain has divided the articles into five knowledge clusters. In the discussion below, these clusters are further examined regarding their contents and prospects of use for RPA deployment for the DT of LSCM.

Cluster 1—Supply Chain Digitalization in Support of a Circular Economy

This cluster of articles (Bag et al., 2020; Del Giudice et al., 2021; Ozkan-Ozen et al., 2020; Shashi et al., 2020) focuses on the DT of supply chains of businesses under a circular economy. The circular economy is a production and consumption model involving reducing, recycling, and reusing existing materials and products. Contrary to the conventional economy, a circular economy keeps products that have reached the end of their lives within the economy whenever possible, thus improving resource utilization and waste management. Generally speaking, the studies in this cluster consider how digital technologies optimize business processes related to procurement, information handling, and operations management for supply chain circularity (E-Fatima et al., 2023). For instance, advanced information processing technologies—in combination with a Procurement 4.0 strategy, planning, and performance review—encourage companies to optimize their business processes. This intention, in turn, results in better resource usage, as per the goals of circular supply chain management.

In the context of supply chain circularity, RPA technology can be applied to better handle data exchange, improve communication between stakeholders, and enhance visibility in resource and demand management. For instance, cognitive RPA bots can be developed to deal with unstructured data from existing software and applications such as enterprise resource planning systems. Such bots can automatically communicate with clients and suppliers to ensure timely and accurate information sharing among supply chain entities. Information sharing with enhanced visibility allows resource managers and stakeholders to make more informed decisions about sustainable resource management (rather than simply disposing of waste). The deployment of RPA technology can also help companies' management teams focus on improving resource utilization instead of the time-consuming exchange of correct data.

Cluster 2—DT of Logistics Service Providers

The second cluster of articles (Cichosz et al., 2020; Heilig et al., 2017; Hartley & Sawaya, 2019; Sabri et al., 2018) focuses on the DT of LSPs. Due to the rapid advancement of digital technologies, many LSPs struggle to achieve up-to-date DT.

To support the DT of LSPs, RPA can consolidate and enter orders from many customers. It is also possible to expand its use to other areas, including compliance with spending limits, reviewing and responding to supplier emails, creating and updating purchase orders, and entering data into spreadsheets automatically (Pathak, 2023). Moreover, RPA is especially useful given that some companies, suppliers, and customers lack electronic data interchange capabilities. Indeed, RPA can provide a valuable and easy way for companies with poor information technology infrastructure to handle high-volume repetitive tasks. In fact, many small and medium-size LSPs tend to have undeveloped information technology infrastructure. Therefore, using RPA technology to eliminate and automate manual standardized processes creates a great potential for transforming traditional LSPs into digitalized LSPs.

Cluster 3—Barriers to DT for Supply Chain Enterprises

The third cluster of articles (Agrawal et al., 2020; Bienhaus & Haddud, 2018; Makris et al., 2019; Preindl et al., 2020) analyzes the barriers to RPA and DT among supply chain enterprises. Since RPA is a relatively new DT technology, it faces barriers similar to those for other enabling technologies, such as the lack of knowledge about data management. It is important to note that RPA technology cannot be used if supply chain members lack knowledge about data management.

Among the barriers identified, the most significant for the DT of supply chain enterprises are lack of knowledge about data management, lack of understanding of decentralized organizational structures for supplier collaborations, and the need for significant investments in Industry 4.0 technologies. Barriers to DT also differ for enterprises of different sizes. On the one hand, large-scale enterprises tend to struggle with standardizing their business processes due to multiple departmental levels. On the other hand, small and medium-size enterprises may find it difficult to finance DT activities, especially when partnering with digital solution providers.

To allow the automated handling of data exchange by RPA, all parties need to be familiar with technological requirements and features. Also, it is important to educate all supply chain members about the proper use of RPA. Finally, during the phase of developing an automation design and an RPA roadmap, it is important to involve all supply chain stakeholders in the decision-making process.

Cluster 4—Factors Affecting DT

The fourth cluster of articles (Belhadi et al., 2024; Nasiri et al., 2020; Ranganathan et al., 2011) analyzes factors that influence a company's DT performance. Key factors that positively affect DT include supplier synergy, information intensity, managerial IT knowledge, interoperability mechanisms, and the extent of web-enabled supply chain management. On the contrary, relative cost-benefit perceptions are negatively associated with DT. Several factors are associated with the success of DT, including appointing a leader to execute a DT vision and the creation of a supportive organizational culture. In other words, having a leader who develops a clear vision of what DT can bring and building a company's culture around this single vision will likely make the DT process more productive (Lam et al., 2024). Apart from the influencing factors, the prospects of enhancing supply chain digitalization with AI-driven innovation and other smart technologies were suggested as areas for future development.

Similar to the factors influencing a company's DT performance, successful RPA deployment requires companies to focus on supplier synergy, accurate information handling, employee IT knowledge, and better resource utilization (Lam & Tang, 2023). In other words, before introducing RPA to facilitate business operations, LSPs must evaluate their performance in areas such as proper communication with vendors, the ability to handle and exchange information in a standardized format efficiently and accurately, and the capability of existing employees to utilize up-to-date technological solutions. More complex areas of logistics, such as supplier risk and compliance management, can soon be facilitated by RPA bots in collaboration with AI and machine learning.

Cluster 5—Determinants of Enterprises' Readiness and Need for DT

The fifth cluster of articles (Greif et al., 2020; Klumpp et al., 2019; Vrchota & Pech, 2019) analyzes factors that highlight companies' readiness and need for DT. The readiness and need for DT can be evaluated through the size of an enterprise and its business perspectives. For example, small or medium-size enterprises lacking human resources and no expansion goals may find it difficult—and, in some cases, not worthwhile—to digitalize. Thus, there is no need to chase DT merely to comply with modern trends. Instead, the genuine needs of an enterprise should be considered as the main decision factor. Taking production logistics as an example, human-intensive operations can be error-prone, motivating the implementation of DT to eliminate human errors specific to standardized and repetitive tasks.

For RPA application, a company's readiness and needs must be assessed in advance. The readiness can be evaluated based on the size of an enterprise and its business perspectives, in both the short and the long term (Nielsen et al., 2023). For instance, enterprises aiming for automation may find full RPA utilization helpful when they are well-prepared for automation and transformation. On the contrary, small or medium-size enterprises with limited knowledge of RPA implementation may consider solving their business challenges with other cost-effective alternatives.

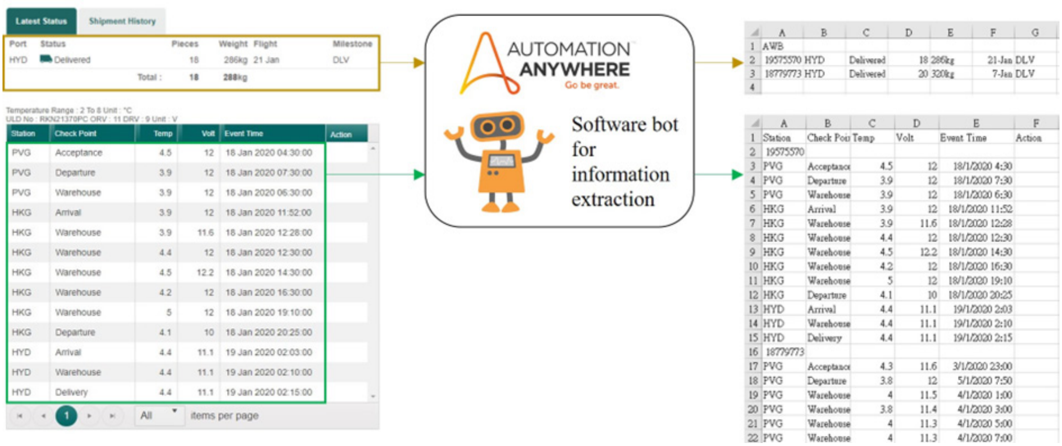
CASE STUDIES OF RPA APPLICATIONS

The case company, F&W Holdings Limited (alias), is an integrated LSP established in Hong Kong in 1978. The company specializes in time-critical freight management and offers comprehensive services, including air and sea freight management, e-commerce logistics, and cold-chain services. F&W caters to diverse industries such as aviation, automotive, chemical, fashion, health care, project cargo, retail, and technology transportation. The company expanded into cold-chain logistics in 2018, providing tailored solutions for temperature-sensitive shipments. Notably, in August 2019, F&W became the first Hong Kong–based global logistics service provider to receive the CEIV Pharma accreditation from IATA. The company’s mission focuses on delivering value-added, customer-driven services, ensuring cargo security and efficiency, and adapting to market changes through partnerships and staff development.

Use Case 1—Automated Shipment Tracking on Carriers' Platforms

In order to obtain the latest shipment status, operators in the back office must visit the carrier's shipment tracking platform, search for the shipments using dedicated air waybill (AWB) numbers, and save the corresponding shipment information in the internal repository. Subsequently, operators are required to follow up with customers when abnormal shipment statuses are identified, while regular

Figure 7. Use case of RPA for shipment tracking



shipment updates can be sent via email. The major problem is manually searching for each AWB number on the tracking platform to confirm the latest shipment information. As many shipments are normally assigned to the carrier daily, it takes a long time for the back-office employees to check the status of all shipments. In addition, since there is no specific time when the shipment information of each cargo is updated, employees must periodically recheck the shipment information.

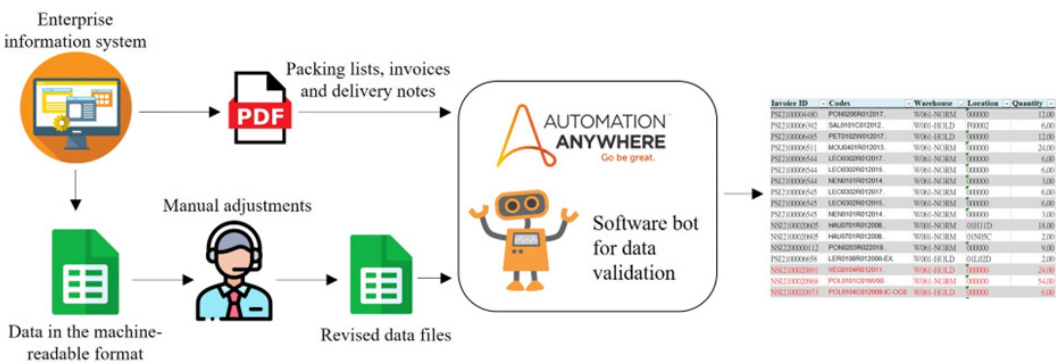
Thus, this use case aims to apply an RPA software bot to handle daily shipment tracking and update the status in the company's internal repository without human supervision. The software bot was programmed using Automation Anywhere (Fig. 7). The event triggers can be set so the bot automatically visits the tracking platform to obtain the latest shipment information according to the given AWB numbers. The collected shipment information includes status, weight, number of pieces, flight date, port, and milestone. Temperature and voltage information can also be extracted for temperature-controlled shipments using active containers to ensure that shipments are properly handled throughout the journey. As expected, the software bot can automatically send confirmation emails to customers when the shipments are delivered and alert operators when abnormalities are observed.

Use Case 2—Automated Data Validation for Warehousing Operations

In the case company's warehousing operations, some customers still provide manually adjusted data files and scanned documents to instruct inbound and outbound operations. Thus, human errors in file preparation, such as incorrect data entry, are inevitable in daily operations. Upon receiving the files, frontline operators are required to double-check the given data files and scanned documents to ensure that the files are correct before entering them into the dedicated warehouse management system. Since hundreds of orders are received daily, this double-checking process is time-consuming, resulting in poor warehousing effectiveness and efficiency.

In view of the above difficulties, the case company applies RPA using Automation Anywhere to extract the data from scanned documents into an Excel format, compare the data with manually adjusted data files, and highlight inconsistent orders (Fig. 8). OCR captures the values in specific regions to read the scanned documents with Automation Anywhere. However, as using OCR to capture data from scanned documents is relatively time-consuming, the case company preferred not to build a new data file based on the scanned documents. Instead, once the ordering data are extracted and validated, the data files are imported to the warehouse management system to instruct the warehousing operations by generating put-away instructions, picking lists, packing lists, and delivery notes.

Figure 8. Use case of RPA for data validation



Discussion of RPA Implementation

Through our analysis of the RPA solutions developed for F&W Holdings Limited, several RPA implementation challenges were identified. The lessons learned can be generalized to apply to most companies with no prior experience with RPA implementation.

First, companies must maintain talented employees who can manage the software bots on the RPAaaS platforms. If it is too costly for companies to hire RPA specialists, they should offer additional training for those who previously performed manual and repetitive tasks. In the case of attended bots, frontline operators are required to work with the bots to complete routine operations. Thus, RPA training sessions and workshops should be regularly held to reduce frontline operators' resistance to change.

Second, comprehensive education on the ethical use of RPA in the logistics industry is essential. The design and development of software bots on RPAaaS platforms is convenient and does not require writing code. As a result, the software bots can easily extract data through HTML tags and OCR modules. When applied to websites through web scraping and crawling, such automatic data extraction may result in ethical problems. First, automated data extraction may consume system resources in targeted web-based applications. Second, such targeted web-based applications may intend to provide the data for business use through APIs with subscriptions rather than unauthorized web scraping and crawling. These applications must frequently change their user interfaces to prevent unauthorized web scraping and crawling activities. In order to balance the benefit of RPA enjoyed by data consumers with the interests of targeted web-based application owners, data collection through web scraping and crawling should strictly follow the terms and conditions defined by the application owners. As such, comprehensive education on the ethical use of RPA in industries is essential; otherwise, a vicious cycle between supply chain entities for data extraction and protection will arise.

Third, selecting appropriate modules for bot setup is crucial but may not guarantee successful RPA implementation. In an era of technology integration, multiple technologies converge to enable the DT of enterprises in previously unforeseen scenarios (Mendhurwar & Mishra, 2021). Numerous additional modules (e.g., OCR) must be incorporated into bots to enhance the effectiveness and efficiency of RPA, and the selection of appropriate modules for bot setup is crucial. In Use Case 2, OCR was implemented to extract data from scanned documents. Unfortunately, this prolonged its operation time due to the large quantities of text that needed to be scanned (a single order file may contain hundreds of pages). Ideally, digitally created and searchable documents instead of scanned ones could be obtained for the RPA by negotiating with customers. Therefore, improved business performance can be achieved only when the implementation of RPA solutions is supported by the right choice of additional modules and with the support of vendors and customers.

PRACTICAL GUIDES FOR FUTURE RPA DEPLOYMENT

Based on the investigation of the theories and use cases of RPA in LSCM, more and more RPA applications are expected to be developed soon to transform logistics and supply chain enterprises digitally. Although several RPAaaS platforms (e.g., the Automation Anywhere platform used in the above case studies) have been developed to support DT, enterprises are uncertain about when to use RPA and which platform should be adopted. Therefore, practical guides for future RPA deployment based on the above two questions are formulated in this section.

The bibliometric analysis has elucidated the criticality of digital transformation within supply chain paradigms, identifying five knowledge clusters that resonate with the insights garnered from RPA deployment in F&W Holdings Limited. The first knowledge cluster (supply chain digitalization in support of a circular economy) underlines the transformative potential of RPA in enhancing the circularity of supply chains, as witnessed in the case where RPAaaS platforms necessitate the cultivation of specialized talent. This potential leads to the second knowledge cluster (DT of logistics service providers), which echoes the need for continuous RPA training and workshops to mitigate resistance to change among employees, a salient point highlighted in the case studies.

Barriers to DT for supply chain enterprises, the third knowledge cluster, exemplifies the ethical dilemmas faced when deploying RPA solutions that may infringe upon web-based applications' terms of service through unauthorized data extraction. This cluster aligns with the case studies' emphasis on the need for comprehensive education on ethical RPA usage to prevent a detrimental data extraction and protection cycle. Furthermore, the fourth cluster (factors affecting DT) is exemplified by selecting appropriate technological modules, such as OCR, for effective RPA implementation. The case studies reveal that while these modules are crucial, their selection must be reasonable to enhance operational efficacy.

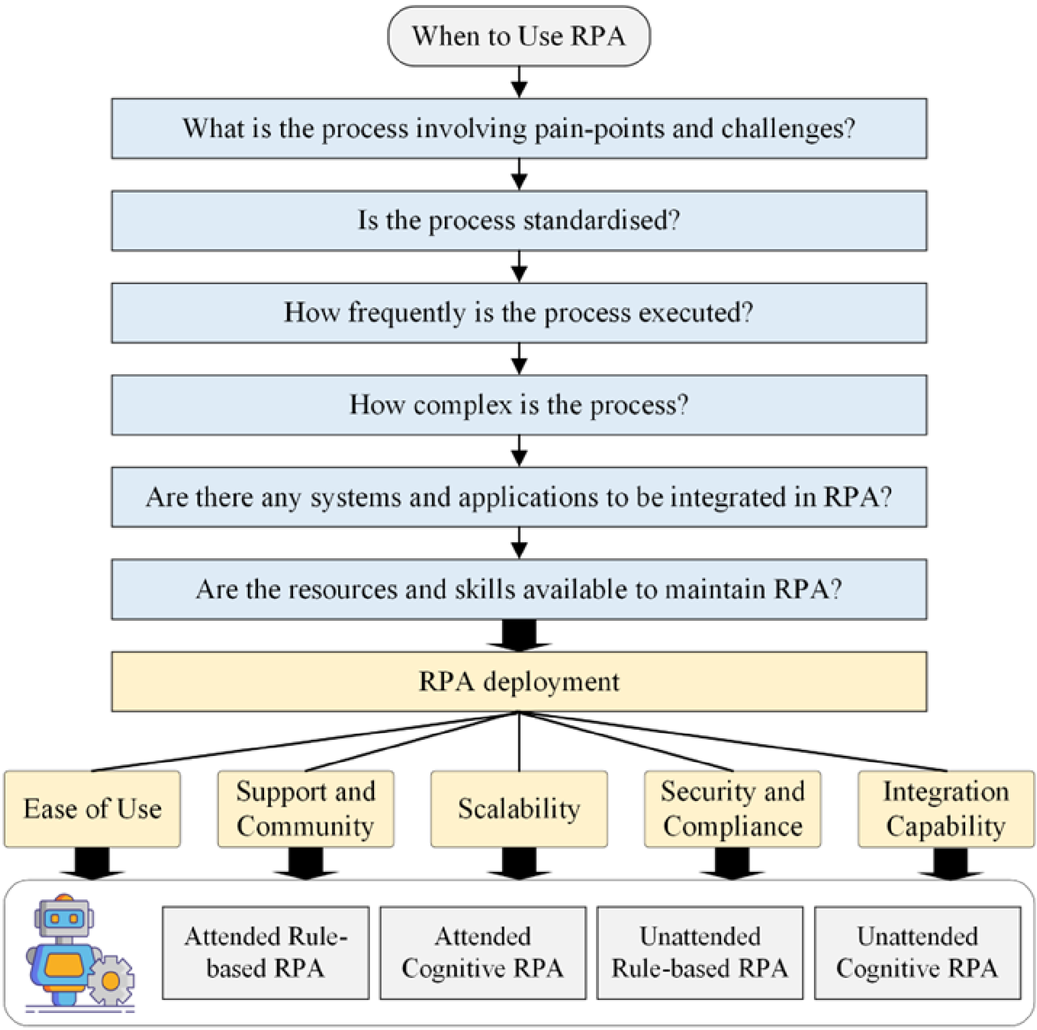
Lastly, the fifth cluster (determinants of enterprises' readiness and need for DT) is reflected in the case studies by securing digital and searchable documents to optimize RPA performance and advocating for strategic collaboration with vendors and customers. Such readiness and the need for DT are not solely predicated on technological capabilities but also the collaborative and strategic approaches of the involved stakeholders, highlighting the interdependence between technological adoption and relational dynamics within the supply chain ecosystem.

When to Use RPA

Based on the case studies discussed in the previous sections, we generated a list of prerequisites for deploying RPA solutions for logistics and supply chain management involving a series of routine operations between humans, systems, and machines (Zimon et al., 2019; Centobelli et al., 2017). This proposed framework may give hints to industrial practitioners, such as logistics service providers, for the necessity of real-life RPA implementation. Organizations should comply with the following prerequisites to ensure the successful implementation of RPA:

- Technical and business readiness: open communication and discussion with supply chain stakeholders is essential to understand their expectations regarding RPA deployment before design and development begin. Companies should clearly understand the scope of the RPA deployment, allowing them to anticipate the benefits and drawbacks and to design the RPA solutions intelligently.
- Process standardization: business challenges intended to be solved with automation need a unified set of standard steps (i.e., standard operation procedures). In order to be automated, selected processes have to be stable, mature, and standardized so that case-by-case considerations and modifications are not needed for end-to-end and standalone automation.
- Talent for RPA maintenance and support: although the RPA solution may be unattended, some employees must be assigned to ensure that bots operate as expected and solve exceptional or

Figure 9. Guides on when to use RPA and which RPAaaS to use



emergency cases promptly. Moreover, adequate training sessions for frontline staff can be provided to boost technological acceptance.

Concerning the appropriate types of RPA software bots for a business, three basic questions can be formulated to understand the current state of business processes (Fig. 9). Bots should concentrate on value-added and standardized processes to streamline business processes and improve performance. For non-value-added and unstandardized processes, business process reengineering and standardization can be applied to optimize business processes before automation. Subsequently, appropriate types of RPA software bots can be suggested according to process requirements.

Which RPAaaS Platform(s) to Use

According to the RPA market overview (Smeets et al., 2021), more than 50 RPA software companies exist in the market, and more service providers are planning to join the market in the near future. Given this diversity of options, selecting the most suitable RPAaaS platform may itself become a challenge for LSPs. In this section, we use market research (Schaffrik, 2021) to summarize and compare the five well-known RPAaaS platforms, which are provided by UiPath, Automation Anywhere, Blue Prism, NICE, and EdgeVerve.

UiPath is renowned for its user-friendly and visual experience, offering a drag-and-drop interface that simplifies the process design (UiPath, 2022). It boasts a large community and marketplace, providing ample resources for users to learn and share reusable components. UiPath caters to all business sizes and has a strong presence in enterprise-scale deployments. The platform is rich in features, including advanced AI capabilities, and supports both on-premises and cloud deployments.

On the other hand, Automation Anywhere emphasizes ease of use with its scriptless automation approach, allowing users without programming skills to automate processes (Automation Anywhere, 2022). It provides a robust support structure and a free community edition for learning. It is also known for its cognitive automation tools incorporating AI and analytics. Automation Anywhere offers flexible deployment options and is aimed primarily at large enterprises, although it is also reaching out to midsize businesses.

Blue Prism is considered more technical and developer-oriented, with a user interface that may appear less intuitive to nondevelopers (Blue Prism, 2022; Khan, 2020). The platform is known for its security and robustness, making it suitable for complex and sensitive processes. While it has traditionally focused on on-premises deployment, Blue Prism is expanding its cloud offerings. The company has been working on enhancing its community support and targets mainly large corporations.

NICE offers a friendly interface tailored more toward attended automation scenarios, which are typically easier to implement and learn (NICE, 2022). The company strongly focuses on analytics and workforce engagement, integrating RPA with its workforce management software. NICE's solutions are often found in call centers and front-office environments, but the company has been broadening its market reach. Deployment can be on the cloud or on-premises.

Lastly, AssistEdge from EdgeVerve provides an environment catering to developers and business users (EdgeVerve, 2024). The platform offers a community edition and strives to simplify the learning curve with a guided experience. AssistEdge stands out for its attended and unattended automation capabilities and integrates well with other EdgeVerve business products. It offers flexible deployment models and is particularly strong in the banking and finance sectors due to its affiliation with Infosys.

In order to compare the RPAaaS platforms provided by the above five leading RPA software companies, five evaluation criteria have been defined (Fig. 9):

- Ease of use: this criterion refers to whether the software is easy to use and learn and is attractive (Axmann & Harmoko, 2021). On-premises RPA software and RPAaaS platforms may refer to the bot creation approach—whether business users can use an easy method to create a bot to support business operations. Ease of use may also include whether bot actions are easy to drag and drop, whether the application interface is straightforward, and whether action palettes are easy to understand and follow.
- Support and community: Sarrab and Rehamn (2014) suggested several quality evaluation criteria for open-source software, including business support by the service provider, community support, documentation, and developer skills. Applying the evaluation criteria to RPAaaS platforms, LSPs may consider RPA software companies' support for learning resources, software communities, complete and detailed bot creation guidelines, and training programs.
- Scalability: the scalability of the RPAaaS platforms is considered along with the growth of the automation. LSPs may consider RPA software that can handle increased loads and more complex processes over time without significant performance degradation. This includes the ability to manage a large number of bots and processes concurrently and the flexibility to expand across various departments or operations within the business.
- Security and compliance: cybersecurity is a critical concern about governance, especially for businesses that handle sensitive data. The RPA solution should offer robust security features,

such as role-based access control, encryption, audit logs, and compliance with relevant industry standards and regulations, such as the General Data Protection Regulation and ISO 27001. These practices protect against data breaches and ensure that automated processes adhere to compliance requirements.

- Integration capability: the chosen RPA platform should integrate seamlessly with existing business systems, including enterprise resource planning, order management systems, warehouse management systems, transportation management systems, and other legacy systems. The ability to work with APIs, web services, and custom applications is crucial for automating a broad range of tasks. Strong integration capabilities ensure that the RPA tool can adapt to the organization's existing technological ecosystem.

Effective and Ethical Use of RPA

In using RPA, stringent data privacy and security measures are imperative to protect against unauthorized data access and breaches, ensuring confidentiality and integrity. The practice of circumventing costs through RPA, particularly to avoid data usage fees (e.g., API services), raises significant ethical concerns, potentially infringing on contractual obligations and intellectual property rights. Additionally, ensuring compliance with legal statutes and industry regulations is critical to avoid legal repercussions and maintain the legitimacy of RPA initiatives. It is incumbent upon organizations to judiciously implement RPA within the boundaries of ethical and legal frameworks to uphold trust and avoid undermining the technology's potential benefits with reputational risks or legal sanctions.

Adhering to legal and compliance standards is a nonnegotiable facet of RPA deployment. Organizations must meticulously align their automation strategies with the pertinent regulatory requirements and legal obligations, ensuring that operational enhancements do not come at the expense of compliance (Zhou et al., 2024). Transparency in the usage of RPA is equally critical, necessitating the establishment of explicit policies that delineate the scope and modalities of RPA operations, ensuring that stakeholders have a clear understanding of the governance mechanisms in place. Engaging stakeholders is an indispensable part of this ecosystem, fostering an environment where feedback and concerns regarding the RPA deployment are actively solicited and addressed. This engagement not only enhances the acceptance of RPA solutions but also reinforces the ethical fabric of its application, ensuring that the deployment of such technologies is congruent with the broader organizational values and societal norms.

As each business case is unique, conducting a cost-benefit analysis for each proposed solution is essential before deciding whether RPA or an alternative solution needs to be deployed (Zhang et al., 2024). Before building an RPA solution, transparent communication should be established among all supply chain stakeholders. This action will ensure that the automation technologies are deployed precisely and purposefully rather than used to address unrelated challenges stemming from the lack of communication among supply chain members. Moreover, to popularize RPA implementation in industries beyond the logistics industry, potential functional and psychological barriers derived from the innovation resistance theory should be investigated (Sadiq et al., 2021; Khalil et al., 2024).

CONCLUSIONS

In an era of technology integration, multiple technologies converge to enable enterprises' DT in previously unforeseen scenarios. In recent years, research and development efforts on the digitalization and automation of LSCM have been extended to RPA. These efforts aim to automate organizational and business processes with enhanced reliability, consistency, efficiency, and cost-effectiveness.

This paper has presented the results of a systematic literature review, co-occurrence analysis, and bibliographic coupling on RPA, identified the guidelines for implementation, and described the future outlook. The systematic literature review revealed the underexploration of high-level deployment and the implementation of RPA as a service in LSCM scenarios. Using these techniques, it examines the theoretical development of RPA in LSCM in the era of DT. Based on the results of the systematic literature review, RPA and DT are enablers and drivers of technology-driven LSCM research. Based on the results of co-occurrence analysis and bibliographic coupling analysis, we identified five knowledge clusters. Despite its benefits, RPA deployment has its challenges. Real-life RPA implementation cases in a third-party logistics company demonstrate the common challenges and provide useful insights related to RPA deployment.

This study has manifold implications. Theoretically, it helps inform practitioners and researchers by providing extensive insights into RPA for DT in LSCM from an industry perspective. From a practical standpoint, it assists LSCM practitioners in avoiding or mitigating the identified challenges and guides a streamlined implementation framework. Due to the observed scarcity of rigorous academic literature on RPA within the LSCM domain, future studies are urged to bridge this dichotomy. Prospective research could adopt a multi-methodological approach incorporating qualitative and quantitative analyses. One avenue could involve longitudinal case studies that track RPA implementation in real time across different industry sectors and organizational scales, providing a granular understanding of the temporal aspects of RPA assimilation.

Additionally, comparative analyses between small to medium-size enterprises and large corporations could yield insights into the scalability and adaptability of RPA solutions across diverse business models. The role of RPA in fostering sustainability within LSCM, particularly how automation can aid in the realization of eco-friendly supply chain practices, also merits exploration. Furthermore, the advancement of RPA into cognitive automation by incorporating AI and machine learning algorithms offers fertile ground for research. This advancement could involve the examination of the transformative impacts of intelligent automation on decision-making processes, risk management, and predictive analytics within the LSCM sphere.

DATA AVAILABILITY

The data used in this study are available upon request.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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