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EVALUATION OF THE EFFECTIVENESS OF INFORMATION SYSTEM IN OPTIMIZING WAREHOUSE PROCESSES

Abstract
The aim of the article was to present research on the application of information systems in optimizing warehouse processes. The theoretical aspects describing the fundamentals of warehouse processes were discussed. The theoretical foundations of information systems were also developed, with particular emphasis on systems used in warehouse processes. The results of conducted research among manufacturing organizations with complex warehouse processes were presented, which declared the implementation of ERP, WMS, and SCM systems. Based on the research findings, conclusions were drawn along with the direction of development in the area of digitizing warehouse processes.

JEL classification: O32, O33

Key words: process optimization, IT systems, management, ERP, WMS, SCM

Introduction

The aim of the article was to present research on the application of information systems in optimizing warehouse processes. In today's world, where every business strives for efficiency and competitiveness, managing warehouse processes plays a crucial role. Each such process is characterized by complexity, and its elements need to be harmonized and

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executed smoothly to achieve the shortest possible completion time. This is particularly important in processes where the flow of materials, semi-finished products, and finished products plays a major role, aiming to minimize losses resulting from production downtime and deliver the final product to the customer within the specified deadline.

In today's times, it is essential to make decisions based on solid, well-documented data that provide not only the necessary information for planning, production, sales, and accounting but also serve as a foundation for making strategic business decisions. In fact, it is unimaginable to envision the functioning of a modern 21st-century enterprise without reliable IT solutions that support and streamline daily operations.

Well-performing companies are those that have access to essential data at any given moment and are aware of their resources and the progress of ongoing processes. In this context, tools that support warehouse processes and assess their effectiveness become indispensable. The article presents the results of research conducted among manufacturing organizations that deal with complex warehouse processes.

1. Characteristics of warehouse processes

Warehouse processes are among the most crucial aspects of efficient functioning for manufacturing organizations. They are defined as a set of activities carried out during the flow of specific values (materials, semi-finished or finished products) through the warehouse, starting from the unloading of external transport vehicles, through receiving, storage, recording, preparation, issuance for production, and packaging and loading of finished products (Niemczyk A., 2008, p. 62). To organize warehouse processes, it is necessary to have space where they are conducted, loading and transportation means, personnel, and a data recording system for material or product flow (Dudziński Z., Warsaw 2000).

The complexity level of warehouse processes depends on various factors, including the size of the warehouse, the characteristics of materials and products, the role of the warehouse in the logistics chain, and the organization of work system in the warehouse.

The average warehousing process is carried out in multiple stages, where it is necessary to determine the chain from material delivery to the dispatch of the finished product for transportation. It is crucial to define functional areas in the warehouse, commonly referred to as zones (C. Skowronek, 2008, p. 142), intended for the execution of the successive stages of this process.

Receiving zone - an area where material is received from inbound transportation, and the verification of the conformity of goods with the declared quantity and quality takes place, along with operations related to the acceptance of goods into the warehouse (sorting, sorting, repackaging, and labeling the delivery according to the established warehouse organization). Proper registration of these goods in warehouse data is also crucial.

Storage zone - an area that constitutes the largest part of the warehouse and its size is determined by the type of stored material and the method of storage. In this zone, racks, automated high-storage warehouses, or designated handling paths for warehouse purposes may be used. In these areas, goods can be stored for short or long term, but their control and proper management of warehouse data are necessary. Depending on the industry, specific environmental conditions related to temperature or air density may also be required.

Picking zone - tasks related to order preparation are carried out in this area, strictly according to the customer's order (rearranging and selecting materials based on the orders, moving materials for issuance).

Dispatch zone - located near the loading docks. In this area, goods are issued from the warehouse, and the necessary loading operations take place, utilizing transportation means. Often, the dispatch zone is combined with the receiving zone, serving both purposes and referred to as the receiving/dispatch zone.

In addition to the mentioned zones, other elements of the internal structure associated with the operation of warehouses include: administrative area, social area, vehicle parking area, battery charging area, evacuation routes, and fire protection areas (Szałek B., 1994).

A method to increase the efficiency of warehouse operations is to adopt specific rules for its functioning in relation to the flow of materials and goods. Describing the flow through the warehouse must be done using fundamental warehouse data. Procedures for selecting the order of outbound and inbound units of goods constitute a significant element of advanced warehouse process management. However, for these procedures to be useful, at least two batches of a specific type of assortment should be stored, differing from each other in any assessable parameter. The primary criteria for selecting the order of outbound and inbound flows in warehouses typically include:

The FEFO (First Expired First Out) principle is applicable wherever there is a concern for expiration dates, such as in the case of perishable goods, pharmaceuticals, etc. It is used when the stored assortment has a short

shelf life. Among units of the same product, the one with the earliest expiration date is issued first.

The FIFO (First In First Out) principle ensures that the batch of goods that arrived at the warehouse first is issued first. It is the most commonly used strategy as it is the most natural approach. It is undesirable for a specific batch of goods to remain in the warehouse for too long. FIFO is typically applied where there is no need for the FEFO principle.

The LIFO (Last In First Out) principle is based on the assumption that the most recent batch of goods received is issued first. It is used less frequently and typically applied when driven by cost accounting strategies and inflationary conditions.

In practice, the HIFO (Highest In First Out) and LOFO (Lowest In First Out) methods are also utilized:

The HIFO (Highest In First Out) principle dictates that the batch of goods with the highest unit cost, among the inventory received, should be issued first.

The LOFO (Lowest In First Out) principle is based on the assumption that the batch of goods with the lowest unit cost, among the inventory received, should be issued first.

These principles provide specific guidelines for determining the order in which goods are issued from the inventory based on their respective unit costs. The HIFO principle prioritizes the higher-cost batches, while the LOFO principle prioritizes the lower-cost bat (Ratkiewicz A., 2019)

The described methods are not rigid rules for storing goods in a warehouse. In practice, it is common to apply multiple criteria for determining the order and location of an order, with each criterion having different weights. Developing algorithms that implement these criteria is a complex task. By following the discussed principles during the storage and issuance processes, the speed of fulfilling customer orders can be improved, leading to lower costs.

The methods of data collection and efficient functioning based on them play a crucial role in organizing the warehouse process described above. Everything that is received and everything that is issued from the warehouse must be recorded in the organization's databases. This is essential not only for production planning and estimating the available materials but also for accounting purposes.

2. Information System in Warehouse Processes

In the context of improving organization and implementing Lean Management philosophy, it is necessary to take specific actions to optimize the execution times of processes and subprocesses based on analyzed data. In the case of warehouse operations, knowledge about the quantity

and type of available materials and goods is crucial. Key directions of development in the logistics context for every management team include supply chain control, internal transportation control, and automation of warehouse processes. This is not possible without a well-functioning flow of information that is faster than the physical flow of materials and goods.

Taking into account the aforementioned elements related to the flow of information and goods, as well as the diversity of warehouses and the standardized, repetitive processes and exceptions occurring within them, three groups of products supporting computerization can be mentioned. They include (Majewski, 2008):

ERP systems (Enterprise Resource Planning) - encompassing the area of supporting the management of the entire enterprise, including the accounting and sales departments, including warehouse processes. Support for warehouse processes is often weakly implemented in these systems, but there is usually the possibility of implementing additional warehouse modules that allow for efficient and effective management of inventory levels.

WMS systems (Warehouse Management System) - specialized systems for managing warehouse processes. They are independent of ERP systems and provide the opportunity to use more advanced functionalities. There is the possibility of integrating them with ERP systems depending on the needs and nature of the organization's production. However, they are characterized by high costs and long implementation times, and usually have limited capability for independent modifications.

SCM systems (Supply Chain Management) - used for managing supply chains. These systems are designed to optimize and coordinate the flow of materials, information, and resources across the entire supply chain, from suppliers to manufacturers to distributors and customers. They enable organizations to monitor and control various aspects of the supply chain, such as inventory management, demand forecasting, order fulfillment, and logistics.

In some sources, you can find information about Warehouse Execution Systems (WES). These systems combine WMS functionality focused on executing processes using existing information in ERP, often in the form of mobile applications on handheld devices with barcode scanners. This solution is relatively easy and quick to implement. However, it requires high costs associated with organizing the infrastructure to leverage these systems.

Regardless of the type, an information system plays a crucial role in managing warehouse processes. It enables organizations to respond adequately to market needs, effectively solve current problems, reduce uncertainty in processes, identify areas requiring corrective actions, and introduce process and product innovations. Investments in an efficient

information system allow for taking actions that result in improved operational efficiency, continuous revenue growth, increased market share, and gaining a competitive advantage over competitors. Therefore, it is necessary to assess the application of information systems in logistics processes.

3. Research on the evaluation of information systems in optimizing warehouse processes

3.1. Characteristics of the research sample.

For the purpose of this article, a study was conducted among 100 organizations utilizing information systems in warehouse processes. The research was carried out using a survey method in the second quarter of 2022. Four criteria were adopted to characterize the research sample: type of business activity, company's scope of operation, number of employees, and type of information system used.

Table 1. Characteristics of the research sample include the following

Form of conducted economic activity	Number	Percentage
Limited liability company	63	63%
General partnership	11	11%
Partner company	14	14%
Sole proprietorship	12	12%
Scope of business		
Local	3	3%
Regional	6	6%
National	13	13%
International	78	78%
Number of employees		
1-9	2	2%
10-49	6	6%
50-249	32	32%
Powyżej 250	60	60%
The type of system used		
ERP	45	45%
WMS	35	35%
SCM	20	20%

Source: own study.

According to the analysis of the data presented in Table 1, the largest group of respondents was comprised of limited liability companies (63%), while other forms of business operations fell within the range of 11-14%. Regarding the scope of business operations, a significant majority of

companies (78%) declared cooperation with foreign entities. Only 3% indicated operating at a local level.

More than half of the companies (60%) employ over 250 employees, while 32% of companies have a workforce ranging from 50 to 249 employees. Only 2 companies employ less than 10 people. The most commonly used information system among the respondents was the ERP system (45%). The WMS system is used by 35% of respondents, while the utilization of SCM solutions is declared by 20%.

3.2. Descriptive statistics of observable variables

In the next stage of the survey, organizations evaluated the variables related to the warehouse information systems used in their operations using a Likert scale presented in the questionnaire.

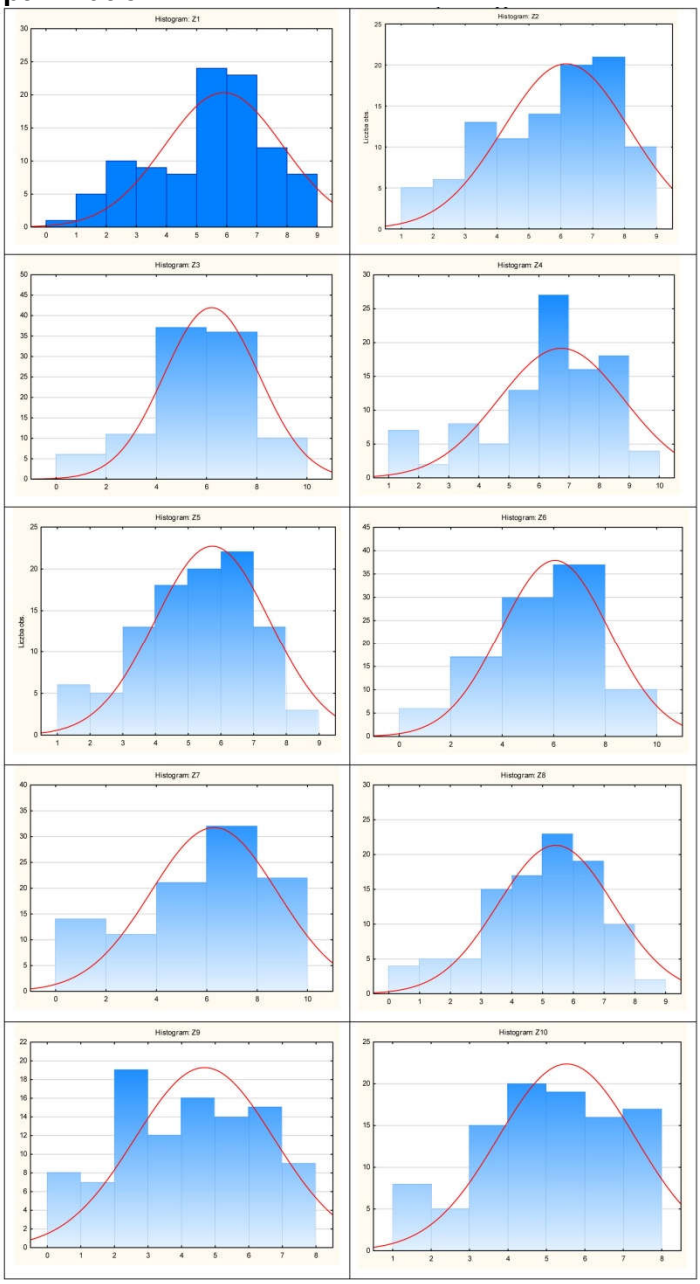
Table 2. Descriptive statistics of the observed variables describing

No.	Specification	Mean	Standard deviation
Z1	Level of advancement of information systems in warehouse processes	5,90	1,96
Z2	Level of training of employees using information systems in warehouse processes	6,17	1,98
Z3	Impact of information systems on streamlining warehouse processes	6,20	1,90
Z4	Level of avoiding quantity errors in material warehouse coordination	6,74	2,08
Z5	Level of avoiding quantity errors in goods warehouse coordination	5,74	1,76
Z6	Evaluation of time optimization of warehouse processes using information system	6,05	2,11
Z7	Level of integration of the information system in the warehouse with accounting document issuance	6,29	2,51
Z8	Economic efficiency of the information system - level of preventing losses in material and goods issuance	5,43	1,87
Z9	Evaluation of the maintenance costs of the information system in the warehouse relative to the benefits of its use	4,68	2,07
Z10	Evaluation of the potential for improving the information system in warehouse processes	5,53	1,78

Source: own study.

Based on the analysis of Table 2, no significant deviations from the mean ratings were observed. The average responses on the Likert scale

Figure 1. Distribution of Observable Variables for the Assessment Parameters of Information Systems Applications in Warehouse Process Optimization



Source: own study.

for all variables ranged from 4.68 to 6.74. This indicates that the respondents rated the variables very highly. The variable regarding the level of avoiding quantity errors in material warehouse coordination received the highest rating. This pertains to the coordination of the receiving and data registration of materials, as well as their issuance for production. It indicates that the implemented system allows for better control over organizational chaos and effectively organizes the quantity flow of materials in the production process. The lowest rating was given to the assessment of the costs of implemented systems, suggesting that they are still a relatively costly endeavor in supporting management. The highest discrepancy between respondent answers, measured by the standard deviation, was observed for the variable regarding the level of integration of the information system used in warehouse processes with accounting document issuance. However, this depends not only on the information system but also on the level of personnel qualifications and collaboration. On the other hand, the most consistent answers were observed for the variable concerning the level of avoiding errors in the registration and issuance of finished products for transportation and sale.

Based on Figure 1, it was observed that all distributions of the observable variables for the assessment parameters of information systems applications in warehouse process optimization were above the mean.

Table 3. Descriptive statistics of observable variables describing

No.	ERP		WMS		SCM	
	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean
Z1	1,81	6,04	1,98	5,85	2,17	5,74
Z2	1,92	6,02	2,08	6,30	2,04	6,29
Z3	1,62	6,22	2,14	6,05	2,13	6,26
Z4	1,94	6,87	2,21	6,40	2,22	6,77
Z5	1,61	5,64	2,05	6,10	1,78	5,66
Z6	2,04	6,04	2,21	5,95	2,18	6,11
Z7	2,52	6,42	2,57	6,25	2,53	6,14
Z8	1,80	5,60	1,96	5,55	1,93	5,14
Z9	2,03	4,84	1,98	5,15	2,13	4,20
Z10	1,80	5,56	1,88	5,80	1,73	5,34
	Mean	**5,925**	**Mean**	**5,94**	**Mean**	**5,765**

Source: own study.

Based on the comparative analysis presented in Table 2, it was observed that both the ERP and WMS systems received the highest ratings, as indicated by the small differences. The SCM system, on the other hand, received lower ratings, which may suggest its less frequent utilization in industrial practice or its greater focus and specialization specifically on the supply chain.

Conclusions

Information systems are essential management tools for organizations. This applies to both organizational and managerial processes, as well as supporting processes, including the storage process. There are many solutions available on the market, including ERP, WMS, and SCM systems examined in this study. This article provides an assessment of the practical application of these systems in the industrial practices of manufacturing companies.

It is worth emphasizing the high ratings of the presented parameters, which exceed the average. Furthermore, the issue of implementation and maintenance costs of these systems remains relevant. Consideration should be given to grants supporting the digitization process through funding consulting or training for companies that already have systems and want to further enhance their utilization. The high ratings of error avoidance in both material storage and finished products, as well as the economic efficiency of the systems, should not be overlooked. In this case, it can be stated that their implementation is advantageous for every organization.

The low standard deviations observed in the conducted research are noteworthy, indicating a consistent evaluation among all respondents. There are individual aspects that influence the assessment of specific variables. However, the effectiveness of information systems in the storage process is a common factor.

In conclusion, it can be stated that information systems are the future of warehouse management, and their digitization cannot be overlooked. Moreover, the efficiency of their implementation directly impacts the finances of companies through optimizing intra-warehouse logistics and minimizing losses.

References

1. Dudziński Z., Kizyn M., Poradnik magazyniera, Polskie Wydawnictwo Ekonomiczne, Warszawa 2000.
2. Dyczkowski M, Identyfikacja i analiza wpływu kierunków ewolucji systemów klasy ERP na strategie informatyzacji obiektów gospodarczych, „Prace Naukowe Akademii Ekonomicznej we Wrocławiu” 2004, nr 1027.

3. Łapuńka I., Knosala R., Analiza systemów klasy ERP w aspekcie planowania realizacji projektu w warunkach zakłóceń, [w:] Grabara J.K., Nowak J.S. (red.), Efektywność zastosowań systemów informatycznych, WNT, Warszawa 2004.
4. Majewski J., Informatyka dla logistyki. ILiM, Poznań 2008.
5. Majewski J., Vademecum rozwiązań i dobrych praktyk w logistyce magazynowej – Edycja 2014, Warehouse Monitor.
6. Niemczyk A., Zapasy i magazynowanie, tom II Magazynowanie, Wyd. Biblioteka Logistyka, Poznań 2008.
7. Panel Polskich Menedżerów Logistyki – Raport 2014, Systemy Informatyczne w polskich magazynach, Badanie zrealizowane przez Logisys Sp. z o.o.
8. Parys T., Bariery wdrożeniowe systemu informatycznego klasy ERP i metody ich przezwyciężania, [w:] Kisielnicki J., Pańkowska M., Sroka H. (red.), Zintegrowane systemy informatyczne, Wydawnictwo Naukowe PWN, Warszawa 2012.
9. Pieles S., Analiza zakłóceń w przepływach logistycznych przedsiębiorstwa produkcyjnego – studium przypadku, „Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie" 2015.
10. Ratkiewicz A., Metodyka projektowania i oceny procesów magazynowania w szeregowo zintegrowanych łańcuchach logistycznych, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2019).
11. Skowronek C., Saryusz-Wolski Z., Logistyka w przedsiębiorstwie, PWE, Warszawa 2008.
12. Szałek B., Milewska B., Milewski D.: Problemy mikrologistyki. Szczecin, 1994.
13. Śmigielska A., Integracja systemów informatycznych a zmiany biznesowe, [w:] Szyjewski Z., Grabara J.K., Nowak J.S. (red.), Strategie informatyzacji i zarządzanie wiedzą, WNT, Warszawa 2004.
14. Varaprasad R.M., Vishnu M.G., DSS for Web Mining Using Recommendation System, [w:] Sreedhar G. (red.), Web Data Mining and Development of Knowledge-Based Decision Support Systems, s. 22-34, IGI Global, Hershey 2017.
15. Walas-Trębacz J., Analiza procesów kształtujących łańcuch wartości przedsiębiorstwa, „Zeszyty Naukowe / Uniwersytet Ekonomiczny w Krakowie" 2013, nr 922
16. Wojciechowski Ł., Wojciechowski A., Kosmatka T.: Infrastruktura ma gazynowa i transportowa. Wyższa Szkoła Logistyki, Poznań 2009.

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Ireneusz Pszczółka*

THE ROLE OF THE EURO AS AN INTERNATIONAL CURRENCY FOR POLISH PRIVATE AND PUBLIC SECTORS – SELECTED ISSUES

Abstract: *The paper discusses the usage of the euro as a parallel currency in Poland. The aim is to assess the importance of the euro as an international currency for Polish residents, with particular emphasis on reserve and investment currency. The main stress is put on the assessment of the use of euro-denominated bank deposits and loans. The paper is based on the international literature and statistical data. Main sources of necessary data were taken from publications delivered by European Central Banka and National Bank of Poland.*

Keywords: *foreign reserves, central bank, bank instruments, international currencies*

JEL classification*: E44, E58, F32.*

Paper type*: Theoretical research article*

1. Introduction

The development of a modern economy could not have been possible without the use of money, also at the international level. The internationalization of a currency begins when individuals or institutions residing in a country other than that of this currency accept or use it as a mean of payment, unit of account and store of value. International currency refers to the same three functions as domestic one, but it is important to

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distinguish between the official sector's use and the private sector's use (Chinn and Frankel, 2005). In private sector international currency is used as a vehicle currency (in goods exchange as well as in currency exchange), a quotation currency (for trade and financial transactions), an investment currency (portfolio allocation and indirect currency substitution) and in public sector as an intervention currency, a pegging currency (reference currency – an anchor of the other currency's exchange rate), a reserve currency (Hartmann, 1998). The official and private uses of an international currency are obviously closely related, but the influence of one on the other is not clear. The choice of an international currency is often said to depend mainly on its private uses and less on government decision but the official use of a currency might influence private market participants' choice (Galati and Wooldridge 2006).

The role of an international currency as a store of value acts as a reserve currency in which international reserves are held and investment currency in which deposits, loans, bonds and other securities are denominated (Kenen, 1983). Reserve currency and investment currency status is the main subject of this paper. The paper focuses mainly on this function due to the availability of relevant data in this area and incomplete data for other functions of money.

Creation of a single European currency is the most important event in the international monetary system since the adoption of flexible exchange rates in the early 1970s. This made the first real competitor for the US dollar since it surpassed the pound sterling as the main dominant currency over the XX centaury (Barkin and Cox, 1998). It also has an impact on the structure of the use of international currencies by Polish residents. Especially that being a member of the European Union with a derogation, the euro is a natural element of the further integration process. Additionally the holding of the euro by National Bank of Poland and major financial institutions reflects to a large extent a desire by households and firms to hold and use it as well (Viceira and Gimeno 2010). Papaioannou, Portes and Siourounis (2006) claim that monetary authorities tend to hold a high share of their reserves in the currency of their main trading partners and the currency composition of foreign debt is a significant factor in the allocation of central banks' reserve holdings.

This paper is a review and its purpose is to assess the importance of the euro as an international currency for Polish residents, with particular emphasis on reserve and investment currency. The paper is based on the international literature and statistical data. Main sources of necessary data were taken from publications delivered by European Central Bank and National Bank of Poland.

2. The determinants of the international use of currencies - literature review

The main factors influencing the use of the national currency as an international currency include: the size of the issuer's economy and its position in global trade, confidence in the currency resulting from the economic policy and political conditions of the country or economic area issuing the currency. Efficient, liquid, safe and competitive financial market is also important as well as the external network effect (Pszczółka, 2020).

Galati and Wooldridge (2006) claim that the larger a country's share in world trade, the more likely that other countries will use its currency either as a monetary anchor or in support of external trade. The greater anchoring role of a currency might mean the larger weight in official reserves, this is due to two reasons. First, if the exchange rate of the domestic currency against a major currency plays an important role in the monetary policy framework, the central bank would typically hold this major currency to be able to intervene in the foreign exchange market. Second, if the country's liabilities are mainly in a major currency, the central bank is likely to hold a significant portion of its assets in that currency.

The second factor is a economic and political stability. This is a basic condition for ensuring a low and stable level of inflation, the significant increase of which may affect the use of a given international currency. An increase in inflation may adversely affect the use of a currency on debt markets due to an increase in interest rates and cause greater volatility of the exchange rate. The instability of the value of a currency increases the investment risk, causing the currency to cease to be an important store of value (Lim, 2006). The mere stability of a currency's purchasing power is not a sufficient factor in determining macroeconomic stability. Fiscal parameters, such as budget deficit and public debt, are also important for full financial stability. The effect of this stability is to build trust in the currency, which is crucial for strengthening the function of the investment currency performed by international money (Eichengreen and Mathieson, 2000). In addition, only a politically stable country or economic union can issue an international currency, as this stability is a factor supporting economic stability (Mundell, 1998). Monetary unions, where monetary integration is tied to political union, have historically been stable (like the United States). On the other hand, international monetary unions, where monetary integration is not tied to political union, have historically failed (Pszczółka, 2011).

A key element is also the developed financial market, which is characterized by the lack of restrictions when making transactions by residents from other countries. An overregulated financial market, characterized by restrictions on the free movement of capital, is ineffective, among others due to limited competition, which leads to overstating

transaction costs. The institutional side of the financial market with a strong central bank, supervisory institutions and a large financial sector is also important. A properly developed and liquid secondary market is also significant, allowing its participants to quickly build or liquidate large positions without fear of losing capital. A large and well-functioning financial market provides investors with access to a wide range of financial instruments, often unavailable on local markets. They are characterized by a diversity of issuers in terms of investment risk (Detken and Hartmann, 2000). It is also worth noticing that the more often a particular currency is used on the financial market, the more likely it is to continue to be used. An equally important element is investors' habit. The euro as an international currency allows the private and public sectors to maintain the value of accumulated savings. In case of private investors, it acts as an investment currency in which money is held, which allows to achieve an optimal balance between the rate of return and the rate of risk (Oręziak, 2008). Well-developed financial system is more likely to attract business from abroad, where financial markets may be less developed. This possibility makes it cheaper for market participants to borrow or invest abroad in an international currency rather than conduct the transactions directly at home in their own currency. On one hand, the introduction of the euro reduced diversification opportunities, so in principle one should have expected a fall in the euro share after 1999. But on the other hand, the euro market has become more liquid and deeper, and foreign exchange transaction costs for the euro have fallen (Papaioannou, Portes, and Siourounis 2006).

Finally, a key factor is "network externalities". This is a phenomenon associated with international currencies. A currency's status depends on others' use of it as a store of value, as a mean of payment and unit of account. The more a currency is used, the lower its transaction costs are and the higher its liquidity is, and hence the more attractive it becomes for new users, so the more a particular currency is used internationally, the more likely it is to continue to be used. The currency's international status tends to change slowly (Lim 2006). The example of this factor are commodity markets. These markets (oil, industrial metals, precious metals, agricultural products) use payments almost exclusively in dollars.

All the above conditions are met by the euro area which supports the process of internationalization of their currency (Pszczółka, 2011). This is mainly due to the advantage of the benefits over the costs of issuing international money. In this context, Chinn and Frankel (2005) indicate the benefits of seigniorage, liquidity discount and exorbitant privilege.

3. Use of the euro by Polish residents in selected areas

Due to the lack of data on the use of the euro by Polish residents in terms of all functions of the international currency in both the public and private sectors, only a selected range will be analyzed. For example, ECB data on the share of the euro in the settlements of Polish trade are available until 2009. The share of this currency was 66.1% for exports and 54.8% for imports (ECB, 2018). The available data relate mainly to the foreign currency reserves of the National Bank of Poland (NBP), the use of euro-denominated bank loans and euro-denominated bank deposits in Poland, currency structure of Poland's international investment position and the currency structure of debt instruments.

The management of foreign exchange reserves is usually constrained by a set of investment policies which define the monetary authority's appetite for currency, credit, interest rate and other risks. Therefore, the relative attractiveness of different international currencies as a store of value will be influenced by the availability of financial instruments for gaining exposure to, or hedging, these risks. The common European currency offers such an opportunity (Pszczółka, 2011), therefore, the euro is one of the two most important currencies in the currency structure of Polish foreign exchange reserves.

The NBP reserve diversification process has led to a significant change in the importance of major international currencies within last two decades. Between 2005 and 2012, the share of the US dollar decreased from 50% to 36%, and the share of the euro from 40% to 32%. In 2007, the NBP decided to start the process of diversifying the currency structure of reserves by adding the Australian dollar (AUD) (at the expense of the US dollar). Continuing the diversification of the currency structure of reserves, in 2008 the Norwegian krone (NOK) was included, limiting the share of the euro. In 2010, the NBP once again decided to reduce the share of the US dollar by 2 percentage points, and Pound sterling (GBP) by 2 percentage points, in favor of the Australian dollar and the Norwegian krone (Pszczółka, 2018). In 2013, the NBP continued to diversify the currency structure of reserves by launching investments in assets denominated in New Zealand dollars (NZD), while reducing the share of assets in GBP by 3 percentage points (table 1).

A significant change in the reserve management policy was introduced in 2015. After analyzing the macroeconomic prospects of the world's major economies, forecasts of developments in global financial markets and the results of optimization and simulation analysis (NBP, 2016), the NBP decided to reduce the share of the common European currency in the currency structure by 3 percentage points to 29%, while increasing exposure to the US currency to 39%.

Table 1. Currency composition of foreign exchange reserves for Poland in 2021-2021 (end of period, at current exchange rates)

Year	EUR	USD	GBP	CAD	AUD	NOK	NZD
2021	20	41	12	10	8	6	3
2020	20	51	12	0	8	6	3
2019	20	51	12	0	8	6	3
2018	27	44	12	0	8	6	3
2017	27	44	12	0	8	6	3
2016	27	44	12	0	8	6	3
2015	29	39	12	0	10	7	3
2014	32	36	12	0	10	7	3
2013	32	36	12	0	10	7	3
2012	32	36	15	0	10	7	0

Source: (NBP, 2022, 2021, 2018).

In 2016 the NBP decided to move forward with the currency structure of foreign exchange reserves and reduce the share of EUR by another 2 percentage points, to 27%, AUD by 2 percentage points, to 8% and NOK by 1 percentage point, to 6%, with an increase in exposure to USD by 5 percentage points, up to 44%. In 2019, the NBP decided again to change the currency structure of the strategic benchmark (increase exposure to USD and reduce the share of EUR). Implementing the Foreign exchange reserves management strategy adopted by the NBP in 2020 (NBP, 2021), including continuing the currency diversification process, in 2021 the share of USD was reduced (by 10 percentage points) to make room for the Canadian dollar (CAD). The share of the euro was retained.

The diversification of the NBP reserves over the last decade has led to a significant decrease in the importance of the euro in the structure of these reserves, although the euro is still the second most important currency.

Another analysis concerns the area of unofficial substitution of assets and liabilities. The euro is important as a currency used in parallel by third-country residents to keep their savings in bank deposits and for financing consumption and investments. Euro-denominated bank loans and deposits dominate in European countries that are not members of the euro area, in particular those that are members of the European Union or are candidates or potential candidates for EU membership.

Table 2. The use of euro-denominated bank loans in Poland in 2012-2021 (end of period)

Year	Outstanding amounts of euro-denominated loans (in EUR millions)	As a percentage of total loans	As a percentage of foreign currency loans	Outstanding amounts of foreign currency loans (in EUR millions)
2021	26150	9.3	53.2	49164
2020	27593	10.3	52.4	52637
2019	28172	9,8	51.0	55212
2018	27538	10.2	48.8	56380
2017	25253	9.7	48.8	55244
2016	25644	10.8	41.9	61177
2015	25074	10.7	39.9	62772
2014	23530	10.8	39.4	59729
2013	21635	10.3	36.6	59155
2012	20568	10.0	33.2	61889

Source: (ECB, 2022, 2020, 2018, 2016).

In the analyzed period, outstanding amounts of euro-denominated loans in Poland grew steadily from over 20 billion euro in 2021 to over 26 billion euro in 2021. A similar trend is noticeable in the percentage share of loans in euro in total foreign currency loans. The dynamic increase in the share of loans in euro from 33.2% in 2012 to 53.2%2 in 2021 is also due to the continuous decrease in outstanding amounts of foreign currency loans in Poland (table 2). This means that the euro is the most important international currency in which bank loans in Poland are denominated.

The Euro remains also the predominant currency of denomination for foreign currency deposits in Poland, and continues to be perceived as a preferable store of value relative to other currencies. The euro's share in total foreign currency deposits remained broadly unchanged compared with 2012 (over 68% in 2021). Outstanding amounts of euro-denominated deposits in Poland grew steadily from over 12 billion euro in 2012 to over 29 billion euro in 2021, this means almost tripling the value of these deposits within a decade. In the analyzed period, the outstanding amounts of foreign currency deposits in Poland changes in a similar way. It is also worth pointing out that euro-denominated bank deposits as a percentage of total deposits grew from 6.2% in 2012 to 8.5% in 2021 (table 3).

Table 3. The use of euro-denominated bank deposits in Poland in 2012-2021 (end of period)

Year	Outstanding amounts of euro-denominated deposits (in EUR millions)	As a percentage of total deposits	As a percentage of foreign currency deposits	Outstanding amounts of foreign currency deposits (in EUR millions)
2021	29361	8.5	68.4	43943
2020	23970	7.5	64.1	37375
2019	24399	7.9	67.9	35956
2018	21644	7.7	66.2	32672
2017	21328	8.0	65.6	32522
2016	17346	7.1	66.5	26100
2015	14748	6.3	65.3	22601
2014	13037	6.1	68.2	19110
2013	12391	6.1	65.4	18953
2012	12173	6.2	66.0	18449

Source: (ECB, 2022, 2020, 2018, 2016)

The last element of the analysis is the assessment of the change in the currency structure of Poland's international investment position separately concerning liabilities and assets.

Three currencies had the largest share in foreign assets of Poland's international investment position at the end of 2021: the euro - 32.3%, the US dollar - 27.3% and the Polish zloty - 15.6%. The total share of these three currencies in total foreign assets amounted to 75.2%. Compared to 2020, the share of the euro in foreign assets decreased slightly. It should be added that the currency structure of NBP reserve assets had a significant impact on the currency structure of foreign assets, its share in total foreign assets amounted to 43.5% (NBP. 2022). Analyzing the entire period from 2012 to 2021, the importance of the euro and the dollar remained stable, with a constant low predominance of the euro.

Table 4. Currency structure of Poland's international investment position (liabilities and assets in %) in 2012-2021

Year/currency	CHF	EUR	GBP	JPY	USD	Others	PLN
liabilities in %							
2021	1.0	30.6	0.7	0.4	4.6	1.6	61.1
2020	1.4	31.1	0.9	0.5	4.7	0.7	60.3
2019	1.4	29.4	0.7	0.5	5.4	0.6	62.0
2018	1.7	30.0	0.5	0.5	7.5	0.8	59.1
2017	2.0	30.0	0.1	0.5	7.4	0.7	59.3
2016	3.3	30.6	1.1	0.7	9.4	0.7	54.1
2015	4.0	30.3	0.6	0.7	6.9	0.7	56.9
2014	4.5	29.0	0.7	0.7	5.6	07	58.8
2013	5.1	28.0	0.9	0.7	5.4	0.7	59.2
2012	5.5	28.2	0.6	0.8	5.8	0.7	58.4
assets in %							
2021	0.4	32.3	5.6	0.1	27.3	18.7	15.6
2020	0.3	33.5	6.0	0.1	29.7	14.4	16.0
2019	0.3	33.1	5.7	0.1	31.1	14.2	15.5
2018	0.3	38.2	5.3	0.1	29.3	12.3	14.7
2017	0.3	38.7	4.4	0.0	29.1	11.6	15.8
2016	0.4	34.7	6.7	0.0	32.2	11.4	14.5
2015	0.5	35.5	6.2	0.1	28.6	13.4	15.8
2014	0.4	37.4	6.6	0.0	24.7	14.5	16.5
2013	0.4	35.8	7.3	0.0	24.3	15.4	16.6
2012	0.4	34.4	8.7	0.0	26.4	15.1	15.2

Source: (NBP, 2022b, 2021b, 2018)

In foreign liabilities of Poland's international investment position at the end of 2021, two currencies had the largest share: Polish zloty - 61.1% and euro - 30.6%. The total share of both currencies in total foreign liabilities amounted to 91.7%. Compared to 2012, the share of the euro increased slightly from 28.2% to 30.6%. The importance of the US dollar differs significantly from that of foreign assets, its share vary from 4.6% in 2021 to 9.4% in 2016 (table 4).

The currency structure of foreign assets, as well as liabilities, have been stable over the last ten years and it is not a subject to significant fluctuations. In both cases, the euro is the most important foreign currency in which the assets and liabilities of the Polish international investment position are denominated.

4. Conclusions

The use of international currencies can take many forms. Foreign residents may hold international currencies to store their wealth or to use

for financing consumption and investments as well as to pay for imported goods and services. This is the situation in the case of Polish residents using the common European currency. The importance of the euro as a international currency in Poland is confirmed by the conducted analysis.

The main findings of this paper have shown that: i) despite the diversification of the NBP reserves and decrease in share of the euro in the structure of these reserves, the euro has kept its role as a second most important currency, ii) more than half of foreign currency bank loans in Poland are denominated in the euro, iii) over two-thirds of foreign currency bank deposits in Poland are denominated in the euro and, iv) the euro is the key foreign currency of the Polish international investment position, v) in Poland, the euro is preferable store of value relatively to other foreign currencies.

Literature

1. Barkin N. & Cox A. (1998). EMU Explained, The Impact of the Euro, Kogan Page, London.
2. Chinn M. & Frankel J. (2005). Will the euro eventually surpass the dollar as leading international reserve currency, NBER Working Paper 11510, July.
3. Detken C. & Hartmann P. (2000). The euro and international capital markets, ECB Working Paper No. 19, April.
4. ECB (2016). The international role of the euro, July.
5. ECB (2017). The international role of the euro, July.
6. ECB (2019). The international role of the euro, July.
7. ECB (2021). The international role of the euro, July.
8. Eichengreen B. & Mathieson D. (2000). The currency composition of foreign exchange reserves: retrospect and prospect, IMF Working Paper 00131, July.
9. Galati G. & Wooldridge P. (2006). The euro as a reserve currency: a challenge to the pre-eminence of the US dollar?, BIS Working Papers No 218, October 2006.
10. Hartmann P. (1998). Currency competition and the foreign exchange market, Cambridge University Press.
11. Kenen P.B. (1983). The role of the dollar as a international currency, Occasional Papers 13, Group of Thirty, New York.
12. Lim E. (2006). The euro's challenge to the dollar: different views from economists and evidence from COFER and other data, IMF Working Paper 06/153, June.
13. Mundell R.A. (1998). What the euro means for the dollar and the international monetary system, Atlantic Economic Journal, Vol. 206, No. 3, September.
14. NBP (2016). Annual Report 2015

15. NBP (2018). Annual Report 2017
16. NBP (2021). Annual Report 2020
17. NBP (2022). Annual Report 2021
18. NBP (2018b). Międzynarodowa pozycja inwestycyjna Polski w 2017
19. NBP (2021b). Międzynarodowa pozycja inwestycyjna Polski w 2020
20. NBP (2022b). Międzynarodowa pozycja inwestycyjna Polski w 2021
21. Oręziak L. (2008). Euro – pieniądz międzynarodowy, Europejska Integracja Monetarna od A do Z, Bank i Kredyt, styczeń.
22. Papaioannou E. & Portes R. & Siourounis G. (2006). Optimal currency shares in international reserves: the impact of the euro and the prospects for the dollar, NBER Working Paper 12333, July.
23. Pszczółka I. (2020). Dolar amerykański i euro jako kluczowe waluty inwestycyjne na międzynarodowym rynku dłużnych papierów wartościowych, [in:] D. Kopycińska, J. Korpys (ed.), Współczesne problemy gospodarowania, Centre of Sociological Research, Szczecin.
24. Pszczółka I. (2018). Zmiany wysokości i struktury rezerw walutowych nbp na tle zmian zachodzących w rezerwach walutowych na świecie, Studia Ekonomiczne. Zeszyty Naukowe Uniwersyetu Ekonomicznego w Katowicach, nr 352.
25. Pszczółka I. (2011). *Współczesne waluty międzynarodowe*, Cedewu, Warszawa.
26. Viceira L.M. & Gimeno R. (2010). The euro as a reserve currency for global investors, Documentos de Trabajo No. 1014, Banco De España.

ARTICLES

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HOW INDUSTRY 4.0 SUPPORTS THE STRATEGIC AGILITY OF COMPANIES. A SYSTEMATIC LITERATURE REVIEW

Abstract:
The aim of the article is to identify and assess the state of knowledge in the field of using and supporting Industry 4.0 technologies for the development of companies' strategic agility. In particular, it is of keen interest how the individual Industry 4.0 technologies selected by the authors support the attributes that contribute to strategic agility. The article uses a systematic literature review (SLR), and strives in a rigorous and reliable manner to organize knowledge of the use of Industry 4.0 technology in the development of strategic agility. The systematic review research procedure consists of a five-stage approach, including: formulation of the research questions and determination of the research objective, selection of the literature sample, evaluation of the identified papers, data analysis and synthesis, and reporting on the results. The applied research method allowed for synthesis and consolidation of the existing scientific achievements in the field of supporting Industry 4.0 technologies in the development of strategic agility in companies, as well as indication of the most desirable directions for further research. Simultaneously, the research results allowed a reasonable context for future research to be defined. The literature clearly indicates a scarcity of papers in the field of linking Industry 4.0 with the agility of companies, as well as a lack of information on the state of research in this area, both in theoretical and empirical terms. There

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is a noticeable shortage of studies identifying which Industry 4.0 technologies support the development of strategic agility, to what extent and in what aspects.

Key words: *Industry 4.0, new technologies, strategic agility, systematic literature review*

JEL codes: *L21, L22, L23, L25, L26, M11, M15*

Research area: *Management*

Introduction

The fourth industrial revolution has attracted growing attention in recent years, as has the concept of strategic agility, which is an extremely important ability whose development, especially in the context of Industry 4.0, is a key competence for companies (da Silva et al., 2020; Osterrieder et al., 2020). The scientific literature emphasizes that the use of modern technologies does not only support business, but more and more often is of strategic importance for companies (Ghobakhloo, 2018; Lin *et al.*, 2018; Akkaya, 2020). From a strategic and technological perspective, a company's transition to Industry 4.0 requires comprehensive agility, which, through the attributes that co-create it, ensures the integration of key areas of the company and the transition to a fully digital organization (Sony and Naik, 2020).

Götz (2019) points to an organization's agility as a very important capability in the context of Industry 4.0, thanks to which companies can effectively respond to changes in the environment and reconfigure their business models. The main opportunities resulting from the implementation of Industry 4.0 solutions include "speed of changes" and "flexible production". Accessing both of these benefits is possible thanks to the attributes of agility. The purpose of the strategic agility concept is to encourage organizations to think forward and be proactive in their approach, especially as they operate in today's complex business environment (Doz and Kosonen, 2008). The critical role of strategic agility in enhancing performance has become more crucial with the growing dynamism of the business environment (Ivory & Brooks, 2018). Strategic agility is crucial in order to maximize strengths and provide what is necessary for the organization's survival (Doz & Kosonen, 2008; Ping *et al.*, 2018; Tallon *et al*. 2019). We agree with Ping et al. (2018) that strategic agility is a weapon that can be used to cope with a turbulent and fast-changing business environment.

In the current literature, there is still a lack of systematic reviews on the impact of the new industrial revolution on the attributes of strategic agility

(Tallon et al., 2019). Previous papers have systematically reviewed the literature for both Industry 4.0 and agility, but separately. The literature clearly indicates a shortage of papers linking Industry 4.0 with the issue of company agility, as well as a lack of information on the state of research in this area, both in theoretical and empirical terms (Schirrmacher & Schoop, 2018; Diegmann et al., 2018; Ciampi et al., 2018). One of the exceptions is an article published by Mrugalska and Ahmed (2021), who reviewed the literature from the perspective of agility in Industry 4.0 and concluded that "agility is important for an organization to adopt Industry 4.0 technologies as it helps companies to cope with the changes that arise along with the adoption of Industry 4.0 technologies". Although both aspects were addressed in their paper, the authors presented an entirely different approach and also set different goals. The purpose of their research was to review the literature from the perspective of agility in Industry 4.0. That is, they treat agility as a dynamic ability for the successful implementation of Industry 4.0 solutions, that is as an enabler for the implementation of new technologies. Our analysis perspective is different, we are interested in the relationship between the use of Industry 4.0 technologies and the development of the adopted agility attributes. There is a noticeable shortage of studies identifying which Industry 4.0 technologies support the development of strategic agility, to what extent and in what aspects (Piccarozzi et al., 2018; Walter, 2021). Tallon *et al.* (2019, p. 4) point out that "the literature is relatively silent on how firms should manage their IT resources to deliver greater agility, the capabilities needed to do this, and the resulting implications for firm performance". Hence, it seems reasonable to pose the following research question: Do industry 4.0 technologies support strategic agility, and if so, to what extent?

Taking the above into consideration, the aim of the paper is to identify and assess the state of knowledge in the field of using and supporting Industry 4.0 technologies for the development of companies' strategic agility.

Our paper systematically reviews relevant articles from peer-reviewed academic journals in the period from 2018 to 2020. Adopted time scope is related to the peak of interest of "Industry 4.0" term during this period according to Google Trends database. The article uses the method of a systematic literature review (SLR), and strives in a rigorous and reliable manner to organize knowledge of the use of Industry 4.0 technology to strengthen strategic agility. The research procedure of the systematic review consisted of a five-stage approach, including: formulation of the research questions and determination of the research objective, selection of the literature sample, evaluation of the identified papers, data analysis and synthesis, and reporting on the results. The applied research method allowed for synthesis and consolidation of the existing scientific

achievements in the field of supporting Industry 4.0 technologies in the development of companies' strategic agility.

The structure of the paper is as follows. First, we discuss the growing importance of Industry 4.0 and strategic agility, including the presentation of the specific characteristics of Industry 4.0 and the strategic agility perspective. Section 2 then presents the systematic literature review method and the fundamental review principles. The next part of the paper illustrates and discusses the results. The paper ends with conclusions and a future research agenda.

1. The growing importance of Industry 4.0 and strategic agility

1.1. Industry 4.0 – a set of integrated technologies

In the time of the ongoing Fourth Industrial Revolution, also known as the Industry 4.0 era, the digital and physical worlds are converging (Pham et al., 2019). So-called "general purpose technologies" (or "founding technologies"), usually perceived to be the computer, internet and smartphone (Jovanovic and Rousseau 2005; Śledziewska and Włoch 2020), continue to have the ability to spread to all sectors of the economy, and are constantly improving and stimulating innovations in many areas of the economy and in society in general. They are also the basis of the ecosystem in which new inventions and innovations appear. Many consulting companies have attempted to identify the technologies that have the greatest potential to disrupt the current functioning of the economy and society (so-called disruptive technologies). Among these, the most frequently indicated are mobile Internet, the Internet of Things, cloud technology, automation and advanced robotics, 3D printing, ICT solutions and BI systems (Henke and Wilmott, 2018). The catalogue of technologies, however, remains open, and the boundaries between them are sometimes difficult to define in practice. Moreover, as W. B. Arthur (2009) points out, a single technology does not arise in a linear manner, but rather as a combination of other technologies. This mechanism was also evident during earlier industrial revolutions, but it was much slower, due, for example, to the pace of knowledge transfer.

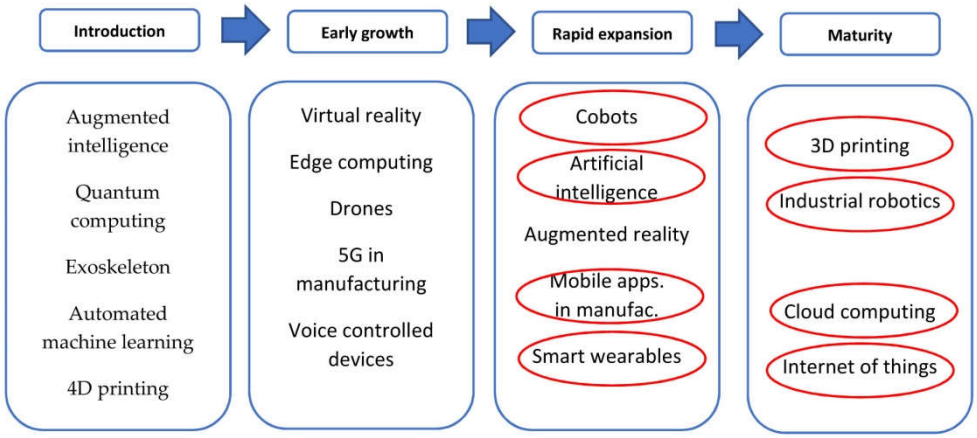
Industry 4.0 technologies create the need for the intensive use of large data sets and processes, organized within various subsystems of an organization. The main goals are improving efficiency, creating new opportunities, and strengthening the resilience of the organization. The transformation of an enterprise forces management to have an understanding of the opportunities, challenges and emerging competency gaps in the implemented business model (Schwab, 2016). The need to implement Industry 4.0 technology has emerged in particular in the face of the COVID-19 pandemic and its consequences, for example, unstable demand or difficulties in coordinating supply chains. The increasingly visible

convergence of the digital and physical worlds has resulted in profound changes that have shaped the value chain. At the same time, the evolution of the technologies themselves, as well as their potential applications, hinder a long-term approach both to investments in such technologies as well as clear planning of the entire ecosystem within which the company operates.

As indicated in a World Economic Forum report (WEF 2020), after 2018 there was a significant acceleration in the implementation of new technologies. The WEF also presents a list of technologies ranked according to the likelihood of their adoption by companies by 2025. Cloud computing, Big Data and e-commerce remain priorities, following the trend set during the Covid-19 pandemic. There has also been a significant increase of interest in encryption, reflecting the weaknesses of the digital age, and a notable increase in the number of companies expecting to use non-human robots and artificial intelligence. A similar observation can be made with regard to the so-called Hype Cycle for Emerging Technologies (prepared by Gartner), which introduces technologies with the greatest potential impact on business, society and people in the medium term.

However, it is worth noting that the essence of an effective digital transformation is the implementation of already existing technologies that can be considered mature. Some Industry 4.0 technologies have matured over the past decade, while others are still in the early stages of development or implementation, or are being tested in laboratory environments. According to one of the latest Kearney reports (2020), Industry 4.0 is essentially an ecosystem of five basic technologies: 1) artificial intelligence, 2) the Internet of Things (IoT), 3) 3D printing, 4) advanced robotics, and 5) wearables, augmented reality (AR) and virtual reality (VR). At the same time, other I4.0 technologies are also quickly being adopted and their market reach has expanded in recent years. Figure 1 shows the key technologies and the level of their maturity.

Figure 1. Maturity levels of I4.0 technologies



* technologies marked with red circles will be of particular interest in the analytical part of the paper
Source: Kearney analysis (2020)

New digital technologies are blurring the lines between the physical and digital spheres of global production systems. Industry 4.0 is turning manufacturing into a more information-intensive ecosystem with a connected environment of Big Data, people, processes, services and production systems. The scale of technology absorption differs depending on the industry analysed. Artificial intelligence is most often adopted in the information and telecommunications industries, as well as in financial services, healthcare and transportation. Big Data, the Internet of Things and robotics are intensively absorbed technologies in the mining and metallurgical industries, while the public sector has a clear focus on encryption (WEF 2020). The implementation of new technologies is aimed at ensuring future growth based on new sets of competences, which is undoubtedly a common feature of digital transformation, regardless of the industry analysed.

1.2. Strategic agility perspective

Today's fast pace of changes in the business environment requires organizations not only to be flexible in their operations, but also to be agile in order to survive (Holbeche, 2018). As Mavengere (2013, p. 327) notes, “growth and survival of companies in the contemporary business environment largely depend on how well the companies understand and relate to the dynamic and increasingly complex business environment”. An increasing number of companies may need to achieve strategic agility and to be flexible and adaptive, while remaining purposeful and consistent in

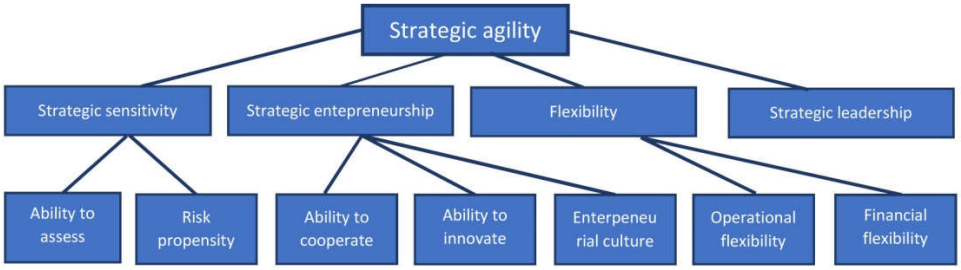
their efforts as they face more diverse and faster competition, strategic redirections and new business models (Doz, 2020).

Strategic agility, defined as the ability to undertake strategic changes aimed at improving company results (Sajdak, 2019b), is a response to the challenges of the modern economy, thanks to which companies can react faster, more efficiently and more effectively. We agree with Doz and Kosonen (2008) that strategic agility constitutes the ability of companies to make strong strategic commitments, while at the same time remaining sufficiently agile so as to manage and adjust to the continuous change caused by growing strategic discontinuities and disruptions. While researchers may agree that agility is about sensing and responding to changes, there are some variations as to the levels on which agility is considered (corporate, business unit, process or work group) and the composition of the construct (Tallon *et al.*, 2019). It may be noticed that the issues of organizational and strategic agility are sometimes treated as synonyms in the literature, emphasizing that agility relates to the ability to detect and respond to opportunities and threats with ease, speed and dexterity (Tallon and Pinsonneault 2011; Ravichandran, 2018).

We assume that strategic agility comprises four attributes, which have been identified as strategic sensitivity, strategic entrepreneurship, flexibility, and strategic leadership (see fig. 2) (Sajdak, 2019b). The first attribute - **strategic sensitivity** (consisting of the ability to assess opportunities and the propensity for risk) relates to the ability to quickly see market opportunities and threats arising from the environment, and the ability to categorize situations as favourable or unfavourable for the company (Zhang & Sharifi, 2000). The aspect of sensitivity concerns the ability to assess emerging opportunities - the company identifies and assesses whether an opportunity is consistent with the company's goals, and whether the company is able to assess the value of the emerging opportunity, regardless of the company's strategy (Maskell, 2001). At the same time, the company knows how to estimate the risk associated with an emerging opportunity (Sajdak, 2019a). Making decisions within the company regarding the use of opportunities is directly related to the attitude of decision-makers towards taking risks and perceiving them as a natural element of the market game (Jambulingam et al., 2005). Risk propensity refers to the propensity of managers to undertake risky projects, and reflects a preference for bold decisions in order to achieve organizational goals. It stands for the tolerance of errors, failures and ambiguities (Chiva et al., 2007). The next attribute is **strategic entrepreneurship**, which contributes importantly in the context of companies' ability to adapt by identifying and exploiting opportunities in the environment, while at the same time being a vehicle of strategic dexterity, flexibility and innovation (Kraus et al., 2011). Strategic entrepreneurship (consisting of the ability to

cooperate, the ability to innovate and entrepreneurial culture) deals with the actions a firm undertakes in exploiting new innovations, which result from the company's efforts to continuously explore opportunities (Sajdak, 2019b). The ability to cooperate is developed thanks to the company's knowledge of how to obtain resources from the environment. Nurturing a network of contacts and developing the company's ability to collaborate with partners (by identifying key partners) can be very helpful (Zhang and Sharifi, 2000; Maskell, 2001). The company's innovative ability manifests itself in the search for innovative technologies and at the same time the resources needed to implement new ideas. As a result, the company is willing to experiment with new concepts and ideas and also becomes known as an innovation leader (Jambulingam et al., 2005; Huang and Li, 2009). Entrepreneurial culture involves promoting attitudes and behaviours in the company so that innovation can develop. The company develops and maintains those values and behaviours that promote innovation and creativity, while the company's structure allows employees to be highly independent (flat organizational structure). Employees' ideas and knowledge are often used, which is conducive to the development of empowerment. The company promotes learning among employees, who, thanks to a wide range of skills, can be more independent in making decisions, and thus management is based on cooperation among multi-functional and committed employees (Vázquez-Bustelo et al., 2007; Huang and Li, 2009). **Flexibility** (consisting of operational and financial flexibility) determines the ability of an organization to respond to changes in the environment by quickly adapting processes and reconfiguring the company's resources to changing needs (Sajdak, 2019b). Operational flexibility - involves a flexible production process (the possibility of quick conversion, changes in manufactured products), a flexible logistics process (supply chain, implementation, control), a flexible marketing process (marketing contracts, communication channels, promotional tools), and a flexible sales process (customer needs research, preparation of offers and finalization of transactions, service) (Chan et al., 2017; Yousuf *et al.*, 2019). Financial flexibility is revealed mainly by the use of targeted sources of financing (loans, guarantees, subsidies) and the use of financial leverage. The fourth and last attribute of strategic agility is **strategic leadership**. Under this concept, leaders can emerge from the group instead of being formally designated, while the essence of leadership is to introduce changes and ensure the company's adaptation to the environment (Crocitto, 2003; Crossan et al., 2008). As Ireland and Hitt (2005) emphasize, the concept of strategic leadership relates to a person's ability to anticipate, maintain flexibility and think strategically, as well as simultaneously work with others to initiate changes that will create a better future for the organization.

Figure 2. Strategic agility concept



Source: own elaboration

1.3. Perspective of previous SLRs on Industry 4.0 and agility

There is still a lack of papers combining Industry 4.0 and strategic agility based on SLR methodology. There are some examples of articles presenting relationships between these two concepts, however they perceive them in different ways, as academics offer various understandings of Industry 4.0 and agility.

For example, Mrugalska and Ahmed (2021) show that agility is one of the most important elements for an organization in adopting Industry 4.0 technologies. They reviewed the literature from the perspective of agility in Industry 4.0. The authors systematically reviewed 381 relevant articles from the years 2016 to 2019, and ultimately analysed 91 of them. They argue that agility helps companies to cope with the changes that arise along with the adoption of I4.0 technologies. In addition, they also show that technologies such as smart manufacturing, cyber-physical systems, big data and analytics, cloud computing and IoT provide companies with enhanced agility in both value and supply chains.

Tallon et al. (2019) used a different theoretical lens to investigate the relationship between IT and organizational agility, as well as how the literature has conceptualized agility, its antecedents and consequences. They took into consideration 169 publications and recognized that companies are unlikely to respond to change by buying new IT resources. Diegmann et al. (2018), meanwhile, analysed a sample of 775 papers. They shed light on the existing knowledge on agile information system development by applying a structured literature review and computer aided analysis consisting of distinct text mining techniques.

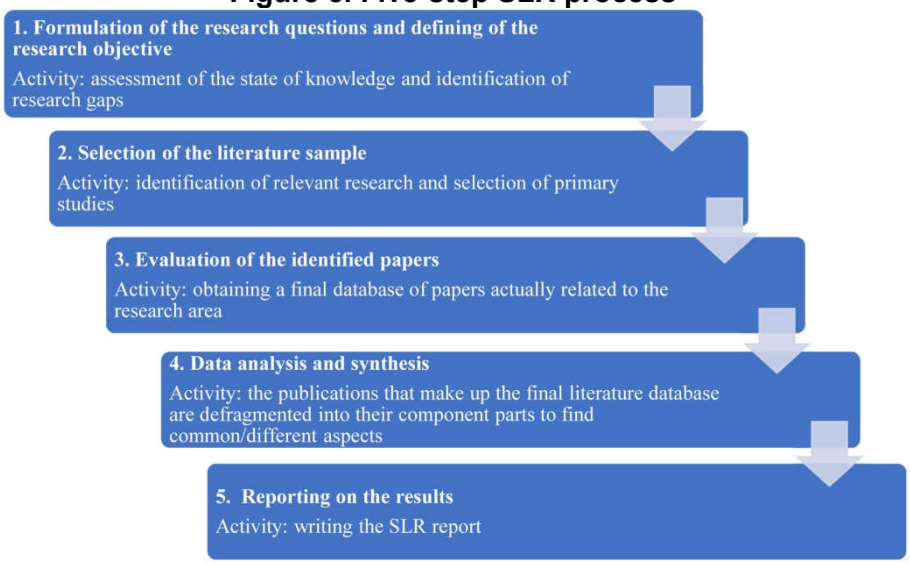
2. Methodology

Taking into consideration the aim of the paper, which relates to identifying and assessing the state of knowledge in the field of using and supporting Industry 4.0 technologies for the development of companies' strategic agility, we applied the Systematic Literature Review (SLR)

method. SLR has become the standard method for locating, selecting and evaluating research and transferring synthesized results (Czakon, 2011; Klimas et al., 2020). In a similar vein, Fish and Block (2018, p.103) indicate that a literature review "serves as the foundation for advancing knowledge, facilitates theory development. An SLR is a complex and comprehensive review identification, evaluation and synthesis of all literature on a given topic". As Okoli (2015) emphasises, an SLR should always be limited to scientific publications directly related to the area of inquiry and studies that provide answers to the research questions.

There are many more or less detailed SLR approaches in the literature, including those with 10 stages (Tranfield *et al*. 2003) and others with only 3 stages (Anello & Fleiss, 1995). Our research procedure for the systematic review followed a 5-stage approach (Booth et al., 2012; Klimas et al., 2020), including: formulation of the research questions and determination of the research objective, selection of the literature sample, evaluation of the identified papers, data analysis and synthesis, and reporting on the results. Exploratory research was carried out of existing review studies, which made it possible to perform an overview of the state of knowledge in the area of Industry 4.0 and strategic agility (Figure 3).

Figure 3. Five-step SLR process



Source: Own elaboration based on Booth et al. (2012) and Klimas et al. (2020)

The first activity provided the basis for formulating research questions and defining the aim of the study, as well as identifying research gaps. At the next stage, a sample of literature was selected. A set of 30 deliberately

selected scientific journals provided the source for the publications identified. In line with Peppard (2018) and Tallon et al. (2019), we selected a list of journals in two areas: strategic management and information systems organization[3].

At the stage of evaluation of the literature sample (the third stage), decisions were also made regarding the appropriate set of criteria, in particular inclusion and exclusion criteria, and the development of the initial database (Zumsteg et al., 2012). This stage involved a cursory review of the literature based on analysis of the content of the titles and abstracts, and an in-depth analysis of the content of the entire publications. Particularly important from the point of view of transparency and the replicability aspect is the definition and description of the criteria for acceptability of works for analysis (eligibility criteria) (Yuan & Hunt, 2009). These criteria can be divided up according to the review stage at which they are implemented. As Fish and Block (2018, p. 104) emphasize "this involves a description of the databases where the literature search was conducted, a definition of the search terms and keywords used to identify literature, and a careful description of the practical (e.g., language, availability) and methodological (e.g., time frame, article type) screening and exclusion criteria used". Based on the screening and the exclusion criteria, the final database relating to the research area was created. The result of this stage was the division of the initial database into three categories: the final database, studies partially of value - useful to some extent or inspiring, and studies entirely excluded from further analysis.

At the fourth stage, the data was analysed and synthesized. Publications comprising the final literature database were defragmented into their component parts so as to identify common aspects, as well as parts that were different, but also complementary. This enabled links

[3] These journals are: Strategic Management Journal, Long Range Planning, Strategic Entrepreneurship Journal, Journal of Management, Journal of Management Studies, Journal of Business Research, Organization Science, Management Decision, Academy of Management Journal, Academy of Management Review, International Journal of Technology Management, Journal of Business Ethics, International Journal of Operations & Production Management, Journal of Business Venturing, Organization Studies, Technovation, Industrial Marketing Management, Journal of International Business Studies, Journal of the Operational Research Society, Technological Forecasting and Social Change, Information Systems Management, Information Systems Research, Journal of Management Information Systems, Journal of Strategic Information Systems, European Journal of Information Systems, International Journal of Information Management, Information & Management, Information Technology & People, Journal of Information Technology, Information and Organization.

between them to be identified. It is suggested that the synthesis and analysis of source data should go beyond simple description, transforming the information so that it is new or different, and developing knowledge that is not evident from individual studies (Okoli, 2015). The fifth and last stage relates to the discussion of the results.

We adopted the first 3 stages of the procedure presented above (Table 1), which enabled further analysis.

Table 1. Replication of the first 3 stages of the SLR procedure

Stage I: Formulating research questions and defining the purpose of the research			
Main goal: identification and assessment of the state of knowledge in the field of using and supporting Industry 4.0 technologies for the development of strategic agility in companies	Research question: do industry 4.0 technologies support strategic agility, and if so, to what extent?		
Stage II: Selection of literature sample			
Databases: academic databases were selected and journals were indexed: EBSCO, Springer, ScienceDirect, Proquest, Emerald Insight and Taylor Francis			
Keywords: "Industry 4.0" *and/or "*Technologies *4.0" and "*Agility" *and/or* "Agile" identified in the same article			
Inclusion criteria: • search in: title or abstract or keywords • year of publication: 2018-2020 • type of publication: scientific articles (published in selected 30 scientific journals) • reviewed: peer review OR double peer review • Access: works available in full version • Language: English • Field: strategic management / information systems	Exclusion criteria: • type of publication: no conference papers, proceedings, book chapters, scientific announcements etc.		
A priori selection process:	**Researcher 1**	**Researcher 2**	**Researcher 3**
*results based on 10 journals assigned to each researcher	56	60	88
Initial database:	204		
Stage III: Initial evaluation of the sample			
A posteriori selection process:	**Researcher 1**	**Researcher 2**	**Researcher 3**
Papers marked as *selected*	17	28	11
Papers marked as *inspiring*	13	18	25
Papers marked as *useless* – off the topic	26	14	52
Final database: 56 papers			

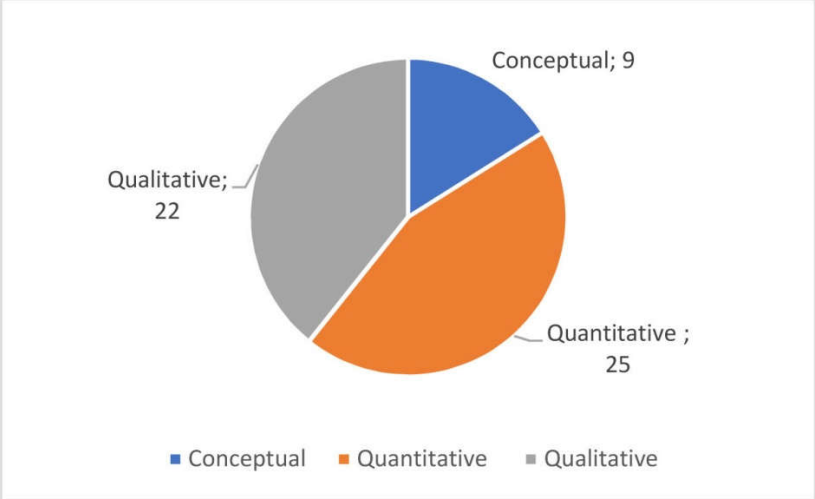
Source: Own elaboration

3. Results and discussion

3.1. Overview of papers included

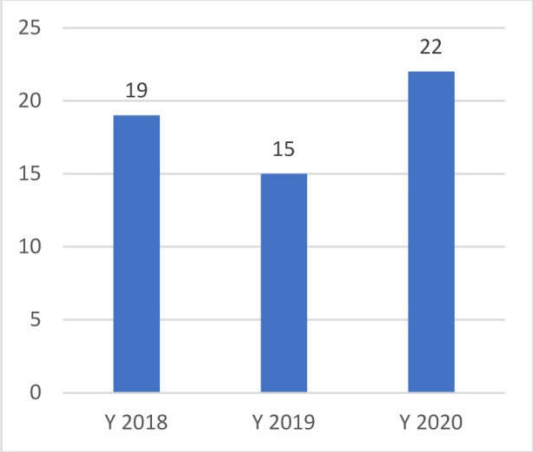
The articles included in the SLR were diverse in many respects, for example, from the point of view of the research methods adopted by the authors. The papers presenting the results of qualitative (22 out of 56) and quantitative research (25 out of 56) were definitely dominant, while relatively few articles were theoretical (9 out of 56).

Figure 4. Type of paper / research method



Source: own elaboration

Figure 5. Year of publication

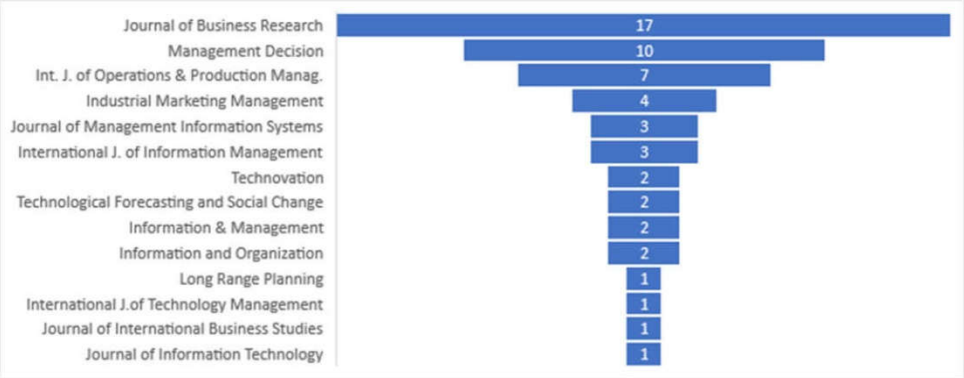


Source: own elaboration

The number of articles in the three years under consideration (Figure 4) remained fairly stable with a slight increase in 2020, which may be associated with an overall increase in interest in Industry 4.0. (according to Google Trends data). However, it should be noted that we were looking for a relationship in the papers between 4.0 technologies and agility, so by definition the number of works included, regardless of the year of publication, was limited.

As part of the adopted SLR procedure, we originally included 30 journals. In the course of the research, however, we identified articles of interest to us in 14 periodicals (Figure 6). It is worth noting, however, that over half of all the articles (34 out of 56) were published in the Journal of Business Research, Management Decision and the International Journal of Operations & Production Management.

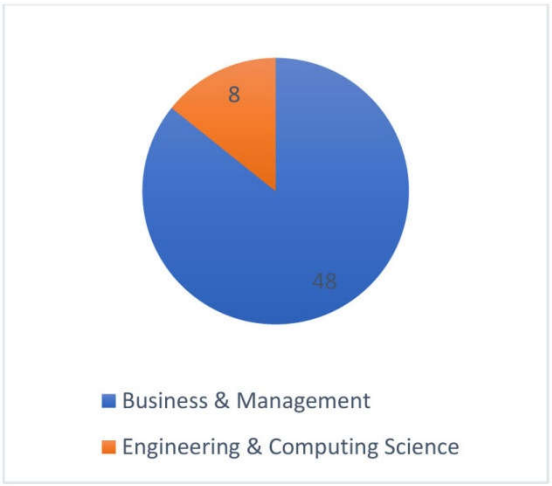
Figure 6. Literature distribution by journal



Source: own elaboration

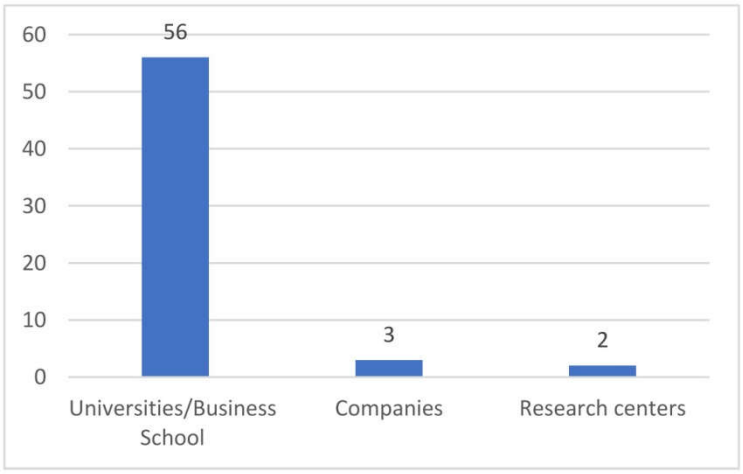
The vast majority of the papers ultimately analysed were in the *Business and Management* area (Figure 7.). This was the product of the final search results in bibliographic and abstract databases based on keywords, followed by qualitative analysis, and not the original list of 30 journals, which covered both areas relatively evenly.

Figure 7. Article main interest area



Source: own elaboration

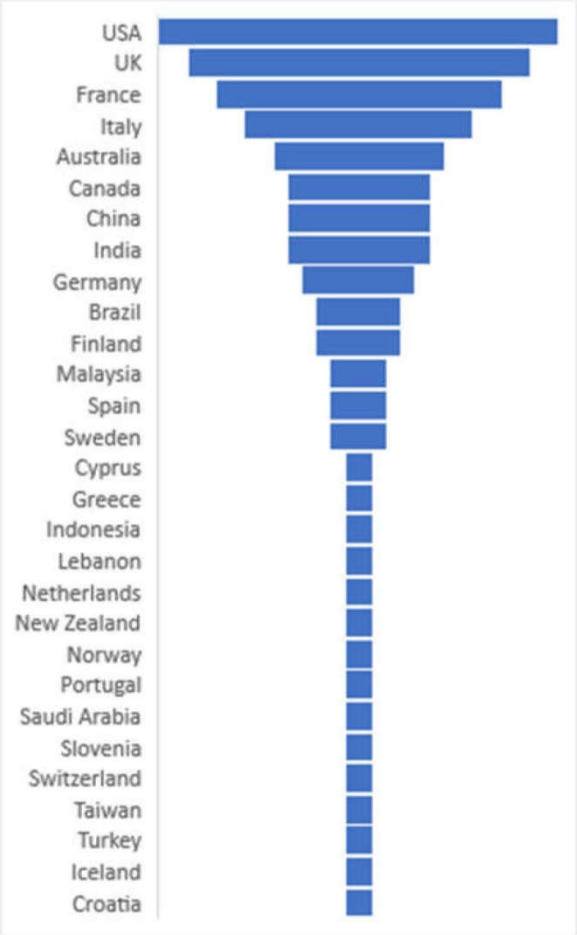
Figure 8. Authors by institution



Source: own elaboration

All the articles included were prepared by academics representing Universities and Business Schools, in 5 cases co-authored by representatives of companies and research centres (Figure 8). Articles co-authored by people from outside the academic community were usually of a slightly more 'practical' nature, although their number is insufficient for drawing further conclusions.

Figure 9. Authors by country of origin



Source: own elaboration

Figure 9. shows the origin of the authors, representing 29 countries in total. Many of the analysed articles were prepared in international teams, which emphasizes the importance of the issue of agility and its connection with the development of technology across a wide geographical scope.
The dominance of developed countries is visible, in particular EU countries, which are interested in the implementation of the Industry 4.0 concept. In these countries, significant public funds are allocated to supporting projects related to digital transformation. It is also worth adding that publications from Europe are dominated by the UK and original EU Member states. CEE countries (except for Croatia and Slovenia) are not represented.

3.2. The scope of using and supporting 4.0 technologies for the development of strategic agility

Objective and comprehensive assessment of technological support for the development of individual agility attributes is a complicated process due to the evolution of the catalogue of 4.0 technologies used across various sectors of the economy. The basis for the set of technologies taken into account in the SLR was the degree of maturity, i.e. the possibility of their wide implementation and adaptation by companies (see Fig. 1). This catalogue was extended to include advanced business intelligence solutions, advanced data analytics / Big Data, blockchain technology and IT systems / solutions, which resulted from the frequency these technologies and solutions were indicated in the analysed articles.

The SLR results show the strong support of technologies such as 1) IoT / M2M, 2) Cloud computing 3) Smart, mobile devices, mobile applications, 4) BI Solutions and 5) advanced data analytics / Big Data. However, the impact of these technologies is observed only in the case of selected agility attributes, in particular such dimensions as: ability to assess opportunities, ability to cooperate, ability to innovate and operational flexibility (see table 2).

In the case of the strategic sensitivity attribute, in particular the ability to identify and assess opportunities, strong support from advanced data analytics / Big Data and IoT / M2M can be noted. The literature suggests that thanks to the implementation of Big Data analytics, companies are able to sense emerging opportunities and threats and adjust their activities based on the trends observed in the competitive environment. As a result, the main competitive distinguishing feature of Big Data is the fact that it facilitates the making of more informed decisions, giving the possibility not only to identify opportunities, but also to evaluate them in the context of their use (Mikalef et al., 2019). Other authors found evidence that Big Data analytics help detect, predict and respond to industry disruptions. By analysing the relationship between levels of data analytics capabilities and strategic dynamic opportunities, they found that descriptive data analytics improves an organization's ability to understand the business context (sensing), and predictive data analytics helps deliver business opportunities (seizing). Their research contributes to the understanding of Big Data analytics as a dynamic organizational ability that supports strategic decision making in times of uncertainty (Rijmenam et al. 2019). Meanwhile, cloud computing can make it easier for firms to scale up and extend their services and IT architecture according to market changes. As Liu et. Al argue “cloud computing can help enterprises rapidly configure IT resources to respond to market dynamics, thus improving operational agility” (2018, p. 102). On the other hand, Leminen et al. (2020) argue that the Internet of Things creates

Table 2. Support of 4.0 technologies for strategic agility attributes based on SLR

Attributes of strategic agility / Industry 4.0 technologies		3D printing/3D scanning	IoT/M2M	Artificial intelligence	Cloud computing	Smart, mobile devices, smart, mobile apps	Industrial robotics, incl. collaborative robots	Advanced BI solutions	Advanced data analytics / Big Data	Blockchain technology	IT systems/ solutions
Strategic sensitivity	Ability to assess opportunities		21,29, 39, 41, 44	3, 28, 36	23,29, 44	11, 21, 46		50	1,2,4, 5, 6 7,9,11,17,19,20,21, 22, 23,24,25,26,27,29, 33,36, 37, 41, 44		18
	Risk propensity		41		23				5, 22, 37, 41		
Strategic entrepreneurship	Ability to cooperate		21,31, 41	3, 43	13, 31	11,13, 21, 47		30,31, 50, 52, 55	1, 5, 6, 7,11, 13, 19,21,25,30, 31, 41,	30,31	13, 18
	Ability to innovate	42	10, 38, 39, 41, 44	3, 38	10,23, 44	10, 11, 54	48	52	1, 5, 6, 7,11, 14, 15, 19,21,25,27, 44, 46		8,18
	Entrepreneurial culture		10, 41	3, 43	10,23	10, 11	16	50, 52, 55, 56	1, 5, 6, 7, 11, 19,21,25, 45		8, 12, 18
Flexibility	Operational flexibility	32	21, 29, 31, 35	3, 28, 34	23,29,31, 34, 35	11, 21, 35	16	31, 34, 35, 49	1, 5, 7,11,19,21,25, 31, 33, 34, 35, 37, 40, 45, 46	31, 51	
	Financial flexibility		21	3		21	53		1, 5, 7,11,19,21,25		
Strategic leadership	Strategic leadership			3	23			30	1, 5, 7,11,19,21,25, 30		

1 - Mariani and Fosso (2020); 2 - Mikalefa et al. (2019); 3 - Makarius et al. (2020); 4 - Yasmin at el. (2020); 5 - Van Rijmenam at al. (2019); 6 - Yunis et al. (2018); 7 - Shastri et al. (2018); 8 - Zhanga et al. (2018); 9 - Merendino et al. (2018);10 - Galindo-Martín et al. (2019); 11 - Côrte-Reala et al. (2019); 12 - Crittendena et al.; 13 - Cenamor et al.(2019); 14 - Ghasemaghaei and Calic (2019); 15 - Ghasemaghaei and Calic (2020); 16 - Ballestar et al.(2020); 17 - Yasmin et al. (2020); 18 - Mariani and Wamba (2020); 19 - Dubey et al. (2019); 20 - Fosso et al. (2019); 21 - Rajput and Singh (2018); 22 - Zeng and Khan (2019); 23 - Gupta et al. (2019); 24 - Fiorini et al.(2019); 25 - Ferraris et al. (2019); 26 - Caputo et al.(2019); 27 - Chierici et al.(2019); 28 - Assunta et al. (2020); 29 - Tortorella et al. (2019); 30 - Faruquee et al.(2021); 31 - Keller et al.(2021); 32 - Hohn and Durach (2021); 33 - Yu et al. (2019); 34 - Seyedghorban et al. (2020); 35 - Lorentz et al. (2021); 36 - Banalieva and Dhanaraj (2019); 37 - Kashav et al. (2020); 38 - Gebauer et al. (2020); 39 - Leminen et al. (2020); 40 - Gupta et al. (2020); 41 – Sestino et al. (2020); 42 - Candi and Beltagui (2019); 43 - Xiong et al. (2020); 44 - Frank et al. (2019); 45 - Roßmann et al. (2017); 46 - Zhao et al. (2020); 47 - Yan et al.(2018); 48 - McKnight et al. (2020); 49 - Rajput and Singh (2019); 50 - Pejic-Bach et al.(2020); 51 - Karamchandani et al.(2020); 52 - Zhou et al. (2018); 53 - Cram and Marabelli (2018); 54 - Tumbas et al.(2018); 55 - Zaitsev et al. (2020); 56 - Wagner et al.(2018).

the potential to transform traditional industry structures, leading to the convergence of industries, but also the emergence of new industry fields not only "between" industries, but also "beyond" these industries.

Summarizing the results concerning strategic sensitivity, it is worth emphasizing that while there is strong support from technologies in terms of the assessment of opportunities, in the case of strengthening the propensity to risk, this impact was much less often indicated in the case of all the technologies considered.

In the case of strategic entrepreneurship, a broad scope of the use of technology 4.0 can be noted in almost all of its dimensions. Cloud computing can play an important role when companies develop collaboration with business partners in the exploration and exploitation of innovation opportunities. The relationships between IT capability and agility have been supported by Ping et al. (2018), who confirmed that IT capability and business intelligence use have a positive impact on strategic agility. Unfortunately, the literature does not indicate how companies should manage their IT resources to deliver greater agility (Queiroz *et al.*, 2018).

Generating valuable information from data can be an important driver of innovation. Accessing and using Big Data from different sources helps companies to come up with new ideas and better understand the needs of consumers. To improve innovation competencies, companies can expand their existing skills, processes and knowledge in product innovation, or renew their knowledge and skills (Ghasemaghaei & Calic, 2019). Digital technologies are based on ICT systems that standardize information and allow organizations to rapidly code, store, formalize and distribute increasing amounts of knowledge, which is becoming ever more diverse. Digital platform capability may enhance the different aspects of network capability. Digital architecture has a significant influence on how internal units and external partners interact (Cenamor et al., 2019).

In turn, artificial intelligence is or can be applied to a wide range of organizational functions, such as assembly lines, interaction with customers, suppliers, employees and making strategic decisions. Successful use of the opportunities AI presents is possible with the full involvement of employees, as they interact with each other and integrate their behaviour with AI systems (Makarius et al., 2020).

It is worth adding that the spreading of IoT guarantees the proliferation of "intelligent spaces" - physical and digital environments where people and technology systems interact in a coordinated and networked manner. These elements relate to the spaces, processes, services and objects that make up engaging, interactive and automated activities (Sestino et al. 2020).

A significant relationship is also noticeable between the use of modern technologies and operational flexibility. As in the first two attributes, the key

technology is Big Data. When it comes to delivering business value, academics note that Big Data analytics help companies improve their business processes or customer experience and satisfaction. The concept of Big Data Analytics (BDA) arose from the need to effectively manage large volumes of data to improve business insight, in particular the operational process (Côrte-Real et al., 2019). In the same vein, Ballestar et al. (2020) argue that robotic devices are associated with better performance, higher productivity and employment rates, as well as a knowledge-driven value process.

IoT is also spreading and can help industries increase the accuracy and precision of their processes, minimize costs and see the benefits of real-time information that can help them make informed decisions. IoT offers the ability to monitor the actual performance and KPIs of an organization (Rajput and Singh, 2018).

In addition, organizations can reap the benefits of AI by building their own innovation ecosystem, or by joining an existing ecosystem of technology partners, vendors, customers and other stakeholders. Building an innovation system requires shifting to an organization that enables interdisciplinary collaboration, data-driven decision making, and an agile, experimental and flexible mentality (Makarius et al., 2020).

The results of our SLR show that the 4.0 technologies investigated support the strategic leadership attribute to a small extent. However, we found some importance in the relationship-building process. Faruquee et al. (2020) studied the effectiveness of management mechanisms in the era of digital transformation (in the context of supplier management). Their findings make it clear that digital connectivity at the company level is not a substitute for building strong interpersonal relationships. Technologies that support relational capital (such as Enterprise Resource Planning software) can be much more helpful than technologies that try to replace relational values (such as artificial intelligence, blockchain). Companies that strive to adopt new technologies should not consider advanced digital technologies as an alternative to trust.

If companies want to survive and operate in an era where speed is paramount, they need to adapt, and to implement the right combination of agility-oriented IT capabilities (Tallon *et al.*, 2019). Ravichandran (2018, p. 23) indicates that “IT enables firms to enhance the flexibility of firm resources”. Highly unpredictable events in the business environment require businesses to be agile, and IT is viewed as a way to respond faster in a changing environment. In previous research, it was found that IT capability strongly relates to agility (Lu & Ramamurthy, 2011).

Concluding remarks

The literature in the areas of strategic management and information systems in organizations indicates a growing interest of researchers in the connection between both issues. The use of Industry 4.0 technologies is not only for business support, but more and more often is of strategic importance for companies (Ghobakhloo, 2018; Młody & Weinert, 2020). The results of our SLR demonstrate that Industry 4.0 technologies support strategic agility. However, the extent of this impact varies. Our results show support from technologies such as 1) IoT / M2M, 2) Cloud computing, 3) Smart, mobile devices, mobile applications, 4) BI Solutions and 5) advanced data analytics / Big Data. A significant impact of these technologies was observed in the case of selected agility attributes, in particular: the ability to assess opportunities, the ability to cooperate, the ability to innovate and operational flexibility.

The volatility of the business environment forces companies even in stable industries to adopt strategic agility based on digital technologies. A static approach may result in a loss of competitive advantage. It is believed that if organizations are to survive and thrive in fast-paced era, they need new ways to create and implement the right combination of agility-oriented capabilities (Tallon et al., 2019).

Strategic agility in the Industry 4.0 era means that an organization can leverage its IT infrastructure, applications and data, as well as a range of assistive technologies, so as to redirect and develop new value propositions to gain a competitive advantage. It is also worth noting that much is still unknown, and, as Jesse remarks: “while there is no doubt about the need for keeping pace with the technical progress it is blurry how much this affects leadership and organizational agility” (Jesse, 2018, p. 486).

Limitations

With regard to the results of this study, several limitations should be noted. Firstly, we decided to use the list of journals suggested by Peppard (2018) and Tallon et al. (2019) as the most influential in the area of strategic management. Embedding strategic agility in the strategic management framework was the basic selection criterion. We are aware that with the use of bibliographic and abstract databases taking into account a wider list of journals and a wider range of languages, the number of identified articles could be greater, but our intention was to reduce the phenomenon of garbage in - garbage out (Klimas et al. 2020). Secondly, the search criteria within the accepted list of journals included subjectively selected phrases determining a priori selection. At the a posteriori selection stage, additional criteria constitute a significant limitation, the consequence of which could be incorrect cleaning of the initial database. However, in

order to minimize the risk, we used researcher triangulation. Finally, we are aware that boundaries between technologies are sometimes difficult to define as they are blurred, e.g. the differences between advanced data analytics solutions, and BI solutions and advanced IT systems. This results from two aspects – first, there are no complex and general definitions, second, the application possibilities are still developing, depending on industry characteristics.

Future research areas

In today's world, agility and new skills have been induced by Industry 4.0 in many organisations, not only in companies. Our SLR can be a starting point for determining the directions of further research that may be required in industries other than manufacturing (Götz, 2019; Hizam-Hanafiah et al., 2020; Walter, 2021). Our results show the connections and dependencies between 4.0 technologies and the attributes of strategic agility, however, the open question remains as to how technologies develop agility, to what extent and for which entities and industries. Future research should use a mixed research approach, including qualitative and quantitative methods. In particular, interviews with senior strategic managers on digital transformation could lead to a better understanding of the impact technology has on strategic agility. In the first place, research should focus on capital-intensive sectors open to the implementation of 4.0 technology, such as the automotive or electromechanical industries.

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References

1. Akkaya, B. (2020). Agile Business Leadership Methods for Industry 4.0, Emerald Publishing Limited.
2. Anello C., Fleiss J. L. (1995), Exploratory or analytic meta-analysis: Should we distinguish between them?, Journal of Clinical Epidemiology, 48(1), pp. 109–116.
3. Arthur B.W. (2009), The nature of technology: What it is and how it evolves, Free Press, New York.
4. Ballestar M.T., Díaz-Chao A., Sainz J., Torrent-Sellens J., (2020), Knowledge, robots and productivity in SMEs: Explaining the second digital wave, Journal of Business Research, 108, pp. 119-131
5. Banalieva, E.R., Dhanaraj, C. (2019), Internalization theory for the digital economy, Journal of International Business Studies, 50, pp. 1372–1387.

6. Booth A., Papaioannou D., Sutton A. (2012), A Systematic Approach to a Successful Literature Review, Los Angeles: SAGE Publications.
7. Candi M., Beltagui A. (2020), Effective use of 3D printing in the innovation process, Technovation, 80–81, pp. 63-73.
8. Caputo F., Cillo V., Candelo E., Liu Y. (2019), Innovating through digital revolution. The role of soft skills and Big Data in increasing firm performance, Management Decision, 57(8), pp. 2032-205.
9. Cenamor J., Parida V., Wincentd J. (2019], How entrepreneurial SMEs compete through digital platforms: The roles of digital platform capability, network capability and ambidexterity, Journal of Business Research, 100, pp. 196-206.
10. Chan, A. T. L., Ngai E. W. T., Moon K. K. L. (2017), The effects of strategic and manufacturing flexibilities and supply chain agility on firm performance in the fashion industry, European Journal of Operational Research, 259(2), pp. 486-489.
11. Chierici R., Mazzucchelli A., Garcia-Perez A., Vrontis D. (2019), Transforming big data into knowledge: the role of knowledge management practice, Management Decision, 57(8), pp. 1902-1922.
12. Chiva R., Alegre, J., Lapiedra R. (2007), Measuring organizational learning capability among the workforce, International Journal of Manpower, 28(3/4), pp. 224–242.
13. Côrte-Reala N., Ruivoa P., Oliveiraa T., Popovič A. (2019), Unlocking the drivers of big data analytics value in firms, Journal of Business Research, 97, pp. 160-173.
14. Cram, W. A., & Marabelli, M. (2018), Have your cake and eat it too? Simultaneously pursuing the knowledge-sharing benefits of agile and traditional development approaches, Information & Management, 55(3), pp. 322-339.
15. Crittendena V.L., Crittendenb W.F. , Ajjan H. (2019), Empowering women micro-entrepreneurs in emerging economies: The role of information communications technology, Journal of Business Research, 98, pp. 191-203.
16. Crocitto M. (2003), The human side of organizational agility, Industrial Management & Data Systems, 103(6), pp. 388–397.
17. Crossan M., Vera D., Nanjad, L. (2008), Transcendent leadership : Strategic leadership in dynamic environments, The Leadership Quarterly, 19, pp. 569–581.
18. Czakon W. (2011), Metodyka systematycznego przeglądu literatury, Przegląd organizacji, 3(854), pp. 57–61.
19. Di Vaio Assunta, Rosa Palladino, Rohail Hassan, Octavio Escobar, Artificial intelligence and business models in the sustainable

development goals perspective: A systematic literature review, Journal of Business Research, Volume 121, December 2020, Pages 283-314
20. Doz Y. (2020), Fostering strategic agility: How individual executives and human resource practices contribute, Human Resource Management Review, Elsevier, 30(1).
21. Doz, Y. L. and Kosonen, M. (2008), Fast Strategy. How strategic agility will help you stay ahead of the game, London: Wharton School Publishing.
22. Dubey R., Gunasekaran A., Childe S. J. (2019), Big data analytics capability in supply chain agility. The moderating effect of organizational flexibility, Management Desicion, 57(8), pp. 2092-2112.
23. Faruquee, M., Paulraj, A. and Irawan, C.A. (2021), Strategic supplier relationships and supply chain resilience: Is digital transformation that precludes trust beneficial?, International Journal of Operations & Production Management, 41(7), pp. 1192-1219.
24. Ferraris A., Mazzoleni A., Devalle A., Couturier J. (2019), Big data analytics capabilities and knowledge management: impact on firm performance, Management Decision, 57(8), pp. 1923-1936.
25. Fiorini P.D.C., Jabbour Ch., Ch. J., Jabbour A.B., Stefanelli O.N., Fernando Y. (2019), Interplay between information systems and environmental management in ISO 14001-certified companies. Implications for future research on big data, Management Decision, 57(8), pp.1883-1901.
26. *Fisch, Christian* and *Joern Block*, (2018), Six tips for your (systematic) literature review in business and management research, *Management Review Quarterly*, **68**, (2), 103-106
27. Fosso Wamba S., Akter S., Trinchera L., De Bourmont M. (2019), Turning information quality into firm performance in the big data economy, Management Decision, 57(8), pp. 1756-1783.
28. Frank Alejandro G., Glauco H.S. Mendes, Néstor F. Ayala, Antonio Ghezzi (2019), Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective, Technological Forecasting and Social Change, 141, pp. 341-351.
29. Galindo-Martín M.A., Castaño-Martínez M.S., Méndez-Picazo M.T. (2019), Digital transformation, digital dividends and entrepreneurship: A quantitative analysis, Journal of Business Research, 101, pp. 522-527.
30. Gebauer Heiko, Alexander Arzt, Marko Kohtamäki, Claudio Lamprecht, Vinit Parida, Lars Witell, Felix Wortmann (2020), How to convert digital offerings into revenue enhancement – Conceptualizing business model

dynamics through explorative case studies, Industrial Marketing Management, 91, pp. 429-441.
31. Ghasemaghaei M., Calic G. (2020), Assessing the impact of big data on firm innovation performance: Big data is not always better data, Journal of Business Research, 108, pp. 147-162.
32. Ghasemaghaei M., Calic G. (2019), Does big data enhance firm innovation competency? The mediating role of data-driven insights, Journal of Business Research, 104, pp. 69-84.
33. Ghobakhloo M. (2018), The future of manufacturing industry: a strategic roadmap toward Industry 4.0, Journal of Manufacturing Technology Management, 29(6), pp. 910–936.
34. Götz M. (2019), The Industry 4.0 Induced Agility and New Skills in Clusters, Foresight and STI Governance, 13(2), pp. 72–83.
35. Gupta S, Qian X., Bhushan B., Luo Z. (2019), Role of cloud ERP and big data on firm performance: a dynamic capability view theory perspective, Management Decision, 57(8), pp.1857-1882.
36. Gupta Shivam, Vinayak A. Drave, Yogesh K. Dwivedi, Abdullah M. Baabdullah, Elvira Ismagilova, (2020), Achieving superior organizational performance via big data predictive analytics: A dynamic capability view, Industrial Marketing Management, 90, pp. 581-592.
37. Henke N., Willmott P. (2008), Digital trends and observations from Davos, McKinsey Digital 2018, https://www.mckinsey.com/business-functions/digitalmckinsey/ourinsights/digitalblog/trendsand-observationsfromdavos2018
38. Hohn, M.M. and Durach, C.F. (2021), Additive manufacturing in the apparel supply chain — impact on supply chain governance and social sustainability, International Journal of Operations & Production Management, 41(7), pp. 1035-1059.
39. Holbeche L. S. (2018), Organisational effectiveness and agility, Journal of Organizational Effectiveness, 5(4), pp. 302-313.
40. Huang Y. Y., Li, S. J. (2009), Tracking the evolution of research issues on agility, Asia Pacific Management Review, 14(1), pp. 107–129.
41. Ireland, R. D., Hitt, M. A. (2005), Achieving and maintaining strategic competitiveness in the 21st century : The role of strategic leadership, Academy of Management Executive, 19(4), pp. 63–77.
42. Ivory S. B., Brooks, S. B. (2018), Managing Corporate Sustainability with a Paradoxical Lens: Lessons from Strategic Agility, Journal of Business Ethics, Springer Netherlands, 148(2), pp. 347–361.
43. Jambulingam T., Kathuria R., Doucette W. (2005), Entrepreneurial orientation as a basis for classificatio within a service industry: the case of retail pharmacy industry, Journal of Operations Management, 23, pp. 23-42.

44. Jesse N. Organizational Evolution - How Digital Disruption Enforces Organizational Agility, IFAC-Papers, Volume 51, Issue 30, 2018, pp. 486-491, https://doi.org/10.1
45. Jovanovic B., Rousseau P.L. (2005), General Purpose Technologies, [in:] Handbook of Economic Growth, P. Aghion, S. Durlauf, t. 1, Elsevier (eds.), Amsterdam, pp. 1181–1224.
46. Karamchandani, A., Srivastava, S. K., & Srivastava, R. K. (2020), Perception-based model for analyzing the impact of enterprise blockchain adoption on SCM in the Indian service industry, International Journal of Information Management, 52,
47. Kashav Shashi, Piera Centobelli, Roberto Cerchione, Myriam Ertz (2020), Agile supply chain management: where did it come from and where will it go in the era of digital transformation?, Industrial Marketing Management, 90, pp. 324-345.
48. Kearney, 2020, The State of Industry 4.0, https://www.kearney.com/operations-performance-transformation/article/?/a/the-state-of-industry-4.0-article
49. Keller, J., Burkhardt, P. and Lasch, R. (2021), Informal governance in the digital transformation", International Journal of Operations & Production Management, 41(7), pp. 1060-1084.
50. Klimas P., Stańczyk S., Sachpazidu-Wójcicka K. (2020), Metodyka systematycznego przeglądu literatury–wyzwania selekcji a posteriori podczas tworzenia bazy literatury, [in:] A. Sopińska i A. Modliński (eds.), Współczesne zarządzanie – koncepcje i wyzwania, pp. 39–52.
51. Kraus S., Kauranen I.,Reschke C. H. (2011), Identification of domains for a new conceptual model of strategic entrepreneurship using the configuration approach, Management Research Review, 34(1), pp. 58–74.
52. Leminen S., Rajahonka M., Wendelin R., Westerlund M. (2020), Industrial internet of things business models in the machine-to-machine context, Industrial Marketing Management, 84, pp. 298-311.
53. Lin D., Lee C.K.M., Lau H., Yang Y. (2018), Strategic response to Industry 4.0: an empirical investigation on the Chinese automotive industry, Industrial Management & Data Systems, 118(3), pp. 589–605.
54. Liu S., Chan F.T.S., Yang Y., Niu B., (2018), Understanding the effect of cloud computing on organizational agility: An empirical examination, International Journal of Information Management, 43(July), pp. 98–111.
55. Lorentz, H., Aminoff, A., Kaipia, R. and Srai, J.S. (2021), Structuring the phenomenon of procurement digitalisation: contexts, interventions and mechanisms, International Journal of Operations & Production Management, 41(2), pp. 157-192.

56. Lu, Y. and Ramamurthy, K. (2011) Understanding the Link between Information Technology Capability and Organizational Agility: An Empirical Examination. MIS Quarterly, 35, 931-954. https://doi.org/10.2307/41409967
57. Makarius E., Mukherjee D., Fox J., Fox A. (2020), Rising with the machines: A sociotechnical framework for bringing artificial intelligence into the organization, Journal of Business Research, 120, pp. 262-273.
58. Mariani M., Fosso Wamba S. (2020), Exploring how consumer goods companies innovate in the digital age: The role of big data analytics companies, Journal of Business Research, 121, pp. 338–352.
59. Maskell, B. (2001), Insight from industry The age of agile manufacturing, Supply Chain Management: An International Journal, 6(1), pp. 5–11.
60. Mavengere, N. B. (2013), Strategic agility and the role of information systems in supply chain: Telecommunication industry study, 7th European Conference on Information Management and Evaluation, ECIME 2013, 16(4), pp. 229–238.
61. McKnight D. Harrison, Liu Peng & Brian T. Pentland (2020) Trust Change in Information Technology Products, Journal of Management Information Systems, 37:4, 1015-1046, DOI: 10.1080/07421222.2020.1831772
62. Merendino A., Dibba S., Meadows M., Quinn L., Wilson D., Simkin L., Canhoto A. (2018), Big data, big decisions: The impact of big data on board level decisionmaking, Journal of Business Research, 93, pp. 67-78.
63. Mikalef P., Bourab M., Lekakosb G., Krogstiea J. (2019), Big data analytics and firm performance: Findings from a mixed-method approach, Journal of Business Research, 98, pp. 261-276.
64. Młody, M., Weinert, A. (2020). Industry 4.0 in Poland: A Systematic Literature Review and Future Research Directions. In: Zakrzewska-Bielawska, A., Staniec, I. (eds) Contemporary Challenges in Cooperation and Coopetition in the Age of Industry 4.0. Springer Proceedings in Business and Economics. Springer, Cham.
65. Mrugalska, B., & Ahmed, J. (2021), Organizational Agility in Industry 4.0: A Systematic Literature Review, Sustainability, 13(15).
66. Okoli C. (2015), A guide to conducting a standalone systematic literature review, Communications of the Association for Information Systems, 37(1), pp. 879–910.
67. Pejic-Bach, M., Bertoncel, T., Meško, M., & Krstić, Ž. (2020), Text mining of industry 4.0 job advertisements, International journal of information management, 50, pp. 416-431.
68. Peppard J. (2018), Rethinking the concept of the IS organization, Information Systems Journal, 28(1), pp. 76-103.

69. Pham, T.T.; Kuo, T.-C.; Tseng, M.-L.; Tan, R.R.; Tan, K.; Ika, D.S.; Lin, C.J. Industry 4.0 to Accelerate the Circular Economy: A Case Study of Electric Scooter Sharing. *Sustainability* **2019**, *11*, 6661. https://doi.org/10.3390/su11236661
70. Piccarozzi, M.; Aquilani, B.; Gatti, C. Industry 4.0 in Management Studies: A Systematic Literature Review. *Sustainability* **2018**, *10*, 3821. https://doi.org/10.3390/su10103821
71. Ping, T. A. et al. (2018), The Impact of Information Technology Capability , Business Intelligence Use and Collaboration Capability on Organizational Performance among Public Listed Companies in Malaysia, Global Business and Management Research: An International Journal, 10(1), pp. 293–313.
72. Rajput S, Prakash Singh S. (2018), Identifying Industry 4.0 IoT enablers by integrated PCA-ISM-DEMATEL approach, Management Decision, 57(8), pp.1784-1817.
73. Rajput, S., & Singh, S. P. (2019), Connecting circular economy and industry 4.0. International Journal of Information Management, 49, pp. 98-113.
74. Ravichandran, T. (2018), Exploring the relationships between IT competence, innovation capacity and organizational agility, Journal of Strategic Information Systems, 27(1).
75. Roßmann, B., Canzaniello, A., Gracht, H.A., & Hartmann, E. (2017), The future and social impact of Big Data Analytics in Supply Chain Management: Results from a Delphi study. Technological Forecasting and Social Change, 130, pp.135-149.
76. Sajdak M. (2019a), Enterprises ' Sensitivity to the Environment from the Perspective of Competitive Advantage – Research Results, Management Issues, 17(2), pp. 252–269.
77. Sajdak M. (2019b), Zwinność strategiczna przedsiębiorstw. Poznań: Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu.
78. Schirrmacher, A.K., Schoop, M., (2018). Agility in Information Systems – A Literature Review on Terms and Definitions *UK Academy for Information Systems Conference Proceedings 2018*. 25.
79. Schwab K. (2016), The Fourth Industrial Revolution, World Economic Forum, Geneva.
80. Sestino A., Prete M.I., Piper L., Guido G. (2020), Internet of Things and Big Data as enablers for business digitalization strategies, Technovation, Vol. 98.
81. Seyedghorban, Z., Samson, D. and Tahernejad, H. (2020), Digitalization opportunities for the procurement function: pathways to maturity, International Journal of Operations & Production Management,. 40(11), pp. 1685-1693.

82. Shastri L. Nimmagadda S.L., Reinersa T. , Woo L.C. (2018), On big data-guided upstream business research and its knowledge management, Journal of Business Research, 89, pp.143-158.
83. Śledziewska K, Włoch R. (2020), Gospodarka cyfrowa. Jak nowe technologie zmieniają świat, Wydawnictwa Uniwersytetu Warszawskiego, Warszawa.
84. Sony M., Naik S. (2020) Critical factors for the successfulimplementation of Industry 4.0: a review and future research direction, Production Planning &Control, 31:10, 799-815, DOI: 10.1080/09537287.2019.1691278
85. Tallon P.P., Queiroz M., Coltman T., Sharma R. (2019), Information technology and the search for organizational agility: A systematic review with future research possibilities, Journal of Strategic Information Systems, 28(2), pp. 218-23.
86. Tallon, P.P., Pinsonneault A. (2011), Competing Perspectives on the Link Between Strategic Information Technology Alignment and Organizational Agility : Insights from a Mediation Model Competing Perspectives on the Link Between Strategic Information Technology Alignment and Organizational Agility, 35(2), pp. 463–486.
87. Tortorella, G.L., Giglio, R. and van Dun, D.H. (2019), Industry 4.0 adoption as a moderator of the impact of lean production practices on operational performance improvement, International Journal of Operations & Production Management, 39(6/7/8), pp. 860-886.
88. Tranfield, D., Denyer, D. and Smart, P. (2003), Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review, British Journal of Management, 14(3), pp. 207-222.
89. Tumbas, S., Berente, N., & Brocke, J. V. (2018), Digital innovation and institutional entrepreneurship: Chief Digital Officer perspectives of their emerging role, Journal of Information Technology, 33(3), pp. 188-202.
90. Van Rijmenam M, Erekhinskaya T., Schweitzer J., Williams M.A. (2019), Avoid being the Turkey: How big data analytics changes the game of strategy in times of ambiguity and uncertainty, Long Range Planning, 52.
91. Vázquez-Bustelo, D., Avella, L. and Fernandez, E. (2007), Agility drivers, enablers and outcomes Empirical test of an integrated agile, 27(12), pp. 1303–1332.
92. Wagner, E. L., Newell, S., Ramiller, N., & Enders, J. (2018), From public ideology to socio-material reproduction of agile principles: The case of pivotal labs. Information and Organization, 28(4), pp. 192-210.

93. WEF (2020), The Future of Jobs Report 2020, Insight report (World Economic Forum), Geneva 2020, https://www.weforum.org/reports/the-future-of-jobs-report-2020
94. Xiong, Y., Xia, S. and Wang, X. (2020), Artificial intelligence and business applications, an introduction, Int. J. Technology Management, 84(1/2), pp.1–7.
95. Yan Jie (Kevin), Dorothy E. Leidner & Hind Benbya (2018), Differential Innovativeness Outcomes of User and Employee Participation in an Online User Innovation Community, Journal of Management Information Systems, 35(3), pp. 900-933.
96. Yasmin M., Tatoglu E., Kilic H.S., Zaim S., Delen D. (2020) Big data analytics capabilities and firm performance: An integrated MCDM approach, Journal of Business Research, 114, pp. 1-15.
97. Yousuf, A. et al. (2019) 'The Effect of Operational Flexibility on Performance : A Field Study on Small and Medium-sized Industrial Companies in Jordan', Montenegrin Journal of Economics, 15(1), pp. 47–60.
98. Yu, W., Chavez, R., Jacobs, M., Wong, C.Y. and Yuan, C. (2019), Environmental scanning, supply chain integration, responsiveness, and operational performance: An integrative framework from an organizational information processing theory perspective, International Journal of Operations & Production Management, 39(5), pp. 787-
99. Yunis M., Tarhini A., Kassar A. (2018), The role of ICT and innovation in enhancing organizational performance: The catalysing effect of corporate entrepreneurship, Journal of Business Reserach, 88, pp. 344-356.
100. Zaitsev, A., Gal, U., & Tan, B. (2020), Coordination artifacts in agile software development. Information and Organization, 30(2).
101. Zeng J., Khan Z. (2019), Value creation through big data in emerging economies The role of resource orchestration and entrepreneurial orientation, Management Decision, 57(8), pp.1818-1838.
102. Zhang, Z. and Sharifi, H. (2000), A methodology for achieving agility in manufacturing organisations, International Journal of Operations and Production Management, 20(4), pp. 496–513.
103. Zhanga M., Hartley J.L. (2018), Guanxi, IT systems, and innovation capability: The moderating role of proactiveness, Journal of Business Research, 90, pp. 75-86.
104. Zhao Xia, Jing Tian & Ling Xue (2020), Herding and Software Adoption: A Re-Examination Based on Post-Adoption Software Discontinuance, Journal of Management Information Systems, 37:2, pp. 484-509.
105. Zhou, J., Bi, G., Liu, H., Fang, Y., & Hua, Z. (2018), Understanding employee competence, operational IS alignment, and organizational

agility–An ambidexterity perspective. Information & Management, 55(6), pp. 695-708.
106. Zumsteg J. M., Cooper J. S., Noon, M. S. (2012), Systematic Review Checklist: A Standardized Technique for Assessing and Reporting Reviews of Life Cycle Assessment Data, Journal of Industrial Ecology, 16(SUPPL.1).