

DIGITAL TRANSFORMATION OF THE STEEL DISTRIBUTION SECTOR IN THE CONTEXT OF INDUSTRY 4.0

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Purpose: Process digitization and artificial intelligence are the needs of today's industry. The Fourth Industrial Revolution along with the concept of Industry 4.0 provides a huge opportunity for the development of many industries. Industry 4.0 imposes high demands on production and logistics in cyber-physical systems. Therefore, the primary objective of this publication is to present the concept of Industry 4.0, with particular emphasis on the impact of its technological solutions on the process of distribution of industrial goods. The challenges and benefits of the concept of Industry 4.0 are also presented in the article.

Design/methodology/approach: The work consists of two parts, the review of literature and the research part. The theoretical part presents the impact of technological solutions on the evolution of the distribution process. The empirical part focuses on the importance of technological solutions in the segment of Polish steel product distributors. In Poland, 9.7 million tons of steel is produced on average annually. In the world, according to the analyzes of the World Steel Association, 1781.5 million tons of steel was produced in 2022. Steel is an important construction and industrial material used in the production of cars, machines, ships, appliances, etc. Research was realized in Polish sector of companies. The questionnaire was build according the structure of Industry 4.0 based on pillars. In the questionnaire was used Likert scale from 1 to 5 with 5 being the highest.

Findings: Steel sector companies are aware of the importance of the technology of Industry 4.0 in improving the course of the process and communication with the market. The respondents highly assessed the importance of the pillars of Industry 4.0 in the processes of storage and distribution of steel products, most often choosing 4 in the Likert scale from 1 to 5.

Originality/value: Studies presented in this paper are strongly linked to the current concept of industrial development, which is Industry 4.0.

Keywords: product distribution, Industry 4.0, steel industry.

Category of the paper: research paper.

1. Introduction

Industry 4.0 is another version of technological progress, better than the previous one, arising in the Fourth Industrial Revolution. Changes taking place in the digitization of processes affect intelligent manufacturing and logistics processes in supply chains. Automation and digitization of production lines and warehouses are supported by global digital technologies that enable the development of cyber-physical systems (Lasi et al., 2014).

The term "Industry 4.0" (originally *Industrie 4.0*) was entered in the high-tech strategy project by the German government, promoting the computerization of manufacturing processes in 2011. It was first used at the Hannover fair (Kagermann et al., 2013) and more and more companies are implementing the latest technologies, which are called the "pillars" of Industry 4.0 (Lu, 2017; Senn, 2019; Erboz, 2017).

The digitization of processes is considered the basis for the development of Industry 4.0 (Kagermann, 2015; Stareček et al., 2023). Information and computer technologies (ICTs) are an opportunity to maintain the flexibility of enterprises, at every level of business activity, in a dynamic environment. In the case of the process of product distribution, the company must take into account flexibility from the moment of planning the warehouse layout (warehousing systems, the possibility of expanding or changing the warehouse design) to the course of logistics processes (the ability to adapt the activity to handle seasonal peaks). Therefore, let's take a closer look at the ongoing transformation of the digital distribution of goods in the conditions of Industry 4.0.

This study consists of the theoretical part - the review of literature, and the empirical part - the results of direct research in the steel product distributor sector in Poland. The research was carried out in enterprises selling steel products. The research architecture was constituted by the pillars of Industry 4.0: Big Data and analytics, AI (Artificial Intelligence), Cloud Computing, AR - Augmented Reality, IIoT - Industrial Internet of Things, 3D printing and additive manufacturing, autonomous robots, horizontal and vertical integration, simulation and digital twin, and cybersecurity. The research sought to determine the importance of the digital transformation of the Polish market for the distribution of steel products in the conditions of strong popularization of the concept of Industry 4.0.

2. Literature review

2.1. Distribution of goods and warehouse management in Industry 4.0

The determinants of the distribution process evolution are strong economic, technological, and social trends. One of them is the digital transformation of business combined with Industry

4.0 technologies (Gajdzik et al., 2021). The ongoing technological transformation, which is attributed to the Fourth Industrial Revolution, concerns every element of the process of goods distribution: people, warehouses, devices, software, transport (Blaik, 2018). Companies that do not take up the challenge of transition to a new stage of operation may lose the market competition for increasingly demanding customers who efficiently use mobile devices, which makes them active partners of the logistics company (Nambisan, 2017).

The distribution of goods in the conditions of Industry 4.0 is increasingly integrated with production and sales, as well as with customer service systems - especially strategic ones (Barreto et al., 2017; Hofmann et al., 2017). This integration of processes and computer systems is made possible by access to Big Data and the Internet of Things. Data collection and processing allow companies to optimize processes in real time (Tabakow et al., 2014; Aamer, and Sahara, 2021; Boyes et al., 2018; Wachnik, 2022). Moreover, based on data collected in sales processes, companies can profile a very accurate picture of a potential customer and their behavior. Access to data also helps companies predict periods of increased sales and effectively manage the needs generated by the market (Ruijgrok et al., 2002; Baber et al., 2019).

The distribution process evolves in the conditions of market economy. B. Ślusarczyk (2019), based on Ibarra et al. (2018, p. 7) describes three basic directions in goods distribution processes. The first is the service and customer service-oriented approach. In the digital world, services are inextricably linked to the product. Smart products need free access to service platforms (Grönroos, Ravald, 2011). The second direction is the network approach with horizontal and vertical integration of the value chain and the related interoperability. In processes, there must be the exchange of information between people, machines, and IT systems. Information flow can take place both within the factory and among supply chain entities. The third direction is based on the user (consumer) and their needs. This approach is called customization and consists in an individual approach to customer needs. New capabilities of technology make manufacturing more responsive to user-centered design and better suited to the processes and contexts of customer value creation (Vargo et al., 2008).

Modern distribution of goods is conducted in a global environment, leading to an increased scale of complexity in distribution processes. There are more and more physical streams of goods and more and more distribution channels in distribution processes. Supply chains must be able to flexibly adapt to changes in market needs. The spatial development of distribution channels is influenced by new possibilities of communicating via the Internet. With the development of knowledge and technology, the efficiency of logistics processes (resource management) is also increasing. The development of the Internet and advanced solutions of telecommunications have created good conditions for obtaining cheap sources of resources (materials, labor) and realizing the orientation towards sales and meeting diversified customer requirements. Quality standards and logistics procedures are being improved internationally.

The spatial and temporal scopes of goods distribution have no limits. Due to the use of increasingly sophisticated tools resulting from technical and technological development, enterprises can organize operational activities on many global markets (Szyszka, 2023). The Industry 4.0 environment supports the global nature of distribution processes, guaranteeing access to any information, at any time and from anywhere. All data regarding process planning, efficiency and quality management are available in real time. Additionally, they can be supplemented using AR (augmented reality) and optimized in the company's integrated IT network (Bieńkowski, 2018).

A. Bujak (2017) emphasizes that modern logistics can quickly respond to customer needs and is characterized by process flexibility (cost-service level) and a high ability to optimally use company resources, including data and information. W. Torbacki (2018a, 2018b), in the presented Industry 4.0 model, states that the actual stock of goods in a store or warehouse, as well as information on the consumption of goods recorded using cyber-physical systems may launch the production process via a cloud-based ERP system (Pohludka et al., 2018). In goods distribution processes, the scope of cooperation between business partners through direct involvement in management processes and creating added value is becoming increasingly stronger and easier.

As already mentioned, one of the megatrends of contemporary goods distribution is customization of products and services offered and the need to shorten the time necessary to meet customer needs (Ruijgrok et al., 2002). Modern market participants expect deliveries of customized products immediately after concluding commercial transactions, most often electronically. Growing market needs require the existence of effective, flexible, and fast distribution channels, as well as fully automated and smart warehouses (Khan et al., 2022; Grondys, 2015). Software helps optimize warehouse space and improve communication with production and logistics. Through warehouse management systems (WMSs) and IoT, sales departments gain direct access to storage systems to quickly ship another batch of goods. With the development of digital technology, "on-stock" production is giving way to "made-to-order" production with direct deliveries. Access to data and integrated IT systems improve the management of the entire supply chain (Domingo Galindo, 2016). Huge data sets and real-time event analysis make it possible to determine the best mode to process and deliver orders and prevent possible difficulties in its course. An important element supporting the functioning of the distribution network are electronic platforms, defined as the distributed environment of functionally integrated IT systems and tools for the purposes of delivering services provided electronically (Rozados, Tjahjono, 2014; Waller et al., 2013; Wang, 2016; Witkowski, 2017).

In the digital space, it is also worth remembering about solutions in terms of visualizing distribution channels and managing them in real time (Brettel et al., 2014). Digital technologies allow for the creation of analytical tools that allow for obtaining data from various, sometimes distant sources (e.g., sales stories, weather forecasts, local news or tracking conversations on social media) and analyze them in order to predict purchasing trends.

The digitization of processes is an opportunity for strong cooperation between the supplier and the customer, and communication with the customer is interactive. Therefore, the ability of the company to co-create value with customers may be demonstrated by the ability to develop existing or initiate new relationships with customers. Mobile devices make it easier for customers to express their opinions about products and service quality, and the Internet is a key medium of interaction between the consumer and the company. The Internet space is an excellent place to disseminate the market offer. Additionally, companies may stimulate customers to express their opinions, share ideas and rate their satisfaction with their relationship with the company through surveys, social media, auctions, etc. (Mitreęa, Laskowska-Witek, 2015; Sawhney et al., 2005; Shah et al., 2006; Wind et al., 2001; Shkurupskaya, Litovchenko, 2016).

The objects of distribution processes are warehouses of goods, which are fully automated in Industry 4.0. Modern warehouse systems are the central place of business in goods distribution processes. The warehouse can be managed better, faster, and cheaper using appropriate digital solutions. State-of-the-art warehouses are managed by computers that provide coordinates to forklift operators regarding the order. Products are identifiable, solutions such as RFID (electric identifiers used to mark cargo) (Barcik, 2019) are used. They provide the necessary information on the current condition and location of goods, as well as ensure the standardization of data transferred in production and distribution processes (Lv et al., 2012).

There is new equipment in warehouses, such as barcode and QR code readers and autonomous carts. Storage, admission, and release processes are supported by computer systems (WMS). Due to such a solution, various parameters are known, for example: duration of product storage in the warehouse, product rotation or product warranty coverage. The systems must be connected to devices used in the warehouse or production center. Machines, robots, devices using the concept of IoT (Internet of Things) need a WMS (warehouse management system) to communicate with each other (Mostafa et al., 2019).

The concept of blockchain technology is also increasingly used in the distribution process. Data blocks are the basis for full process transparency and greater security of goods (Ayan et al., 2022). Access to data throughout the entire product lifecycle on global markets makes it easier to report socially responsible business (Breese et al., 2019, Munir et al., 2022; Nitsche, Straube, 2021).

The evolution of goods distribution processes is a construct of Logistics 4.0, which was created by adapting Industry 4.0 technologies to the specificity of logistics processes within enterprises and in supply chains. The determinants of the acceleration of changes are: access to large sets of data and commercial information, the dominance of virtual tools in promoting a comprehensive structure of integrated marketing communications; interactive nature of relationships between chain participants and reduction in indirect connections, chain participants' access to IoT applications; switching to a new form of customer service (virtual seller), development of "social" communication channels and monitoring digital data about consumers (Bujak, 2016; Pfohl, 2016; Bracik, 2019).

3. Digital transformation in the steel product distribution process

3.1. Scope of research

The steel sector in Poland consists of 14 large manufacturers of steel products, with raw steel produced in 7 steel companies (HIPH, 2023). Distribution is dealt with by enterprises belonging to capital groups of steel producers or enterprises that are financially independent from steel producers (Gajdzik, 2011). In PKD (Polish Classification of Activities), manufacturers and distributors of steel products belong to the following sections: processing industry, metal and metal product manufacture section. Steel product distribution centers, in addition to organizing the distribution process, deal with processing steel products and provide services at the customer's request, e.g., cutting steel products, applying protective coatings, etc.

The research presented in this part of the study was carried out in companies dealing with the distribution of steel products. The authors' own survey questionnaire was used for the purposes of the research (Gajdzik, 2022). The questions in the questionnaire were used to determine the degree of digital transformation based on the technology of Industry 4.0. The research was conducted on a sample of 79 enterprises from the Silesian Voivodeship, selected using a non-random method. The results are presented in the author's monograph (Gajdzik, 2022). According to the data from the Steel Distributors' Union, the steel product distribution segment consists of 25 companies. Of these, 22 participated in the research. The survey questionnaire concerned the importance of key Industry 4.0 technologies in the entire value chain of the steel market in Poland. The impact of technology was marked TF: Technological Factor and was measured on a 5-point Likert scale.

3.2. Research results

This part of the publication presents the results of the research conducted in the Polish sector of steel product distributors. The examined technological factors were grouped according to the pillars of Industry 4.0.

The first scope of technological transformation was related to the degree of warehouse automation, from partial and incomplete automation, through full automation with integrated and autonomous warehouse management systems equipped with devices belonging to the category of autonomous robots and vehicles (TF_1). The respondents (enterprise management staff) indicated the high importance of full automation of steel product warehouses in the ongoing digital transformation of the process. The majority (74% of the respondents) rated the impact 4 or 5 (Figure 1). None of the respondents rated 1, which means that all the respondents are aware of the importance of the influence of automation of steel product warehouses on the development of the steel distribution market in Poland.

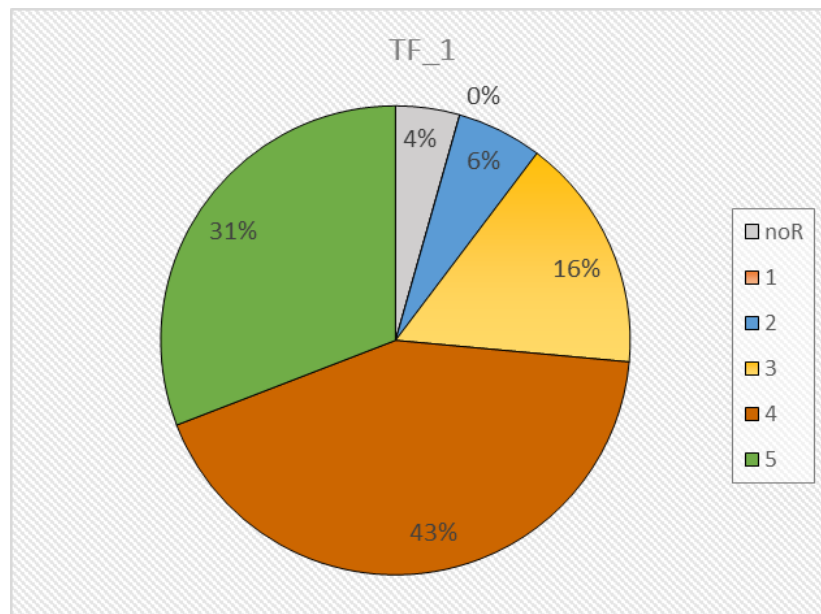


Figure 1. Warehouse automation.

Source: own research.

Another research area concerned network (chain) integration by integrating IT and computer systems of the process participants (TF_2), equipping warehouses with RFID and intelligent sensors (TF_3), and using logistics platforms, Cloud Computing and IIoT (TF_4). The research results are presented in the following figures (Figure 2 and Figure 3).

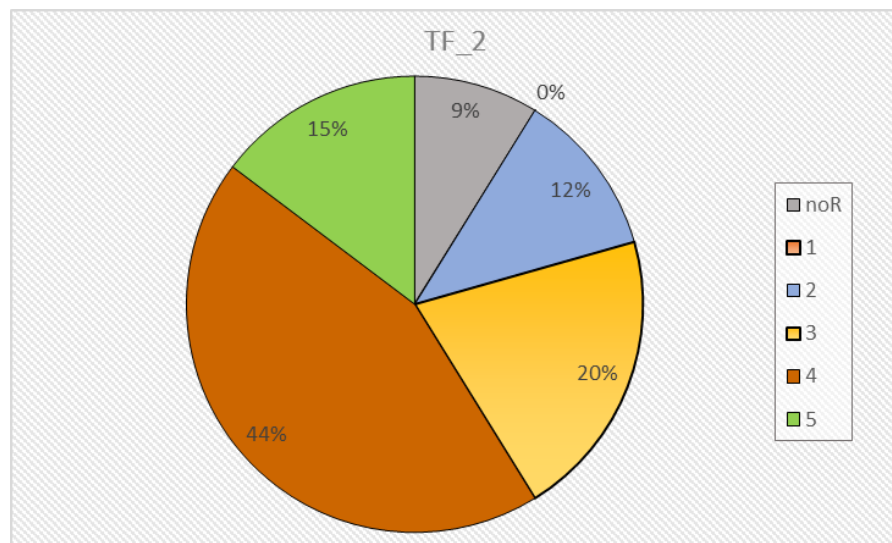


Figure 2. Compatibility and integration of IT and computer systems.

Source: own research.

The respondents most often assessed the impact of the integration of computer systems between participants of the distribution process rating 4. It can be assumed that after two decades of process digitization, the IT and computer systems used have already been refined. The respondents emphasized the growing importance of the ERP system in the product distribution process and the WMS system in warehouse management.

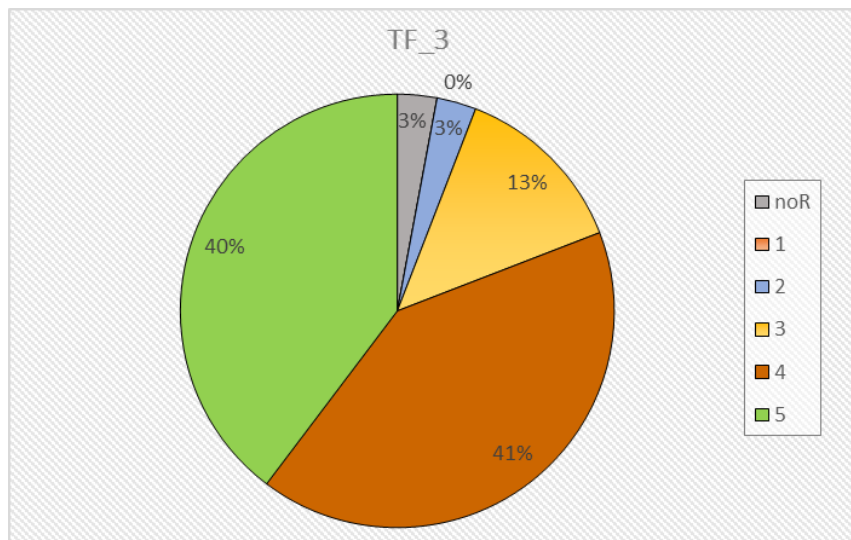


Figure 3. Equipment: RFID, intelligent sensors, autonomous vehicles and other solutions.

Source: own research.

Improving warehouse management requires investing in new generation equipment: readers, product identification systems, etc. The respondents are aware of the importance of these new technologies in the development of the steel product distribution process, their ratings were very high, most often the respondents rated 4 or 5.

The next segment concerned Big Data, Cloud computing, IIoT (TF_4). The respondents most often rated 4. Among the solutions mentioned, the respondents particularly emphasized the importance of IIoT, without which warehouses will not be intelligent (Figure 4).

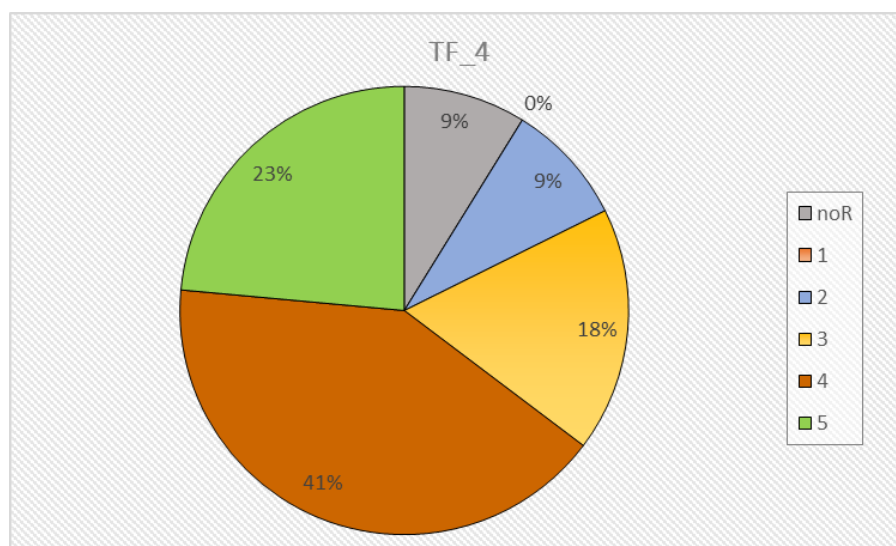


Figure 4. IIoT, cloud computing, Big Data.

Source: own research.

The respondents are aware of the importance of vertical and horizontal integration (TF_5): 85% of the respondents rated either 4 or 5 (Figure 5). Integration is a necessary mechanism enabling optimal and efficient execution of processes within the enterprise, it is a look at the functioning of the organization from the perspective of operations and activities, the so-called

process orientation, the aim of which is to increase the effectiveness of the company's activities, the quality of their results and to reduce the costs and time of task completion.

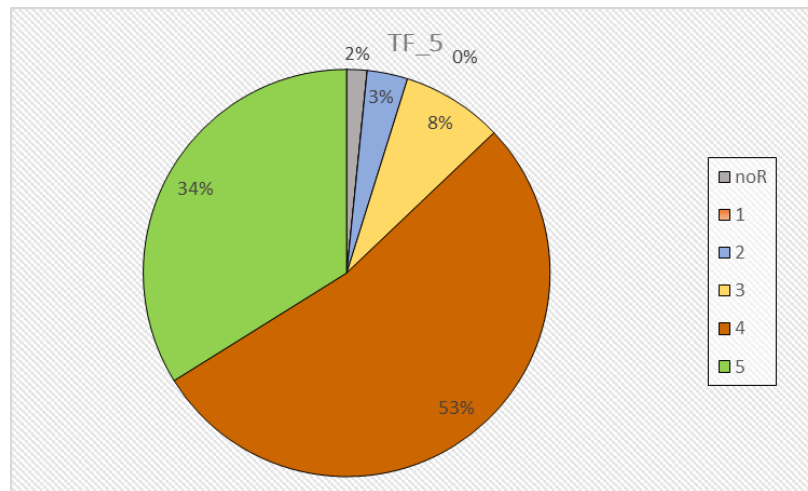


Figure 5. Vertical and horizontal integration.

Source: own research.

The next area of the research is blockchain (TF_6), which is considered a market protection instrument in the process of distribution of steel products. The respondents are aware of the transparency of data on steel products, as they most often rated 4 and 5 (Figure 6).

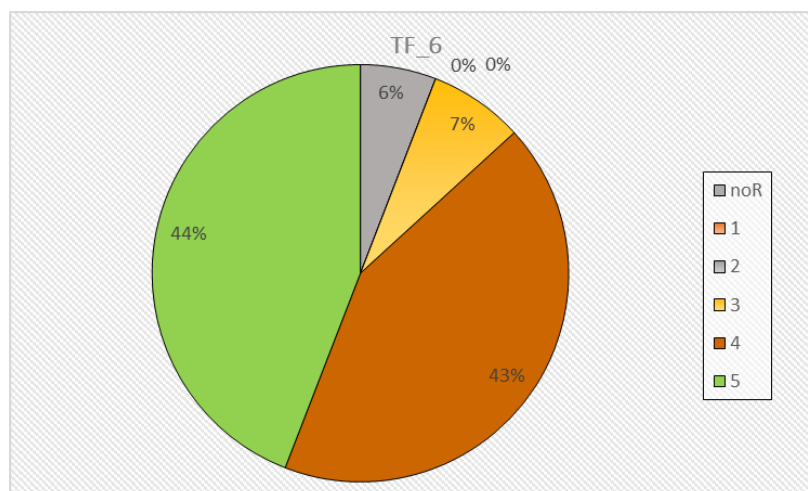


Figure 6. Blockchain.

Source: own research.

The last main area was cybersecurity, the importance of which increases with process digitization. The respondents most often rated 5 (Figure 7).

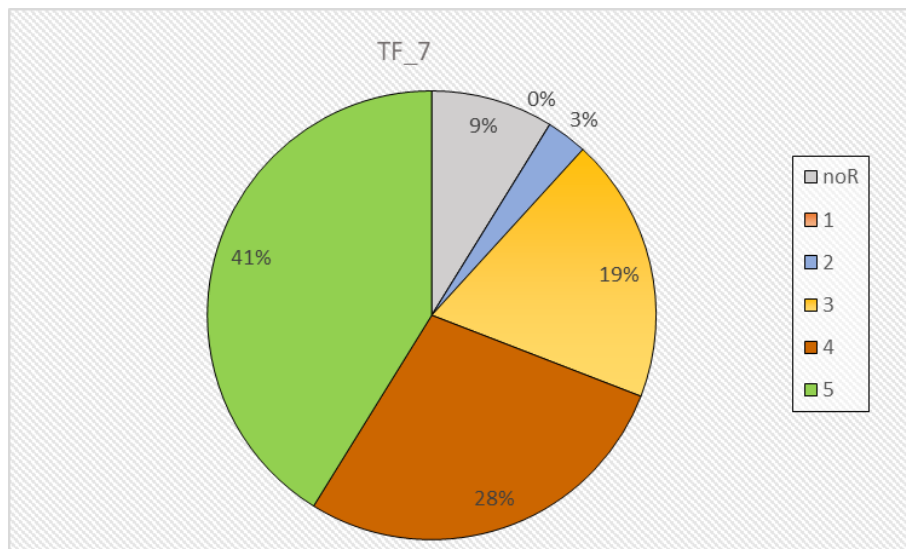


Figure 7. Cybersecurity.

Source: own research.

Since the steel distributor sector also deals with the processing of steel products (manufacturing steel structures, cutting steel products, welding, etc.), a question about additive manufacturing was added to the questionnaire (Figure 8).

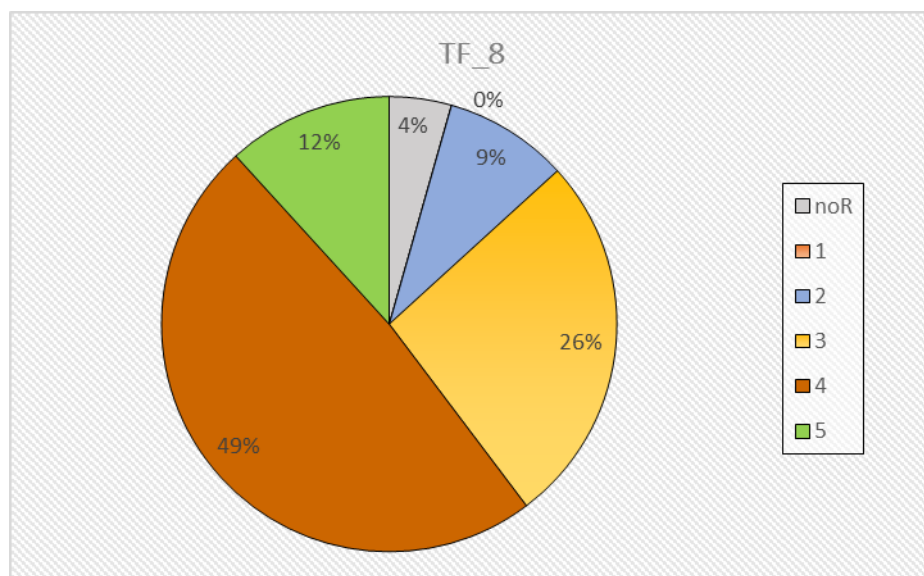


Figure 8. Additive manufacturing.

Source: own research.

4. Summary and conclusions of the research

There are many challenges that companies must face as they enter the stage of distribution of industrial goods, and one of them is the concept of Industry 4.0. The modern distribution of industrial products is a dynamic process that is constantly evolving. The ongoing transformation

concerns every element of the distribution process: people, warehouses, devices, and software used. Companies that do not take up the challenge of transitioning to a new stage of operation may lose the competition for increasingly demanding customers on the market. Industry 4.0 and digital transformation are an opportunity for development, but also a huge challenge that requires implementing the results of the Fourth Industrial Revolution. Distributors use new technologies to ensure digital communication and improve data exchange between all elements of the supply chain - people, devices, machines, products, processes. In distribution, the importance of data flow and analysis is growing, as well as the connection of information from various sources and their coordination with the work of machines, devices, storage systems, goods, and people.

In Industry 4.0, the flexibility of enterprises is possible to achieve due to continuous analysis of available data. By means of this, companies can more effectively predict periods of increased customer activity and increased demand, and thus quickly adapt logistics processes and the course of the supply chain to market requirements.

In the steel industry, which is sensitive to business cycles, any sudden change in demand may affect order fulfillment times. Hence the desire to respond quickly and adapt the distribution process to current needs (steel recipient markets). The flexibility of enterprises on the steel (steel products) distribution market is a key factor. Steel sector companies are aware of the importance of the technology of Industry 4.0 in improving the course of the process and communication with the market. The respondents highly assessed the importance of the pillars of Industry 4.0 in the processes of storage and distribution of steel products, most often choosing 4 in the Likert scale from 1 to 5.

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