

USING AUTOMATIZATION AND DIGITIZATION MEASURES TO SUPPORT BUSINESS CONTINUITY OF ENTERPRISES IN THE COVID-19 PANDEMIC

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Purpose: The paper aims to identify how and where elements of digital transformation of activities implemented in enterprises can increase the resilience of the production system to pandemic threats.

Design/methodology/approach: The paper presents the selected results of a survey conducted using the mixed-mode CATI and CAWI on a representative group of 600 manufacturing enterprises in Poland. An analysis of measures used in the case of COVID-19 infections in the company to support business continuity and enhance resilience was carried out. A quantitative evaluation of the collected data, oriented to identify the level of application of emergency response measures, was conducted, including the support of statistical tools (Statistica software).

Findings: The study identified dozens of different measures implemented in manufacturing enterprises. Among the measures studied, there were those related to automation and digitalization of activities in the organization of production processes. The data analysis showed that there were significant correlations between the type of measures used, as well as the characteristics of the enterprises, and the production processes implemented in them.

Research limitations/implications: Future studies should also include companies with a high degree of automation and digitization of production. In addition to descriptive analysis, a quantitative-statistical approach should be used.

Practical implications: On the practical side, it was pointed out how and where elements of digital transformation of activities implemented in enterprises can increase the resilience of the production system to pandemic threats. Digitization and automation measures should be used by managers to support the implementation of production processes also in the context of improving the efficiency of enterprises.

Social implications: Enterprises can use the study results to improve business continuity policies and preparing for threats similar to the COVID-19 pandemic.

Originality/value: The novelty of the survey is the comprehensive assessment of the use of solutions from the ICT area in manufacturing enterprises, analyzed in different cross sections (size, industry, occurrence of the COVID-19 case).

Keywords: business continuity management, production processes automation and digitalization, COVID-19 pandemic.

Category of the paper: Research paper.

1. Introduction

The COVID-19 pandemic forced state governments to put in place various economic and social arrangements to allow various business entities to operate under a sanitary regime. This was aimed at preventing the transmission of the coronavirus, limiting the spread of the pandemic, and maintaining the continuity of economic activity. Mass vaccination was supposed to make it possible to mitigate the pandemic significantly. However, it turned out that due to new mutations of the virus, the vaccines were not as effective as expected. In the future, in similar situations, it may be necessary to use the measures used so far again.

The research presented in the paper focuses on real manufacturing processes carried out in manufacturing companies belonging to various industries. The authors did not identify similar studies in the literature for the manufacturing area and only single research for service enterprises. They included five solutions in the area of production organization that can protect against the development of pandemics: automated transportation, performing quality control in a remote form, digital work instructions, automated collection of production data, and replacing hard copy documentation with digital documentation. The main advantage of these solutions is the digitalization and automation of activities, with the additional benefit of reducing the spread of pathogens. The novelty of the survey also lies in obtaining a wide range of data from a representative sample of enterprises of different sizes and from different industries.

The subject of the study was to identify and evaluate the scope of the application of measures introduced in production enterprises in connection with the COVID-19 pandemic. The paper analyses in detail selected pandemic protection from the area of production process organization, based on automation and digitalization solutions. The paper aimed to analyze and evaluate the solutions implemented to ensure business continuity when faced with COVID-19.

In this context, it became essential to answer ten research questions. The first group of research questions concerns the analysis of the use of automation and digitization measures according to the enterprise size, the industry, and the type and form of production organization. The second group of questions focuses on analyzing the replacement of paper documentation with digital documentation depending on the industry and size of the enterprise, as well as the automation of data collection. The third group of questions focuses on the use of automation and digitization measures depending on the occurrence of COVID-19 in the enterprise and the analysis of their usage at different levels of enterprise maturity. Answering research questions made it possible to verify the three hypotheses set.

The structure of the work is as follows. The introduction presents the objectives of the work and their significance. Then a review of the literature on the subject of the study is presented. After that, the approach to the study is presented, including the design of the survey questionnaire, the selection of the research sample, and the selection of tools for developing the results. The following section presents the results of the study. Finally, the analysis and discussion of the results are presented. Conclusions summarize the results obtained, highlighting the value of this survey and its potential for further development into a repository of good practices for ensuring business continuity under strict sanitary regimes.

2. Literature review and hypotheses development

Guidelines from international and governmental organizations focus on personal and collective protection measures (masks, disinfection, social distance, and separation partitions). The EC-operated European Agency for Safety and Health at Work has published a workplace guide in all official EU languages (OSHA, 2020). The International Labor Organization provides detailed policies for employers to mitigate the severe effects caused by the COVID-19 pandemic in the workplace (ILO, 2020). Based on these recommendations, many countries have developed national guidelines for entities operating in their area, for example in the United States – the International Facility Management Association (IFMA, 2020), in Poland – the Ministry of State Assets, the Ministry of Climate, and the Government Security Centre (MSA/MC/GSC, 2020).

Many sectors of the economy have widely implemented solutions based on remote contact between people – education, administration, and services (banking, insurance, partly health, e-commerce). There have been publications on the organization of remote learning (Feghali, Offiler, 2021; Kucharska, Rostek, 2021; Mishra et al., 2020), and work organizations in healthcare entities (Kruszynska-Fischbach et al., 2021; Özkan et al., 2021). The framework of office work modification towards the use of remote working tools was presented by (How et al., 2021) with the author's prediction that the trend of moving towards remote working will also continue in the post-pandemic period. For example (Lee, 2021), points out that changes in workplace practices during the COVID-19 pandemic have psychological and emotional consequences for employees. However, some sectors of the economy cannot move their activities to the Internet or use remote communication channels in their operations. These include the transportation sector, the construction industry, a large part of health care, and most importantly, the manufacturing industry.

The introduction of advanced technologies and related digitalization in manufacturing is now becoming an important need for enterprises. Their integration is very helpful in improving efficiency, better productivity, process organization, and waste management. Digitalization is

essential, especially in a sustainable manufacturing environment. The continuous improvement of production has influenced technological evolution by introducing advanced information and communication technologies, including digitalization, artificial intelligence, data analysis tools, etc. Automation and robotics complement manufacturing to perform tasks with human input or remotely (Bahrin et al., 2016).

Automation and digitalization are now finding a wide variety of applications in manufacturing. In the context of the issues addressed in the paper, this includes automation of operator training (Pérez et al. 2019), automation of robotic production (Tang et al., 2019), automation of material handling systems including material delivery (Luciano et al., 2019), production scheduling and control (Rojas, Rauch, 2019), execution of operational activities (Turner et al., 2019). The COVID-19 pandemic should further increase interest in these types of technologies, the application of which may increase the chances of maintaining continuous production operations.

Automation of production and application of technological solutions of Industry 4.0 is seen by many authors as a way to reduce the spread of pandemics. Authors (Kumar et al., 2020) predict that traditional solutions used in manufacturing products should be gradually replaced by digital technologies specific to Industry 4.0 such as AI, 3D printing, robots, cyber-physical systems, etc. During the COVID-19 pandemic, many companies have increased their interest in robots because the use, even partially, of robots and autonomous systems, results in reduced transmission of the virus compared to traditional human labor (Shen et al., 2021).

Digitization of manufacturing systems is an evolving process in manufacturing companies. However, the process is progressing relatively slowly. Business decisions in this regard have been made primarily from the perspective of process efficiency. Digitization requires allocating adequate financial resources, breaking down mental barriers, and dealing with the risks that occur during technology implementation. Digital transformation accelerated after the outbreak of the COVID-19 pandemic, and it is reasonable to assume that this will be a lasting phenomenon (Henderson, Graebner, 2020). Digital transformation also leads to the necessity of redefining ongoing business processes. Under normal circumstances, this process can proceed in a stabilized manner. During extreme conditions, enterprises must change business processes immediately (Swain, Garza, 2022).

In this context, it is essential to conclude that the crucial management task is to be aware of the organization's need to prepare for business continuity. The occurrence of the COVID-19 pandemic has largely verified the readiness of organizations to maintain business continuity. This verification yielded a negative result in a broad spectrum of cases (Röglinger et al., 2022; Theuerkauf, 2021). As indicated by (Łacka, Wojdyła, 2023), decisions to implement digitalization are mainly made based on efficiency criteria. Companies do not pay attention to the aspect of maintaining business continuity under pandemic conditions. However, a positive effect of the pandemic has been a leap in the awareness of companies of the need to prepare for business continuity and to have adequate resilience to crisis events (Santos et al., 2021).

The literature also highlights the significant role of Robotic Process Automation (RPA) technology. RPA allows organizations to maintain business continuity, improve the management of business processes as well as relieve the personnel workload. Such effects occurred in companies using RPA during the COVID-19 pandemic. Some research describes this (Siderska, 2021), but it only deals with applications of RPA technology in 110 Polish service companies. The technology applies to the building, deploying, and managing of programmed robots that emulate human actions in interactions with digital systems.

Recently, in Europe, there has also been a development of the concept of Industry 4.0, called Industry 5.0. Under this concept, it assumes that industry and purely economic aspects should also significantly affect areas of social life. According to the assumptions, the industry should be the basis for the functioning of societies in prosperity and the wellbeing of employed workers. Research and innovation can be the driving factor, making development more sustainable. Thus, the industry is to build value for all stakeholders involved in the industry's business processes. Noteworthy is the assumption that the design of industrial enterprises' operations should be resilient to external disturbances (Industry 5.0, 2021).

The above literature research conducted indicates a lack of analysis on the application a specific digital security measures in production companies. These prior empirical results allowed us to assume the following research hypotheses (H):

1. Automation and digitalization of manufacturing processes are significant measures in various production companies to maintain business continuity during the COVID-19 pandemic.
2. The production organization differentiates the measures used in companies during the COVID-19 pandemic.
3. There is a different level of implementation of measures depending on the occurrence of COVID-19 in enterprises.

Given the adopted research objective, the following research questions (RQ) were formulated:

1. Is the use of automation and digitization measures differentiated by the size of the enterprise?
2. Does the use of automation and digitization measures vary by the industry to which the company belongs?
3. Is the use of automation and digitization measures differentiated by the type of production used?
4. Is the use of automation and digitization measures differentiated by the form of production organization?
5. Does the replacement of hard copy documentation with digital documentation vary according to the size of the enterprise?
6. Does the replacement of hard copy documentation with digital documentation vary by the industry to which the enterprise belongs?

7. Does the automated collection of production data vary according to the size of the enterprise?
8. Does the use of automation and digitization measures vary according to the occurrence of COVID-19 in the enterprise?
9. Does the use of automation and digitization measures at different maturity levels vary depending on the occurrence of COVID-19 in the enterprise?
10. Does the use of automation and digitization measures at different maturity levels depend on the occurrence of COVID-19 in the enterprise?

3. Methods

The paper presents selected results of a survey conducted in a mixed-mode CAWI/CATI (Computer Assisted Web Interview/Computer Assisted Telephone Interview) on a representative sample of 600 manufacturing enterprises in Poland. The enterprises were selected by stratified random sampling, within the divisions of Section C (Industry) of the Polish Classification of Goods and Services. The survey covered enterprises operating in 21 industry sectors. The scope of the survey covered protection measures used in enterprises after the beginning of the pandemic, from a set predefined by the authors based on an analysis of literature, legal acts, research reports, and others, but also their own experience. Measures outside this set, declared individually by each company, were also included. The survey was conducted one year after the WHO announced the COVID-19 pandemic, between February 5 and March 5, 2021. The research method ensured obtaining data on applied security measures from enterprises manufacturing various products, using various production technologies, applying various forms of organization of the production process, and diversified conditions of workplaces. The surveyed sample included enterprises of four sizes:

1. Very small enterprises (microenterprises), with less than 10 employees (183 in the research sample).
2. Small enterprises, from 10 to 49 employees (there were 192 such enterprises in the research sample).
3. Medium-sized enterprises, from 50 to 249 employees (153 in the research sample).
4. Large enterprises, with 250 employees and more (there were 72 in the research sample).

The research presented in the paper focuses on real manufacturing processes carried out in manufacturing companies belonging to various industries. The survey included 42 protective measures classified into five groups:

1. Legal and regulatory measures.
2. Personal protective measures.
3. Protective measures for groups of workers.

4. Work organization measures.
5. Measures of production organization.

They included five solutions in the area of production organization that can protect against the development of pandemics: automated transportation, performing quality control in a remote form, digital work instructions, automated collection of production data, and replacing hard copy documentation with digital documentation.

The analysis was performed in the following cross-sections:

1. The use of a particular measure in a group of enterprises according to selected criteria concerning the characteristics of enterprises, such as enterprise size, industry, type, and form of production organization.
2. The scope of implementation of specific measure by the percentage share of workstations/operations, in which a particular measure was used for selected protections.
3. The association of the use of specific measures with the occurrence (or not) of COVID-19 infections in the enterprise.

Four key industries in Poland were selected to present the results. These were the manufacture of food products (59 entities), manufacture of products of wood, cork, straw and wicker (63 entities), the manufacture of metal products (126 entities), and the manufacture of furniture (60 entities). Enterprises belonging to these industries accounted for over 52% of entities in the research sample.

The study also analyzed the extent of implementation of particular solutions in enterprises, expressed as a percentage of positions or a percentage of operations where a specific solution was applied. Five levels of maturity of implementation of particular solutions were defined:

1. Maturity level 1 (ML 1); 0–20% of the workplaces have implemented the measure.
2. Maturity level 2 (ML 2); 21–40% of the workplaces have implemented the measure.
3. Maturity level 3 (ML 3); 41–60% of the workplaces have implemented the measure.
4. Maturity level 4 (ML 4); 61–80% of the workplaces have implemented the measure.
5. Maturity level 5 (ML 5); 81–100% of the workplaces have implemented the measure.

The systematic literature review analysis publications in scientific databases (Scopus, WoS, among others), research reports published by consulting companies, and legal acts issued by national and international organizations. The review focused on publications presenting measures applicable to enterprises, with a particular reference to manufacturing companies. The literature analysis provided was crucial to the measures selection and identified a research gap in the ongoing research in the form of the lack of recommendations of solutions possible for manufacturing enterprises in response to the COVID-19 occurrence.

TIBCO Software Inc.'s STATISTICA package, v. 13.3.721.0, and MS Excel were used for data analysis.

4. Results

The results of the study are discussed below. They cover the extent of the use of automation and digitization measures depending on four factors: the size of the enterprise, the industry it belongs to, the production type used, and the form of production organization (Fig. 1-4). Fig. 5-7 show the occurrence of COVID-19 infections at the company premises according to the use of the analysis measures and their maturity levels. The results are presented below in the arrangement of addressing a specific hypothesis and a specific research question within the hypothesis.

HIRQ1. The measure with the highest share among the surveyed entities (46%) is replacing hard copy documentation with digital documentation. The proportion of other activities was less than 23%. The distribution of measures implementation by enterprise size varies. Similar levels of implementation can be observed for two or three types of enterprise size – no one type is dominant for each measure. The highest adoption is in medium-sized enterprises, for most measures. Only in the case of replacing hard copy documentation with digital documentation, the highest share of implementation is found in small enterprises. In this case, the difference with respect to medium-sized enterprises is only 1%. For two solutions (automated collection of production data and automated transportation), the implementation volumes in small, medium-sized, and large enterprises are comparable (differences of 1-2%). In the case of replacing hard copy documentation with digital ones, the level of implementation is similar for micro, small, and medium-sized enterprises (difference 1-2%) (Fig. 1).

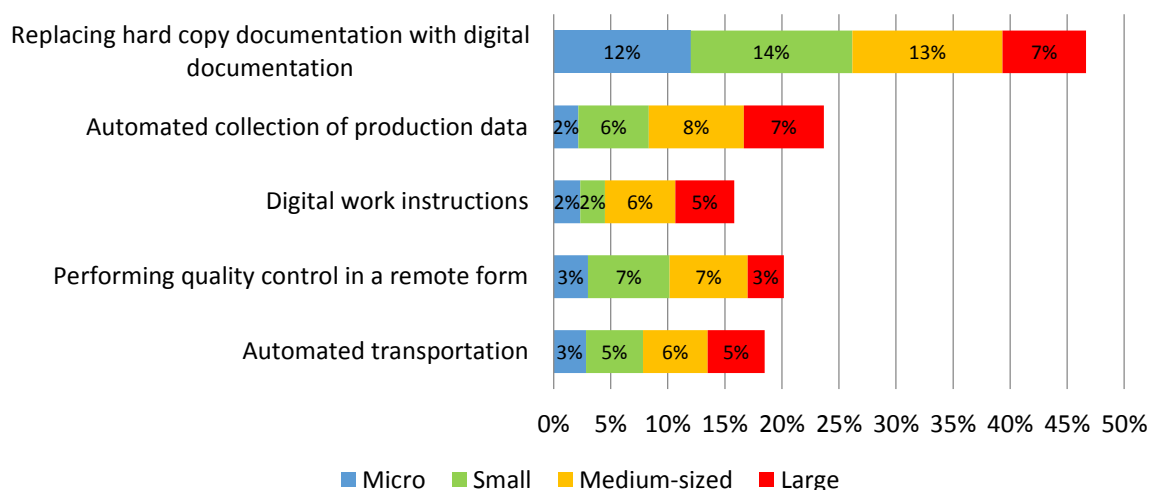


Figure 1. Use of automation and digitization measures by enterprise size.

Source: own elaboration.

HIRQ2. Within the industries surveyed, replacing hard copy documentation with digital documentation received a notably high level of implementation at 22%. The extent of implementation of other measures ranges from 7% to 13%. In the manufacture of metal

products, the maximum level of deployment was obtained, for all solutions surveyed (10%). In this case, the differences between the highest and the lowest level of deployment are 2-6%. Another remarkable industry is the manufacture of food products, for which the level of deployment ranges from 2 to 4%, for all surveyed entities (Fig. 2).

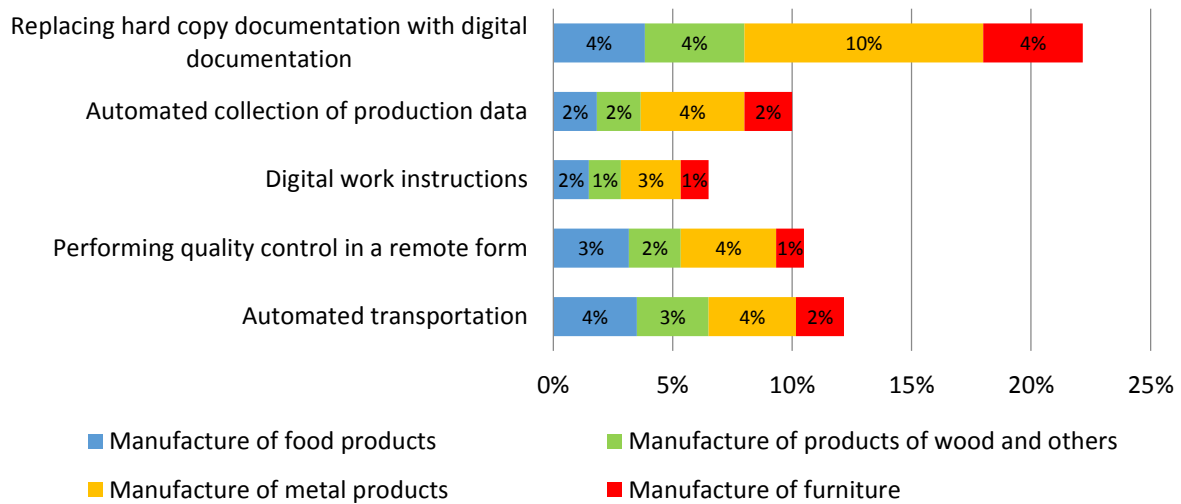


Figure 2. Use of automation and digitization measures by industry to which the company belongs.

Source: own elaboration.

H2RQ3. It is possible to notice a high share of the introduction of digital documentation (in place of hard copy documentation) at nearly 60% of entities differentiated by the production type. The extent of implementation of other solutions varies from 21% to 30% (Fig. 3). The four of the five analyzed solutions had the highest degree of adoption in batch production. The highest difference from mass production was 8 percent for replacing hard copy documentation with digital documentation. It also notes that this measure is likewise often used in job production (resulting in 22%).

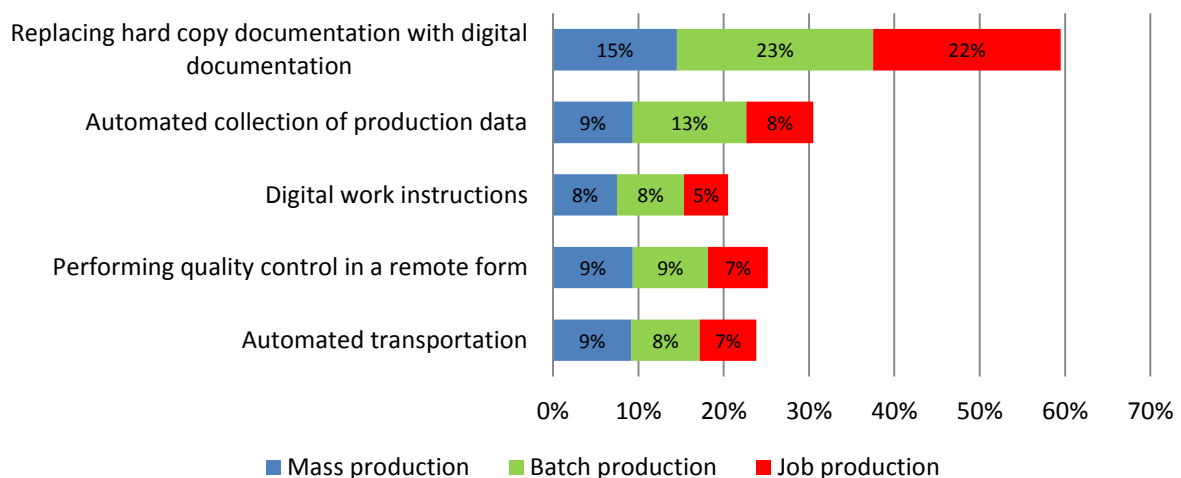


Figure 3. Use of automation and digitization measures by the production type used.

Source: own elaboration.

H2RQ4. In the scope of the forms of production, a high level of deployment was achieved by replacing hard copy documentation with digital documentation (54%). The range of implementation of other measures varies from 19% to 28%. In terms of all measures, no form is dominant. Replacing hard copy documentation with digital ones is more often used in production implemented in non-pipeline form – the difference to pipeline form is 8%. Other measures are mostly used in the pipeline form of production – the difference is between 0.4% and 4% (Fig. 4).

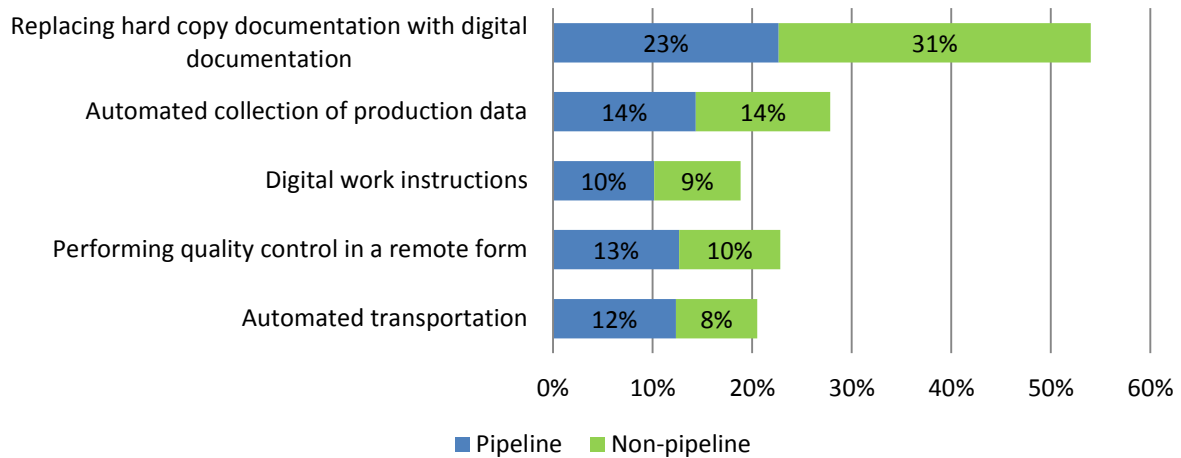


Figure 4. Use of automation and digitization measures by the form of production organization.

Source: own elaboration.

H1RQ5. As for the use of digital documentation at the company employment level, it is notable that the use of this solution in microenterprises is significantly high in the scope of 81-100% of workplaces. Due to the low costs of implementing the solution (connected with a small number of employees), it gets used more often throughout an organization – maturity level 5. In other enterprises, this solution receives to a greater extent, especially in the case of 41-60% of workplaces (Fig. 5). The figure next to the maturity level (ML) symbol shows the numbers of enterprises for that level.

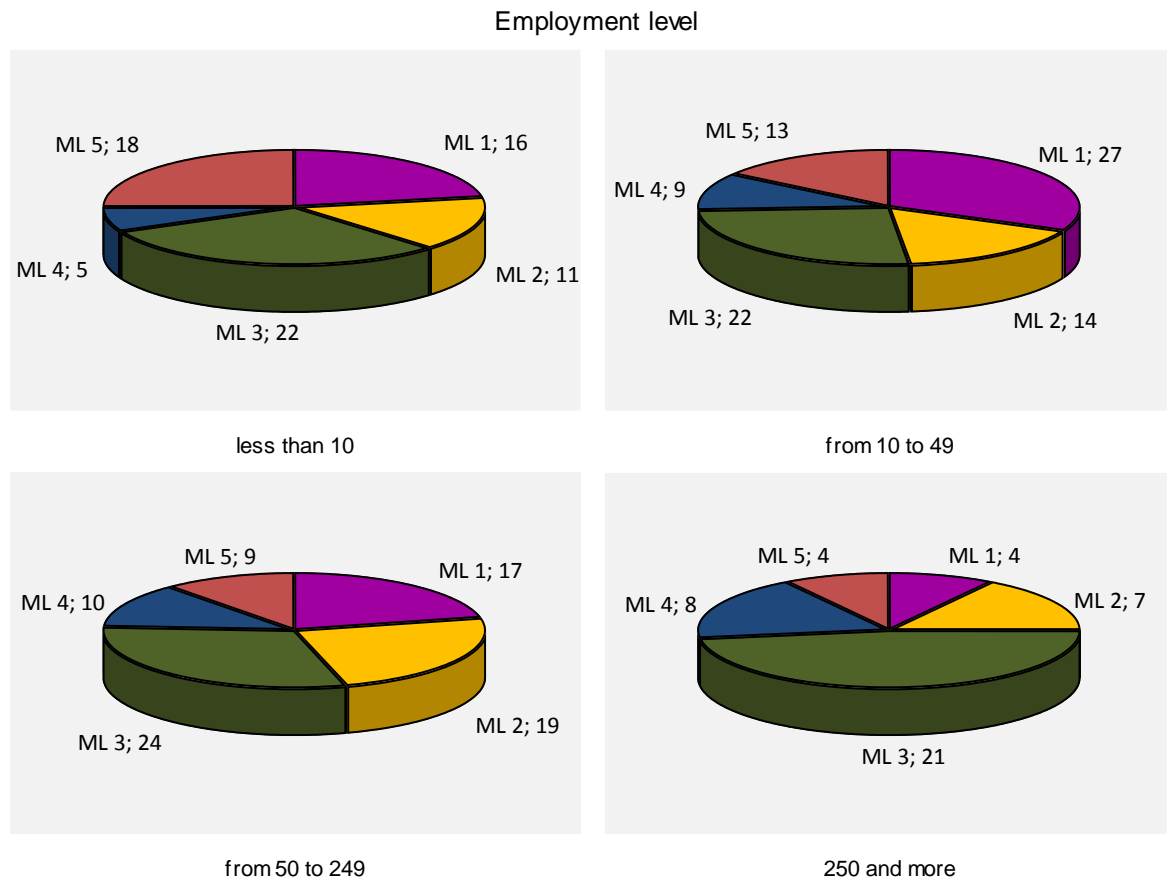


Figure 5. Replacing hard copy documentation with digital documentation by enterprise size.

Source: own elaboration.

H1RQ6. The analysis of the implementation of the solution according to the selected industries shows it is the highest for 41-60% (ML 3). The selected industries, due to their size, most often belong to medium/large enterprises, hence probably a lower implementation share. In the case of repetitive production, it is not worth investing in electronic documentation readers for a large number of workstations. A cheaper solution is to print documentation, which remains unchanged at a workstation for a long time. This applies, for example, to work instructions, product quality cards, design, and technological documentation (Fig. 6).

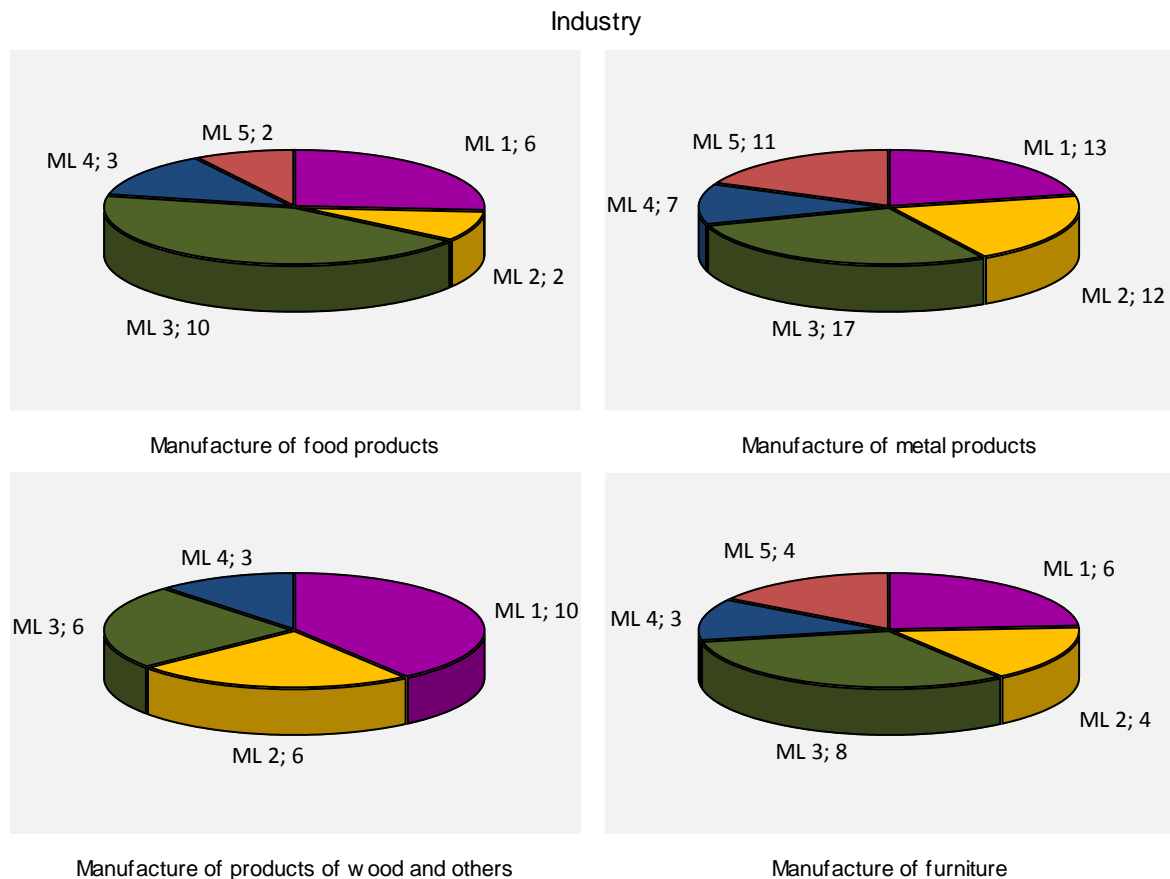


Figure 6. Replacing hard copy documentation with digital documentation by industry to which the company belongs.

Source: own elaboration.

H1RQ7. In terms of the use of an automated collection of production data in relation to the size of the enterprise, the solution was used at a low level. However, if implementation did take place, it was at a high level of maturity – ML 5 (Fig. 7). In this case, the investment in software and instrumentation is crucial, but once implemented, most of the organization's workplaces can be engaged.

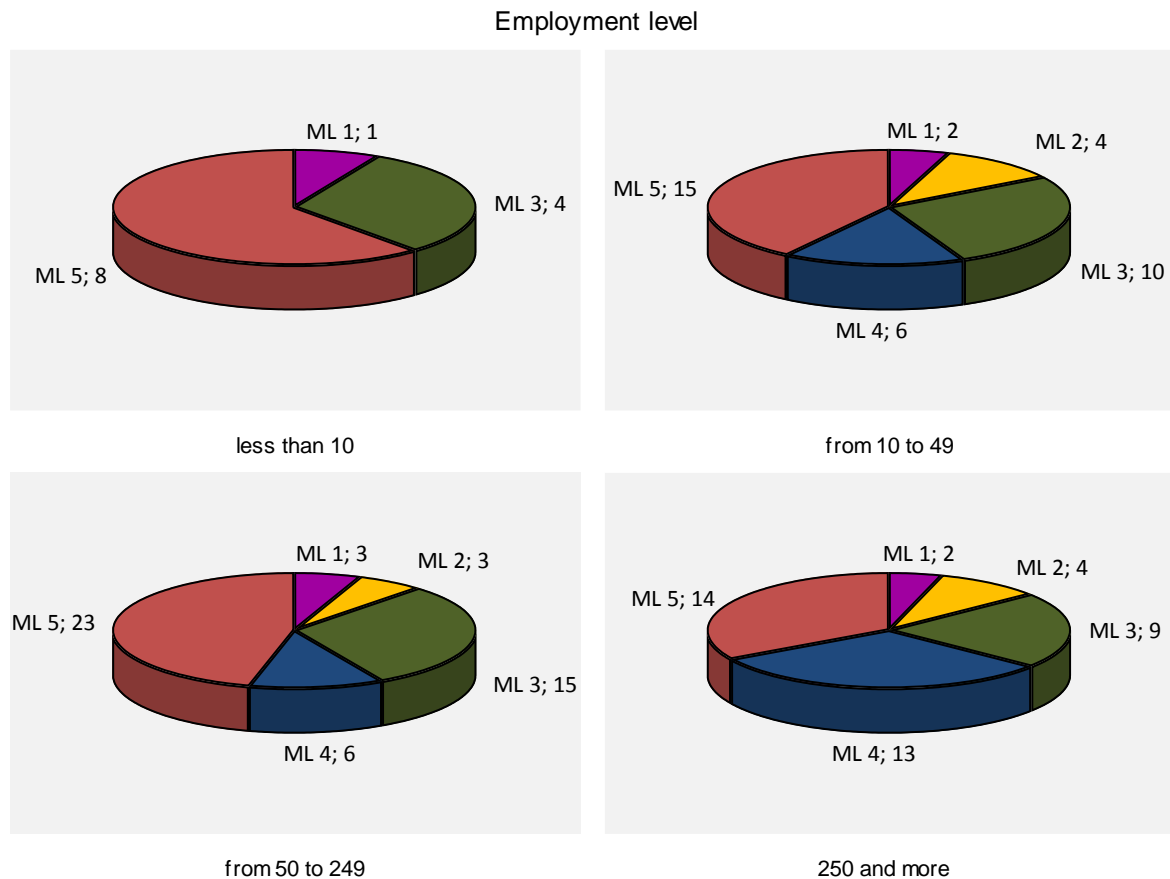


Figure 7. Automated collection of production data by enterprise size.

Source: own elaboration.

H3RQ8. For the occurrence of COVID-19 in the enterprise, the measure of replacing hard copy documentation with digital ones received the highest share. The level of completion of the other measures is similar to that in the study of dependence on enterprise size. The significant difference in the level of deployment of individual measures, as indicated, depends on the occurrence or non-occurrence of COVID-19. The highest difference occurs in two cases – the automated collection of production data and the replacement of hard copy documentation with digital ones. Accordingly, the difference is 11% and 10%. The differences range from 4 to 7% for the remaining measures (Fig. 8).

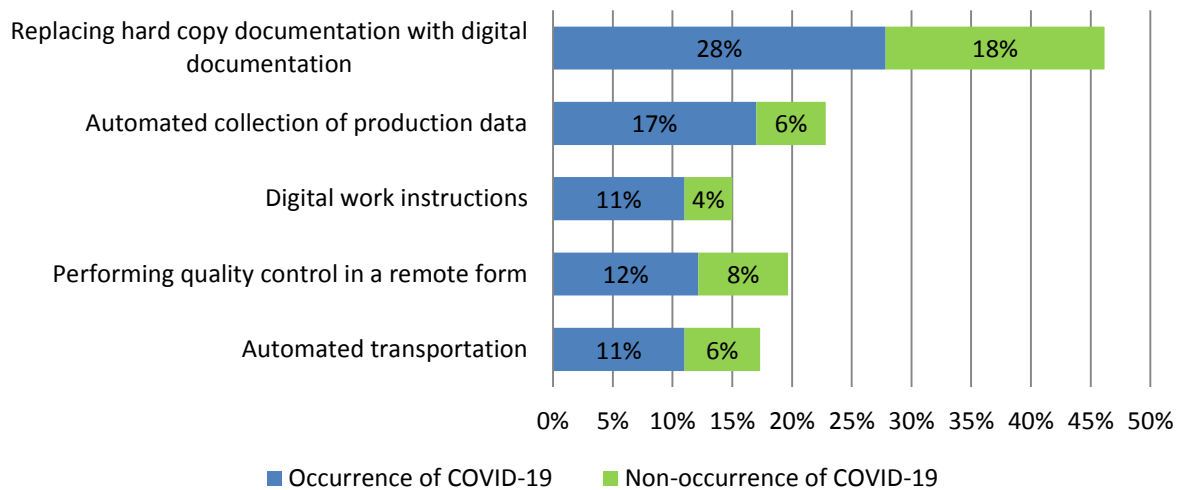


Figure 8. Use of automation and digitalization measures depending on the COVID-19 occurrence in the enterprise.

Source: own elaboration.

H3RQ9. An in-depth analysis of the use of digitalization/automation of production measures was conducted, for both groups of enterprises (with and without COVID-19 cases). This research was carried out only for entities that declared to have implemented the measure.

Most of the measures (four out of the five) were implemented at ML 3 and covered from 41 to 60% of workstations/operations. Deployment at ML 3 was declared by 24 to 35% of enterprises for all measures. For ML 4, the same level of deployment of individual activities can be observed. In such a case the implementation of measures at 61-80% of positions was declared by 13 to 19% of enterprises. Lower values were obtained for deployment on ML 2 and ML 5. The automated collection of production data on ML 5 was declared by as many as 44% of enterprises. This measure is important for preventing the development of pandemics, due to the restrictions on the movement of employees and unnecessary contact between them. The exchange of information and transfer of key data regarding the implementation of the production process can be done digitally, for example, using Industry 4.0 solutions.

It should be noted that a fairly high share of respondents' answers for the implementation of measures at ML 1 was obtained. These results (excluding the previously mentioned automated collection of production data) are between 17 and 26% (Fig. 9).

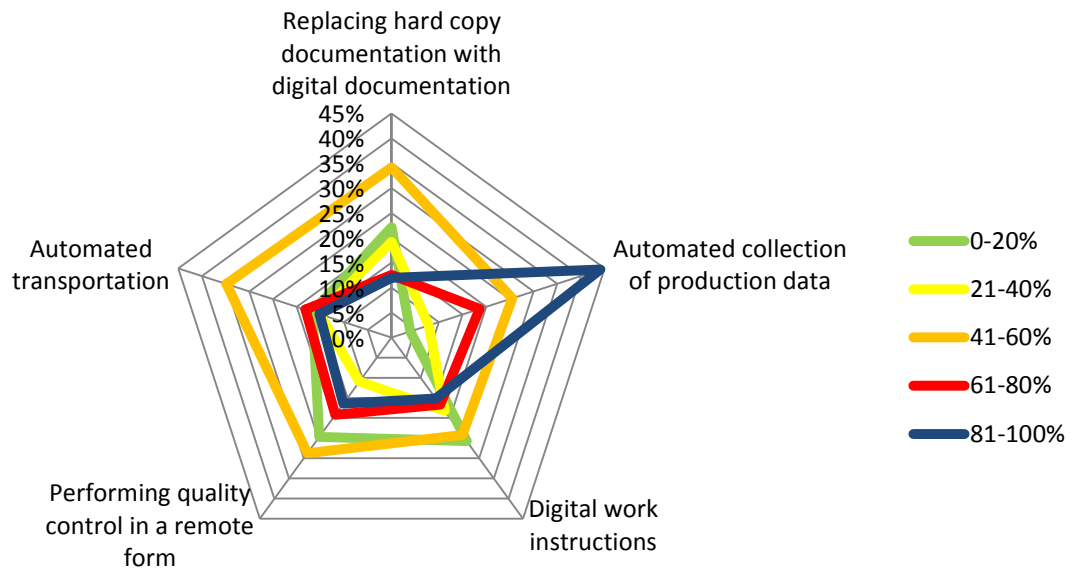


Figure 9. Use of automation and digitalization measures at different maturity levels when COVID-19 occurs in the enterprise.

Source: own elaboration.

H3RQ10. In the case of enterprises that avoided the occurrence of COVID-19, the implementation of measures at ML 5 received the highest share of responses for the three measures. These were: digital work instructions (42% of responses), automated collection of production data (37% of responses), and performing quality control in a remote form (31% of responses). Three measures were a high rate of importance at ML 3. These were: an automated collection of production data (34% of responses), automated transportation (32% of responses), and replacing hard copy documentation with digital ones (27% of responses). For the deployment of measures at ML 1, a relatively high share of responses was obtained. It was the same as in the case of enterprises where the COVID-19 was occurred. The results are at the level of 24-29%, excluding the automated collection of production data (9% of responses).

Remarkable is the high level of implementation of the automated collection of production data – implementation on at least 40% of workstations was declared by 82% of entities (Fig. 10).

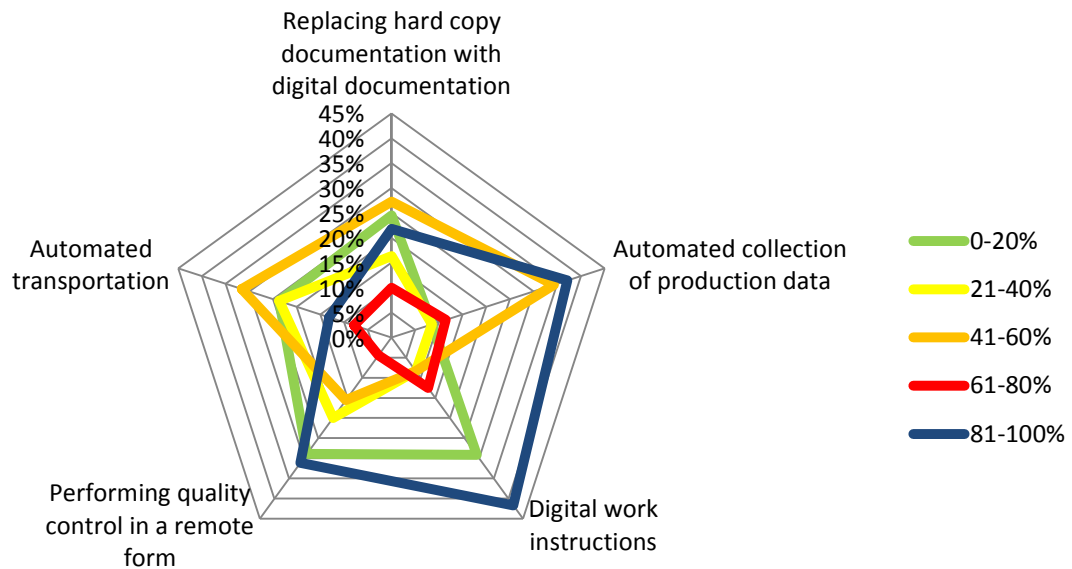


Figure 10. Use of automation and digitalization measures at different maturity levels when COVID-19 does not occur in the enterprise.

Source: own elaboration.

One can see a significantly higher share of deployment of the given measures at ML 5 in enterprises without COVID-19 cases. The highest difference occurs in replacing hard copy documentation with digital ones (27%). This may indirectly prove the effectiveness of automation and digitization measures, provided that they are common practices in the enterprise (applied at all positions).

5. Discussion

The results of the study indicate that production automation and the use of ICT and Industry 4.0 technology solutions can be a way to mitigate the spread of the pandemic.

On the basis of the research data, it seems that most of the identified digitalization and automation measures were implemented to the greatest extent in medium-sized enterprises, employing between 50 and 249 workers. Due to their scale of operations, these enterprises can afford to introduce various solutions with less financial outlay than, for example, large companies with more resources (machines, employees). In the case of the measure of replacing hard copy documentation with digital ones, it is possible to pay attention to quite a high share (12%) of very small enterprises. Additionally, this share is much higher than in large enterprises – the difference amounts to 5%. In the case of this solution, it is easier to introduce digital document circulation or equip employees with portable devices (such as laptops, tablets,

and graphic tablets) in smaller enterprises than in large ones due to the scale of implementation. The purchase of several devices for less than 10 employees is many times less outlay than for more than 250 people. In the PARP report was noted that the estimated investment cost of implementing COVID-19 protection measures during the first 6 months of the pandemic was about EUR 3,300 for medium-sized enterprises, while for very small enterprises it was about EUR 112 (PARP, 2020). Also, the level of sophistication of digital document workflow solutions is lower for very small enterprises, as they can often use free solutions offered in the market for communication between people.

In the scope of four key industries, in enterprises in the manufacture of metal products, the largest share of deployment was obtained for each measure. Due to the increase in production efficiency, enterprises in this industry implement many solutions leading to the automation of operations performed. The size of the processed products or the workplace accidents also leads to the deployment of these measures. In the conducted survey, enterprises in the manufacture of metal products were two times more than other enterprises (according to the distribution of industries in Poland). However, the results for individual solutions do not reflect this division. A significant difference can be seen only for the measure of replacing hard copy documentation with digital documentation – the distribution analogous to the market share of industries. Therefore, it is the manufacture of food products that indicates a high level of implementation of selected digitalization/automation solutions, for example, such as automated transportation or the performing quality control in a remote form. The manufacture of food products is characterized by a high number of manufactured products, which influences the necessity of introducing production automation solutions to the implemented processes. They increase process efficiency. Another aspect is the need to comply with the requirements of various standards and norms related to food production (e.g. HACCP, GMP). Automation of technology, transport, and storage operations reduces the possibility of contact between employees and food due to sanitary requirements while reducing the possibility of virus transmission.

Analyzing the indications of respondents in relation to the type of production realized in the enterprise, differences in the level of implementation of a given measure between successive solutions were noted. For example, the high share of replacing hard copy documentation with digital documentation (22%) is noteworthy. There is also a big difference in comparison to mass production. In job production, the digitalization of documentation can be observed due to the high variability of manufactured products and the necessity to prepare new construction and technological documentation for each new product. The opportunity of using computers to store it and mobile devices to access it is beneficial in terms of time and cost. In mass production, on the other hand, SOPs (standard operations procedures) are developed and fixed at the workstations for multiple uses and protected against damage. This document does not change during the realization of repetitive production processes, therefore once printed and secured (foiled) it can be used for a longer time.

In terms of the form of organization of production, the results obtained are not clear. For most of the solutions, the level of implementation of automation/digitalization solutions is higher in processes carried out in a pipeline form. The course of these processes is fixed and repeatable, therefore the introduction of automated transportation or performing quality control in a remote form is quite easy from the organizational point of view. It is known what devices and instrumentation should be used and on which workstations. The only deviation from the observed regularity is a higher share of replacing hard copy documentation with digital ones in a non-pipeline form. The use of this solution is indicated by 31% of enterprises that identified it as a dominant non-pipeline form of production. The reason for this, as in the case of job production, is the high variability of the operations performed and the lack of fixed assignment to a specific workstation or device. Therefore, the transfer of information in the remote form is more flexible and less costly.

There was a much higher level of implementation of all of the analyzed measures in enterprises where COVID-19 was identified. It is impossible to eliminate the spread of the virus. However, when the pandemic occurred, some organizations implemented measures based on government and industry recommendations or their knowledge and experience. These references were indicated by respondents. As the pandemic unfolded and lasted longer, more organizations implemented measures not only because of lockdown and existing obligations, but also because of the negative economic impact of temporarily excluding employees from work due to illness, imposed quarantine, or childcare leave. These factors were listed as significant sources of difficulties for enterprises in a report (PwC, 2020) on the study of Polish micro, small and medium-sized businesses in the face of the COVID-19 pandemic. Thus, the results obtained significantly indicate that the high share of examined measures in enterprises with COVID-19 cases is due not only to the imposed obligations but also to the registration of the negative results of COVID-19. Noteworthy is the fact that replacing hard copy documentation with digital ones proved to be particularly popular, due to the relative ease and possibility of rapid implementation of the measure. It is especially in specific production conditions or to the size of employment, as described in the earlier part of the paper.

Overall, the hypotheses set can be considered mostly verified. The research led to results that quantify the application level of identified security measures in manufacturing companies. The study was conducted in several cross-sections to obtain detailed answers to the formulated research questions. The obtained results and the interpretation of the research findings made it possible to verify the hypotheses presented. Hypothesis 1. was proved by the research conducted. Hypothesis 2. was proved in the area differentiated by the type of production in processes carried out in a pipeline form. Hypothesis 3. was proved in its entirety.

Conclusions

The development of the COVID-19 pandemic has influenced the implementation of selected measures in Polish enterprises due to the introduced government or industry recommendations, and primarily based on the findings of COVID-19 cases in the enterprise. The growing interest in digitally-enabled solutions observed in the research is consistent with the recommendations in (Kumar et al., 2020) and (Shen et al. 2021).

The research shows that of the five measures studied, replacing hard-copy documentation with digital ones was the most popular. The other measures were used to a lesser extent. It is also difficult to find dominant relationships regarding the deployment of these measures depending on the size of employment, industry, or production conditions.

The results show the scope/degree of application of solutions from the ICT and Industry 4.0/5.0 area in manufacturing enterprises, analyzed in different cross-sections (size, industry, occurrence of the COVID-19 case), concerning building the resilience of the manufacturing system to pandemic threats.

Practical lessons from the research demonstrate that digitization/automation measures should be used by managers to support the production processes execution. It is not only in the context of improving the efficiency of enterprises but also in terms of increasing their resilience to pandemic disruptions, in case similar events occur in the future. The implementation of solutions from the area of digitization of enterprises should be primarily aimed at improving the efficiency and security of the processes implemented. The research shows that these solutions can also increase the resistance of the production system to pandemic threats. The results obtained are interesting both in the area of management, digitalization, and automation (determining the benefits of the application of these solutions) and crisis management (identifying measures to minimize the effects of a pandemic).

The research was conducted in enterprises in Poland. The results testify to the low degree of implementation of automation and digitalization solutions in Polish enterprises. This confirms the very distant place of the Polish industry on the list of countries with the highest level of robotization in the industry (in 2020 – Poland has 42 robots, and leading Singapore 831 per 1000 employees; based on <https://corobotics.pl/robotyzacja-w-polsce/>).

Theoretical conclusions indicate the scope of application of selected solutions from the digitalization/automation area to the type of enterprise (size, industry, production conditions) and their possible impact on ensuring business continuity in pandemic conditions. The poor level of application of these solutions is confirmed by Poland's distant position on the list of countries implementing some automation technologies and tools.

In light of the results obtained, it seems desirable to periodically repeat the studies conducted. It would make it possible to compare how companies implement the lessons learned during the pandemic. It would also be possible to identify what other measures in the area in

question implement by companies. It would also be advisable to extend the research to companies characterized by a high degree of automation and digitalization of production. In terms of research methodology, when planning similar studies in the future, one can consider developing a quantitative-statistical approach, which was not assumed in the current study.

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