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Ensuring the business continuity of production companies in conditions of COVID-19 pandemic in Poland – Applied measures analysis

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1. Introduction

A black swan is a term used in economic sciences to mean an unexpected event that (almost) no one can predict. Such events often have a powerful impact on the world and negatively affect the economy and society [1]. However, the current COVID-19 pandemic crisis can be considered more like a grey rhino - according to the concept introduced by Michele Wucker at the World Economic Forum in Davos in 2013 [2]. It means an event with a very high impact on reality but is predictable and probable, while people long ignore or underestimate the risk involved. In contrast to highly improbable black swans, grey rhinos are highly possible and affecting but neglected threats.

The COVID-19 pandemic has had an overwhelming impact on global society and the world economy. It has drastically changed the international economy and all human activities. Manufacturing companies have faced a particular challenge, as it is of great economic and social importance to ensure the continuity of their operations during a pandemic.

Since the outbreak of the COVID-19 pandemic, international organisations, state, and local governments have prepared several official documents characterizing the specificity of the disease, introducing measures to protect against virus transmission, and providing guidelines and recommendations for risk management activities in the workplace. There have been reports from consulting...
companies on the impact of the global COVID-19 pandemic crisis on business organisations and research papers presenting findings on
the organisation of safe workplaces in health care, education, and office work. The literature review of these studies suggests a lack of
research on solutions to protect against the pandemic spread in industrial enterprise settings.

Given the identified research gap, the research described in the paper focuses on solutions implemented in manufacturing companies
during the COVID-19 pandemic. The study was conducted by a research team from the Warsaw University of Technology, specializing in production management and critical infrastructure management. The contractor for the survey was a company selected on commercial terms and specializing in survey research. The scope of the study covered protection measures used in enterprises after the occurrence of the pandemic, from a predefined by the authors’ list, and measures outside the list, declared individually by each of the companies. Organisational, technical, and economic information characterizing the studied enterprises was also collected. The structure and content of the study were developed based on the literature analysis and the authors’ knowledge of production organisation and business continuity maintenance of these manufacturing enterprises.

Poland is an European country with a diversified economy, with many industrial sectors developed. Industrial production in Poland yields about one-quarter of GDP and employs approximately 30% of the total workforce. During the studied period, the development of pandemics in Poland (measured by the number of cases per 100,000 inhabitants) was similar to that of other large European countries. Similar “anti-pandemic” solutions were also applied, such as lockdown, remote working, and learning, quarantine, testing rules, etc. The findings may be interesting for countries with similar economic structures and pandemics and regulatory solutions, notably European countries.

A list of possible solutions included in the survey was determined based on recommendations of international and national crisis management entities, the authors’ practical knowledge of work and production organisation and interviews conducted in the companies. The identified protection measures were divided into five groups. The level of use of each particular measure in each group was examined and frequency distributions were analysed according to the company size and industry. The results indicate that the COVID-19 pandemic affected manufacturing companies at different levels, and they implemented both recommended and proprietary solutions to varying degrees.

The pandemic will continue. It is necessary to “learn” to live and work in such a situation, as well as to prepare for future critical events raising similar problems. Good practices for maintaining the business continuity of manufacturing enterprises under pandemic conditions identified in the research project undertaken will be useful in the event of pandemic threats other than COVID-19. They can also be applied to other threats that may result in the interruption of business continuity of manufacturing enterprises (e.g., terrorism, extreme climatic events).

The paper is structured as follows. Section 1 contains the aims of the study and their relevance. Section 2 provides a literature review on the occupational health and safety guidelines formulated about the COVID-19 pandemic by international and national organisations, professional associations, etc. It also presents the significant problems in the operation of enterprises, identified in connection with COVID-19 based on reports of consulting companies and solutions developed to ensure business continuity in organisations of different types, presented in the articles. Section 3 presents the research methodology, including the construction of the survey questionnaire, the selection of the research sample, and the selection of tools for processing the results. Section 4 presents the results of the research, and in Section 5 they are analysed and discussed in detail. Section 6 summarizes the results obtained, highlighting the value of this research and the possibility of further developing it towards the formulation of a repository of good practices for ensuring business continuity under a strict sanitary regime.

2. Literature overview

2.1. Public guidance to the COVID-19 pandemic

Different countries use different threat classifications in crisis management, and pandemics are taken into account in different ways. The classification of threats used in Poland includes four basic categories related to the sources of their emergence: natural, technical, socio-economic and military threats. A pandemic occurs in the category of natural threats, caused by physical factors and natural forces and phenomena [3]. Until the global COVID-19 pandemic, national emergency management plans developed in various countries lacked detailed solutions for pandemics. For example, in the Polish National Crisis Management Plan [4], an epidemic is identified as a national security threat with a medium probability of occurrence and medium consequences. Pandemic and global pandemic does not occur at all. In the case of Poland, the difference in terminology may indicate a primary focus from “a local” perspective covering part or all of the state’s territory, and no global interactions. Although human civilization has faced global pandemic threats in the past, they did not spread as quickly and on such a large scale as the COVID-19 pandemic. Nor was this reflected in preparations for crisis management on a global scale.

The first general guidelines on the principles for organising safe workplaces under pandemic conditions were formulated by the World Health Organisation in a document [5], published on 13.03.2020. This document was followed by recommendations from various international organisations. The European Commission (EC), in a document [6], published on 18.03.2020 indicated basic recommendations to limit the spread of the virus. The recommended measures are social distance, strict hand hygiene, face covers, suspension of mass events, remote learning and working, etc.). The EC-operated European Agency for Safety and Health at Work has published a workplace guide in all official EU languages [7]. The guide outlines the principles for identifying and assessing risks in COVID-19 workplaces and describes safe practices to minimize exposure to COVID-19 in the workplace, primarily including personal protective equipment, disinfection and cleaning products, as well as physical barriers separating workplaces. The International Labour Organisation provides detailed policies for employers to mitigate the severe effects caused by the COVID-19 pandemic in the workplace [8],
Based on these recommendations, many countries have developed national guidelines for entities operating in their area, for example the International Facility Management Association in United States published in May 2020 “Pandemic manual – planning and responding to a global health crisis for facility management professionals” [9]. In Poland, three groups of guidelines and recommendations were in force. The first one was developed by the Ministry of State Assets and the Government Security Centre for critical infrastructure operators [10]. The second one, of general application, was developed by the Ministry of State Assets, the Ministry of Climate, and the Government Security Centre [11]. The third one, for industries, was developed by the Ministry of Development and Technology [12].

2.2. Industry-driven workplace guidelines in papers and reports

The pandemic was officially recognized by the WHO on 11 March 2020. It is a relatively new phenomenon, so it has not received many publications in social science journals. Publications on the topic of modelling and forecasting the development of a pandemic dominate [13]. There are also available macroeconomic studies on the impact of COVID-19 on the global economy [14], individual countries, and industries in terms of economic indicators [15].

There have been publications on the organisation of remote learning [16-18], and work organisations in health care entities [19]. Office work modification towards the use of remote working tools, e.g. Refs. [20,21], analysing the results of the survey of Poland’s economy in terms of the impact of COVID-19 on individual sectors of the economy, it is noticeable that the group particularly affected by the effects of the COVID-19 pandemic are businesses providing consumer services. In the second place is the industrial enterprise sector.

Interesting information about the impact of the pandemic on the functioning of manufacturing companies is the subject of research reports conducted by consulting firms and international organisations. The first research conducted back in 2020 by PwC for 756 small and medium enterprises in Poland shows that [22]: 63% of medium-sized manufacturing companies have reduced their operations due to the socio-economic changes following the COVID-19 pandemic, 51% of companies in the industrial sector have reduced employment due to the situation caused by the COVID-19 threat, and 36% of all companies participating in the survey estimate that they can maintain liquidity and pay obligations to contractors and employees for up to 3 months. The PwC report identifies the following key issues affecting business during the COVID-19 pandemic: decline in demand; supply chain disruptions; employee vacations (related to child care), quarantine or illness of employees, closure of country borders; inability to maintain health and safety policies (e.g., lack of protective equipment), delayed payments from customers.

Manufacturing companies pointed primarily to external factors such as a decline in demand or delays in payments from customers, mainly affecting the company’s financial liquidity. Also indicated were reasons associated with disruptions in the supply chain, making it impossible to obtain a sufficient number and type of materials, parts, and components for the uninterrupted implementation of manufacturing processes. Among internal factors, there was the employee absence indicated. Reasons for absence included illness, quarantine, and childcare leave, as well as the inability to provide employees with adequate protection from the pathogen. It was related, among other things, to the lack of protective measures due to difficult access to hygiene products, especially in the first months of the pandemic. The authors of the article concluded that this problem requires a detailed study.

With the global expansion of the COVID-19 pandemic, more and more research has been conducted on the situation of Polish enterprises. In September–October 2020, research was conducted under the project “Measuring the Business Pulse. COVID-19 Business Pulse Survey (COV-BPS) - Poland” carried out by the World Bank and the Polish Agency for Enterprise Development [23]. The survey covered 646 business entities, including 264 industrial enterprises. The survey aimed to determine the impact of the COVID-19 pandemic on companies in Poland, leading to the identification of effective solutions to support entrepreneurs during the pandemic, among which the following were identified: 100% of companies are aware of at least one sanitation procedure to minimize the risk of infection in the workplace, 96% of companies are implementing sanitation procedures and preventive measures against COVID-19, 75% of companies have implemented sanitation procedures for employees or customers, 29% of companies have implemented more flexible work arrangements/timetables, 32% of companies that previously did not accept contactless payments have decided to introduce it.

According to reports from consulting firms, the main objective of introducing solutions in industrial enterprises to minimize the possibility of spreading the COVID-19 virus was to ensure the safety of employees on the premises. Other goals were to mitigate the threat from outsiders on the company’s premises and to be able to identify potentially infected employees in the event of a COVID-19 case within the organisation.

In the reports presented above, the research looked at the impact of COVID-19 on the functioning of Polish companies, but there is no research focusing on the analysis of specific industries. This information can be found in another research report conducted in March 2021 for the European Parliament’s Committee on Industry, Research, and Energy (ITRE), included in the report “Impacts of the COVID-19 pandemic on EU industries” [24]. This research indicated that there are significant differences between the impact of the pandemic on different economic sectors within the European Union. Among the businesses best able to cope with the impact of the COVID-19 pandemic is digital and healthcare. A rapid decline followed by slow growth in revenues is observed in industries such as chemicals, food and drinks, pharmaceuticals, and construction. The most affected industries are those based on human interaction (aerospace, creative and cultural), which have experienced the largest revenue declines and are likely to take the longest to recover.

There is a lack of research on the actual measures taken in companies, the reasons for taking them, the effects achieved, and the conclusions for the future.

In publications on how manufacturing companies operate under pandemic conditions, the authors identify two leading trends that will guide changes in the area of production and operations management:
• changes in supply chain management will be geared towards a gradual shift away from global suppliers to suppliers operating in the local market, thus giving the company more flexibility to manage the materials, parts, and components ordered [25,26]; and there is a new problem of disposing of used masks and gloves [27];
• current production facilities should shift to digital manufacturing (or industry 4.0 based manufacturing), and promote the digital technologies such as AI, 3D printing, Robots, Cyber-physical systems, Digital manufacturing, Blockchain, etc. for production of goods [28–30].

The impact of the COVID-19 pandemic was significant for all analysed industries in which manufacturing companies operate. Addressing the topic of limiting the negative effect of the pandemic on the operation of industrial enterprises is a socially and scientifically important topic and, given the situation that still prevails, still timely. While the COVID-19 pandemic has persisted for more than 18 months, it is still uncertain how it will evolve and affect the operation of industrial enterprises. Manufacturing companies have introduced different solutions, tailored to their specific business, as there is a social and economic dimension to ensuring the continuity of their operations under pandemic conditions. These solutions go a bit further than the common rules of disinfection and social distancing. According to research [31], workplace solutions are an important means of minimizing the risk of workplace infections and translate into reduced stress and employee health and should be constantly strengthened.

The idea of researching solutions to ensure the continuity of production companies under conditions of the COVID 19 pandemic is original. The authors found information regarding research conducted in the area of COVID-19, however, none of them analysed in such a detailed way specific security measures possible to be applied in production companies. Manufacturing enterprises are characterized by different working conditions than other business enterprises, e.g. service enterprises, due to the type of their operations and applied technologies.

The key is to identify appropriate measures to minimize the impact of the pandemic on the functioning of the company. They are appropriate to the capabilities, size, or profile of the company. Each organisation will strive to minimize the risk of spreading the effects of the pandemic while minimizing the financial expenses incurred for this purpose.

3. Methodology

The aim of the questionnaire was to identify which formal, legal, technical, and organisational solutions are used in conditions of the COVID 19 pandemic in production enterprises in Poland.

Study characteristics:
• Research method: multi-mode CAWI/CATI (Computer Assisted Web Interview/Computer Assisted Telephone Interview)/survey;
• Date of study: from 5.02.2021 to 5.03.2021;
• Sample size: 600 manufacturing companies;
• Sample selection: stratified random sampling; the stratum in the survey were the selected Divisions of Section C (Industry) of the Polish Classification of Products and Services; within a specific stratum, the randomization of entities for the survey took place (based on [32]).

The following parameters were adopted to consider the sample as a representative: confidence level 0.95, the proportion of the phenomenon in the general population \( P = 50\% \), maximum estimation error \( e = 4\% \) (based on [33]). The sample size was calculated

### Table 1
Sample selection for the CATI/CAWI survey.

| Selected divisions in section C (Manufacturing) | Number of entities | Percent of all entities in section C | Sample at \( n = 600 \) |
|-----------------------------------------------|--------------------|-------------------------------------|-------------------|
| 10 - Manufacture of food products             | 32 569             | 9.82%                               | 59                |
| 11 - Manufacture of beverages                 | 1713               | 0.52%                               | 3                 |
| 13 - Manufacture of textiles                  | 10 669             | 3.22%                               | 19                |
| 14 - Manufacture of wearing apparel           | 27 289             | 8.22%                               | 49                |
| 15 - Manufacture of leather and related products | 5915             | 1.78%                               | 11                |
| 16 - Manufacture of wood, cork, straw and wicker | 34 969             | 10.54%                              | 63                |
| 17 - Manufacture of paper and paper products  | 5261               | 1.59%                               | 9                 |
| 18 - Printing and reproduction of recorded media | 17 636             | 5.32%                               | 32                |
| 20 - Manufacture of chemicals and chemical products | 5499             | 1.66%                               | 10                |
| 21 - Manufacture of pharmaceutical products   | 758                | 0.23%                               | 2                 |
| 22 - Manufacture of rubber and plastic products | 15 068             | 4.54%                               | 27                |
| 23 - Manufacture of other non-metallic mineral products | 19 366             | 5.84%                               | 35                |
| 24 - Manufacture of basic metals              | 2230               | 0.67%                               | 4                 |
| 25 - Manufacture of metal products            | 70 074             | 21.12%                              | 126               |
| 26 - Manufacture of computer, electronic and optical products | 6410             | 1.93%                               | 11                |
| 27 - Manufacture of electrical equipment      | 4312               | 1.30%                               | 8                 |
| 28 - Manufacture of machinery and equipment   | 9261               | 2.79%                               | 17                |
| 29 - Manufacture of motor vehicles, trailers and semi-trailers | 2649             | 0.80%                               | 5                 |
| 30 - Manufacture of other transport equipment | 3778               | 1.14%                               | 7                 |
| 31 - Manufacture of furniture                 | 32 760             | 9.87%                               | 60                |
| 32 - Other manufacturing                     | 23 618             | 7.12%                               | 43                |

Source: own study based on Local Database of the Central Statistical Office (stat.gov.pl – accessed on December 10, 2020).
as:
\[ n = \frac{N \left( Z^2 + P(1 - P) \right)}{N \cdot e^2 + Z^2 + P(1 - P)} \]

where:
- \( n \) – sample size.
- \( N \) – population size
- \( e \) – maximum possible error of estimation.
- \( P \) – estimated proportion in the population.
- \( Z \) – the value resulting from the adopted confidence level (for 95% confidence level \( Z = 1.96 \)).

The population of national economy entities for selected Divisions of Section C in Poland, according to the local database of the Central Statistical Office in Poland [34], amounts to 331,804 entities. The survey should be conducted on a sample of \( n = 600 \) to achieve a representative sample with the assumed parameters. Two additional requirements were introduced. The sample is to include a minimum of 70 large enterprises with 250 employees and more, and a minimum of 150 medium-sized enterprises from 50 to 249 employees. The exact sampling is reflected in Table 1.

The survey included the following groups of protective measures: (1) legal and regulatory measures; (2) personal protective measures; (3) protective measures for groups of workers; (4) work organisation measures; (5) measures of production organisation.

There were 6–12 questions in each group concerning the identified solutions and an additional open-ended question – "What are the other applied measures?" Fig. 1 presents the method of selection of measures for the research questionnaire. The measures identified taking into account the recommendations of international organisations and national guidelines (cf. Section 2.1) and those identified based on interviews in manufacturing companies, as well as own knowledge and experience, were included. The examined measures are presented in Table 2, with the basis for their inclusion in the research indicated by colours.

In Table 2, one of the measures – special protection for key employees (with unique skills) – is highlighted as required for Critical Infrastructure Operators. That is due to the tasks performed by Critical Infrastructure entities, which are necessary to ensure the availability of important resources, products, and services – key to the functioning of the state and society. These requirements are
more restrictive than for other companies in the “Industry” section.

The research conducted by the authors of this paper details the research conducted by Margherita & Heikkilä [35] on a purposive sample of 50 leading global companies. Margherita & Heikkilä based on secondary sources, identified areas of strategic action taken to business continuity under COVID-19 conditions. There were 5 areas: 1) Operations and Value System, 2) Customer Experience and Support, 3) Workforce and Human Capital, 4) Leadership and Change management, 5) Community and Social Engagement. At the operational level, the groups of measures (1), (2), and (3) selected in this paper, were found to largely coincide with the measures proposed by Margherita & Heikkilä in group 3). In parts (4) and (5), the questionnaire of the paper provides a detailed elaboration of the measures “Update or reengineer production to enhance workforce security” in the strategic area classified by Margherita & Heikkilä in group 1).

The analysis of the results was performed using the STATISTICA TIBCO Software Inc. package, version 13.3.721.0, and MS Excel.

4. Results

The study yielded a comprehensive set of results describing the actions taken by industrial companies during the pandemic to prevent the spread of infections caused by the SARS-CoV-2 virus. Results were analysed in several sections and are presented below by the five groups of safeguards identified in the columns of Table 2.

The extent of the use of each solution among all surveyed enterprises is presented in each group. The results of the analyses of the implementation of a specific measure sorted by the size of the enterprise (expressed in the number of employees) are described. The following groups were analysed:

- very small enterprises (microenterprises), with less than 10 employees (183 in the research sample);
- small enterprises, from 10 to 49 employees (there were 192 such enterprises in the research sample);
- medium-sized enterprises, from 50 to 249 employees (153 in the research sample);
- large enterprises, with 250 employees and more (there were 72 in the research sample).

The extent to which the identified measures were applied by industry was examined. The research aimed to verify the occurring differences in the implementation of individual solutions. The results were related to the type of manufactured products and the related specificity of the production process. In the analysis of the dependence of used measures on the industry, the four most numerous Divisions of the Section C (due to the number of enterprises) were taken into account. The selected sections covered more than 52% of the surveyed enterprises, including:

| (1) Legal and regulatory measures | (2) Personal protective measures | (3) Protective measures for groups of workers | (4) Work organisation measures | (5) Measures of production organisation |
|----------------------------------|----------------------------------|-----------------------------------------------|-------------------------------|----------------------------------------|
| Business continuity plan | Temperature checks | Periodic COVID-19 testing | Rotating staff schedule (teams do not contact each other) | Production flow pattern (with a minimum distance of 1.5 m between workstations) |
| Crisis management team | Saturation checks | Mandatory quarantine rules (and shortening quarantine options) | Workstation scheduling (restricting contacts between employees at a single workstation) | Restricting access to workstations (physical barriers) |
| Pandemic handling procedures | Nose and mouth covers | Disinfection procedures in workplaces | Workcell scheduling (restricting contacts between employees within workcell) | Workspace special layout (minimizing the employee contacts) |
| Employees training on pandemic procedures | Full face shields | Disinfection schedule of common places | One-way paths | Room-to-room airlocks |
| The employee’s daily statement of health | Safety gloves at work | Ventilation of indoor spaces | Permanent assignment of work-tools to the employee | Disinfection of manufacturing products and work-tools |
| Internal control of the compliance with security requirements | Full-body protective suit | Social distance enforcing | Special protection for key employees | Automated transportation |
| Regular hand sanitization | Flexible work schedule | Maintenance performed outside of working shifts | Remote quality control |
| Limiting the number of persons in the room | Remote work of supervisory staff | Digital work instruction |
| Dedicated spaces for key employees (when remote working is not possible) | Automated collection of production data |
| Digital documentation | Larger batch sizes (less frequent supply) |
| Inventory increase (compensate for delivery delays) |

Legend:
Requirements found in national governmental recommendations (various ministries) and documents of international organizations
Additional requirements indicated for Critical Infrastructure Operators (owners, regulators)
Suggestions from the expert team (submitted in addition to the identified national and international requirements)
Source: own study
• Division 10 - Manufacture of food products covering 59 entities, which accounts for 9.82% of the surveyed population of enterprises;
• Division 16 - Manufacture of products of wood, cork, straw, and wicker covering 63 entities, which constitutes 10.54% of the surveyed population of enterprises;
• Division 25 - Manufacture of metal products covering 126 entities, which accounts for 21.12% of the surveyed population of enterprises;
• Division 31 - Manufacture of furniture covering 60 entities, which accounts for 9.87% of the surveyed population of enterprises.

4.1. Legal and regulatory measures

The safeguards used in the legal and regulatory measures group represent solutions implemented by companies in the form of internal regulations. They regulate formal aspects of how a company should operate during a pandemic. For example, they may concern procedures to be followed in emergencies, e.g. the procedure to be followed in the event of an infection on the premises of the company. They may answer the questions: which employees should be isolated; in which room should the isolation take place. It may also refer to the establishment of specific units to support the work of the enterprise in preventing threats, such as a crisis management team, and the assignment of formal tools to carry out the assigned responsibilities, e.g. procedures of conduct, organisation of training, making statements by employees.

Within the framework of the analysed formal and legal measures, the most frequently applied solutions (with the frequency of occurrence exceeding 50%) are the development of procedures for handling situations related to pandemics (69% of entities) and conducting training of employees in the scope of knowledge of the developed procedures at the level of over 80% of trained people (53% of entities). Less commonly used solutions (found in more than 30% of companies) are the development and implementation of a business continuity plan (42% of entities) and the introduction of internal control of compliance with security requirements, with the assumption that the control is performed daily and covers the entire production area (34% of entities). The least frequently used solution in this group of measures is the daily statement of the employee’s state of health before starting work – a widespread use (at the level of at least 80% of employees) of this measure is declared by only about 10% of entities (Fig. 2).

The analysis of the use of formal and legal measures indicated that each solution analysed is more often used in large enterprises. The maximum difference between the group average and the result for a large enterprise is over 45%. A similar trend is found in medium-sized enterprises, however, the maximum difference is much lower (11%).

In large companies, two solutions were rated highest: development and implementation of procedures to deal with various situations related to a pandemic (almost 96% of companies) and development and implementation of a business continuity plan (over 76% of companies). The presented situation demonstrates that larger companies have decided to apply systemic formal and legal solutions in a wide range. They were introduced to apply throughout the company, not relying only on individual actions taken by employees (Fig. 3).

The distribution of the most commonly used solutions in the formal and legal measures is relatively even in each industry. The distribution is in the range of 63–71% for using procedures and in the range of 43–57% for providing training. The highest frequency of use of this measure is in food manufacturing industry. In this group, it was very frequent to develop and implement a business
continuity plan, establish a crisis management team, or conduct an internal audit of compliance with safety requirements (Fig. 4).

4.2. Personal protective measures

Protective measures used within the group of personal protective measures represent solutions of direct protection of an employee against infection. They are most often part of the outfit of a worker’s work clothes (in the case of direct production workers) or additional clothing (for the duration of a pandemic) and actions taken by the individual (e.g. temperature measurement, saturation measurement, or hand disinfection).

In the group of personal protective measures, the most commonly used solution is covering the mouth and nose (in the form of masks, visors, etc.). In more than half of the entities, this solution is used by more than 80% of employees (Fig. 5). The survey was conducted almost a year after the beginning of the pandemic in Poland. Despite many recommendations in the form of the necessity to
cover mouth and nose, this measure is still not used in the vast majority of researched enterprises, and only in more than half of them. This solution has not always been obligatory in Polish enterprises (especially when the number of covid cases was minimal), however, during the research it was one of the legal requirements. At a similar level (in nearly 40% of enterprises) is the mandatory measurement of temperature, which is not present in any of the requirements developed by government bodies. It is considered a measure to minimize the possibility of virus transmission in larger gatherings of people (for example, in large stores, cultural centres, or schools). Then, with a frequency below 30% of the surveyed companies, there are other measures of individual protection, such as the use of gloves during work by more than 80% of employees (30% of entities), the use of full protective clothing, e.g., overalls (more than 28% of entities), the use of a full face shield by more than 80% of employees (21% of entities) or performing systematic hand disinfection exceeding 10 cases per working shift (more than 15% of entities).
Companies with higher employment levels are more likely to use mouth and nose protection as well as mandatory temperature measurement for each employee. Both solutions are used by nearly 70% of large companies. However, in companies with lower employment levels, the incidence of these solutions decreases significantly. The values obtained for large and medium-sized enterprises are much higher than the population average (Fig. 6).

The opposite trend can be seen with the use of gloves at work for more than 80% of the employees. Very small companies have the highest percentage of using this solution, with more than 40%. The percentage of workers using full-face shields has increased over the pandemic, and this is particularly evident in large companies.

The distribution of the use of mouth and nose covers by more than 80% of workers is even across each of the four industries analysed. For the most part, this measure is used in at least 50% of the companies in three major manufacturing industries: furniture, metal products and food products (Fig. 7).

Less commonly used solutions include the use of gloves at work (at least 31% of entities), the use of full protective clothing (at least 32% of entities), and mandatory temperature measurement (at least 25% of entities). All of the above elements were examined under the assumption that at least 80% of employees use a given solution, based on the assumption that only then can they be considered as common solutions, widely used in the enterprise.

It should also be noted the high percentage (more than 57% of subjects) of use of gloves during work for more than 80% of workers engaged in the production of wood, cork, straw, and wicker products. It is likely that the use of gloves, in this case, is related to the nature of the operations carried out during the implementation of the production process, where gloves are normally used to protect the hands of workers from cuts or lacerations. During the period of the pandemic, they also serve the function of protection against virus transmission. It is also necessary to remember about their appropriate disinfection or systematic replacement.

In the food manufacturing industry, it is worth noticing two solutions: obligatory temperature measurement (more than 52% of enterprises), and systematic hand sanitization (more than 32% of enterprises with more than 10 cases per working shift). Probably the presented solutions were easier to implement due to numerous requirements concerning health and safety at work (such as HACCP, ISO 9001, ISO 22000, and others).

4.3. Protective measures for groups of workers

Protective measures for groups of workers represent solutions that protect an appropriately large group of workers. They can be organisational (e.g. implementation of systematic disinfection procedures or flexible working time) or of a technical nature (e.g. regular air exchange in rooms).

Within the framework of the analysed group of protection measures, the most frequently applied solutions (with the frequency of occurrence exceeding 50%) are the development and implementation of a workplace disinfection procedure (over 69% of entities) and the development of a schedule for its systematic performance (51% of entities) - Fig. 8. The mentioned solutions are included in the
government recommendations.

The least common approaches (less than 5% of entities) include periodic testing for COVID-19 and the development of policies to conduct and shorten quarantine for all employees according to national guidelines (e.g., performing PCR tests after a few days of quarantine). The first solution is relatively expensive due to the unit cost of testing. In Poland, tests are still chargeable (even for
workers), but in many European countries (e.g., Germany), their application was currently free of charge for several months. At the same time, the cost of application of a given solution increases with the size of a company and at the same time with an increased possibility of contact of an infected employee with other employees. The second solution associated with the need to perform a test for COVID-19 is additionally difficult to carry out from a formal point of view. Therefore, in addition to high costs, the vast majority of companies decide to carry out a standard quarantine of employees.

For most solutions, the percentage of their use in medium and large enterprises is higher than the average values (percentage share for all enterprises) - (Fig. 9). A particularly large difference occurs in the two cases. The first one is a development and implementation of a workplace disinfection procedure. It is applied in over 91% of large enterprises and nearly 78% of medium-sized ones. The second one is a technique of enforcing social distance. It is applied in over 55% of large enterprises and 32% of medium-sized ones. The most common solution in medium-sized enterprises is to implement a schedule for disinfecting common places every one shift (found in over 60% of entities).

The distribution of the most frequently used protection measures for group of workers is even across the analysed industries (Fig. 10). The development and implementation of a workplace disinfection procedure are used in at least 61% of entities. It is over 93% of entities in the food production industry. Another solution used much more frequently in this industry is the implementation of a schedule for disinfecting common places at least once per working shift (over 64% of entities). The observed results are related to the implementation and adherence in these entities to strict standards for maintaining safe and sanitary working conditions even before the pandemic period.

There is also a high share of enterprises manufacturing wood, cork, straw, and wicker products, which use continuous air exchange in rooms in the form of filtration or ventilation (at the level of almost 62% of companies). The described situation may be related to the specificity of manufacturing processes in the industry, where is high dust pollution at workplaces.

4.4. Work organisation measures

Work organisation measures represent solutions concerning the way of performing assigned production tasks. Most often they are in the form of organisational measures, which minimize the risk of infection of employees. For example, by defining the way of performing duties remotely, or building a new work schedule taking into account a minimum 1-h break between successive production teams.

Within the analysed measures of work organisation, the most frequently applied solutions (with a frequency of occurrence above 30%) are the preparation of a dedicated places for key personnel (more than 41% of entities), the use of rotational work to limit contacts between employees (more than 37% of entities), the establishment of a permanent assignment of work-tools to the employee

![Fig. 10. Protective measures for groups of workers in selected manufacturing industries.](image-url)
(more than 34% of entities) and the performance of maintenance on non-production shifts (more than 30% of entities). None of the solutions is used in the majority of the surveyed entities (more than 50%) therefore the measures used are not dominant (Fig. 11). The least used solutions (less than 5% of entities) include the implementation of production supervision work in remote form and the use of one-way transport paths in more than 80% of cases of transport routes.

For a considerable number of solutions, the average values for medium-sized and large enterprises are exceeded (Fig. 12). A particularly large difference is observed in four cases: rotating staff schedule (applied in nearly 71% of large enterprises and over 49% of medium-sized enterprises), workstation scheduling (applied in 50% of large enterprises and 30% of medium-sized enterprises), the performance of maintenance outside of working shifts (applied in over 55% of large enterprises and nearly 44% of medium-sized enterprises), and preparation of dedicated spaces for key employees (applied in over 61% of large enterprises and over 47% of medium-sized enterprises). In very small enterprises, the most common solution is the permanent assignment of work tools and instruments to more than 80% of employees (found in more than 49% of entities). Likely, the solution is widely used due to the low level of employment, where equipping each person is necessary when performing work at the same time or of a different nature requiring dedicated equipment.

Most of the solutions are dominated by those from food manufacturing industry. In the case of using rotational work to reduce contact between workers, the difference is 29%. In the case of performing maintenance on non-production shifts, the difference is nearly 17%. When preparing dedicated spaces for key personnel, the difference is more than 12%.

In two of the analysed industries: the production of wood, cork, straw, and wicker products and the production of metal products, a permanent assignment of work tools to more than 80% of employees is a common solution - the share of entities is almost 35% for the manufacturing of wood products and more than 36% for the manufacturing of metal products (Fig. 13).

The use of this measure has a positive effect on minimizing the possibility of virus transmission. It is probably related to the specificity of operations performed as part of the technological process. In such cases, employees with appropriate qualifications perform specialized activities or activities are performed in parallel (at the same time), so each employee has dedicated work tools. A similar trend was noted in very small enterprises in the earlier analysis.

The measure of special protection for key employees (with unique skills) was identified as one of the specific requirements for Critical Infrastructure Operators. This measure was implemented in a small number of enterprises - less than 15% of entities. It was often used in large enterprises (nearly 21% of entities) than in small enterprises (10% of entities). Significant variation in the

![Fig. 11. Work organisation measures in enterprises.](image-url)
Fig. 12. Work organisation measures with regard to employment level.

Fig. 13. Work organisation measures in selected manufacturing industries.
introduction of this measure occurs between the analysed industries. It is more than twice as often used in food manufacturing (20% of entities) than in the manufacturing of wood, cork, straw, and wicker products (less than 8% of entities). Protection of employees with key competencies is important to ensuring business continuity. Limiting their availability makes the delays in the course of the process, and may even cause the stopping of production.

4.5. Measures of production organisation

Measures used within the measures of production organisation group represent technical solutions closely related to the specificity of the implementation of production processes. They mainly concern the mounting of additional elements of equipment or their appropriate arrangement to minimize the possibility of infection of employees performing operations (tasks) in different production conditions (mass or unit production, production realized in various forms).

Within the framework of the analysed measures of the production organisation, the most frequently applied solution (over 88% of entities) is the production flow pattern that enables maintaining a distance of at least 1.5 m between workstations (Fig. 14). Quite a high share in enterprises (about 50% of entities) has also recorded two other solutions: disinfection of manufacturing items and work-tools (over 48% of entities) and replacement of the hard copy production documentation with the digital version (over 46% of entities). The least frequently used solutions (less than 10% of entities) include changing the supply rules – reducing the frequency of deliveries and increasing the batch size at the same time (nearly 8% of entities) and placing room-to-room airlocks (7% of entities).

Fig. 14. Measures of production organisation in enterprises.
The level of application of all measures in large enterprises exceeds average values for the population (Fig. 15). Differences are visible in three cases: the restricting access to workstations in the form of glass, plexiglass walls, distance barriers or floor markings (solution implemented in more than 73% of entities), the use of automated transportation (solution implemented in more than 41% of entities) and execution of automated collection of production data (solution implemented in more than 58% of entities). The higher the level of employment, the greater the share of measures is. Very small enterprises use measures to a much lesser extent, and the biggest difference to large enterprises is 52%. Some of the measures presented in this group are connected with a high level of production organisation. They can be introduced in companies prepared for Industry 4.0 or in companies where Industry 4.0 solutions have already been applied. These solutions are connected with high investment costs, which makes it difficult to implement them in smaller enterprises.

The distribution of measures used in the production organisation is in most cases even (Fig. 16). Production flow pattern with a minimum distance of 1.5 m between workstations is characterized by a high level (above 85%) in three of the four industries (wood manufacturing, metal manufacturing, and furniture manufacturing). In food manufacturing, it is also high, at nearly 70%.

For the four measures, the highest level of implementation is in food manufacturing industry. The difference between the highest and lowest levels of implementation is more than 20% for remote quality control, nearly 19% for restricting access to workstations, more than 18% for automated transportation, and nearly 18% for disinfection of manufacturing items and work tools. All of these solutions are linked to the implementation of and adherence to strict standards for maintaining safe and hygienic working conditions. They were applied even before the pandemic, including because of the implementation of streamline production associated with greater possibilities of automation.

Large variation in implementation in entities from different industries occurs for the measure of inventory increase. It is used in furniture manufacturing companies (over 40% of entities). In other industries it is much less popular, reaching the level of implementation in more than 8% of entities for the food manufacturing.

5. Discussion

The previous chapter focused on presenting the overall results, in the form of the degree of use of the identified metrics in manufacturing companies. The percentage of solutions to the number of employees in the enterprise as well as the industry was also the focus of the research. The conducted literature research and research reports indicated that these could be factors determining the varied implementation of particular solutions. Attempts have also been made to undertake such research but in general rather than specific terms.

The survey also included an analysis of the level of use of a given security measure across companies. A simple “Yes” or “No” answer to the question about the use of a given solution is insufficient. Detailed questions about the extent to which a security measure is used by a percentage of employees in a given enterprise illustrate the scale of implementation (e.g., a solution is used by selected employees, managers, all employees, or up to 20% of employees use a given solution, etc.). A five-level maturity scale was adopted according to the principle:

![Fig. 15. Measures of production organisation with regard to employment level.](image-url)
maturity level 1 (ML 1) - 0–20% of the workplaces have implemented the measure;
maturity level 2 (ML 2) - 21–40% of the workplaces have implemented the measure;
maturity level 3 (ML 3) - 41–60% of the workplaces have implemented the measure;
maturity level 4 (ML 4) - 61–80% of the workplaces have implemented the measure;
maturity level 5 (ML 5) - 81–100% of the workplaces have implemented the measure.

Figs. 17–21 show the maturity level of implementation of selected measures in each of the 5 groups by enterprise size. The charts show the number of entities in each enterprise group that is at a particular maturity level from 1 to 5.

In the group of legal and regulatory measures the measure of employees training on pandemic procedures was analysed in detail (Fig. 17). The obtained results are very distinctive. In each of the enterprise groups, the majority of the enterprises are on a level 1 and level 5 of maturity, with the dominant solution of level 5. The share of enterprises varies between 43 and 110 entities. The highest
percentage in a given group for large enterprises (at nearly 60%), and the lowest (at 47%) for very small enterprises. The high frequency of solutions with a very low level of employee training (maturity level 1) - especially in very small enterprises, where such training is a relatively simple activity to be performed due to the small number of employees, and yet it is not performed to a large extent. Training in procedures related to dealing with various situations associated with COVID-19 is mentioned in all government requirements for enterprises in Poland.

In the group of personal protective measures, the measure of nose and mouth covers was analysed in detail (Fig. 18). An analysis has shown that this solution is used to a large extent (maturity level 5) in companies with more than 50 employees. The results are as follows: for medium-sized companies – in 85 entities, which represents more than 55% of companies in the group, for large companies – in 50 entities, which represents more than 69% of companies in the group. In smaller enterprises (with less than 50 employees), the use of nose and mouth covers for more than 80% of employees is used in less than half of the enterprises, while the high share of enterprises at maturity level 1 is significant, ranging from 54 entities for small enterprises (28%) to 64 entities for very small enterprises (35%). Individual enterprises did not answer this question, which practically does not affect the evaluation of the results.

There was a significant increase in the use of two solutions already during the pandemic: full-face shields and regular hand disinfection. It is likely that these practices will be adopted as good practices and will continue to be used in manufacturing companies for a long time, possibly even after the pandemic has ended.

In the group of protection measures for groups of workers, a measure of disinfection procedures in workplaces was analysed in detail (Fig. 19). As part of the research, 417 respondents provided answers, while in 183 enterprises no answer or a negative answer was obtained which means that given measure is not use in the company. Most among very small and small enterprises, 72 and 65 respectively, and some medium enterprises (31 entities) do not use this measure. Individual enterprises did not answer this question, which practically does not affect the evaluation of the results. Among the companies that replied affirmative answers, the results were as follows.

Analysis showed that this measure is widely used (maturity level 5) in large companies – in 40 entities, which constitutes 60% of companies in this group of those who answered. The measure is also quite widely used in smaller enterprises at the level of 58 entities in very small (over 52% of this group) and 62 entities (50% of this group) in small enterprises. Regardless of the level of employment, a group of entities in which the measure was implemented at the first or second level of maturity (in individual groups of enterprises only from 3 to 23 entities) is small, which proves that the measure is used in most enterprises to a large extent.

In the group of work organisation measures, the solution of applying rotating staff schedule was analysed in detail (Fig. 20). As part of the research, 225 respondents provided answers, while in 375 enterprises no answer or a negative answer was obtained which means that given measure is not use in the company. The number of enterprises not using this measure decreases with the size of the
enterprise. Among very small enterprises it is dominant (over 85%), among large ones it is significant (nearly 30%). Individual enterprises did not answer this question, which practically does not affect the evaluation of the results. Among the companies that replied affirmative answers, the results were as follows.

An analysis has shown that this solution is used extensively (maturity level 5) in very small companies – it occurs in 16 entities (which constitutes 47% of the companies in this group of those who answered). As the level of employment increases, the degree of the introduction of rotating staff schedule for workstations decreases, as well as the share of entities in which this solution has been introduced in less than 20% of workstations increases.

In the group of measures of production organisation, the measure of production flow pattern keeping a distance of at least 1.5 m between workstations was analysed in detail (Fig. 21). The analysis shows that in companies with a higher level of employment (medium and large enterprises), the percentage share of workstations with the possibility of maintaining a distance of at least 1.5 m decreases. In most of the surveyed micro and small enterprises, employees keep a distance of 1.5 m during their duties. Medium and large enterprises have to introduce additional solutions to limit the transmission of the virus because the distance of 1.5 m cannot be maintained due to the prevailing production conditions. This is probably related to the aim to optimize the use of space allocated for the implementation of the production process and the tools used following the concept of lean manufacturing (elimination of barriers between workstations, one-piece flow, etc.). Redesigning the layout would entail a large financial outlay.

A significantly higher proportion of enterprises employing less than 50 people can ensure that a distance of at least 1.5 m is maintained between workstations at maturity level 5. It is true for 139 very small and 122 small enterprises which correspond to 88% and 71% of enterprises in the given group of those who answered. Probably, this fact influences the degree of application of the next measure from the group of measures of production process organisation - application of solutions protecting access to posts. The detailed analysis shows that in enterprises employing more than 50 people these solutions are used much more often, possibly precisely because of the problems of maintaining an appropriate distance between workplaces. In each group of enterprises, there is a noticeable number of enterprises not using this measure. The highest number is among very small enterprises (more than 12%). Individual enterprises did not answer this question, which practically does not affect the evaluation of the results.

6. Conclusions

The authors intended to present the results of the research work in theoretical and practical aspects. The applied research methodology made it possible to realize these intentions.
6.1. Theoretical aspects of research results

In the area of risk and crisis management theory, the paper focused on pandemics as a threat that has rarely been described before from a “non-medical” perspective, namely the management of organisations under pandemic conditions. Solutions for dealing with pandemics in industrial plants were collected and organised. The analysis was based on the recommendations of global health organisations, government recommendations (in Poland), and scientific studies, as well as on the knowledge and experience of experts supported by interviews in enterprises. As a result 42 measures possible to use in manufacturing enterprises to limit the spread of the pandemic were identified. To systematize the work, they were divided into five groups: formal and legal measures, individual protective measures, protective measures for groups of workers, work organisation measures, and measures of production organisation. The research findings can be used to develop and detail at the operational level the integrated frameworks developed by other researchers, in which they proposed specific strategic responses for increasing the level of organisational resilience [35,36].

An epidemic as an emergency prompts spontaneous responses in organisations, some of which are innovative and can be models of good practice. The research presented in the paper was carried out within the research project “Models of the adaptation of work organisation in manufacturing enterprises to the limitations of public life (associated with a pandemic) in line with the demands of business effectiveness and efficiency”. This project aims to develop model organisational solutions for manufacturing enterprises, increasing their ability to ensure business continuity under conditions of a pandemic. The product of the project is to be a Good Practice Repository containing model organisational solutions, scenarios and processes for their implementation, and recommendations for enterprises operating in various production conditions.

6.2. Practical aspects of research results

Results can be viewed from the perspective of company employees and managers. For workers, it confirms that their safety in the working environment and the continuity of the business is a combination of many different measures (personal protection, physical barriers, organisational solutions, and compliance with procedures). For managers, it may be interesting to compare the measures used in their company with the extent to measures used in companies of a similar type within their industry. The research has shown that the frequency of using each of the tested security measures in organisations depends on the company’s employment or the industry within which it operates.

The results of the analysis show that large enterprises apply the proposed measures much more frequently. Moreover, the scope of their application expressed by the percentage of employees/workstations covered by the given measure is also much higher than in smaller entities. These actions require more complex organisational activities and higher financial expenditures, which was confirmed in the report [22].
The results obtained to the industry in which the company operates indicate that the higher frequency of application of almost every security measure occurs most often in food manufacturing industry. This phenomenon is particularly evident in the group of formal and legal measures and protective measures for groups of workers. Due to the nature of its business, food manufacturing follows many health and safety requirements (e.g., enforced by the HACCP system) that were already in place before the pandemic. Preliminary results also indicate that the frequency and scope of application of a given measure are related to the level of organisation of production processes and the related possibility of automation of performed operations or implementation of solutions recommended within the framework of Industry 4.0.

The introduced maturity scale defines the degree of advancement of the implementation of a given security in an enterprise. It also makes it possible to determine the scope of applicability of a given solution. It answers the question of whether it has a local character (used by a limited group of people in a structured or sometimes even accidental way), or whether it can be considered a systemic solution (used in a structured way by over 80% of employees).

Analysis was conducted on Polish companies and is a look at the research problem from the perspective of Poland, but it seems that the results may be interesting for other countries of the European Union, due to similar legal regulations and similar characteristics of manufacturing companies, as well as close mutual location and close economic relations and experiencing the same effects of the pandemic. More than 10% of enterprises as a part of multinational corporations and/or operate in international markets were part of the study. The local nature of the research, limited to one country, may introduce some limitations to the universal interpretation of the results - due to local differences in legislation and the local culture of work resulting from the mentality of employees, their attitude to the respect of laws and local recommendations.

6.3. Further research directions

The presented results showed the necessity of conducting a detailed analysis of the solutions used by enterprises. They also indicate that some solutions were applied by enterprises in an accidental and non-systematic way. There is a lack of methodology for dealing with similar situations in the future, such as a new pandemic. Therefore, the subject of the authors’ further research will be:

- Analysis of the detailed solutions used in the surveyed companies. Sample research questions: Which solutions are used most often? What solutions (good practices) were indicated by respondents beyond the survey answer cafeteria? Which solutions are most effective: recommended by legal acts and regulations in force, own solutions, good practice examples used by others? What is the difference between the solutions used by companies that have identified COVID-19 cases at their premises and those

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Fig. 20. Work organisation measures – rotating staff schedule.
that have not? Does the extent of protection apply to depend on characteristics other than the size of the company and the industry, e.g. the specific features of the production process (type and form of production organisation, layout)?

- **Develop a repository of good practices and detailed recommendations for their use to ensure the continuity of operations of manufacturing enterprises in conditions of the COVID-19 pandemic in Poland.** These solutions should be in part common to all manufacturing enterprises, and in part adapted to the specific operating conditions resulting from the way in which production is organised (assembly line manufacturing, layout, level of process automation, etc.). Developing a methodology for a model procedure in the event of another pandemic or other phenomena leading to an interruption in the continuity of operations of a production enterprise (e.g., long-term reduction of supplies due to the disruption of the continuity of suppliers; difficulties in the flow of materials and components on a macro scale; the need to limit the work of a particular group of people due to the threat) may facilitate the drawing up of business continuity plans.

Based on what has been observed so far, it seems that the pandemic will stay with us for longer and that vaccination (even mass vaccination) will not eliminate the threat, as new mutations of the virus appear. The world community has become aware of the real threat of new viruses. Neither individual governments nor international organisations can completely prevent pandemics. The “Pandemic” factor should be more widely considered in the methodology of developing crisis management plans at all administrative levels.

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