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## Article

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Journal of Open Innovation: Technology, Market, and Complexity

## Provided in Cooperation with:

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*Suggested Citation:* Gajdzik, Bozena; Wolniak, Radosław (2022) : Influence of industry 4.0 projects on business operations: Literature and empirical pilot studies based on case studies in Poland, Journal of Open Innovation: Technology, Market, and Complexity, ISSN 2199-8531, MDPI, Basel, Vol. 8, Iss. 1, pp. 1-20,  
<https://doi.org/10.3390/joitmc8010044>

This Version is available at:

<https://hdl.handle.net/10419/274348>

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Article

# Influence of Industry 4.0 Projects on Business Operations: Literature and Empirical Pilot Studies Based on Case Studies in Poland

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**Abstract:** For the past decade, Industry 4.0 has become the basis for building competitive advantage for business operations. The key technologies of Industry 4.0 are implemented in enterprises of various industries. This paper focuses on presenting the results of research on the influence of the Industry 4.0 concept on the operations of enterprises that are implementing smart manufacturing (SM) projects. The paper analyses the following areas of influence of projects on the enterprises' operations: productivity, agility and speed, quality, competitiveness and enterprise value, profitability, staff reduction, delivery improvements, vertical and horizontal integration, resource savings, reduction of operating costs, technology adaptability and quality of machine operations. The paper belongs to the research paper category. The research tool was a questionnaire. The research was carried out in the segment of steel enterprises in Poland. The results of the presented research belong to pilot research of a segment of steel industry in Poland. The main conclusion of the study is that implementation of Industry 4.0 in the Polish steel sector had a positive influence on many factors strictly connected with the innovativeness of the company. Especially, the implementation of this conception in the steel sector leads to an increase in the quality of the product and the possibility to achieve a good level of customization of the product. Those factors are very important for the steel sector potential to succeed on the competitive market. The individual SM projects that were evaluated were a form of case study. The participants of the research were employees in managerial positions and operating technological installations in steel sector enterprises. In the opinion of the surveyed (79 people), depending on the type and scope of changes implemented in the company in the direction of Industry 4.0, decision-makers expect a higher quality of processes and products, the ability to meet customer requirements—the direction of the personalization of products and services, agility and flexibility of performed operations with the use of smart technology and accuracy and precision of performance higher than in the case of manual human activities.

**Keywords:** Industry 4.0 (I 4.0); smart manufacturing (SM); steel sector; innovativeness



**Citation:** Gajdzik, B.; Wolniak, R. Influence of Industry 4.0 Projects on Business Operations: Literature and Empirical Pilot Studies Based on Case Studies in Poland. *J. Open Innov. Technol. Mark. Complex.* **2022**, *8*, 44. <https://doi.org/10.3390/joitmc8010044>

Received: 5 February 2022

Accepted: 23 February 2022

Published: 24 February 2022

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## 1. Introduction

The active involvement of enterprises in the changes associated with the fourth industrial revolution requires the implementation of many projects to modify the means of production and new technological investments. The technologies of Industry 4.0 provide the possibility of greater efficiency (productivity) of business operations in companies.

The concept of Industry 4.0 appeared in 2011 in the German government's strategic document in the area of computerisation of manufacturing processes and implementation of high technologies into manufacturing companies [1]. As time passed, the concept of Industry 4.0 became a business paradigm marking a new direction of manufacturing referred to as smart manufacturing or smart production in a smart factory. After a decade since the appearance of the concept, the range of technological solutions offered to companies

has been significantly expanded. In general definition, Industry 4.0 means full integration of the real world, that is, production machines, with the virtual world by Internet and information and communication technologies (ICTs). In Industry 4.0, machines, people and information systems work together. Companies use information and computer systems and numerically controlled machines with access to the Industrial Internet of Things and Services (IIoT and IIoS) to be smarter in their business operations. The pillars of Industry 4.0 are: computer information systems, Industrial Internet of Things (IIoT), direct communication machine-to-machine (M2M), simulation techniques, vertical and horizontal integration of software, augmented reality (VR) technologies, predictive techniques, cyber-physical systems, autonomous robots, cyber security, additive technology, mass individualisation, innovative methods for collecting and processing Big Data and many real-time data analysis techniques with the possibility of cloud computing potential [2,3]. Technologies and innovative solutions have been grouped into key categories. Greengard (2015) [4] proposed four components: cyber-physical systems (connections between the real and virtual worlds), the Internet of Things (IoT), which increases the data available as different products can be connected to the Internet, the Internet of Services (IoS) and the smart factory. In companies, particular technological changes are classified according to the level of Cyber-Production Systems (CPS). The structure of the CPS was proposed by Lee et al. (2015) [5]. According to Lee et al. (2015), the architecture of the CPS creates five levels: connection level, conversion level, cyber level, cognition level and configuration level [5].

The changes introduced in manufacturing systems cannot be generalised because companies use different strategies for building competitive advantage in Industry 4.0 [6]. Companies differ in their levels of maturity for Industry 4.0 [7]. The significant variation in the extent of change on the way of companies to Industry 4.0 is due to the fact that this concept consists of a number of technologies to lead companies to smart manufacturing. The choice of the way to Industry 4.0 is an individual decision of the company. SM projects implemented in companies differ in the scope of change, complexity of change, level of change and results of change.

The main aim of this paper was to identify homogeneous categories of the influence of Industry 4.0 technologies on business operations in the steel sector in Poland.

The paper is based on the results of quantitative empirical research conducted in a pilot segment of steel sector enterprises in Poland. The research was an experiment in ordering the areas of influence of key Industry 4.0 technologies (developed and implemented SM projects) on improving business operations. The study involved 79 companies, which were sorted by size into small, medium, large and very large based on the number of people employed. The paper consists of a theoretical part based on the literature review and an empirical part—the results of direct research carried out in the segment of steel companies in Poland. In our research, we try to do research connected with the problems about transformation of the Polish steel industry to Industry 4.0.

The research is a part of a large research area of the author B. Gajdzik, within the framework of a scientific project entitled: ‘Transformation of the Polish steel industry to Industry 4.0’. The presented part of the research concerns the influence of changes based on realized SM projects in the steel sector in Poland in the area of research on the influence of SM projects on business activity in study enterprises on the basis of respondents’ knowledge about realized projects in their enterprises.

In our research we formulated the following research question: What are the main categories of the influence of the SM Industry 4.0 projects on business operation in the Polish steel sector.

**Hypothesis (H1).** *The main category of the influence of the SM Industry 4.0 projects on business operations in the Polish steel sector is quality and personalization.*

**Hypothesis (H2).** *The most important categories of the influence of the SM Industry 4.0 projects on business operations in the Polish steel sector have an influence on the innovativeness of the industry.*

## 2. Literature Review

Industry 4.0 technologies are introduced in companies and supply chains [8]. The scope of the changes introduced can be micro (enterprise), meta (region) or macro (economy) [9]. Research on the effects of Industry 4.0 on the manufacturing process is also being conducted in the area of the functioning of societies [10] and the achievement of sustainability [11]. Research about influence of new technologies on business is realized by academics, companies and organisations (e.g., Deloitte, BCG, McKinsey, PwC, Astor, Siemens, Mitsubishi Electric Corporation) and government agencies in different countries. Research is local and sectoral or cross-local and multi-sectoral or comparative. Industry 4.0 is being implemented in many enterprises, very large and large enterprises, and SME (small and medium-sized enterprises) [12,13]. More and more companies have realised that Industry 4.0 is a necessity for the revolution that is happening.

Many benefits of Industry 4.0 have been presented in the literature, with a list of changes presented by Hermann et al. (2015) among others: increased productivity, improved working conditions, better product quality, unlimited access to information, resource savings, speed, precision and adaptability of production, optimised business planning, higher sales revenue, low equipment failure rates and increased plant reliability, product personalisation, etc. [2]. Among the benefits of Industry 4.0, the author of this publication studied the impact of Industry 4.0 technology on productivity, agility and speed, quality, competitiveness and enterprise value, profitability, workforce reduction, delivery improvements, vertical and horizontal integration, resource savings, operational cost reduction, technology adaptability, precision of machine operations.

The problems connected with new technologies are strictly connected with innovativeness. The increase of innovativeness should lead to the development of a new technological solution and its usage in organizations. According to K. Pavin, many technologies are complex and their effect is cumulative. Those technologies are used by organizations where the technological activity is dominant [14]. To have possibility to utilize an invention and turn it into a new innovation, an organization should combine human resources, information, material resources and financial resources. In addition, there is a need for a functional distribution system [15].

We can divide innovation into product, process and organizational innovations. In the steel production organization, especially important are process innovations [16–19]. Process (technological) innovation is a change in the company's manufacturing methods / methods of providing services, as well as in the ways of communicating to customers [20,21]. These methods may consist of changes in equipment or in the organisation of production; they may also be a combination of those two types of changes or result from the use of new knowledge [22–24]. They may aim to produce or provide new or improved products that could not be produced or they may aim to produce or deliver new or improved products that could not be produced or delivered by conventional methods [25]. They may also aim to increase the efficiency of the production or delivery of existing products. An example of process innovation may be the installation of new or improved production technology, such as, for example, automation of a production line [26–28].

Innovation, according to many studies, can lead to reduction of the use of resources and all the internal processes within the organization can be optimised [29]. Now, a very important topic of international researchers is also connected with problems like: the influence of Industry 4.0 on innovativeness, the consumer response on the new products and created innovations, portfolio management, strategy to enter new markets, strategies of market retention, survival strategies, methods of marketing in web environment, the complexity of production and service processes [30,31]. In addition, an important problem is connected with the analysis of an impact of business innovations on performance of particular organization [32]. Some researchers also try to analyse relations between inno-

ventions and sales and profits [33,34]. They think that innovative companies have better sales and profits compared to non-innovator companies, especially when policies and legal certainty in the country are consistent.

According to international specialists [35], the implementation of Industry 4.0 can maximise the potential for innovations especially in the case of new services and new business models. The implementation of new technological solution can lead in organizations to an increase of the potential of the business capacity and can lead to better business operations [36,37].

There are many industry trends connected with new, Industry 4.0 connected solutions. Especially among new top 10 Industry 4.0 trends, we can distinguish: human augmentation and extended reality; artificial intelligence; network and connectivity; cloud computing; internet of things; advanced robotics; additive manufacturing; big data analysis; digital twin and cybersecurity [38].

Many Industry 4.0 related technologies have an impact on business models used by organizations. The Industry 4.0 conception is usually connected with very rapid innovations called disruptive innovations [39]. They have a very big impact on radical and rapid changes in the technological processes used by a particular organization. To face digital transformation by organizations in the direction of Industry 4.0, it needs to deal with many very important issues like: flexibility and personalization; networking and reduction of barriers; low price; local production fragmentation of value chain; smart good and services; fragmentation of the value chain; integration of production systems, globalization and decentralization of production [40–43].

Industry 4.0, especially digital transformation, should incorporate in the organization many new innovative solutions [44,45]. The major challenges for this digital transformation are [46]: limited experience with transformation, limitation in skills and resources, cultural limitation, complex relationships with many business partners, huge upfront investment. To deal with those problem, it is important to use an open innovation based approach. The conception of open innovation refers to a paradigm that assumes potential use by the organization of external ideas together with internal ideas and conceptions when the organization tries to implement a new technology, product or solutions [47].

In the steel industry, the diffusion of new processes and technologies is connected with an increase of interactions between producers and users and suppliers, and leads to deepening the system of production and innovations. The implementation of Industry 4.0 solutions gives this industry an opportunity to build a innovative and competitive organization which focuses on incorporation of autonomous processes.

According to Peters' researches, we can distinguish the following main implications of Industry 4.0 on the functioning of steel industry [48]:

- full traceability of the partial products and final product,
- the usage of Cyber Physical Production Systems within the plant,
- intensive communication and network of all plants inside the company,
- intelligent production systems are given the opportunity to have knowledge about their own quality and their production history,
- suitable handling and usage of the data,
- intensive communication systems along the whole supply chain,
- decentralization instead of the usage of central solutions.

Analysing the processes of implementation of Industry 4.0 solution in the steel industry, we should take into account that the current demand of steel mills for Internet of Things technology is rather low [49]. This is mainly because IoT platforms as yet are not mature enough and also because steel industry organizations are reluctant to share their data. This could be the problem with the implementation of new Industry 4.0 technologies. Steel industry organization also have some concerns connected with data security because organizations do not want to share all their internal information with the external environment. They are also afraid of cyberattacks which can be increasingly frequent in the future. For example, de Paula [50,51] cited two cyberattacks on steel mills. In one of them, there

was physical damages connected with preventing operations of the blast furnace. In this context, there are some obstacles connected with implementation of innovative Industry 4.0 related solutions in the steel industry.

The implementation of Industry 4.0 brings organization many benefits, but we can also find some barriers in this process [52–56]. To the main barriers in the Industry 4.0 implementation, we can include on the basis of a literature analysis: work circumstance and human resources, the lack of financial resources, problems with standardization, risk of fragility, problems connected with cybersecurity and ownership of data, the integration of technology, problems with coordination of organizational units, the lack of activities and planning skills, organizational resistance [52,57–63].

The main barriers for the implementation of Industry 4.0 projects in metallurgical companies are: (1) high prices of raw materials, including energy (transitional stage related to the European policy of diversification of energy sources), (2) lack of human resources on the labour market with IT skills on the basis of metallurgical knowledge (in Poland, out of 14 technical universities, the faculty of Metallurgy is run by four universities [64]), (3) situation in the steel market in Poland (persistent negative balance of foreign trade since 2005, an increase in the share of steel imports from countries outside the EU in steel consumption in Poland, a decrease in steel production in the period of the COVID-19 crisis, etc.) [65].

Oláh et al. [66], analysed the negative and positive impact of Industry 4.0 on organizations in the context of sustainability. The team of authors performed a systematic literature review on the topic of the impact of Industry 4.0 on the organisation. In the analysis of publications, the authors divided the impact of Industry 4.0, including technologies that build Smart Manufacturing, into several segments. The base (start) segment included: Added Value to Consumers and Additional Values to Companies. Subsegments were a breakdown of the impact of technological solutions of I 4.0 on the organisation and its business processes according to different scenarios in the context of sustainability, and the last two by benefits and by disadvantages and advantages of I 4.0. The list of advantages includes: flexibility, production efficiency, increased economic stability in the market, higher product quality, personalisation, customisation, reduced cost, co-operation in supply chain, saving of resources, etc. On the basis of this study [66], and the publications of other authors [67–71], it can be assumed that the areas of influence of I 4.0 technology or Smart Manufacturing projects on business operations typified in the publications can also be the subject of empirical research.

### 3. Methodology

In analyses of the influence of Smart Manufacturing (SM) projects on business operations, quantitative empirical research on the steel sector in Poland was realized. The tool of research was a questionnaire. The questionnaire was developed with the participation of experts from the steel industry in Poland. The experts were: scientists, employees of technical universities and scientific institutes, representatives of industry institutions associated with the surveyed companies, and the management staff of the companies. The questionnaire was validated using descriptive statistics, e.g., internal correlations between dimensions. Prior to the actual research, the questionnaire was re-evaluated by experts whose knowledge of SM was verified through screening questions. The range of screening questions addressed the essence of the Industry 4.0 concept and individual technologies. Those who did not obtain the required score in the expert knowledge test did not participate in the questionnaire versioning. The research was conducted among 79 companies, between December 2019 and June 2020. The segment of companies was too small for scientific research; therefore, the results were presented as a pilot. The enterprises were differentiated by size according to the number of employees: a very large enterprise employed more than 500 people, a large enterprise between 250 and 500 people, a medium enterprise between 50 and 250 people, and a small enterprise up to 50 employees. The share of very large enterprises in the total was 20.3%, the share of large enterprises

was 36.7%, medium enterprises was 21.5%, and small enterprises also was 21.5%. The enterprises belonged to the steel sector in Poland. All enterprises are realising the SM projects aiming at increasing productivity. Participants in the research were representatives of the surveyed companies: middle management, employees on independent positions in production processes, operators of key technologies, and representatives of the segment: experts, including persons combining scientific and industry functions. Participants were selected based on a question checking their knowledge of Industry 4.0 and applied 4.0 technologies in the steel sector. The analysed categories of influence of the SM projects on business operations are presented in Table 1. The categories presented in Table 1 are a form of grouping the experts' statements on the influence of Industry 4.0 on business processes in metallurgical enterprises. The list is open and does not exhaust all aspects of the positive impact of the introduced smart solutions in steel enterprises. The scope of changes is much more extensive than used in the research. Steel companies in Poland have only started to build Industry 4.0 [18,19]. A leader of change in the Polish steel market is ArcelorMitta, which implements digital projects strongly associated with Industry 4.0 technologies. On the company's website, chief technology officer Pinakin Chaubal presented the key areas of changes [72], such as: centres of digital excellence, Data collection, drones, automation, Artificial Intelligence (AI), digital twinning, Virtual reality (VR). The adoption of many projects has been accelerated by the decreasing cost of capturing, storing, and computing information. Additionally, the innovational solutions are creating potential savings related to energy, water, and wear and tear on machinery.

Descriptive statistics in the paper used: for questions rated using a Likert scale from 1 to 5, where 1 is the most vivid rating and 5 is the highest rating, a measure of symmetry of distribution and a measure of concentration of distribution were used (for each of the 11 categories of impact of SM projects on business processes studied). In order to determine the association between the impact of the projects on business operations and the size of the company, the analysis of variance Tukey's test for the comparison of multiple groups and Chi-square test of dependence were used). In addition, using Excel and Rstudio, basic tests of static significance were applied, including: the Bartlett test and the KMO-coefficient to assess the adequacy of the correlation matrix we use—the Kaiser-Mayer-Olkin coefficient. Using descriptive statistics—chi-square test:  $p < 0.0001$  it can be concluded that there is a statistically significant difference in the evaluation of the impact factor of the project on business processes and the size of the company. The greatest impacts were assessed by the very large enterprise segment.

**Table 1.** Categories of influence the SM projects on business operations.

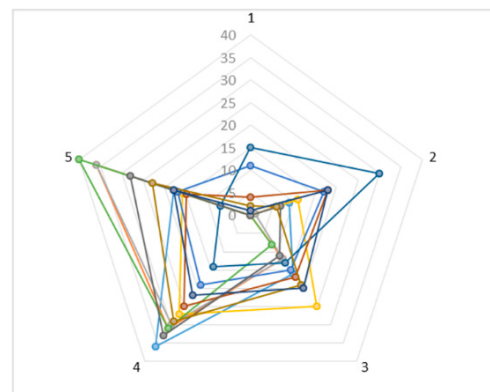
| Number of Category | Name of Category            | Description of Category                                                                                                                                                                                                                                                                                |
|--------------------|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R_1                | productivity and management | Influence of SM projects on machinery productivity and improved energy and raw material management                                                                                                                                                                                                     |
| R_2                | speed and agility           | Improving the analysis of production and production-related processes by obtaining information about the entire process in real time and through intelligent decision-making systems (Intelligent Decision-Making) with AI algorithms and high speed information technologies (High Speed Information) |
| R_3                | adaptability and precision  | Increasing the ability to perform business processes and the accuracy of operations, as well as increasing the speed of operations in entire production systems                                                                                                                                        |

**Table 1.** *Cont.*

| Number of Category | Name of Category                     | Description of Category                                                                                                                                                                                         |
|--------------------|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R_4                | flexibility and reliability          | Increasing the flexibility of business processes through quick responding to changes and increase of the reliability of machinery operation—less technological downtime                                         |
| R_5                | staff and manual reduction           | Reducing the number of direct production workers and manual activities                                                                                                                                          |
| R_6                | quality and personalisation          | Improving the quality of products and increasing the personalisation of products—greater possibility of individual adjustment of products and services to customer needs, including the reduction of complaints |
| R_7                | cost reduction                       | Decreasing of the costs of production and other business costs                                                                                                                                                  |
| R_8                | profitability                        | Increasing of the profit: income from the production of unique products of high quality and personalized products in relation to production costs                                                               |
| R_9                | enterprise value and competitiveness | Increasing of the market value of the enterprise through automation and robotization of operations (substitution of manual work by technology) and smart technological solutions                                |
| R_10               | supply and cooperation               | Increasing the flexibility of deliveries according to the JiT concept (quick and improved order processing)                                                                                                     |
| R_11               | integration and block chain          | Increasing the involvement of companies (capital groups) in supply chain management (product tracking) and block chain activities on the steel global market                                                    |

#### 4. Results of the SM Projects in Steel Enterprises Based on Empirical Research

The analysed results of the influence of the SM projects on enterprise operations were evaluated on a scale from 1 to 5, where 1 was a very low impact, and 5 the highest impact of projects on the enterprise operations. The results of analyses are summarised in Table 2 and Figure 1.



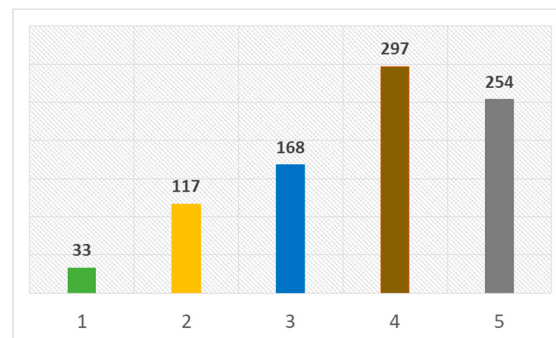
**Figure 1.** Assessments of the influence of realized SM projects on business operations. Source: own research [73].

**Table 2.** Influence of the Industry 4.0 projects on enterprise operations.

|       | 1  | 2   | 3   | 4   | 5   | Total |
|-------|----|-----|-----|-----|-----|-------|
| R_1   | 0  | 9   | 16  | 36  | 18  | 79    |
| R_2   | 0  | 0   | 12  | 31  | 36  | 79    |
| R_3   | 0  | 1   | 12  | 30  | 36  | 79    |
| R_4   | 0  | 11  | 25  | 27  | 16  | 79    |
| R_5   | 11 | 17  | 15  | 19  | 17  | 79    |
| R_6   | 0  | 0   | 8   | 31  | 40  | 79    |
| R_7   | 15 | 30  | 13  | 14  | 7   | 79    |
| R_8   | 4  | 18  | 17  | 25  | 15  | 79    |
| R_9   | 0  | 7   | 11  | 33  | 28  | 79    |
| R_10  | 2  | 6   | 19  | 29  | 23  | 79    |
| R_11  | 1  | 18  | 20  | 22  | 18  | 79    |
| Total | 33 | 117 | 168 | 297 | 254 |       |

Source: own research [73].

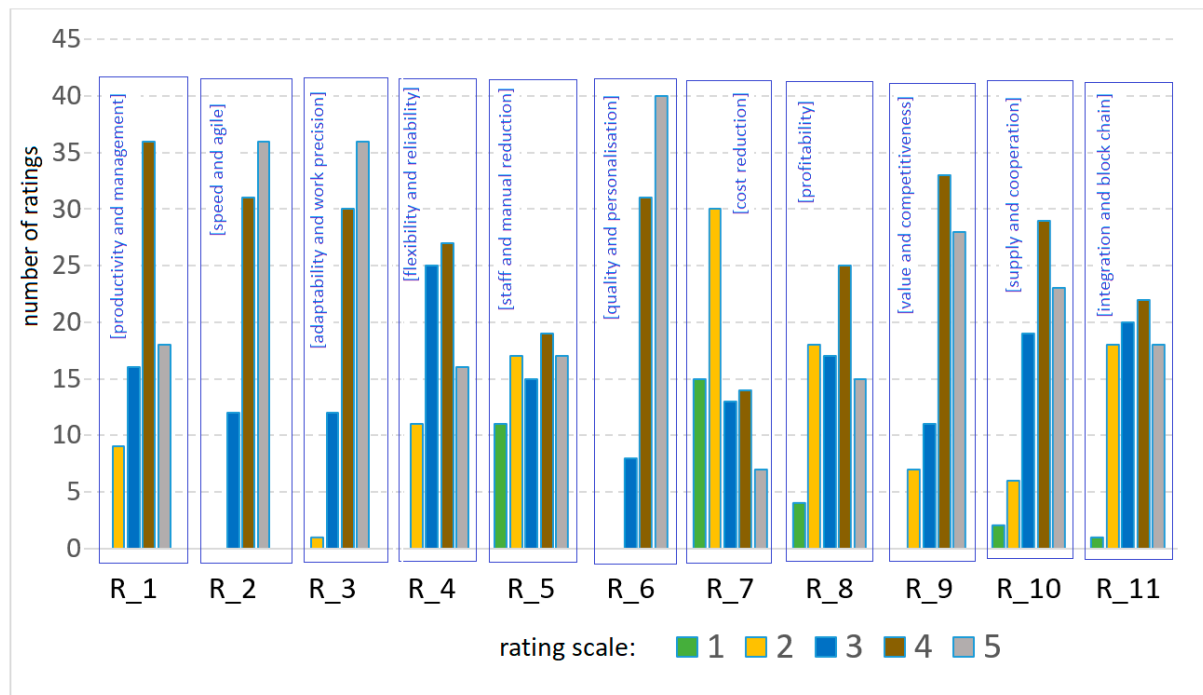
On the basis of the radar diagram, it was found that the companies evaluated the individual impacts by selecting medium (3), high (4) or very high (5) evaluation. The evaluation of low (2) and very low (1) was chosen by few companies (their share in the total number of companies did not exceed 25% with the exception of category R\_7—the impact of implemented projects on the reduction of operation costs (18.99% of companies indicated a very low evaluation (1) and 37.97% a low evaluation (2). Low ratings for category R\_7 indicate the lack of a strong impact of the implemented projects (at the current stage of change) on the costs of operations. The next figure shows the sum of the companies' choices. The highest number of indications was for positive evaluation—297 times evaluation 4 was chosen and 254 times evaluation 5 was assigned (Figure 2).

**Figure 2.** Total indications according to the used scale from 1 to 5 for all categories. Source: own research [73].

The next step was to analyse the particular categories of the impact of Industry 4.0 technology on company operations (Figure 3). In the categories: 'quality and personalisation' and 'speed and agility', there were no low—no ratings: 1 and 2. These two categories were rated high and very high—in terms of the positive impact of technology on enterprise operations. In four categories: 'productivity and management', 'adaptability and work precision', 'flexibility and reliability', 'value and competitiveness', there was no rating of very low—1. The most highly rated categories (5 points) were: 'speed and agility' and 'adaptability and work precision', and the category with the lowest scores was 'cost reduction'.

The results of the research were ordered according to the impact of Industry 4.0 (SM projects) on the operations of enterprises, taking into account only the highest scores

assigned by companies to various projects (4 point or 5 point). The ordered categories from the highest to the lowest scores are presented in Table 3.



**Figure 3.** Distribution of ratings according to different categories of influence of SM projects on enterprise operations. Source: own research [73].

**Table 3.** Influence of the SM projects on business operation according to categories with the highest ratings.

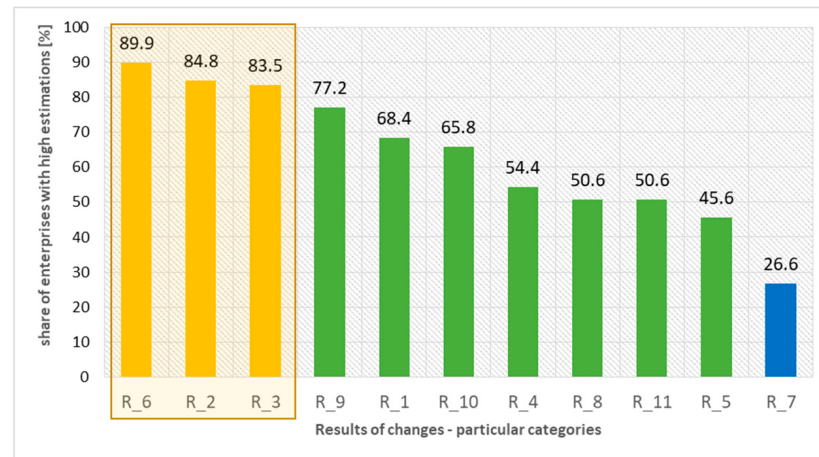
| Position | Symbol | Category                                       | Number | %    |
|----------|--------|------------------------------------------------|--------|------|
| 1        | R_6    | quality and personalisation                    | 71     | 89.9 |
| 2        | R_2    | speed and agility                              | 67     | 84.8 |
| 3        | R_3    | adaptability and work precision                | 66     | 83.5 |
| 4        | R_9    | value and competitiveness                      | 61     | 77.2 |
| 5        | R_1    | productivity and management                    | 54     | 68.4 |
| 6        | R_10   | supply and cooperation                         | 52     | 65.8 |
| 7        | R_4    | flexibility and reliability                    | 43     | 54.4 |
| 8        | R_8    | profitability                                  | 40     | 50.6 |
| 9        | R_11   | integration and block chain                    | 40     | 50.6 |
| 10       | R_5    | staff reduction and manual operation reduction | 36     | 45.6 |
| 11       | R_7    | cost reduction                                 | 21     | 26.6 |

Source: own research [73].

The top three ranked categories for assessing the impact of SM projects on improving business operations are: ‘quality and personalisation’, ‘speed and agility’, ‘adaptability and work precision’. The results obtained in the paper support the fifth hypothesis that the main category of the influence of the SM Industry 4.0 projects on business operations in the Polish steel sector is quality and personalization. It can be observed that problems connected with quality of the product and its personalization for particular customers are the most important in the case of influence of the SM projects on business operations.

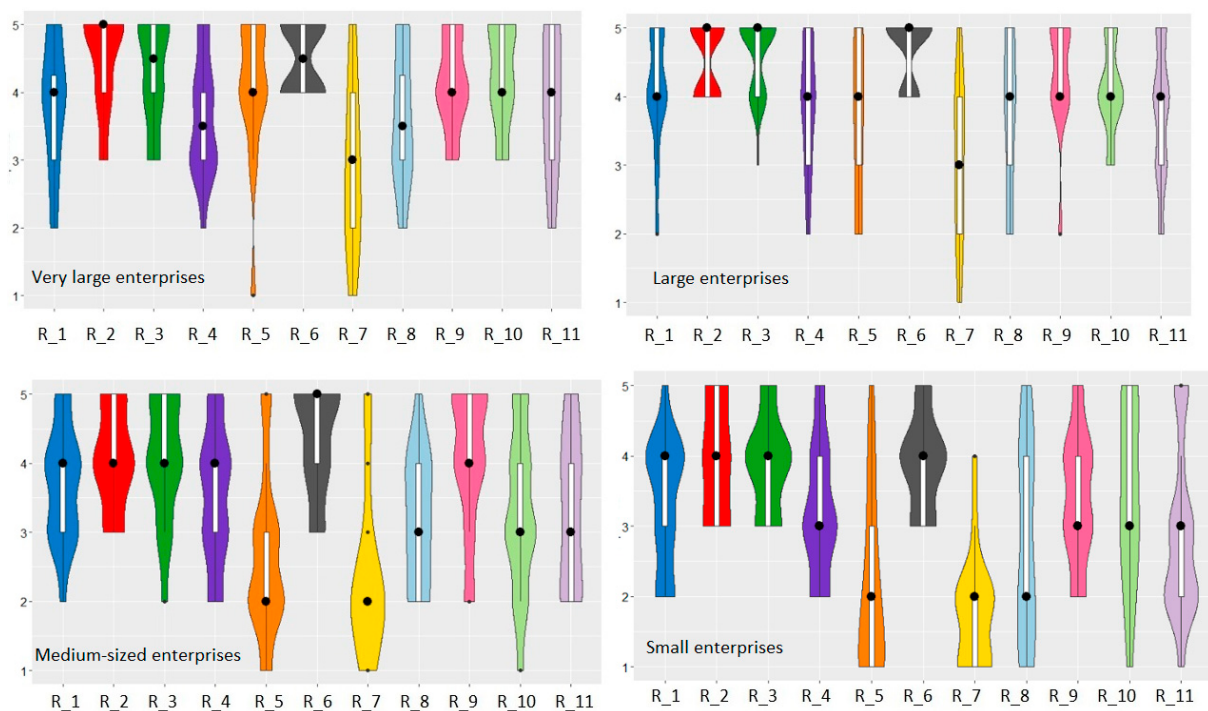
More than 80% of companies indicated these effects as the most important during the implementation of SM projects, assigning them high or very high ratings—points 4 or 5

(Figure 4). On the other hand, the least high marks were given to the effect named: ‘cost reduction’—only 26.6% of the companies assigned high ratings to individual SM projects when assessing their impact on reducing operating costs. The impact of SM projects on cost reduction depends on the ROI of each project and the surveyed companies expect a decrease in production costs only after a comprehensive implementation of multiple, related projects that allow the companies to achieve a high level of smart maturity.



**Figure 4.** Ranking of the impact of SM projects on enterprise operations based on high scores. Source: own research [73].

The final stage of the research was to present the resulting assessments of the impact of the Industry 4.0 concept on company operations by company size. The results of the analysis are given in the charts (Figure 5).

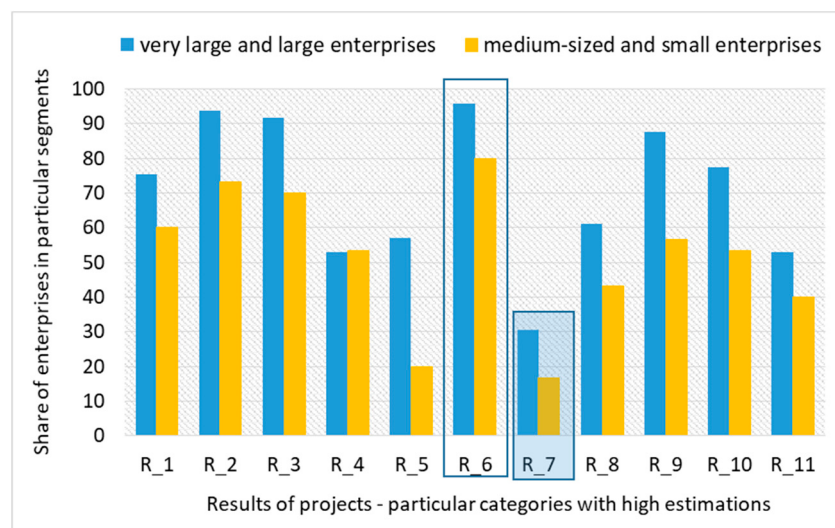


**Figure 5.** Influence of SM projects on business operations in particular segments of enterprises. Source: own research [73].

In all groups of enterprises, what deserves special attention is above all the use of Industry 4.0 technology in order to increase the quality of products and the possibility of

servicing new sales markets, a greater possibility of individual adjustment of products and services to customers' needs, which has an impact on the decrease in product complaints (category: quality and personalisation). In this category, all respondents gave high answers. The respondents also gave high marks to the impact of the surveyed concepts on the analysis of production and production-related processes in real time/Intelligent Decision-Making systems/increase in the speed of data transmission and use of information (High Speed Information) and on greater ability to implement processes and greater accuracy, greater speed of operations, greater supply of information. Then, for very large, large and medium-sized enterprises, also an increase in the market value (competitiveness) of the enterprise through automation and robotisation of work (replacement of manual work with technology) is important, as well as for very large and large enterprises higher flexibility of supplies—JiT/quick realization of suppliers/improved order picking. According to all respondents, implementation of Industry 4.0 technology has relatively the smallest impact on cost reduction. Medium and small companies also do not feel a reduction in the number of employees (direct production) and a reduction in manual operations.

At the end of the study, the highest scores were compiled for the two segments. The first segment was formed by very large and large companies, and the second segment by medium and small companies. On the basis of the obtained assessments, it was found that very large and large companies (together) rated the individual categories of the influence of SM projects on the improvement of operations much higher than the segment of medium-sized and small companies. The results of the analysis are presented in Figure 6. The highest scores in these segments have the category 'quality and personalisation' and the lowest 'cost reduction'. The studied segments differed the most in the assessment of the 'staff reduction and manual operation reduction' category—the segment of medium and small companies did not share the opinion of very large and large companies as regards the visible influence of SM projects on the reduction of staff and labour intensity.



**Figure 6.** Ratings for particular categories in all enterprises divided into two groups. Source: own research [73].

## 5. Discussion

The adjustment of business operation in the steel sector in the Industry 4.0 condition can lead to the better innovativeness of this business. Many categories of influence of SM projects on business operation in the steel sector are strictly connected with the increase of the innovativeness of the sector in the case of a totally new solution or small adjustment of production of services processes.

The best ranked category in our research was quality and personalisation of the products. Some international studies point out that the increase of quality is connected with

new innovative solutions [74]. For example, there is some indirect evidence about the effect of quality on the relationship between innovativeness and the organization performance. Especially, a new product on the market should have a good quality level to have potential to achieve success on the market [75]. Maruyama has developed on the basis of his research a model of relations between quality and innovativeness. He thinks that the better quality leads to better innovativeness and this leads to growth of the organization [76]. In the times of Industry 4.0, there is a conception Quality 4.0—which means the use of an Industry 4.0 technological solution in the area of quality [77]. The implementation of Quality 4.0 and quality improvements in much research, like in our paper, is one of the most important elements of proper Industry 4.0 implementation [78].

We think that in as competitive a market as the steel sector, to have a possibility to sell the product to customers is connected with very good quality. This means we need to implement the Quality 4.0 conception to increase the quality of production processes in the steel sector. Quality is also strictly connected with the personalisation of the product. The better quality nowadays means the better adjustment of the product to specific customer needs. The customers in industry should be able to produce products best tailored for the customer's needs, tastes and their lifestyle [79]. Even in a big organization, the paradigm of mass production has changed in the last years and we can observe the tendency to produce products tailored to particular customer needs [35,80–84]. The personalization of the product can allow customers to feel that they are important for us—this is as important on the industrial market as in the steel sector. In those sectors, organizations use so called mass customization of the product which is a personalization of the product in a big organization with mass production systems—like in the steel sector [85–87]. It leads to personalization of products and services at the mass-production process for the mass customer. This leads to new process innovation which can give the steel sector company a competitive advantage on the market [88,89].

The next very important category, according to our research, which leads to a positive impact of Industry 4.0 on business operations, is connected with better speed and agility of an operation. Industry 4.0 is widely analysed and presented in modern publications [90]. Companies can implement single projects or an integrated complex project to be smarter than before the investment. To win on the competitive market, an organization should to be agile, especially in the case of operational management and development [91–94]. When we want to implement a new, innovative solution, within an organization, the agility leads to strengthening of the team role and gives the possibility for easier implementation of the adjustment of the production process to new solutions [95–97]. The implementation of Industry 4.0 in the steel sector because of better agility will improve the potential of this industry to grow and develop in a competitive market. According to international researchers, agility refers to important abilities connected with possibilities to cope with a dynamic, difficult business environment and because of that, an organization can adapt, sense, and respond on environment demands [98–100]. Strategic agility in times of Industry 4.0 is a set of activities implemented by a particular organization which can add value in the forecast and volatile business conditions [101,102]. This type of agility in their business operations helps organization to avoid so called rigidity traps and also problems with over-focusing their activities on external embeddedness [103–107]. The better flexibility achieved in this way leads to easier implementation of new, Industry 4.0 technological solution within the organization.

The speed of operation is also a very important factor which can be better because of new Industry 4.0 project implementation. Speed can be defined as the time between initial development efforts in the case of a particular product and the introduction of this product on the marketplace [108]; but it should be taken into consideration to link the speed of the new project with the quality of processes. In some situations, the speed of new solution implementation on the market, when it is not linked with extensive quality, can lead to non-fulfilling customer needs and decreasing the level of the overall customer satisfaction [109]. Today, the speed in the process of project and product realisation is very

important because of big competitiveness. In the literature, there is a division of two main determinants of new, product success: the innovativeness of the product and the speed of its implementation on the market [110]. The new product development and its speed is a critical source of organization competitive advantage on today market. It could lead to the creation of competitive differentiation, establishing an entry barrier on the market, increasing revenue and the potential to open a new market for the organization's product. Speed can also give the organization the possibility to circumvent limitations of a weak legal system in a particular country. It can give the possibility, for example, to protect the value of innovation, which is very important in the case of steel industry [111].

The next very important factor of Industry 4.0 solution implementation in the steel sector is connected with adaptability and work precision. According to the Tuominen, adaptability can drive organization innovativeness level. He found that many components of adaptability have a positive impact on the innovativeness of the organization. Because of that, managers wanting to achieve better innovativeness should concentrate on simultaneously addressing the market, technology, and issues related with the organization. This can lead to the conclusion that the positive impact of new Industry 4.0 projects in the steel industry on adaptability can also lead to better innovativeness in this industry [112].

The analysis presented in the discussion positively supports the hypothesis H2 that the most important categories of the influence of the SM Industry 4.0 projects on business operations in the Polish steel sector have an influence on the innovativeness of the industry. All the most important factors are strictly connected with innovativeness and on the basis of this, it can be supposed that the implementation of a Industry 4.0 solution in the Polish steel sector has a positive influence on the level of innovativeness within this sector.

On the basis of our own research [113], we can say that the three most important factors of Industry 4.0 related projects implementation in the steel industry—R\_6 quality and personalisation, R\_2 speed and agility, and R\_3 adaptability and work precision—can have a positive influence on innovativeness in this industry, especially process innovations in the field of business operation. This conclusion, we think, means that the whole implementation of an Industry 4.0 related solution has a positive effect on the steel industry organization and its activities. We can say that the implementation of Industry 4.0 in this industry can be very beneficial and organizations should do it to adjust their business operation to today's competitive market. Without implementation of Industry 4.0 solutions, it will be difficult to beat the competitors, giving to the customer good quality innovative products which can fulfil their expectations.

Our research shows that implementation of Industry 4.0 solutions can lead to an increase of the quality of products and the possibility to achieve a good level of customisation—the adjustment of this product to the particular customer needs. This is very important to achieve success on the steel industry market. In addition, some other international researchers pointed out that the quality of the product is one of the most important factors on this market [114,115]. The analysed sector of industry takes an important place in the economy, so the realized changes are very important for its development on the way to Industry 4.0 [116]. Besides the analyzed results, we realized research about the influence of Industry 4.0 innovations on energy efficiency in the steel sector of industry in Poland [117]. When the steel mills invest in new technologies of Industry 4.0, the energy intensity and resources intensity falls [118,119].

Industry 4.0 is an ideal model to which companies aspire. In the steel sector studied in our paper (pilot study), changes are being implemented that make production smarter. Each company establishes its own internal path towards the ideal concept of smart manufacturing. In direct research, researchers (scientists, consulting companies) try to determine the different scope of changes implemented on the way of enterprises to Industry 4.0 and their generalization to the needs of a new business model and a new value chain. Universal constructs for enterprise maturity models for Industry 4.0 have not yet been developed. Government organisations are testing the first digital maturity models on Industry 4.0 platforms, and consulting companies are offering their maturity measurement services.

This publication is a form of participation in the research on change, and the scope of the research will be developed along with the expansion of SM projects in companies and the willingness of companies to share quantitative results of the changes, rather than just expressing opinions in the form of a description of the post-positive impact of projects on business processes.

## 6. Conclusions

On the basis of the research, it has been established that in the course of implementing projects aimed at modifying production technology towards smart production, enterprises from the steel sector in Poland mainly perceive benefits related to ensuring a high quality of products and personalisation of the market offer—the category ‘Quality and personalisation’ was highly ranked. High positions in the ranking of assessments of the impact of Industry 4.0 technology on enterprise operations were also given to the categories ‘speed and agility’, ‘adaptability and work precision’. The lowest scores were given to the ‘cost reduction’ category. At the current level of implementation of SM projects in companies, the cost reduction of operations is the least visible (for companies) criterion of project implementation.

The results obtained in the research positively support hypothesis H1, that the main category of the influence of the SM Industry 4.0 projects on business operations in the Polish steel sector is quality and personalization, and H2, that the most important categories of the influence of the SM Industry 4.0 projects on business operations in the Polish steel sector have influence on the innovativeness of the industry.

The changes in enterprises that have joined the creation of Industry 4.0 will be implemented over the next decades and will be more and more radical. The creation of new solutions of flexible cyber-production will require many changes of various levels of enterprises’ functioning. The purpose of this publication was to present the empirical results of project impact assessments in enterprises that are already on the way to Industry 4.0. The general conclusion of the research is as follows: at the current stage of transformation of steel enterprises in Poland to Industry 4.0, companies focus on market criteria: quality and personalisation, and operational criteria of implemented changes, including the speed of performing operations by new technologies, agility, and flexibility of operations through equipment access to data in real time and their use to optimise processes, and the accuracy of performed operations by machines with a high degree of independence from humans and their activities.

Especially, the open innovations and business models connected with open innovation can be useful in this case [120–123]. Business models are useful concepts of organization functioning that describe the methods particular businesses use. Especially, open business models are useful to benefit open innovation [124–126]. In the case of Industry 4.0, there are not for now identified business models especially dedicated to this conception. In the future in the steel industry, an organization should try to prepare and implement open business models which are more innovative compared to traditional business models [127–129]. In the steel industry, to have a successful open business model which boasts innovativeness, it is very important to properly link the current business model and perform an extensive review of the process of commercialization of the product to use the non-linearity of the innovation process. On this base, an organization can define its innovative abilities and define the moderators of the innovation process for particular steel industry enterprise [20,23].

Our research has some limitations. The first limitation is connected with the operability of the variables. Other researchers could use another form of questionnaire than used in the research and other questions (variables) in the questionnaire. The second limitation is connected with the sample of researched companies. The sample was relatively small (79 companies) and so we cannot use the results as representative research; it is rather a case study about the situation in Poland. We think the results are a good view on the problem but the topic needs more research.

We think that in the future, it would be good to do the research on a bigger sample to obtain statistically representative results. It would also be interesting to do the research in other European Union countries to compare results. In addition, the next research could give us a dynamic view on the problem and give the opportunity to compare how the situation of Industry 4.0 implementation in the case of its influence on business operation in Poland is changing in time.

The main theoretical implication of the study is a categorization of the influences of the SM projects on business operation and the rating of these categories in the Polish steel sector. It gives us an opportunity to build the model of factors with the biggest positive effect in the case of Industry 4.0 implementation in the steel industry. It also has practical implication because the organization knows that the Implementation of Industry 4.0 in this sector can bring the organization many potential benefits. In addition, the model of categories with their ratings can be used to manage an organization. The main important factors are those that needed special attention. Organizations wanting to improve their business operation should improve these areas of their business especially: quality and productivity; speed and agility; and adaptability and work precision.

**Author Contributions:** Conceptualization, B.G. and R.W.; literature review: R.W., and B.G.; methodology B.G.; validation, B.G. and R.W.; formal analysis, B.G.; investigation, B.G. and R.W.; writing—original draft preparation, B.G. and R.W.; writing—review and editing, B.G. and R.W.; funding acquisition, B.G. and R.W. All authors have read and agreed to the published version of the manuscript.

**Funding:** BK The analysis in this publication was made in the course of an internal research project at Silesian University of Technology 13/010/BK\_22/0065, 13/010/RGJ21/0055 and 11/040/RGP20/0020.

**Institutional Review Board Statement:** According to our University Ethical Statement following the following shall be regarded as research requiring a favourable opinion from the Ethic Commission in the case of human research (based on document in polish: <https://prawo.polsl.pl/Lists/Monitor/Attachments/7291/M.2021.501.Z.107.pdf> (accessed on 4 February 2022)): research in which persons with limited capacity to give informed or research on persons whose capacity to give informed or free consent to participate in research and who have a limited ability to refuse research before or during their implementation, in particular: children and adolescents under 12 years of age, persons with intellectual disabilities persons whose consent to participate in the research may not be fully voluntary prisoners, soldiers, police officers, employees of companies (when the survey is conducted at their workplace), persons who agree to participate in the research on the basis of false information about the purpose and course of the research (masking instruction, i.e., deception) or do not know at all that they are subjects (in so-called natural experiments); research in which persons particularly susceptible to psychological trauma and mental health disorders are to participate mental health, in particular: mentally ill persons, victims of disasters, war trauma, etc., patients receiving treatment for psychotic disorders, family members of terminally or chronically ill patients; research involving active interference with human behaviour aimed at changing it research involving active intervention in human behaviour aimed at changing that behaviour without direct intervention in the functioning of the brain, e.g., cognitive training, psychotherapy psychocorrection, etc. (this also applies if the intended intervention is intended to benefit (this also applies when the intended intervention is to benefit the subject, e.g., to improve his/her memory); research concerning controversial issues (e.g., abortion, in vitro fertilization, death penalty) or requiring particular delicacy and caution (e.g., concerning religious beliefs or attitudes towards minority groups) minority groups); research that is prolonged, tiring, physically or mentally exhausting. Our research is not done on people meeting the mentioned condition. Any of the researched people: any of them had limited capacity to be informed, any of them had been susceptible to psychological trauma and mental health disorders, the research had not concerned mentioned above controversial issues, the research had not been prolonged, tiring, physically or mentally exhausting.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Data are contained within the article.

**Conflicts of Interest:** The authors declare no conflict of interest.

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