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# Digital Revolution in Sustainable Business Models and Finance Management

Edited by
Adam Jabłoński, Marek Jabłoński and Dariusz Zarzecki

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Adam Jabłoński is Associate Professor and Head of Management and Quality Institute of UWSB MERITO University in Poznań, Is also President of the Board of a well reputable management consulting company "OTTIMA plus" Ltd. Katowice and Vice-President of the Association "Southern Railway Cluster" Katowice which supports development in railway transport and innovation transfer, also towards cooperation with European railway clusters (European Railway Clusters Initiative member). He holds a Postdoctoral degree in University of Łódź, (Department of Management), POLAND, specializing in Management Science (Business Models, Strategic Management). Working as a management consultant since 1997, his experience and expertise has grown through his contact with a number of leading companies in Poland and abroad. He is the author of a variety of studies and business analyses in the Strategic Performance Management Concept, Value Based Management, and designing of Digital, Social Business Models fields. He has also written and co-written several monographs and over 100 scientific articles in the field of management, published both in Poland and in abroad. Currently, He is also a member of Scientific Boards of International Journals (inter alia Management Decision (Impact Factor – 5.589) and/or he is the Scientific Reviewer in different entities (USA, India, Canada, Switzerland) and in Scientific Boards of National Journals and He is a Scientific Reviewer in many entities. He is also Member of Academy of Management, USA. Author of numerous monographs, publications, articles and scientific concepts published in Poland and internationally in prestigious publishing houses, including Taylor & Francis Group - Routledge, Palgrave Macmillan, Springer Nature, Cambridge Scholar Publishing, Nova Publishers, IGI Global. Author of many scientific articles published in world-renowned journals. Speaker at many scientific and industry conferences and congresses. Initiator of many scientific and business ventures.

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# Preface to "Digital Revolution in Sustainable Business Models and Finance Management"

At present, the digital economy is creating a new approach to sustainable development. In particular, this relates to the transformation of the traditional economy under the influence of digitalization on finance management processes. The digital economy is affecting changes in resource management processes. Dynamic digital transformation processes are currently taking place and exerting influence on the shaping of new business models. Existing business models are changing, particularly in the context of their life cycle [1]. The new economy means that social factors have greater importance in terms of creating value for people and the natural environment [2]. Trust for financial institutions, a factor in sustainable business models, is an important criterion in business research [3]. The economic model based on the irresponsible use of natural resources has been heavily criticized for years [4]. Societies are beginning to reject business models that have a negative impact on the environment. The use of natural resources should be responsible, especially in the context of investment. Digitalization in financial management processes and investments is a key challenge in theory and practice [5,6]. The impact of the digital revolution on the financial management strategies of enterprises and financial institutions has not yet been widely studied. Additionally, the phenomenon of digitalization in terms of its impact on shaping social business models should be subjected to extensive scientific research. Digitalization is changing the current order and balance of power in global business [7]. Additionally, this process means that traditional business model concepts need to be redefined [8]. The ecological aspects of the economy and their growing role in financial decisions require analysis and empirical verification. The digitalization of financial management processes, especially as it relates to sustainability, has not yet been widely analyzed and studied. Digitalization changes the current view of banking services and investment financing [9]. Additionally, it alters the current principles on which the processes of social economy are based [10]. Therefore, we believe that this topic requires extensive scientific research in order to develop a new and relevant perspective on the area. It is necessary to collect and verify the current state of scientific research in this field. The purpose of this Special Issue is to present the results of research on the current trends and challenges related to the digital revolution in financial management for sustainable development, an issue that requires extensive research and analysis.

On the basis of the above-mentioned assumptions, the key questions to answer are:

How does the digital revolution affect sustainable financial management strategies?

How does the digital revolution affect the shape of sustainable business models?

Does digital transformation support the assumptions of the Triple Bottom Line concept?

Does the digital economy have a positive impact on ecological aspects?

Does digitalization in financial management processes matter for the development of the concept of sustainability?

Do digital technologies increase the chances of optimizing the use of natural resources in economic processes?

How is trust in financial institutions changing in the context of the development of the digital economy?

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# Using Network DEA to Explore the Effect of Mobile Payment on Taiwanese Bank Efficiency

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**Abstract:** In order to explore the potential influence of new mobile payment services on the Ephesus model developed by Kao and Hwang (2008), we investigated the relative performance of 19 Taiwanese banks from 2018 to 2021. The network efficiency was divided into two parts: management efficiency and profitability efficiency. Only one bank achieved total efficiency from 2019 to 2021. The stage efficiencies showed increments during the first three years (2018–2020), but they declined in 2021. Most banks had low efficiency in the management stage and high efficiency in the profitability stage, suggesting that there are weaknesses in the management of physical resources but high awareness that mobile payment services can be exploited to achieve high profitability. Our results prove that mobile payment is a potential and profitable new service that Taiwanese banks should take advantage of. Comparing the results between the CCR model and the NDEA model, we observed that the NDEA model has more explanatory power, as it provides insight into the internal structure of the working process of Taiwanese banks.

**Keywords:** NDEA; Taiwanese banks; management efficiency; profitability efficiency; mobile payment

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## 1. Introduction

Technology is a driving force for development in many industries. Innovations in technology can lead to both social and economic growth. In 1912, Schumpeter first developed a theory of innovation based on technology and economics. Later, economists continued to expand this theory to explain the relation between technological evolution and economic development. In recent decades, the world has witnessed the rapid advancement of information technologies. The use of the internet and mobile phones has become a norm in both daily and business activities. E-commerce provides various advantages, including a large range of goods and services, accessibility, and an international reach [1]. This has led to new anxieties for both buyers and sellers. One party is anxious about the quality of goods and services, while the other worries about receiving their payments. Credit risks, identity theft, internet fraud, and fraudulent card use are problems that need to be addressed.

Mobile payment started as early as 1997, when Coca Cola first experimented with vending machines that accepted SMS payments [2]. Since then, alongside the development of e-commerce, mobile payment has been widely investigated. However, most research concentrated on how the technology has been applied and how consumers have adopted the new payment method [3–5]. There are other aspects of mobile payment that can be explored. One possible approach is to observe its impact on commercial banks, as mobile payments are both a complement and a substitute for banking services. Previous studies on this topic are very few and have usually focused on internet banking [6].

With the utilization of new technologies on mobile devices, mobile banking has become a popular banking channel offered by banks. It is now a worldwide phenomenon [7–9], with benefits for both customers and banks. Mobile banking services facilitate online

money transfers, automatic check payments, bill payments, savings plans, etc. The growth of this channel has helped extend the adoption of banking services to rural areas in both developed and emerging countries, which in turn has encouraged banks to adopt more services based on mobile technologies. Mobile payment services represent an aspect of this growing trend [10].

Moreover, new opportunities have been created through the fast evolution of e-pay technology. Instead of letting non-bank competitors take away potential customers, taking advantage of the new technology and providing mobile payment services not only generates more profit but also reduces costs for banks [11]. Along with mobile banking, various banks now allow their customers to pay utility fees using their banking app or offer point-of-sale services for cashless payment. One such service in Taiwan is Taiwan Pay, a mobile paying network that has the cooperation of 16 financial institutions. Even so, in addition to the benefits of mobile payment, banks have also had to face new obstacles. Different types of costs and risks are associated with developing and sustaining new services. As a result, it would be beneficial for banks to gain insights into whether adopting mobile payment would actually increase their profitability.

The purpose of this paper is to examine how mobile payment services affect the efficiency of Taiwanese banks using the shared-input network data envelopment analysis (NDEA) model. Data envelopment analysis (DEA) is a non-parametric mathematical programming technique that can be used to estimate the efficiency of a process in accordance with its inputs and outputs. The traditional DEA, or black-box DEA, first proposed by Charnes et al. (1978) [12], has been applied to a wide variety of research in the banking sector. However, as its name suggests, traditional DEA bypasses the finer details of a production process; the whole process is considered to be a black box, and it only focuses on how inputs create final outputs. Consequently, with this technique, when there is more than one stage, we are unable to observe what happens in the actual process. To compensate for this, NDEA, developed by Färe and Grosskopf (1996) [13], opens "the box" and lets us examine the internal structure of these frameworks.

Not many studies have used NDEA to examine the performance of the financial industry. Seiford and Zhu (1999) [14] were the pioneers in this field, who employed a two-stage NDEA to examine the profitability and the marketability of US banks. Kao and Hwang (2008) [15] proposed a method to calculate the efficiency of a two-stage NDEA using data from Taiwanese non-life insurance companies. Galagedera et al. (2017) [16] introduced a three-stage NDEA model to appraise the efficiency of US mutual funds. Zhou et al. (2019) [17] explored a bank's internal structure with three sub-stages: capital organization, capital allocation, and profitability.

The banking sector is one of the most important industries, and it is one of the main contributors to a country's wealth [18]. Wang et al. (2014) [19] indicated that the banking sector plays an increasingly critical role in the development of the financial system. With the development of mobile payment, it is important to explore its impact on the efficiency of banks. Berger, Hunter, and Timme (1993) [20] stated that for banks, efficiency represents profitability, capital inflows, consumer prices, improved service quality, and the security to increase capital buffers and absorb risk. Therefore, we referenced the works of Seiford and Zhu (1999) [14] and Kao and Hwang (2008) [15] and employed a two-stage NDEA model to examine the effects of mobile payment services on Taiwanese banks' efficiency in this paper. The model also exhibits shared resources, which are fixed assets and employees, since these inputs are needed in both stages to generate their respective outputs [17,21]. Using empirical research, we attempted to observe evidence of changes and investigate whether adopting e-payment services is a profitable decision for traditional banks.

Investigating the effects of mobile payments on efficiency has some significant benefits. Firstly, by understanding internal efficiency, banks would be able to evaluate the value of mobile payment services and utilize them to their full potential. Secondly, this research provides warnings about operational inefficiencies, allowing managers to reconstruct future strategies and reduce operating costs. Finally, this research can help the government under-

stand the situation and provide suitable regulations to encourage the further development of mobile payments. Moreover, there have been few applications of NDEA in research into mobile payments. Our paper contributes to bridging this gap in the literature.

In summary, our main research questions are as follows: Q1: Does mobile payment impact the performance of Taiwanese banks? Q2: Does NDEA have a stronger discriminating power in analyzing efficiency than traditional DEA methods in mobile payment cases? Q3: Does mobile payment influence management efficiency as well as profitability efficiency? Q4: How do inefficient DMUs improve their sub-branch efficiencies as well as their overall efficiency?

The structure of this paper is organized as follows: In the next section, we introduce mobile payment and the current situation in Taiwan. In Section 3, we summarize some of the literature regarding the NDEA model. In Section 4, we present our model and data. In Section 5, we analyze and discuss the results. The final section presents the conclusion.

## 2. Mobile Payment and Literature Review

### *2.1. Mobile Payment*

Electronic payment in general consists of an automatic teller machine (ATM), point of sale (POS), mobile money transfer (MMT), and online money payment (WEB). Among these, the use of ATMs began as early as 1967. Most platforms providing payment services were created by non-financial institutions. These services are referred to as internet third party payment (TPP) services, which connect to bank payments and settlement systems of e-commerce companies and commercial banks [22]. TPP is a method used to resolve obstacles related to trust and security between suppliers and consumers [23]. PayPal was a pioneer of this branch of service, having been offered in the US market since 1998. TPP has utilized the innovative payment technology offered by the internet to provide a safe and convenient environment for e-commerce practice [24].

The COVID-19 pandemic has had a heavy negative impact on household consumption, especially in urban areas. Most offline shopping has shifted to online shopping. Liu et al. (2020) [25] found that "mobile payment can improve transaction efficiency and facilitate consumption while overcoming the traditional space-time limitations. Thus, mobile payment can induce the transition from offline to online consumption." Furthermore, according to the State of the Union: Global Digital Payments and Fintech Ecosystem Report (2021) [26], digital wallets now account for a large proportion of global consumer spending. "In 2020, wallets represented 27% of in-store spending, 41% of e-commerce spending and 46% of m-commerce spending. By 2025, they will account for more than $10 trillion in global transaction volume between in-store and e-commerce." The pandemic created an environment for a larger and faster surge of mobile payments compared to the pre-pandemic period.

There are many studies regarding mobile payments and electronic payments. According to Dahlberg et al. (2015) [2], most studies focused on technological aspects or customer intentions. Oliveira et al. (2016) [27], for instance, used survey research and the SEM model to try to determine the key factors influencing the uptake of mobile payments and the likelihood that users would suggest this technology to others. Regression analysis was used by Humbani and Wiese (2018) [28] to examine customer preparedness to embrace mobile payment services and the moderating role of gender. Little research has paid attention to how companies, especially financial institutions, have adjusted to these accelerated changes and developments in technology. Therefore, this is a gap in the literature that can possibly be exploited.

According to the Financial Supervisory Commission's (FSC) data, there are 29 TPP institutions in Taiwan, including Jkopay Co., Ltd., O'Pay Electronic Payment Co., Gama Pay Co., Ltd., etc. The real e-payment transactions in July of 2020 amounted to 5.27 billion TWD (175.67 million USD). The government has also enacted various laws and acts to regulate electronic payment services and institutions. In 2019, the Financial Supervisory

Commission asked the Financial Information Service Co. to set up a platform that merged all services from all 29 electronic payment companies.

In addition to the international services offered by famous TPPs, such as Google Pay, Line Pay, Apple Pay, etc., Taiwanese banks started to introduce their own applications. Along with their own mobile banking apps, 16 Taiwanese banks cooperated to create a mobile payment platform called Taiwan Pay. This tool not only allows users to make payments directly by scanning QR codes, but also includes a function for users to pay utility bills and taxes. Due to the cooperation of the banks, users can use Taiwan Pay or any banking application belonging to the 16 banks to pay using their phones.

After the pandemic started in 2019, there were changes in the attitudes toward adopting mobile payment in Taiwan. According to a Mastercard survey, more than 75% of consumers in Taiwan increased their use of mobile payments due to the social distancing policy. The older generation became more reliant on mobile payments, as 30% of respondents aged 60 or older confirmed the use of contactless payments on a daily basis [29]. The technical requirements for extending the use of mobile payments have already been satisfied in Taiwan. The new environment caused by the pandemic might allow Taiwan's immersion in this cashless payment method to be accelerated.

### *2.2. Literature Review*

The data envelopment analysis (DEA) model is a mathematical programming approach that evaluates the relative efficiency of peer decision-making units (DMUs) with respect to multiple inputs and outputs [30]. It was first mentioned by Charnes et al. (1978) [12]. They proposed the constant return to scale (CCR) model, which suggests that any change in inputs should produce a proportional change in outputs. Later, in 1984, Banker et al. [31] developed the BCC model, which assumed a variable return to scale and did not require efficient DMUs to have the same outputs over inputs ratio as the most productive DMU. This type of simple DEA model is called the black-box model because it considers the production system as a single process and neglects possible divisions existing in the internal workings of a firm.

To examine how external factors or qualitative indicators affect the performance of firms, an external two-stage DEA model is used by many economists [32,33]. This type of model consists of calculating the efficiency indices at the first stage and using these indices to power other techniques which can be some type of regression, such as an analytical hierarchy process (AHP) or an artificial neural network (ANN), at the second stage [34]. In terms of evaluating efficiency scores, this model uses the traditional DEA, so it has all the weaknesses of the black-box model. However, the extra stage provides a means to determine the impact of exogenous elements on firm performance.

To obtain more reliable and detailed information, DMUs can be viewed in a network structure. Instead of just considering a whole manufacturing process a black-box system, the entire production can be divided into various sub-processes or sub-stages. The network DEA model (NDEA) was developed to provide both overall and divisional efficiency. It was first introduced by Färe and Grosskopf (2000) [35] and extended by other authors, such as Kao and Hwang (2008) [15], Chen et al. (2009) [30], and Tone and Tsutsui (2010) [36]. From explaining the relational relationship between divisions to presenting methods for calculating each stage's weight, research has gradually polished the NDEA model.

The DEA model has been applied to explore the efficiency of financial institutions in many studies. Kao and Hwang (2008) [15] and Yakob et al. (2014) [37] used a two-stage DEA model to investigate the performance of insurance companies. Banks play a big role in the financial industry; therefore, studies to gain an understanding of their efficiency and productivity are essential. Numerous analyses have been conducted by scientists. Wanke and Barros (2014) [38] stimulated the network DEA model to observe the efficiency drivers in Brazilian banks. Yang and Liu (2012) [39] observed the management efficiency of branches in the Taiwanese banking system and evaluated the results between state-owned

and mixed-ownership banks. Henriques et al. (2020) [34] reviewed more than 50 articles using two-stage DEA to evaluate the performance of the banking sector.

Different types of DEA models are used to estimate banks' activities. A two-stage DEA with double bootstrapped truncated regression has been applied to examine if changes in financial conditions would affect banks' performances [40]. NDEA, consisting of more than two stages, is often implemented to evaluate the level of efficiency of the banking sector [17,41]. The dynamic NDEA and the slack base NDEA models are also used [42–44]. Researchers have explored a wide range of topics, but there are rarely any studies about the effect of fintech and other high-tech services on the operation of the banking industry. One of the few papers that addressed this issue is by Yang et al. (2017) [45], who used the cost Malmquist productivity index to estimate the effect of fintech on the banking sector.

The Malmquist index measures the change in productivity between two periods by dividing it into several components, including technical efficiency change and technological change. This method has been applied in various disciplines. Andrejić et al. (2021) [46] developed a DEA model to evaluate the change in efficiency over time, using logistic companies as their sample. Coelli et al. (2005) [47] used the Malmquist index to evaluate the efficiency of Australian banks over the period of 1998–2002 and found the increasing productivity of the banking sector during this period was driven mainly by technological change.

Seiford and Zhu (1999) [14] applied a two-stage NDEA model to examine 55 US banks. They found that bank size might have a negative impact on marketability. In addition, by being aware of inefficient processes, banks could devise strategies to improve their performance. Wanke and Barros (2014) [38] showed that most Brazilian banks were more efficient at converting their expenses into assets and equity than managing their physical resources.

Most previous studies on mobile payment have focused on examining human behavior and individuals' reactions to mobile payment adoption using the structural equation modeling (SEM) model or qualitative analysis [27,28]. These studies have helped in understanding people's attitudes towards mobile payment. Although regression analysis could provide an understanding of how certain factors affect productivity as a whole, it is challenging to observe the effect on the internal operations of firms. They also have not provided useful insights into how mobile payments impact DMUs overall performance or how to influence the operational processes of financial intermediaries.

Traditional DEA models are based on the assumption of the "black-box" production process. Since we have no sense of what happens within the production process at large, such models are not only limited to identifying inefficient factors but, more seriously, often lead to misleading assessments of decision-making units (DMUs) [17,48]. In particular, since banks are considered financial intermediaries, neglecting their transitional activities could distort scientific results. To correct this weakness, several papers have tried to construct banking production under a network framework. Seiford and Zhu (1999) [14] and Luo (2003) [49] split the banking production into two stages, profitability and marketability. Similarly, some studies split banks' operational processes into productivity and profitability [50,51].

In this paper, we propose a two-stage network structure to explore the impact of banking businesses using innovative mobile payments. The NDEA model enables us to investigate the influence of mobile payment on both the overall and sub-process efficiencies, providing a more comprehensive and useful view for managers. Therefore, we focused on how mobile payments, as a part of the internal working structure of a bank, affect a variety of efficiencies of sub-branches.

## 3. Methodology and Data

### *3.1. DEA–CCR Model*

The black-box DEA model introduced by Charnes et al. (1978) [12] is a simple non-parametric model in which the ratio between outputs and inputs is used as a proxy to

gauge the performance of companies. We assume that there is a set of n DMUs denoted by DMU*j* *(j = 1, . . . , n)* and that each DMUj has m inputs denoted by $x_{ij}$ *(i = 1, . . . , m)*. The outputs are denoted by $y_{rj}$ *(r = 1, . . . , s)*. *w* and *u* are *x* and *y* respective weight. The efficiency of this model, $\theta_j$, is calculated as follows:

$$\theta_j = max \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} w_i x_{ij}}$$

$$s.t. \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} w_i x_{ij}} \leq 1; j = 1, 2, \ldots, n$$

$$w_i, u_r \geq 0; i = 1, 2, \ldots, m; r = 1, 2, \ldots, s \quad (1)$$

*3.2. NDEA Model*

In this paper, the two-stage network DEA was employed to analyze the efficiency indices of the DMUs. Figure 1 illustrates our proposed framework for the evaluation of the impact of mobile payment services on banking systems.

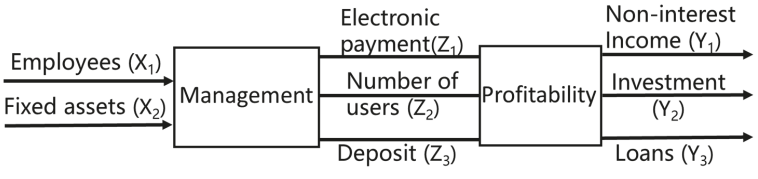


**Figure 1.** Bank's production process.

An additive two-stage DEA framework was proposed by Chen et al. (2009) [30], who suggested that the total efficiency of an entire system can be determined by the weighted average of the two sub-stage efficiencies. As shown in Figure 1, the model includes inputs, intermediates, and outputs. Therefore, based on the proposed structure for the NDEA model [30], each stage's efficiency can be obtained through Equations (2) and (3):

$$e_i^A = \frac{q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}}{v_1 x_{1o} + v_2 x_{2o}}$$

$$s.t. \frac{q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}}{v_1 x_{1o} + v_2 x_{2o}} \leq 1; \forall j$$

$$q_1, q_2, q_3, v_1, v_2 \geq 0 \quad (2)$$

$$e_i^B = \frac{u_1 y_{1o} + u_2 y_{2o} + u_3 y_{3o}}{q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}}$$

$$s.t. \frac{u_1 y_{1o} + u_2 y_{2o} + u_3 y_{3o}}{q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}} \leq 1; \forall j$$

$$q_1, q_2, q_3, u_1, u_2, u_3 \geq 0 \quad (3)$$

Suppose that there is a set of n DMUs denoted by DMUj (j = 1, . . . , n), and the first stage has two inputs, denoted by $x_1$ and $x_2$. There are 3 intermediates denoted by $z_1$, $z_2$, and $z_3$. The outputs of the second stage are denoted by $y_1$, $y_2$, and $y_3$. The first and second stage are denoted by $e_i^A$ and $e_i^B$, respectively.

As we applied the additive method from Chen et al.'s work (2009) [30], the weights for the weighted average of efficient scores of stages 1 and 2 were computed as follows:

$$w^A = \frac{v_1 x_{1o} + v_2 x_{2o}}{v_1 x_{1o} + v_2 x_{2o} + q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}}$$

$$w^B = \frac{q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}}{v_1 x_{1o} + v_2 x_{2o} + q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}} \quad (4)$$

Here, $w^A = w^B = w$ are the weights that represent the importance of two sub-stages in the overall efficiency of each DMU. The total efficiency is the weighted average of both stages.

$$e_o = w^A e_o^A + w^B e_o^B = \frac{q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o} + u_1 y_{1o} + u_2 y_{2o} + u_3 y_{3o}}{v_1 x_{1o} + v_2 x_{2o} + q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}} \quad (5)$$

In the calculation, we first attempted to obtain the overall indices using Equation (5) with the following constraints:

$$e_o = max \frac{q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o} + u_1 y_{1o} + u_2 y_{2o} + u_3 y_{3o}}{v_1 x_{1o} + v_2 x_{2o} + q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}}$$

$$s.t. \frac{q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}}{v_1 x_{1o} + v_2 x_{2o}} \leq 1; \forall j$$

$$\frac{u_1 y_{1o} + u_2 y_{2o} + u_3 y_{3o}}{q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}} \leq 1; \forall j$$

$$q_1, q_2, q_3, v_1, v_2, u_1, u_2, u_3 \geq 0 \quad (6)$$

However, model (6) is the envelopment form of the DEA model, and thus, we needed to exercise the transformation method from Charnes and Cooper's work (1962) [52] to put the model into its linear multiplier form.

$$e_o = max\ q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o} + u_1 y_{1o} + u_2 y_{2o} + u_3 y_{3o}$$

$$s.t.\ v_1 x_{1o} + v_2 x_{2o} + q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o} = 1$$

$$q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o} \leq v_1 x_{1o} + v_2 x_{2o}$$

$$u_1 y_{1o} + u_2 y_{2o} + u_3 y_{3o} \leq q_1 z_{1o} + q_2 z_{2o} + q_3 z_{3o}$$

$$q_1, q_2, q_3, v_1, v_2, u_1, u_2, u_3 \geq 0 \quad (7)$$

After achieving the total scores, Equations (1) and (2) could be used to gain sub-process efficiency. Based on one stage's result, we applied Equation (5) to obtain the other stage.

### *3.3. Variable Definition and Statistical Descriptive*

We attempted to use the model in this paper to measure the impact of mobile payments on the efficiency of banking activities. To observe how mobile payments affect the final income, the process was divided into two stages. The first stage, called the management stage, is where resources are generated to provide the service. The second stage, the profitability stage, reflects how efficient the new service is at raising income.

The first stage, the management stage, is where resources are generated to provide the service. The second stage, the profitability stage, reflects how efficient the new service is at raising income.

The selection of input and output variables is based on the DEA literature, such as Wang et al. (2014) [19] and Ashrafi and Jaafar (2011) [53]. In a one-stage case, employees

and fixed assets are usually set as inputs, while non-interest income, investments, and loans are set as outputs. In a two-stage NDEA case, based on Seiford and Zhu (1999) [14] and Zhou et al. (2019) [17], at the first stage, the management stage, the number of employees and fixed assets are utilized to produce the intermediate services, which include payment volume, number of users, and deposit. At the second stage, while intermediates are inputs, the final output of this stage consists of the financial profit or loss represented by non-interest income, investment, and loans. Table 1 provides the comprehensive definition of our variables.

**Table 1.** Variable definitions.

| Input and Output Variables | | | | |
|---|---|---|---|---|
| **Type** | **Code** | **Name** | **Description** | **Sources** |
| Inputs | X1 | Employees | Number of employees in the examined year | TEJ |
| | X2 | Fixed assets | Total amount of fixed assets in the examined year | TEJ |
| Intermediate | Z1 | Payment volume | The e-payment institution collects and makes payments for real transactions as an agent | FSC |
| | Z2 | Number of users | Number of users who have registered and opened an e-payment account but have not terminated yet | FSC |
| | Z3 | Deposit | Including demand deposits, fixed deposits, foreign exchange deposits, public inventory funds, etc. | TEJ |
| Outputs | Y1 | Non-interest income | Other operating income, total non-interest operating income, and equity-accounted profit/loss-operating | TEJ |
| | Y2 | Investment | All securities, investment in property, and insurance assets | TEJ |
| | Y3 | Loans | Short-term and long-term loans | |

The official website of the Taiwanese Financial Supervisory Commission (FSC) only provides the complete data on e-payment services relating to 19 Taiwanese banks in the period from 2018 to 2021. As a result, the sample only covered 19 banks, among the 36 banks that currently exist, in these 4 years. Other data were taken from the TEJ database.

The basic statistics of key variables are shown in Table 2. As we can see, there was a case of extreme values in one variable, where the minimum value was 0.004 and the maximum was 1464.773. This variable was the number of users (Z2). Another variable that exhibited the same extremity was the payment volume, with the minimum being $10^{-8}$ and the maximum being 17.1827. The gaps between the biggest and the smallest number were large. This was caused by the variance in the size of banks and the duration for which banks have provided mobile payments to their customers.

**Table 2.** Descriptive statistics for 19 Taiwanese banks (from 2018 to 2021).

| **Variable** | **N** | **Mean** | **Std Dev** | **Minimum** | **Maximum** |
|---|---|---|---|---|---|
| Employees (X1) | 76 | 6.5829 | 2.5609 | 2.0370 | 12.3170 |
| Fixed assets (X2) | 76 | 24.9598 | 26.6979 | 2.7254 | 139.1615 |
| Payments Volume (Z1) | 76 | 1.0179 | 3.3952 | $10^{-8}$ | 17.1827 |
| Number of Users (Z2) | 76 | 105.2438 | 285.0787 | 0.0040 | 1464.7730 |
| Deposit (Z3) | 76 | 1970.0491 | 943.6479 | 413.0530 | 4209.1840 |
| Non-interest income (Y1) | 76 | 14.2355 | 10.2926 | 1.5356 | 46.9349 |
| Investment (Y2) | 76 | 593.7153 | 336.1083 | 95.9149 | 1339.2248 |
| Loans (Y3) | 76 | 1400.9646 | 646.1395 | 310.7868 | 2940.4495 |

UNIT: billion TWD; thousand people.

Most banks increased their number of users during this period (2018–2021). However, Far Eastern, the bank with the smallest number of users, did not gain any new clients; their number of users remained at a constant of 0.038. This was the smallest number from 2019 to 2021.

## 4. Empirical Results

The NDEA model in this paper included two stages: management and profitability. At the first stage, management efficiency shows how efficiently banks use their physical resources, such as fixed assets and employees, to generate profitable services. The second stage shows how banks utilize their resources to transform these services into actual income and earning assets. In this case, our focus was on the impact of the electronic payment services, as represented by the intermediaries, payment volume, and number of users.

### *4.1. Management Efficiency*

We investigated data from 4 years, 2018–2021, but we only presented the results of the last 2 years for the sake of a concise explanation. Table 3 displays the results of management efficiency in the period from 2020 to 2021. For management efficiency, in 2020, six banks had full efficiency. All the banks in the top tier remained the same compared to 2019. Most banks increased their efficiencies, except for Taishin International Bank and Taiwan Business Bank. Their scores decreased to 0.52 and 0.66, respectively. On the other hand, Shanghai Commercial & Savings Bank, which was at the bottom of the ranking in the previous year, improved significantly and reached 0.9 along with Taipei Fubon Bank. In 2020, no bank had an efficiency score below 0.5. Taishin International Bank had the worst score of 0.52, which was an obvious step up from the previous year. The average efficiency reflected this improvement by rising to 0.82.

**Table 3.** Management efficiency of 19 Taiwanese banks with weights (2020–2021).

| Name | 2020 | | | | 2021 | | | |
|---|---|---|---|---|---|---|---|---|
| | Management Efficiency | | Management Weight | | Management Efficiency | | Management Weight | |
| Bank of Taiwan (Taipei, Taiwan) | 1.0000 | (1) | 0.5000 | (19) | 1.0000 | (1) | 0.5000 | (15) |
| Bank Sinopac (Taipei, Taiwan) | 1.0000 | (1) | 0.5000 | (14) | 1.0000 | (1) | 0.5000 | (15) |
| Cathay United Bank (Taipei, Taiwan) | 0.6209 | (17) | 0.6169 | (3) | 0.6149 | (17) | 0.6192 | (3) |
| Chang Hwa Commercial Bank (Taipei, Taiwan) | 0.7071 | (13) | 0.5858 | (7) | 0.7075 | (14) | 0.5857 | (6) |
| Chinatrust Commercial Bank (Taipei, Taiwan) | 0.6756 | (15) | 0.5968 | (5) | 0.6460 | (16) | 0.6075 | (4) |
| E. Sun Commercial Bank, Ltd. (Taipei, Taiwan) | 1.0000 | (1) | 0.5000 | (15) | 1.0000 | (1) | 0.5000 | (15) |
| Far Eastern International Bank (Taipei, Taiwan) | 1.0000 | (1) | 0.5000 | (17) | 0.9261 | (7) | 0.5192 | (13) |
| First Commercial Bank (Taipei, Taiwan) | 0.8014 | (11) | 0.5551 | (9) | 0.7603 | (11) | 0.5681 | (9) |
| Hua Nan Commercial Bank (Taipei, Taiwan) | 0.7581 | (12) | 0.5688 | (8) | 0.7570 | (12) | 0.5691 | (8) |
| Land Bank of Taiwan (Taipei, Taiwan) | 1.0000 | (1) | 0.5000 | (17) | 1.0000 | (1) | 0.5000 | (15) |
| Mega International Commercial Bank (Taipei, Taiwan) | 1.0000 | (1) | 0.5000 | (15) | 1.0000 | (1) | 0.5000 | (15) |
| Shin Kong Commercial Bank (Taipei, Taiwan) | 0.8643 | (10) | 0.5364 | (10) | 0.8299 | (9) | 0.5465 | (11) |
| Sunny Bank (Taipei, Taiwan) | 0.5417 | (18) | 0.6486 | (2) | 0.5298 | (18) | 0.6537 | (2) |
| Taipei Fubon Bank (Taipei, Taiwan) | 0.9651 | (7) | 0.5089 | (13) | 1.0000 | (1) | 0.5000 | (14) |
| Taishin International Bank (Taipei, Taiwan) | 0.5252 | (19) | 0.6557 | (1) | 0.4884 | (19) | 0.6719 | (1) |
| Taiwan Business Bank (Taipei, Taiwan) | 0.6617 | (16) | 0.6018 | (4) | 0.6756 | (15) | 0.5968 | (5) |
| Taiwan Cooperative Bank (Taipei, Taiwan) | 0.8936 | (9) | 0.5281 | (11) | 0.8513 | (8) | 0.5402 | (12) |
| The Shanghai Commercial & Savings Bank (Taipei, Taiwan) | 0.9144 | (8) | 0.5224 | (12) | 0.8152 | (10) | 0.5509 | (10) |
| Yuanta Bank (Taipei, Taiwan) | 0.6889 | (14) | 0.5921 | (6) | 0.7136 | (13) | 0.5836 | (7) |
| Average | 0.8220 | | 0.5535 | | 0.8061 | | 0.5585 | |

In 2021, slight changes occurred. Six banks were champions. However, Taipei Fubon replaced Far Eastern in the top tier. This was interesting, as these banks practically reversed their ranks; Taipei Fubon had ranked 7 in 2020, and Far Eastern ranked 7 in 2021. Taishin was still at the bottom of the ladder with a lower efficiency (0.49). It was the only bank with an efficiency below 0.5. This decrease was not an exception in 2021, as most banks lost their upward trend and exhibited lower management efficiencies. The average efficiency dropped from 0.82 to 0.8.

Among the six champions in 2021, five had a large number of deposits: more than two trillion NTD, which was the average for the 19 banks. Only Sinopac had lower numbers,

at approximately 1.7 trillion. As deposits are the main funding source for banks, it is understandable why banks with high deposits achieve high management efficiency. In addition, both Sinopac and E. Sun had the highest number of users. Their payment volumes were among the best as well. On the other hand, Land Bank was among the banks with the lowest payment volumes in 2021, but its other outputs were high enough to compensate for this. Therefore, at the first stage, the management stage, deposits play a vital role in achieving efficient performance because they are the main sources of the generation of loans and investments for banks at the next stage. Non-interest services, such as electronic payments, in this case, can enhance the result but are not the main contributors.

We can consider the operation of a specific champion. For example, Taipei Fubon invested in developing its own digital platform, collaborating with the Taipei City Government to create a smart payment platform called "pay.taipei". It also introduced a "credit factory" model, which allows the bank to fully automate its loan approval process and reduce the turnaround time. The bank won an award, the "World Economic Magazine Awards 2021—Best Micro Fintech Finance Bank Taiwan", from World Economic Magazine. Taipei Fubon increased its investment in mobile payments and received notable results.

By comparing one of the champions, Sinopac, to the bank with the worst managerial result, Taishin, we can partly illustrate the causes of the differences in this stage's efficiency. In 2021, Sinopac had half the number of inputs, in terms of both fixed assets and employees, but achieved a similar volume of deposits and more than 20 times the number of users (434,002–23,191). Moreover, Sinopac had a coherent strategy and budget for research and development in digital banking, while the annual report of Taishin presented an ambiguous plan.

Furthermore, from 2020 to 2021, observing the intermediates, it could be seen that only deposits uniformly increased in all six efficient banks. The number of users increased for most, except for Mega and Taipei Fubon. Mega lost more than half of its number of users, from one thousand seven hundred down to approximately eight hundred. On the other hand, only a handful of users, 34, stopped using Taipei Fubon's services. The general upward trend in this factor was a sign that banks were aware of the opportunity electronic payment services present and were expanding them by attracting more customers. Payment volumes also increased slightly during this period, except for Mega and Taipei Fubon. The coronavirus pandemic, or COVID-19, was not at its peak during this period. Economies around the world were gradually recovering, and Taiwan was not an exception. People started to increase their spending, but economic activity was still low. These might partially explain the light growth in payment volume in 2021.

From 2020 to 2021, the average weight of the first stage had risen slightly, from 0.553 to 0.558, which coincided with a drop in the average efficiency, from 0.82 to 0.8. In 2021, Taishin International Bank had the highest weight of 0.67, but this bank only achieved 0.49 in management efficiency, the lowest score this year. Sunny Bank (0.65) was in second place, with a management efficiency of 0.53. The lowest weight was 0.5. All six champions in the management stage achieved this weight. This suggests that banks should equalize their use of resources. A heavy focus on management would only lead to low efficiency. This was further proven by the slight increase in the average management weight in 2021 (0.55), which coincided with the decrease in average efficiency. Far Eastern, which fell out of the top tier, had a higher weight (0.52) compared to 2020 (0.5). On the other hand, Taipei Fubon reduced its weight to 0.5 and attained full efficiency in management.

Among the intermediate inputs, deposit was the focus output of this stage. It was the main activity in banks and an important contributor to stage efficiency. On the other hand, payment volumes and numbers of users reflected the activities of mobile payment services in commercial banks. As deposits exhibited a stable rise in these years, the imperfect management efficiency suggests that banks did not use their resources to generate the electronic payment services efficiently. This result is appropriate because these non-interest services have been new expansions for banks in recent years. Many banks are concentrating more on their traditional activities, and mobile payment only accounts for a small branch

of their services. However, banks remain aware of the opportunity to profit from this type of service and improve their efficiency over time.

### *4.2. Profitability Efficiency*

In contrast with the first stage, the average profitability efficiency at the second stage was close to the peak in both 2020 and 2021, but it was also on a downward trajectory. As shown in Table 4, the average efficiencies were 0.91 (2020) and 0.88 (2021). In 2020, there were five banks with full efficiency scores. This number lowered to four in 2021, but the winners remained the same, except for Taiwan Business. While Chinatrust, Land Bank, Taishin, and Shanghai remained in their champion positions, Taiwan Business lost its title. Its efficiency dropped to 0.98. In 2021, E. Sun kept its seat at the bottom with 0.58. Most of the top-tier banks in this stage did not generate a large number of outputs in the first sub-process, but the profit earned at the second stage was high in comparison.

**Table 4.** Profitability efficiency of 19 Taiwanese banks with weights (2020–2021).

| Name | 2020 | | | | 2021 | | | |
|---|---|---|---|---|---|---|---|---|
| | Profitability Efficiency | | Profitability Weight | | Profitability Efficiency | | Profitability Weight | |
| Bank of Taiwan | 0.8394 | (16) | 0.5000 | (1) | 0.8745 | (14) | 0.5000 | (1) |
| Bank Sinopac | 0.8343 | (17) | 0.5000 | (1) | 0.7275 | (18) | 0.5000 | (1) |
| Cathay United Bank | 0.9356 | (8) | 0.3831 | (17) | 0.8207 | (16) | 0.3808 | (17) |
| Chang Hwa Commercial Bank | 0.9147 | (10) | 0.4142 | (13) | 0.8967 | (9) | 0.4143 | (14) |
| Chinatrust Commercial Bank | 1.0000 | (1) | 0.4032 | (15) | 1.0000 | (1) | 0.3925 | (16) |
| E. Sun Commercial Bank, Ltd. | 0.7395 | (19) | 0.5000 | (1) | 0.5820 | (19) | 0.5000 | (1) |
| Far Eastern International Bank | 0.8923 | (13) | 0.5000 | (1) | 0.8923 | (10) | 0.4808 | (7) |
| First Commercial Bank | 0.9176 | (9) | 0.4449 | (11) | 0.8874 | (11) | 0.4319 | (11) |
| Hua Nan Commercial Bank | 0.9063 | (11) | 0.4312 | (12) | 0.9007 | (7) | 0.4309 | (12) |
| Land Bank of Taiwan | 1.0000 | (1) | 0.5000 | (1) | 1.0000 | (1) | 0.5000 | (1) |
| Mega International Commercial Bank | 0.9457 | (6) | 0.5000 | (1) | 0.9088 | (6) | 0.5000 | (1) |
| Shin Kong Commercial Bank | 0.8741 | (14) | 0.4636 | (10) | 0.8636 | (15) | 0.4535 | (9) |
| Sunny Bank | 0.8663 | (15) | 0.3514 | (18) | 0.8778 | (13) | 0.3463 | (18) |
| Taipei Fubon Bank | 0.9358 | (7) | 0.4911 | (7) | 0.8816 | (12) | 0.5000 | (1) |
| Taishin International Bank | 1.0000 | (1) | 0.3443 | (19) | 1.0000 | (1) | 0.3281 | (19) |
| Taiwan Business Bank | 1.0000 | (1) | 0.3982 | (16) | 0.9773 | (5) | 0.4032 | (15) |
| Taiwan Cooperative Bank | 0.8971 | (12) | 0.4719 | (9) | 0.8968 | (8) | 0.4598 | (8) |
| The Shanghai Commercial & Savings Bank | 1.0000 | (1) | 0.4776 | (8) | 1.0000 | (1) | 0.4491 | (10) |
| Yuanta Bank | 0.7955 | (18) | 0.4079 | (14) | 0.7887 | (17) | 0.4164 | (13) |
| Average | 0.9102 | | 0.4465 | | 0.8830 | | 0.4415 | |

The average weight of the profitability stage was 0.45 in 2020, and it fell to 0.44 in 2021. The highest weight at the second stage was 50 percent. However, only one bank achieved full efficiency in the profitability stage and had a weight of 0.5. Other top-tier banks demonstrated that the lower their weight, the higher their efficiency. The most exemplary case was Taishin International Bank, which had the lowest efficiency rank in 2019 and soared to the maximum score in 2020. At the same time, Taishin's second-stage weight dropped from 0.43 (2019) to 0.34 (2020). Similarly, Taiwan Business' weight increased while its efficiency decreased. There was a slight fall in the average weight of the second stage from 2020 to 2021. Nevertheless, the change was not significant, being only 0.1 percent. This indicated that banks were more focused on generating services and funding than turning them into income.

At the second stage, there was a role reversal compared to the previous stage, as the champion became the "loser", and vice versa. Taishin had the worst result in the management stage, while E. Sun was one of the best. As this stage focused on profitability, we could observe that E. Sun possessed a huge number of users (1,464,773) and a large payment volume (15.3) compared to Taishin (23,191; 0.15). However, the non-interest income that E. Sun generated was less than twice the amount of Taishin. This proved that E. Sun was inefficient in turning its services into actual profit.

In the profitability stage, the most efficient banks were those with a large amount of non-interest income, mostly higher than the average of the 19 banks. The Land Bank of Taiwan was an exception, but it also had far fewer intermediates than other banks in the same rank. This suggests that the good results at this stage were not only dependent on their success in traditional services reflected in loans and investments, but also on non-interest services such as e-payment. However, the profitability stage does not require a lot of attention. More concentration at this stage would lead to low efficiency. This was reflected in the efficiency scores and weights in this stage.

The profitability stage measures the capability of Taiwanese banks to turn services into income. Based on the table above, the second division, the profitability process, appeared to have highly positive results. This suggests that mobile payment services represent a potential investment, and banks recognize this prospect.

### *4.3. Overall Efficiency*

In this research, we examined the effect of e-payment services on Taiwanese banks' efficiency, which was reflected in the intermediate products of this model, payment volume, and numbers of users. Our data covered 4 years, from 2018 to 2021. However, we only show the results of 2021 in Table 5 for the sake of our explanation.

**Table 5.** Overall efficiency of 19 Taiwanese banks with weights and CCR efficiencies (2021).

| Name | 2021 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Management Efficiency | | Management Weight | Profitability Efficiency | | Profitability Weight | Overall Efficiency | | CCR |
| Bank of Taiwan | 1.0000 | (1) | 0.5000 | 0.8745 | (14) | 0.5000 | 0.9373 | (4) | 0.9850 |
| Bank Sinopac | 1.0000 | (1) | 0.5000 | 0.7275 | (18) | 0.5000 | 0.8638 | (8) | 0.9350 |
| Cathay United Bank | 0.6149 | (17) | 0.6192 | 0.8207 | (16) | 0.3808 | 0.6932 | (17) | 1.0000 |
| Chang Hwa Commercial Bank | 0.7075 | (14) | 0.5857 | 0.8967 | (9) | 0.4143 | 0.7859 | (14) | 0.9010 |
| Chinatrust Commercial Bank | 0.6460 | (16) | 0.6075 | 1.0000 | (1) | 0.3925 | 0.7849 | (15) | 1.0000 |
| E. Sun Commercial Bank, Ltd. | 1.0000 | (1) | 0.5000 | 0.5820 | (19) | 0.5000 | 0.7910 | (13) | 0.8990 |
| Far Eastern International Bank | 0.9261 | (7) | 0.5192 | 0.8923 | (10) | 0.4808 | 0.9098 | (5) | 1.0000 |
| First Commercial Bank | 0.7603 | (11) | 0.5681 | 0.8874 | (11) | 0.4319 | 0.8152 | (11) | 0.9730 |
| Hua Nan Commercial Bank | 0.7570 | (12) | 0.5691 | 0.9007 | (7) | 0.4309 | 0.8189 | (10) | 1.0000 |
| Land Bank of Taiwan | 1.0000 | (1) | 0.5000 | 1.0000 | (1) | 0.5000 | 1.0000 | (1) | 1.0000 |
| Mega International Commercial Bank | 1.0000 | (1) | 0.5000 | 0.9088 | (6) | 0.5000 | 0.9544 | (2) | 1.0000 |
| Shin Kong Commercial Bank | 0.8299 | (9) | 0.5465 | 0.8636 | (15) | 0.4535 | 0.8452 | (9) | 0.9710 |
| Sunny Bank | 0.5298 | (18) | 0.6537 | 0.8778 | (13) | 0.3463 | 0.6503 | (19) | 0.9240 |
| Taipei Fubon Bank | 1.0000 | (1) | 0.5000 | 0.8816 | (12) | 0.5000 | 0.9408 | (3) | 1.0000 |
| Taishin International Bank | 0.4884 | (19) | 0.6719 | 1.0000 | (1) | 0.3281 | 0.6562 | (18) | 1.0000 |
| Taiwan Business Bank | 0.6756 | (15) | 0.5968 | 0.9773 | (5) | 0.4032 | 0.7973 | (12) | 1.0000 |
| Taiwan Cooperative Bank | 0.8513 | (8) | 0.5402 | 0.8968 | (8) | 0.4598 | 0.8722 | (7) | 0.9020 |
| The Shanghai Commercial & Savings Bank | 0.8152 | (10) | 0.5509 | 1.0000 | (1) | 0.4491 | 0.8982 | (6) | 1.0000 |
| Yuanta Bank | 0.7136 | (13) | 0.5836 | 0.7887 | (17) | 0.4164 | 0.7449 | (16) | 0.8160 |
| Average | 0.8061 | | 0.5585 | 0.8830 | | 0.4415 | 0.8294 | | 0.9635 |

In terms of overall efficiency, only one of the nineteen banks achieved the unique overall efficiency of 1. This showed that few banks had managed to effectively exploit the new services during the whole process. Divisionally, each performance stage had more banks with full efficiency scores. The management stage provides evidence that despite deposits being the main activity in bank operation, non-interest services such as mobile payment are important contributors to banks' efficiency. However, generating a large number of deposits and services does not equate to the ability to turn these into income. In the profitability stage, the banks achieving high efficiency had a lower-than-average number of users and payment volume and a small number of deposits, but they incurred high non-interest income, investments, and loans, which suggests that banks were better at profiting from their services.

According to the results from Table 5, only the Land Bank of Taiwan achieved 100% efficiency in both years. The runner-up in 2021 was Mega, with a 95% level of efficiency. Sunny Bank achieved the lowest results in overall efficiency in both years: 0.65. From 2019 to 2020, the mean scores increased to 0.85 due to the rise in management efficiency and the changes in the weight of each stage. However, this still showed that many banks could not completely exploit the benefits of the new service, mostly because of their low score in the management stage. In 2021, as both stages' efficiencies adopted downward trends,

the average overall efficiency also decreased to 0.83. This might have been caused by the reduced online consumption after the pandemic.

In terms of applying new technology, Landbank launched its digital finance transformation in line with government policy and fintech development. To provide customers with new options for mobile use, Landbank initiated various projects, such as big data applications, digital financial infrastructure, intelligent services, the optimization of the internet and mobile banking APP, mobile payment, mobile phone transfer, Taiwan Pay a bonus point service, a single-service platform for personal finance, etc., and cooperated with various electronic payment institutions (e.g., JKOPAY, LinePay, iPASS, etc.). This explained the steady rise in the intermediates of the bank over the years and the high management efficiency. Moreover, the bank also provided training on digital banking and fintech to employees, as well as investing in various research to improve their electronic services.

In general, most banks had one good stage and one bad stage. As there were less efficient banks and a stronger fluctuation in efficiency at the second stage, this could have implied that the second stage was the main problem causing inefficiency. Another possible explanation is that the Land Bank of Taiwan was good at allocating resources to accomplish the highest result in each sub-process. They did not accumulate a large number of any inputs or intermediates; everything was in medium proportion compared to others, allowing them to control their resources more efficiently by moderating an appropriate number of inputs for each division. On the other hand, the inefficiency of the management stage, the focus of the bank on this process, and its lower-than-average quantity of intermediates and outputs were the reasons Sunny Bank stayed at the bottom of the ranking.

According to the work of Kao and Hwang (2008) [15], the rank of a bank should lie between the ranks of its sub-processes or in its neighborhood. From the rank of the efficiency scores, there were large differences between the overall ranking and the divisional ranking. Large differences among these ranks revealed the source of the problem. For example, the Bank of Taiwan achieved the highest rank (1) at the first stage and was among the worst (14) at the second stage. As a result, it ranked fourth in overall efficiency. Similarly, Sinopac, E. Sun, and Taipei Fubon all ranked first in management, but they had low ranks in profitability: 18, 19, and 12, respectively. In terms of overall efficiency, their ranks were 8 (Sinopac), 13 (E. Sun), and 3 (Taipei Fubon). On the other hand, China Trust, Taishin, and Shanghai all had perfect profitability efficiencies, but their management efficiency scores were low. Their first-stage rankings were 16, 19, and 10, respectively. Therefore, their overall scores were the same as the champions of the first stage.

In Table 6, a steady increase in management efficiency from 0.78 to 0.82 over the first three years was observed, followed by a drop to 0.8 in 2021. This was concurrent with a gradual decrease in management weight and a sudden increase in 2021. In contrast, average profitability efficiency had been declining over the years, decreasing from 0.93 to 0.88. This was reflected in the increase in average weights from 0.43 to 0.44. This suggests that the decision of the banks to reduce the resources of the first stage was a viable strategy. However, banks need to increase the number of outputs produced at the second stage to prevent the intermediates generated at the first stage from becoming burdens for the entire operation. Furthermore, the constant increase in overall efficiency in the first three years (2018–2021) and its decline in the last year indicated that overall efficiency was significantly influenced by management efficiency. Banks with higher management efficiency were better able to compensate for their weaknesses than those with high profitability efficiency.

The current main disadvantages of most Taiwanese banks are their inability to fully exploit new services. Despite being able to generate huge amounts of services and funds, banks are unable to transform them into profit. This is reflected in the discrepancy between management efficiency and profitability efficiency. As a result, they achieved a low score overall. The Land Bank of Taiwan was the only bank to be successful in both stages, which suggests that Taiwanese banks should re-examine their strategies on how to allocate their resources as well as how to utilize them to generate profitable services.

**Table 6.** Average efficiency scores and weights of Taiwanese banks (2018–2021).

| | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|
| Management efficiency | 0.7839 | 0.7936 | 0.8220 | 0.8061 |
| Management weight | 0.5657 | 0.5638 | 0.5535 | 0.5585 |
| Profitability efficiency | 0.9250 | 0.9137 | 0.9102 | 0.8830 |
| Profitability weight | 0.4343 | 0.4362 | 0.4465 | 0.4415 |
| Overall efficiency | 0.8350 | 0.8332 | 0.8518 | 0.8294 |

### *4.4. Comparing NDEA with the Black Box Method*

To emphasize the explanatory power of our model, we compared the performance indices between two models: the CCR model without the intermediate processes and the two-stage network DEA model. Table 7 lists the results of banks' overall efficiency scores in 2020–2021. We found that the two models indicated similar situations. The average efficiency decreased. In terms of the number of efficient DMUs, the CCR model provided 13 in 2020 and 10 in 2021, while our model only generated 1. The average score in 2021 was 0.96 for the CCR model and 0.83 for the NDEA model.

**Table 7.** Efficiency scores—comparing two models (2020–2021).

| Name | 2020 | | 2021 | |
|---|---|---|---|---|
| | Overall Efficiency | CCR | Overall Efficiency | CCR |
| Bank of Taiwan | 0.9197 | 1.0000 | 0.9373 | 0.9850 |
| Bank Sinopac | 0.9171 | 0.9440 | 0.8638 | 0.9350 |
| Cathay United Bank | 0.7414 | 1.0000 | 0.6932 | 1.0000 |
| Chang Hwa Commercial Bank | 0.7931 | 0.9200 | 0.7859 | 0.9010 |
| Chinatrust Commercial Bank | 0.8064 | 1.0000 | 0.7849 | 1.0000 |
| E. Sun Commercial Bank, Ltd. | 0.8697 | 1.0000 | 0.7910 | 0.8990 |
| Far Eastern International Bank | 0.9462 | 1.0000 | 0.9098 | 1.0000 |
| First Commercial Bank | 0.8531 | 1.0000 | 0.8152 | 0.9730 |
| Hua Nan Commercial Bank | 0.8220 | 1.0000 | 0.8189 | 1.0000 |
| Land Bank of Taiwan | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| Mega International Commercial Bank | 0.9728 | 1.0000 | 0.9544 | 1.0000 |
| Shin Kong Commercial Bank | 0.8688 | 0.9700 | 0.8452 | 0.9710 |
| Sunny Bank | 0.6558 | 0.9350 | 0.6503 | 0.9240 |
| Taipei Fubon Bank | 0.9507 | 1.0000 | 0.9408 | 1.0000 |
| Taishin International Bank | 0.6887 | 1.0000 | 0.6562 | 1.0000 |
| Taiwan Business Bank | 0.7964 | 1.0000 | 0.7973 | 1.0000 |
| Taiwan Cooperative Bank | 0.8953 | 0.9060 | 0.8722 | 0.9020 |
| The Shanghai Commercial & Savings Bank | 0.9553 | 1.0000 | 0.8982 | 1.0000 |
| Yuanta Bank | 0.7324 | 0.8030 | 0.7449 | 0.8160 |
| Average | 0.8518 | 0.9725 | 0.8294 | 0.9635 |

Moreover, regarding the dispersion of the scores' distribution, the minimum values from the CCR model were 0.8 and 0.81 for 2020 and 2021, respectively, which were higher than those from the NDEA model (0.66 and 0.65), as shown in Table 8.

**Table 8.** Descriptive Statistics of Efficiency Score—comparing 2 models (2020–2021).

| | 2020 | | 2021 | |
|---|---|---|---|---|
| | Overall Efficiency | CCR | Overall Efficiency | CCR |
| Mean | 0.8518 | 0.9725 | 0.8294 | 0.9635 |
| Min | 0.6558 | 0.8030 | 0.6503 | 0.8160 |
| Max | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| Standard dev. | 0.0995 | 0.0516 | 0.0994 | 0.0527 |
| Median | 0.8688 | 1.0000 | 0.8189 | 1.0000 |

Furthermore, with a black-box model, it is impossible to understand which factors play the main roles in creating inefficiency and how to improve the current state of affairs. The two-stage NDEA model allowed us to pinpoint the exact culprit of low performance and strategize appropriate solutions. Therefore, it is obvious that the discriminating power of network DEA models is significantly higher in comparison to the CCR model.

### *4.5. Mann–Whitney U Test*

We used the Mann–Whitney U Test to determine if there was a significant difference between the efficiencies of the NDEA model and the CCR model. Our $H_0$ was that the efficiencies of the NDEA model were not statistically different from the CCR model. After testing, the U value was 36 and the *p*-value was 0.00001. Therefore, we rejected $H_0$ ($p < 0.05$). The results of the two models were significantly different.

## 5. Conclusions

### *5.1. Managerial Implications*

Currently, the Taiwanese government is encouraging the use of mobile payments. It is expected to penetrate 90% of the population through tax incentives and infrastructure. According to FSC data, the number of users of electronic payments in July 2020 reached 9,664,000. Taiwan's e-payment business is still growing. Therefore, by offering mobile payment services, banks can exploit great opportunities and increase profitability.

From the results above, it can be seen that Taiwanese banks are aware of this perspective and are trying to maximize their results from this new branch of services. However, there are limitations to their efforts. As mobile payment development in banks is in its initial stages, the number of services generated is low. To fully take advantage of the current situation, banks should utilize their resources to produce more suitable products. In addition to implementing diversified services, extending the area of applicability is also necessary to attract new customers.

Based on the current evidence, we suggest that banks with large amounts of resources, employees, and fixed assets should strategize to take advantage of the current situation. With large budgets and customer bases, they should focus on transforming them into profit rather than just generating new services. The current government policies have created good opportunities for banks to take advantage of.

Medium- and small-sized banks are already aware and are concentrating on this new opportunity. However, despite being able to turn the services into revenue, they lack the resources to generate them. As a result, these banks should initiate strategies that can help them manage their assets and personnel more efficiently.

### *5.2. Conclusions*

All our four main research questions, shown in the introduction, have been explored, and some innovative results have been verified. For Q1: Does mobile payment impact the performance of Taiwanese banks? With NDEA, although we assume that mobile payment might impact a bank's operation, the empirical results do show that it significantly affects the performance of the sub-branches and the whole system of banks. It is further verified, by the Mann–Whitney U-test in Section 4.5, that taking into account the impact of mobile payments will result in a different empirical outcome.

For Q2: Does NDEA have a stronger discriminating power in analyzing efficiency than traditional DEA methods in mobile payment cases? Our empirical results show that, compared to the traditional DEA model, the NDEA model has more explanatory power in analyzing the operational performance of Taiwan's banks impacted by mobile payment. For example, despite having some efficient DMUs in each sub-stage, the number of banks that achieved full overall efficiency was limited. In 2019 and 2020, only the Land Bank of Taiwan reaches an overall efficiency of 1.

For Q3: Does mobile payment influence management efficiency as well as profitability efficiency? Despite different degrees, our empirical results show that mobile payments do

influence management efficiency and profitability efficiency. Furthermore, we find that banks with high management efficiency would achieve low profitability efficiency, and vice versa. As a result, the actual obstacle might be the second stage, in which most banks are not able to achieve perfect results.

For Q4: How do inefficient DMUs improve their sub-branch efficiencies as well as their overall efficiency? We find that the rise in profitability weight that coincided with the slight dip in its efficiency implies that the increasing focus on the second stage does not necessarily create much benefit. Banks should apply better strategies to adopt and exploit mobile payment services. Furthermore, banks should better allocate resources to generate services and concentrate on turning these services into actual income.

Few DEA literatures have dealt with the new fintech tools in banking systems. We have successfully set up a NDEA model to account for how mobile payments impact the operation of Taiwan's banking industry. Although we did make some insights to bridge the gap in the literature, our paper has some limitations. First, the sample size can be increased. Although we exploit 19 Taiwanese banks over a four-year period, the sample can be expanded to include international banks. Second, the main variables of mobile payment, payment volume and the number of users can be enriched to capture all aspects of mobile payment. Third, the actual internal operation processes of banks could be more complicated than the two stages NDEA set forth in this study.

Future research can address these limitations by incorporating more data from other countries, such as China and Southeast Asia, to increase the reliability and representativeness of the results. Combining the Malmquist Index with NDEA could be a useful approach to investigating efficiency changes over time, both overall and divisional. Furthermore, finding other variables that better reflect the properties of mobile payment can improve the accuracy of the model. Finally, extending the model to a three-stage NDEA or a parallel structure model can provide a more comprehensive understanding of the true properties of mobile payment.

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# Value-Creation Efficiency as a Decision-Making Basis and Its Assessment in the Financial Management of Energy Companies: Evidence from the Polish Capital Market

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**Abstract:** A study of the efficiency of the energy companies that are listed on the Polish capital market, which will be the object of the analysis in this paper, is focused on assessing the degree of accomplishment of their basic financial objectives, namely, the maximization of their market values. The main research methods that are used in the article are methods for analyzing and evaluating the literature (in order to present the current scientific achievements in the field under study) and descriptive statistics and mathematical statistical methods for analyzing the interdependence of the phenomena (used to characterize and compare the analyzed energy-sector companies, as well as to quantify the determinants of the value-creation efficiency of these companies). This article is focused on the conditions and problems that are related to the decision-making processes that are aimed at increasing efficiency in the area of building enterprise-value. These require the use of tools for efficiency measurement that enable management to quantify and assess changes in an enterprise's market value and the efficiency of its creation. Within the conducted research, it has also been proven that this is the market perspective that is of key significance from the point of view of the criteria of making financial management decisions. The market perspective reflects the expectations of the majority of company stakeholders, to the fullest. The study showed that the allocation of capital in the listed energy companies during the period of 2014–2020 was subject to a relatively high risk of losing the economic value of the invested capital. In terms of asset value, dividing the studied group of companies into portfolios of two groups of companies additionally showed that the volatility of the market and equity returns for the smaller companies was higher than it was for the larger companies.

**Keywords:** financial management; value-based management; value-creation efficiency; value-focused decision-making; energy companies

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## 1. Introduction

As the entirety of actions that are aimed at the efficient use of an enterprise's economic resources that are focused on the implementation of previously formulated expectations, management is closely connected with the objectives of business activity. The problem of the objective as a directional determinant of the management process appeared in the 1950s and 1960s in works by P. Drucker, who was the author of the management-by-objectives concept [1,2]. When explaining the essence of management, he stated directly that it was the process of formulating business objectives and indicating the proper methods and means to accomplish them. Striving for the implementation of business objectives is directly related to the notion of the efficiency of action. At the same time, the requirement for the rationality of management necessitates the respect for cost-efficiency principles in the course of fulfilling the objective, which is related to the need to consider the relationship

between incurred outlays on the one hand and the effects that are achieved because of them, on the other. This requirement, in turn, is connected to the notion of efficiency, reflecting the ability of a firm to implement its assumed objectives. The lack of a relationship between the accomplishment level of business objectives and its efficiency level in extreme cases would result in the creation of attitudes that are based on striving for the accomplishment of the set objective at all costs, which would be contrary to the basic principles of economic accounts, and threaten the further existence of a business. Such a way of perceiving management makes business objectives a substantial determinant for both those decisions that are made in the course of managing them, and the criteria and methods for assessing the effects that are accomplished. It is obvious that, within the company efficiency management, there must be cohesion between the criteria and the methods for evaluating the effects of an enterprise's functioning and the criteria and methods that are used for the needs of making management decisions that can contribute to the achievement of the desired effects.

Making strategic and operating decisions is an integral element of the management process, that is focused on the efficient accomplishment of business objectives. From the point of view of enterprise management, the efficiency of the allocation of inputs and the efficiency of using economic resources are of key importance. The issues of economic efficiency considered from the perspective of economics, on the other hand, emphasize the concept of technical efficiency (including pure technical efficiency and scale efficiency) [3]. Referring to issues of economic efficiency for the essence of an enterprise, from the essence of the enterprise based on the use of organized economic resources on the one hand to the conditions of raising and using those resources on the other, it is necessary to indicate the following key areas of making strategic decisions in firms:

- Making choices with regard to selecting and raising necessary economic resources and searching for ways of their optimum allocation;
- Raising and creating unique resources, the skillful use of which nowadays is becoming a key source of benefits for enterprises and their stakeholders;
- Efficient shaping of relationships with stakeholders, in order to create optimum conditions for company functioning and development;
- Searching for paths and methods for improving enterprise functioning in order to increase its efficiency, thus raising competitiveness and achieving market advantage;
- Building the ability of the enterprise to effectively and efficiently respond to changes in its environment, including the occurrence of crisis situations caused both by economic reasons (e.g., the global economic crisis of the first decade of the 21st century) and extra-economic reasons (e.g., the global crisis related to the COVID-19 pandemic and the war in Ukraine caused by the aggression of Russia).

During the assessment of enterprise efficiency for making management decisions and verifying their results, it is necessary to use efficiency measures that are based on four potential perspectives of research [4]:

- Book perspective—whose foundation is the enterprise's financial book system and the rules arising from its application for establishing financial results (profit or loss) of the enterprise, based on the accrual principle;
- Cash perspective—discussing enterprise efficiency from the point of view of the cash principle, which is the basis for determining cash flows;
- Market perspective—primarily related to the need for measurement and assessment of enterprise value-creation and business valuation;
- Performance measurement perspective—as a comprehensive system integrating book, cash, and market perspectives to enable a multi-criteria performance measurement through the use of a set of measures for the quantification of the effectiveness and efficiency of company activities, as well as the efficiency of management decisions that are made.

The study of the efficiency of the listed companies, which will be the object of the analysis in this paper, is focused on assessing the accomplishment degree of their basic

financial objective; namely, the maximization of their market values. This maximization is an obvious objective of both the current shareholders of those companies and potential investors who are evaluating the profitability of the investment process from the point of view of the achievable rate of return on the invested capital. It is also a key problem from the point of view of managing a company's finances and assessing its efficiency. Regardless of the frequently exposed need for a multi-criteria approach to the essence of an enterprise's objective, in addition to its economic expectations (while also considering the social expectations that are formulated by the numerous enterprise stakeholders) [5,6], the area of special interest is, therefore, their ability to create value efficiently in the cases of the mentioned companies. Therefore, any decisions that are made by the managers of those companies must also be focused on maximizing their value-creation efficiency. As a result, it is the market perspective that is of key significance from the point of view of making management decisions and the assessment of their efficiency. The market perspective most fully reflects the expectations of the three mentioned groups of enterprise stakeholders. In this context, the authors noticed an interesting research gap that was related to highlighting the decision-making function of the market-performance measures of an enterprise that are oriented at measuring and assessing the effectiveness of enterprise-value creation. This function is related to the use of the above-mentioned measures as the bases for making management decisions and assessing their effectiveness. Therefore, the aim of this article is to present and exemplify the possibility of using value-creation measures for the needs of financial management, with a particular emphasis on making management decisions and assessing their efficiency.

The fulfillment of the mentioned objective is related to the necessity of answering the following research questions:

- What was the influence of the development of enterprise-efficiency research tools on the criteria and methods of making management decisions and their assessment?
- Looking from the point of view of financial management, what is the usefulness of the value measures (including making management decisions and evaluating them in an enterprise)?
- Does the size of the companies measured by the values of their total assets influence the value-creation efficiency and the level of the market rate of return of the studied companies?
- What was the impact of the capital structure on the market value of the studied companies?

By providing answers to the formulated research questions (which enabled us to fill the research gap and realize the purpose of the article), we treat the features of originality of the conducted research as its key achievement.

As the objects of empirical research, we chose companies from the energy sector that are listed on the Polish capital market—on the Warsaw Stock Exchange—and are part of the WIG-Energia (WIG-Energy) sector index. WIG-Energia is a sector index that includes energy companies that participate in the WIG index (the main index of the Polish Stock Exchange). The WIG-Energia index currently includes 13 companies. When examining the above-mentioned companies from the point of view of the effectiveness of value creation, it should also be noted that the energy sector is one sector that is of strategic significance for the whole economy. This fact has been confirmed by, among others, the current situation on the global fuel and energy market that is being caused by the war in Ukraine and the related sanctions that have been imposed on Russia (an important supplier to the world markets of natural gas, crude oil, and coal). Thus, the efficiency of the functioning of the mentioned companies is also an object of special interest to the state (as their important stakeholder) (A broader description of the energy sector in Poland is included in Article [7]).

The following research methods were used in the article:

- Methods for analyzing and evaluating literature that presents current scientific achievements in the field under study;
- Statistical methods in the form of descriptive parameters such as average and variability measures as well as in the form of mathematical-statistics methods for the

analysis of interdependence of phenomena [6]; listed statistical methods have been used to characterize and compare analyzed energy-sector companies with the use of selected economic values and indicators, as well as to quantify the determinants of value-creation efficiency of those companies;

- Methods of tabular and graphical presentation of the quantified determinants of value-creation efficiency of the analyzed energy-sector companies.

The article is structured as follows. First, we present the theoretical background according to the market perspective of the efficiency assessment in enterprise management, followed by a description of the applied materials and methods. The next section presents our research results, as well as a discussion. Finally, we present the conclusions that resulted from our conducted research.

## 2. Market Perspective of Efficiency Measurement in Financial Management—Theoretical Background

The emergence, improvement, and development of the applications of the market measurement of enterprise efficiency that are related to the measurement of the partial and synthetic effects of its value creation are a consequence of the development of economies, the transformations of business models, and the mechanism of enterprise functioning. The mentioned circumstances mean that the efficient management that is related to the permanent process of making decisions that are focused on fulfilling an enterprise's objectives requires the use of efficiency measurement tools that enable us to quantify and assess changes in the enterprise's market value and the efficiency of its creation.

An enterprise-efficiency measurement is based on the requirements of the economic-value-measurement theory as a new book paradigm that created a need for developing analytical tools that are focused on the consideration of market determinants of enterprise efficiency. The following transformations were of key significance from the point of view of efficiency assessment:

- The growing importance of financial markets, which has led to the identification of capital market indicators and the analysis of the market value of shares and capital, based on their use as areas of indicator analysis of the company, among other things [8];
- The creation and popularization of the cash-flow concept, with its use for the needs of business valuation [9];
- The creation and development of applications of value-based management—the effects of which are primarily pioneer works by T. Copeland, T. Koller, J. Murrin [10], J.M. McTaggart, P.W. Kontes, M.C. Mankis [11], A.P. Black, P. Wright, J.E. Bachman [12], J.A. Knight [13], and J.D. Martin, J.W. Petty [14];
- The creation and development of enterprise value-creation measures, which are the bases of market perspective of study on efficiency; in this regard, the most important were works by G.B. Steward [15], A. Ehrbar [16], and S.D. Young and S.F. O'Byrne [17], who indicated new directions of evolution in perceiving and diagnosing enterprise efficiency related to the new paradigm of economic-value measurement;
- The creation and development of such value-based management instruments as business-value analysis, value controlling, pro-value motivation systems, and pro-value restructuring [18];
- The development of business-valuation methods through the use of value measures for the needs of a business-valuation account [19];
- Creating deterministic models of cause analysis referring to changes in enterprise value, and integrating book, cash, and market perspectives, which are used for the needs of enterprise-value analysis [20], value controlling [21], and pro-value restructuring [22];
- The use of book, cash, and market-efficiency measures for the needs of creating pro-value motivation systems for managers [23,24];

- The creation of comprehensive performance-measurement systems and business performance-measurement systems as examples of the integration of absolute and relative book, cash, and market measures [25,26];
- The isolation of the area of value-based restructuring within existing restructuring processes and its implementation as a tool for the growth of enterprise value-creation efficiency [27];
- The growth of the significance of innovation in shaping enterprise-value and the isolation of methods that are dedicated to assessing enterprise innovativeness in the context of efficiency of the innovation-management process [28,29];
- Creating business models that are focused on increasing the effectiveness of creating enterprise value [30,31];
- The use of value measures for the needs of building bankruptcy-prediction models, setting a new direction for developing discriminant-analysis in this regard [4].

The need to quantify the business-value-multiplication process in order to enable us to assess the fulfillment level of the basic financial objective of an enterprise and the rationalization of the decision-making process in this regard requires the use of adequate efficiency measures that are purposefully defined as market measures or value-creation measures. These measures occur in the form of absolute measures and relative measures; the former enable us to measure the value stream that an enterprise generated during a single period or over subsequent periods, while the latter is measures enterprise efficiency—not only from the point of view of the generated values but also via their reference to the value or cost of the capital that is engaged to achieve specific absolute effects. Absolute measures and relative measures can take the form of internal measures (based on quantifying the internal effects of value-creation in an enterprise) and external measures (also considering the verification of the business value and the capital-market mechanism) at the same time. A synthetic classification of enterprise-efficiency market measures is shown in Table 1.

**Table 1.** Market measures of enterprise efficiency. Source: own study based on [15,16].

| | **Absolute Measures** | **Relative Measures** |
|---|---|---|
| **Internal measures** | Measures based on economic-profit concept<br>measures of value added for shareholders | Standardized measures based on economic-profit concept<br>Capital cost-efficiency measures<br>Value-creation indices |
| **External measures** | Measures of value-added<br>Measures of enterprise value | Capital-market indicators<br>Indicators of market rates of return for shareholders |

The experiences that have resulted from the use of the market perspective of efficiency measurement and its integration with the book and cash perspectives have contributed to the emergence of new analytical solutions for various scopes of performance measurement in recent years. In this context, the following suggestions are interesting in this regard:

- The use of managerial cash-flows in analyzing the financial condition of geothermal companies in Poland [32];
- The financial assessment of renewable-energy projects using book and cash measurements [33];
- The value-creation performance evaluation for Taiwanese financial holding companies [34];
- Using the concept of value added for purposes of measuring and assessing the effectiveness of intellectual capital [35];
- The use of EVA as a market measure of efficiency in performance management from the point of view of growth efficiency [36];
- The analysis of creating and distributing value-added from the perspective of company stakeholders [37].

We are convinced that the proposal to use the market perspective of effectiveness research for the purposes of management decision-making will be a reasonable complement to and development of the above-mentioned research. In this regard, we identify a significant gap in the research on the criteria for management decision-making and assessing its effectiveness. Noticing the need to ensure the cohesion of the management decision-making process in an enterprise with the criteria of its efficiency and the principles of the pro-value motivation of managers, the authors therefore formulated a postulate for using the market perspective of efficiency measurement for the needs of decision-making, which would contribute to the growth of enterprise market-value and its creation efficiency. This is important because, with the emergence and development of the applications of the value-based management concept, the systems of rewarding managers have spread; this is based on the use of value-creation measures to stimulate the pro-value system of making decisions in an enterprise, among others. This exposes the decision-making function of the mentioned measures, thereby completing their functions of information, control, and assessment; thus, we indicate a new area of using the market perspective of studying efficiency in addition to the existing previously mentioned areas.

## 3. Materials and Methods

The study involved companies that represented the energy sector, were listed on the Warsaw Stock Exchange (WSE), and were included in the WIG-Energia index. The time span of the analysis includes seven years in total; namely, the period of 2014–2020.

The list of the studied enterprises is presented in Table 2, along with the dates of their debuts on the stock exchange and their major shareholders.

**Table 2.** List of energy-sector companies listed on Warsaw Stock Exchange (WSE). Source: own study based on https://www.biznesradar.pl/gielda/sektor:ene (accessed on 20 October 2022).

| Company's Full Name | Company's ID | Date of Debut on WSE | Major Shareholders |
|---|---|---|---|
| Elektrociepłownia Będzin S.A. | BEDZIN | December 1998 | W. Witkowski—35.31%<br>VALUE Investment Fund—10.76%<br>K. Kwiatkowski—10.37%<br>BGK—9.89%/**<br>Familiar S.A., SICAF—SIF—9.76%<br>AutoDirect S.A.—8.19% |
| ČEZ A.S. | CEZ | October 2006 | State Treasury of Republic of Poland/*—5.00%<br>State Treasury of Czech Republic/*—69.78% |
| ENEA S.A. | ENEA | January 2009 | State Treasury of Republic of Poland/*—42.92% |
| AB Inter RAO Lietuva | INTERAOLT | December 2012 | RAO Nordic OY/***—51.00%<br>UAB Scaent Baltic—29.11% |
| Zespół Elektrociepłowni Wrocławskich Kogeneracja S.A. | KOGENERA | May 2000 | PGE Group S.A.—58.07% |
| Polenergia S.A. | PEP | May 2005 | MANSA INVESTMENT—42.84%<br>BIF IV Europe Holdings Limited—31.91% |
| PGE Polska Grupa Energetyczna S.A. | PGE | December 2009 | State Treasury of Republic of Poland/*—60.86% |
| Tauron Polska Energia S.A. | TAURONPE | June 2010 | State Treasury of Republic of Poland/*—30.06%<br>KGHM Polska Miedź S.A.—10.39%/**** |
| Zespół Elektrowni Pątnów-Adamów-Konin S.A. | ZEPAK | October 2012 | Z. Solorz with subsidiaries—65.96% |

Designations: /*—state-owned shares; /**—Bank Gospodarstwa Krajowego—state-owned Polish bank; /***—major shareholders of RAO Group are Russian state-owned entities; /****—major shareholder is State Treasury of Republic of Poland.

Based on the data that is presented in Table 2, we can observe that, out of the companies that qualified for the study, the company that has been listed the longest is Elektrociepłownia Będzin S.A. (with more than 20 years of activity on the market), and the shortest is AB Inter RAO Lietuva. Two companies that were included in the WIG-Energia index

(as of October 2022) did not qualify for the study, namely, ML System S.A., and Photon Energy N.V. This was due to the short periods of their presence on the WSE (since 2018 and 2021, respectively). As a result, this made it impossible for us to conduct a comprehensive analysis and assess the value-creation efficiency with the use of market measures in the studied time-horizon in the case of these companies. Among the studied enterprises, there were two foreign companies that were included in the WIG-Energia index: ČEZ A.S. (from the Czech Republic), and AB Inter RAO Lietuva (from Lithuania). To carry out the analysis and assess the value-creation efficiency of the studied companies more precisely, they were divided into two groups that differed significantly with regard to their different values of total assets. This division resulted from our striving to ensure the high economic comparability of the studied companies. For the needs of our analysis, two groups that represented the energy sector were isolated:

- Group A—larger companies whose values of total assets were more than PLN 12 billion (PLN—Polish national currency. Currency exchange rates (EUR/PLN) at the ends of each of the analyzed years: 2014—4.2623; 2015—4.2615; 2016—4.4240; 2017—4.1709; 2018—4.30000; 2019—4.2585; 2020—4.6148. Current exchange rate as of October, 28 2022: 4.7199) (TAURONPE, PGE, ENEA, and CEZ);
- Group B—smaller companies whose values of total assets were less than PLN 10 billion (BEDZIN, INTERAOLT, KOGENERA, PEP, and ZEPAK).

When analyzing the shareholding structure of the Group A companies, it should be noted that, in the case of all of the companies that were included in this group, the dominant shareholder is the state treasury; this is a consequence of recognizing the strategic importance of these companies for the functioning of economies. Significant state involvement (direct and indirect) in the ownership structures of those companies that were included in Group B applies to such entities as BEDZIN, INTERAOLT, and KOGENERA. The ability of the state to influence the decision-making processes in companies in which it is a dominant or significant shareholder may lead to these companies treating political goals as being superior to economic goals in many cases. The state is a political institution, not an economic one; therefore, its priorities are often different than those of private investors. Thus, in the case of most of the analyzed companies in the energy sector, the role of the state as an important stakeholder of an enterprise results not only from the influence of the state as an entity in the regulatory sphere (which applies to all enterprises operating in the economy) but also from its involvement as an investor in or shareholder of the companies.

Table 3 presents descriptive statistics (measures of central tendency and measures of dispersion) for selected values and economic indicators that characterize the studied companies during the analyzed period.

Based on the data that is included in Table 3, we can claim that the median value of the sales revenues that were achieved by the studied Group A companies of the energy sector in Poland was more than 20 times greater than the median value of the Group B companies. On the other hand, the greatest loss made by the Group B companies was less than half of those from Group A. In addition, the values of the statistical measures for the D/E ratio are worth noticing; what results from these is that the value of the liabilities of at least half of the studied Group B energy companies exceeded the value of their equities. On the one hand, this proves the greater earning and developmental potential of the mentioned energy companies; on the other hand, the allocation of capital in such enterprises is burdened with higher risk, related to the probability of the occurrence of problems with debt servicing.

Interesting conclusions are provided by an analysis of the differentiation of the companies that belong to Groups A and B, based on the use of measures of dispersion such as kurtosis and skewness. These are measures that show the degree and direction of the dispersion of the analyzed values (variables) as related to the mean, as well as the degree and direction of the distribution asymmetry. In each case, the reference object is the normal distribution. When comparing the values of kurtosis and skewness for the analyzed variables (absolute values and debt ratio), it should be noted that the companies that belong to Group A are more similar to the normal distribution than the companies of Group B. With

regard to the Group A companies, kurtosis takes a negative value for three variables (sales revenues, total assets, and D/E-ratio), which means that we are dealing with a platykurtic distribution in the cases of these companies. This proves the large diversification of the values of the analyzed variables. Only in the case of net profit does kurtosis take a positive value. This creates a situation that is characteristic of the leptokurtic distribution, in which the values of the variables cluster around the mean. The situation is significantly different in the case of the Group B companies. For three variables (net profit, total assets, and D/E-ratio), kurtosis assumes positive values (leptokurtic distribution)—for net profit, it is clearly the highest value (22.988) among all of the kurtosis values. For only one variable (sales revenues) is kurtosis negative (platykurtic kurtosis).

**Table 3.** Selected descriptive statistics for selected values and economic indicators that describe studied companies from energy sector during period of 2014–2020. Source: own calculations.

| Book Values and Ratios | Min | Me | Max | Ku | Sk |
|---|---|---|---|---|---|
| Group A companies | | | | | |
| Sales revenues (in 1000 PLN) | 9,848,392.00 | 21,733,700.00 | 45,766,000.00 | −0.642 | 0.335 |
| Net profit (in 1000 PLN) | −3,928,000.00 | 933,831.00 | 3,657,000.00 | 0.035 | −0.721 |
| Assets in total (in 1000 PLN) | 18,108,040.00 | 51,606,883.00 | 123,140,887.00 | −1.142 | 0.512 |
| D/E | 0.475 | 1.002 | 2.004 | −0.200 | 0.559 |
| Group B companies | | | | | |
| Sales revenues (in 1000 PLN) | 135,965.00 | 1,045,992.00 | 3,448,712.00 | −1.247 | 0.408 |
| Net profit (in 1000 PLN) | −1,879,808.00 | 40,949.00 | 250,286.00 | 22.988 | −4.493 |
| Assets in total (in 1000 PLN) | 173,054.00 | 2,325,690.00 | 6,867,688.00 | 0.342 | 0.700 |
| D/E | 0.429 | 1.126 | 6.127 | 6.240 | 2.383 |

Designations: Min—minimal value; Me—median; Max—maximum value; Ku—kurtosis; Sk—skewness; D/E—debt-to-equity ratio.

In the case of the second measure of dispersion (which is skewness), its values take the same sign in both groups of companies. Positive skewing (right-skewed distribution) occurs in the case of three variables (sales revenues, total assets, and D/E-ratio), which means that most of the values of these variables are lower than the mean value. However, the skewness measures have similar values for both groups of companies in the case of the first two variables, while a much higher value of the measure is clearly visible for those companies that belong to Group B in the case of the third variable (D/E-ratio); therefore, the peak distribution of the variables for this group of companies is shifted more to the left than for the Group A companies. Negative skewing (left-skewed distribution) applies only to net profit. Again, the Group B companies are characterized by a much higher absolute value of the skewness measure; therefore, the peak of the distribution of the variables for this group of companies is shifted more to the right, as compared to the Group A companies.

In order to conduct the measurement and assessment of the value-creation efficiency of the studied companies, value measures whose characteristics are presented in Table 4 will be used.

**Table 4.** Value measures used for measurement and assessment of value-creation efficiency of studied energy-sector companies. Source: own study based on [10,14].

| Measures | Calculation Formulas | Designations |
|---|---|---|
| TSR | $\frac{DPS_t+(P_t-P_{t-1})}{P_{t-1}} \cdot 100\%$ | TSR—total shareholders return in period $t$<br>$DPS_t$—dividend per share in period $t$;<br>$P_t$—market price of shares at end of period $t$;<br>$P_{t-1}$—market price of shares at end of period $t-1$. |
| EVC | $NP_t - E_{t-1} \cdot c_{E,t-1}$ | EVC—estimated value created in period $t$;<br>$NP_t$—net profit in period $t$;<br>$c_{E,\,t-1}$—cost of equity at end of period $t-1$;<br>$E_{t-1}$—equity at end of period $t-1$. |
| SEVC | $\frac{EVC}{E_{t-1}} \cdot 100\%$ | SEVC—standardized estimated value created in period $t$;<br>other designations—as before. |

## 4. Results and Discussion

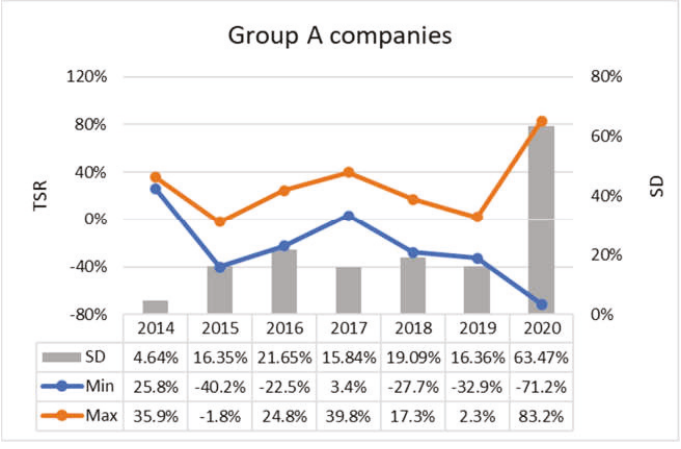
The analysis and assessment of the value-creation efficiency in this paper were conducted in two stages:

- Measurement of direct effects of shareholder value-creation;
- Measurement of value-creation efficiency in studied companies.

In the first stage, the total-shareholder-return measure (TSR) was used, in order to measure the direct effects of the shareholder value-creation. The shaping of the maximum and minimum shareholder-return of the analyzed energy companies and the risk of the capital allocation measures in the studied portfolios of the companies are presented in Figure 1.

Based on the data that is included in Figure 1, we can see that the volatility of the rates of return on the Group B companies was higher than the standard deviation of the rates of return on the portfolio of the Group A companies in as many as five of the analyzed periods. At the same time, this makes us believe that investing in the portfolios of smaller energy companies is related to a higher risk than in the case of those companies with more assets. This is also proven by the values of the minimum and maximum shareholder-returns that were achieved by the energy-company portfolios during the studied period. In four of the studied periods (approximately 57% of our observations), the maximum rates of return on the portfolio of the Group B companies exceeded the highest results for investors that were achieved by the Group A companies. However, it should be emphasized that the Group B companies marked the highest levels of shareholder wealth destruction, as compared to the minimum rates of return on the portfolio of the larger energy entities during six of the discussed periods (approximately 86% of our observations).

In the second stage of the analysis, two value measures that were based on the economic-profit concept were used: estimated value created (EVC), and standardized estimated value created (SEVC); the obtained results were compared to the debt-to-equity ratio (D/E). To determine the equity cost of the studied energy-sector companies, the Damodaran model was used [38]. The essence of this method consisted in estimating the cost of equity of a company embedded in the realities of the American economy, which is also the basis for comparisons with a company that operates on the local market—taking the specifics of the studied company (sector and financial structure) into account. The values of the parameters that were used for the analysis are presented in Table 5, whereas the median and arithmetic mean of the estimated equity cost of the studied energy companies during the period 2014–2020, are presented in Figure 2.



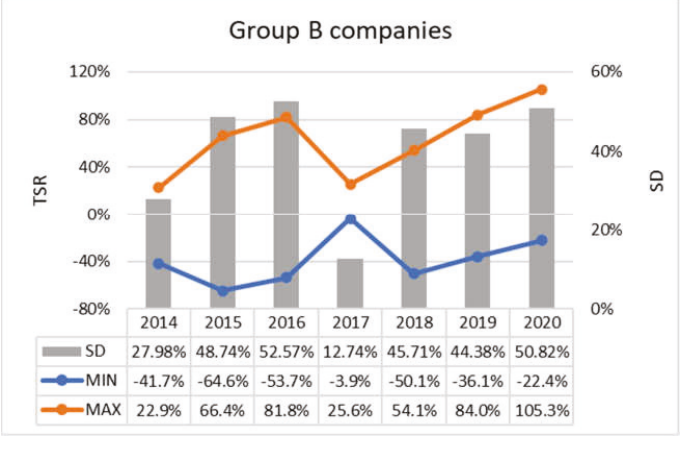




**Figure 1.** Standard deviation and maximum and minimum shareholder-returns of studied companies from energy sector during period of 2014–2020. Source: own study. Designations: Min—minimal value; Max—maximum value; SD—standard deviation.

**Table 5.** Parameter values for the application of Damodaran model. Source: own study based on https://www.investing.com/rates-bonds/poland-10-year-bond-yield (accessed on 15 July 2021); http://pages.stern.nyu.edu/~adamodar/New_Home_Page/dataarchived.html#returns (accessed on 15 July 2022).

| Book Values and Ratios | Unit of Measurement | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| Average geometrical return on ten-year treasury bonds of American Government (estimated since 1928) | % | 5.00 | 4.96 | 4.91 | 4.88 | 4.83 | 4.88 | 4.95 |
| Deleveraged "β" index for energy sector ("Power") from American market | - | 0.52 | 0.49 | 0.32 | 0.32 | 0.34 | 0.37 | 0.38 |
| American market risk premium (MRP) | % | 5.75 | 6.25 | 5.69 | 5.08 | 5.96 | 5.2 | 4.72 |
| Polish credit-default-swap premium (CDS) | % | 1.73 | 1.4 | 0.97 | 0.57 | 0.97 | 0.85 | 0.75 |
| Standard deviation of return on Polish Treasury Bond Market | % | 0.74 | 0.38 | 0.29 | 0.21 | 0.18 | 0.43 | 0.75 |
| Standard deviation of return on Polish Stock Market (WIG) | % | 3.30 | 2.84 | 4.23 | 3.43 | 4.61 | 2.68 | 10.36 |
| Standard deviation ratio of returns on Polish Stock and Bond Markets | % | 0.045 | 0.074 | 0.149 | 0.166 | 0.250 | 0.063 | 0.138 |
| Inflation rate of Polish economy | % | 0 | 0.9 | −0.6 | 2 | 1.6 | 2.3 | 3.4 |
| Inflation rate of American economy | % | 0.8 | 0.7 | 0.21 | 1.9 | 1.9 | 2.3 | 1.2 |

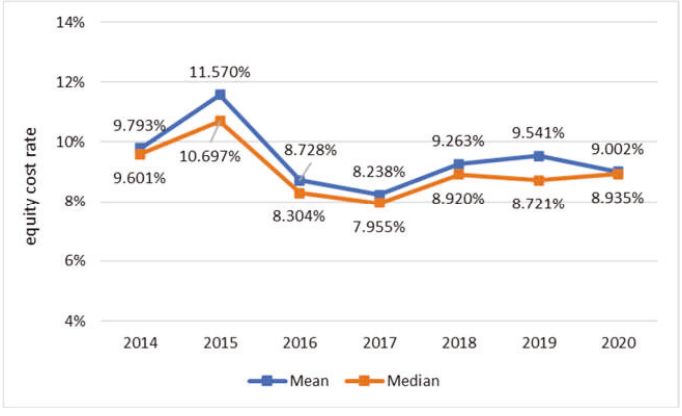



**Figure 2.** Arithmetic mean and median of equity cost of studied energy-sector companies during period of 2014–2020. Source: own study.

When observing the mean and median of the equity cost values, it should be noted that the growth of the cost that was related to capital allocation in the energy companies was observed during the period 2014–2015; this proves the progressive increase in the risk of their activities. During the years of 2015–2017, the cost of equity decreased; during the following years, (2017–2019), there was a slight upward trend; and in 2020, another non-significant decrease in the cost of equity occurred (approx. 9%). The highest average level of equity cost was marked in 2018 (at a level of approximately 21–22%). During the last year that was included in the analysis, the average and middle levels of the equity costs for the studied group of enterprises decreased by more than ten percentage points. The level of the estimated value that was created with the selected statistical measures is presented in Table 6.

**Table 6.** Estimated value created (EVC) of studied energy-sector companies during period 2014–2020 (in 1000 PLN). Source: own calculations.

| Company Name | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|
| Group A companies | | | | | | | |
| TAURONPE | −431,919.68 | −3,900,879.67 | −1,793,366.53 | −1,032,338.98 | −3,460,714.73 | −1,766,197.74 | −2,487,877.00 |
| PGE | 39,741.24 | −7,627,601.37 | −2,221,388.48 | −2,741,389.99 | −6,546,168.84 | −8,121,459.82 | −3,387,327.36 |
| ENEA | −45,047.13 | −1,768,021.77 | −729,741.17 | −742,574.08 | −2,101,664.73 | −871,086.69 | −2,234,337.00 |
| CEZ | −499,868.30 | −1,780,865.12 | −4,068,499.89 | −3,990,563.52 | −9,356,648.30 | −1,807,850.14 | −3,231,543.97 |
| Min | −499,868.30 | −7,627,601.37 | −4,068,499.89 | −3,990,563.52 | −9,356,648.30 | −8,121,459.82 | −3,387,327.36 |
| Me | −238,483.41 | −2,840,872.39 | −2,007,377.51 | −1,886,864.49 | −5,003,441.79 | −1,787,023.94 | −2,859,710.49 |
| Max | 39,741.24 | −1,768,021.77 | −729,741.17 | −742,574.08 | −2,101,664.73 | −871,086.69 | −2,234,337.00 |
| Group B companies | | | | | | | |
| BEDZIN | 10,360.72 | −11,055.20 | −12,711.55 | −23,036.18 | −52,989.85 | −137,344.57 | -(Negative equity) |
| INTERAOLT | −44,773.15 | −1,808,953.28 | −683,574.80 | −694,979.76 | −2,036,716.00 | −821,841.74 | −1,153,458.31 |
| KOGENERA | −53,056.34 | −5372.81 | −4968.67 | −48,254.31 | −254,559.80 | −40,859.56 | 875.73 |
| PEP | −16,816.55 | −99,475.04 | −318,144.45 | −286,179.17 | −282,219.03 | 2447.40 | −1723.55 |
| ZEPAK | −256,707.60 | −2,397,076.57 | −20,647.84 | −125,656.00 | −967,071.65 | −621,294.62 | −343,920.56 |
| Min | −256,707.60 | −2,397,076.57 | −683,574.80 | −694,979.76 | −2,036,716.00 | −821,841.74 | −1,153,458.31 |
| Me | −44,773.15 | −99,475.04 | −20,647.84 | −125,656.00 | −282,219.03 | −137,344.57 | −172,822.06 |
| Max | 10,360.72 | −5372.81 | −4968.67 | −23,036.18 | −52,989.85 | 2447.40 | 875.73 |

The level of the EVC measure was estimated for seventy-two cases in total; of these, a positive level of economic profit was marked in only three cases (approximately 4% of our observations). The highest level of economic destruction of the equity value that was invested by the owners was marked by CEZ in 2018—more than PLN 9.3 billion. On the other hand, the greatest increment of the estimated value created was reached by PGE in 2014—more than PLN 39.7 million. When analyzing the shaping of the median of estimated value that was created for both of the studied groups of enterprises, we can observe fluctuations in the economic-loss levels during the period 2014–2017. Over the whole period, the most critical year with regard to the negative level of EVC value was 2018, with median loss-values of PLN −5 billion (for the Group A companies) and PLN −282 million (for the Group B companies). It is worth noting that companies such as CEZ and KOGENERA achieved positive financial results on their operating levels over the whole analyzed period; thus, they were distinguished by book profitability. When considering also the necessity of the charge for the equity cost, the conducted analysis ultimately showed that the mentioned companies turned out to be unprofitable from the point of view of their value-creation efficiency. This confirms a significant difference between the accounting perspective of the enterprise's efficiency assessment (without taking the cost of equity into account) and the market perspective of this assessment (taking the cost of the entire enterprise's capital into account).

The following section studies the economic profit-creation efficiency in the relative approach; the obtained results are then compared to the equity-debt ratio (Table 7). In order to examine the power and direction of the relationships between the two analyzed variables (D/E and SEVC), the Pearson correlation coefficient is used (Figure 3). Referring to the data that are included in Table 7, we find that the highest level of economic deficit over the whole analyzed period was marked for CEZ (of the Group A companies) in 2018 and BEDZIN (of the Group B companies) in 2019. In turn, their levels of economic loss were −22.54 and −79.74%, respectively; this means that, for every PLN 1 of capital that was invested by the owners, there was as much as PLN 22.54 and 79.74 of economic loss, respectively.

**Table 7.** SEVC and D/E ratios of studied energy-sector companies during period 2014–2020. Source: own calculations.

| Company Name | Ratio | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| Group A companies | | | | | | | | |
| TAURONPE | SEVC | −2.43% | −21.68% | −11.17% | −6.19% | −19.15% | −9.58% | −13.68% |
| | D/E | 0.920 | 0.998 | 1.006 | 0.981 | 1.013 | 1.195 | 1.540 |
| PGE | SEVC | 0.09% | −16.99% | −5.50% | −6.41% | −14.12% | −16.99% | −8.01% |
| | D/E | 0.475 | 0.517 | 0.577 | 0.556 | 0.588 | 0.800 | 0.919 |
| ENEA | SEVC | −0.39% | −14.66% | −6.02% | −5.71% | −15.01% | −5.79% | −15.46% |
| | D/E | 0.501 | 0.896 | 0.886 | 1.022 | 0.991 | 1.122 | 1.483 |
| CEZ | SEVC | −1.26% | −4.36% | −9.48% | −9.33% | −22.54% | −4.52% | −7.69% |
| | D/E | 1.362 | 1.214 | 1.414 | 1.462 | 1.957 | 1.759 | 2.004 |
| Group B companies | | | | | | | | |
| BEDZIN | SEVC | 12.18% | −9.13% | −9.34% | −14.79% | −31.23% | −79.74% | - |
| | D/E | 0.429 | 4.183 | 3.665 | 3.186 | 2.847 | 6.127 | - |
| INTERAOLT | SEVC | −0.39% | −15.06% | −6.03% | −5.71% | −15.57% | −5.83% | −7.98% |
| | D/E | 0.507 | 1.028 | 1.015 | 1.165 | 1.126 | 1.272 | 1.013 |
| KOGENERA | SEVC | −4.43% | −0.43% | −0.36% | −3.37% | −16.90% | −2.79% | 0.06% |
| | D/E | 0.665 | 0.647 | 0.595 | 0.544 | 0.626 | 0.657 | 0.699 |
| PEP | SEVC | −3.26% | −7.46% | −22.77% | −22.58% | −23.88% | 0.21% | −0.13% |
| | D/E | 1.048 | 1.289 | 1.347 | 1.254 | 1.576 | 0.915 | 1.129 |
| ZEPAK | SEVC | −6.79% | −62.76% | −1.10% | −5.86% | −42.71% | −36.83% | −29.29% |
| | D/E | 0.798 | 1.639 | 1.240 | 0.968 | 1.295 | 1.651 | 2.026 |

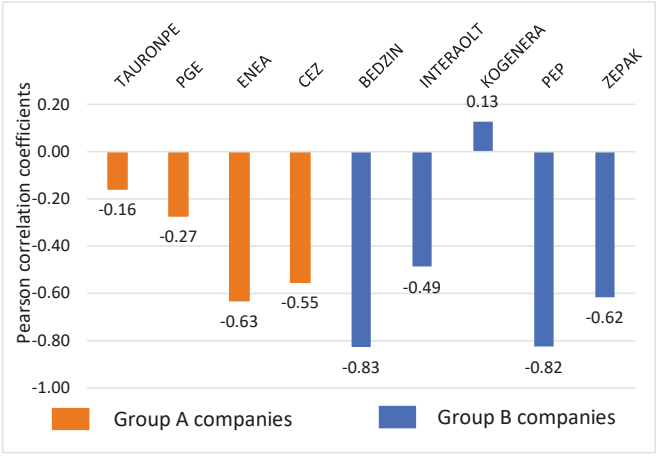



**Figure 3.** Pearson correlation coefficients for D/E and SEVC variables of studied energy-sector companies during period 2014–2020. Source: own study.

The conducted empirical research that referred to the direction and power of the relationship between the debt level of the energy-sector companies in Poland and the efficiency of the owners' economic-,value creation became the basis for drawing the following conclusions:

- In the cases of eight out of the nine analyzed companies (89%), there was a negative correlation; this means that the increase in the debt levels as compared with the share of equities negatively (degressively) affected the value-creation efficiency for the owners of the energy entities. Only in the case of KOGENERA was there a slight positive correlation, proving that the debt had a positive impact on the aforementioned efficiency.
- With reference to the Group A companies, two strong relationships between the studied variables (for ENEA and CEZ), one case of an average relationship (for PGE), and one case of weak correlation (for TAURONPE) were observed.
- In four cases of the Group B companies (the largest number in the whole study), a very high correlation was found between the analyzed variables (for BEDZIN, PEP, and ZEPAK); in one case, the conducted research proved an average correlation for INTERAOLT, and in one mentioned case (KOGENERA), there was a slight positive correlation.
- In four of the five discussed cases (84%), there was a very high relationship level among the studied variables in the Group B companies; this supports the assertion that the growth of the debt level among those energy companies with relatively smaller assets can lead to a dilution of the value-creation efficiency for the owners.

## 5. Conclusions

Efficient financial management is a constant process of making decisions that are focused on fulfilling a company's strategic and operating objectives. Nowadays, managers who perform management functions have a number of instruments that can help rationalize this process—particularly in the context of diversifying stakeholders' expectations of the results. In a special way, this article focused on the conditions and problems that are related to the financial decision-making processes that are aimed at increasing efficiency in the area of building enterprise-value. These require the use of tools for efficiency measurement that enables management to quantify and assess changes in an enterprise's market value and the efficiency of its creation. Therefore, these measures of enterprise value-creation were presented and used within the conducted research; they are particularly important from the point of view of the decision-making process and the assessment of its efficiency. It has also been proven that it is the market perspective that is of key significance from the point of view of the criteria of making management decisions. The market perspective reflects

the expectations of the majority of the company stakeholders to the fullest. Therefore, the emergence of the market perspective on the study of business efficiency has, to a large extent, made it possible to improve the criteria and methods for making management decisions and evaluating their effects. This is particularly important in the cases of the listed companies, as it has contributed to the consistency of the mentioned criteria and methods, together with the expectations of the shareholders of these companies, in terms of maximizing their market values. Thus, the conducted analysis allowed us to answer the first and second research questions.

In conclusion, the study showed that the allocation of capital in the listed energy companies during the period f 2014–2020 was subject to a relatively high risk of losing the economic value of the invested capital. In terms of asset value, dividing the studied group of companies into portfolios of two groups of companies (A and B) additionally showed that the volatility of the market and the equity returns for the smaller companies (Group B) was higher than it was for the Group A companies. This therefore answers the third research question.

Referring to the fourth research question, it should be noted that, in the cases of four companies (out of the nine studied), the increased levels of debt in relation to the values of the equities of the smaller energy companies (Group B) led to a deepening destruction of the equity value for the owners.

Due to the relatively small research sample, however, it should be emphasized that the conducted analyses should be treated primarily as a basis for further multidirectional research on enterprises that operate in other branches of the economy, using more-advanced statistical instruments as well as alternative measures for measuring and assessing the effectiveness of value creation. In future research, it will also be important to take into account the sectors of the economy that operate to the greatest possible extent according to free market principles, without a significant impact of control and regulatory mechanisms (as is the case in the energy sector).

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# Application of the DEA Method for Evaluation of Information Usefulness Efficiency on Websites

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**Abstract:** The article presents analysis and evaluation of information usefulness efficiency for recipients with secondary and higher education using the example of information and shopping websites. Different levels of quality and information usefulness efficiency have an impact on different ways of processing information by users which, in turn, may result in different consumer behavior and their decisions. The study describes the basic methodological assumptions, the research evaluation procedure of information usefulness efficiency, and the forms of informational content and various forms of information presentation and visualization, as well as the results of data analysis from the study conducted on a group of respondents. In order to determine the factors that have the greatest impact on the perception of information usefulness on websites by users, the data obtained from the study using various methods, such as online questionnaire, usability testing and heuristic analysis, were analyzed using the DEA method, which is usually used for the analysis and evaluation of efficiency. The results of the research presented in this article can be useful in creating assumptions for methods of content presentation and visualization of various forms of content building for the needs of different user groups for information and business websites.

**Keywords:** information usefulness efficiency; forms of information and content presentation; online questionnaire; usability testing; heuristic analysis; DEA method

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## 1. Introduction

In today's increasingly developed information society, one of the most popular media for years, allowing almost unlimited access to information from anywhere in the world, is the Internet. Thanks to web pages, websites and internet services, web users can browse any informational content, watch multimedia materials, communicate, shop or use online programs and applications. However, with the growing number of possible applications of the Internet, the amount of data collected in it also grows year by year. As a result, finding interesting content often becomes very difficult, time-consuming, and sometimes even impossible. Therefore, currently one of the main problems in accessing the requested information on the Internet is not the lack of its occurrence, but huge overloading, information gap and asymmetry, useless and incomprehensible ways of organizing and presenting information, or the multitude of IT tools enabling access to content on different ways. Therefore, appropriate ways of defining, describing, organizing and presenting content on websites are becoming more and more important for users, which in turn affect the usefulness of shared information and the increased effectiveness of mutual communication using websites and internet services. In turn, the most important goals for companies and organizations, operating online and striving for a high level of efficiency in their business, should be sustainable activities in relation to economic, social and environmental performance, otherwise referred to as corporate sustainability [1,2]. Moreover, such institutions should also be interested in using the idea of digital sustainability, that is, the use of IT

tools for creating, using, transmitting, or sourcing electronic data for organizational activities, as well as introducing modern digital innovations and smart technologies into its business in order to ensure sustainable economic growth now and in the future [3,4]. Another important aspect of digital sustainability should also be attention paid to a high level of digital products and resource usability, due to the fact that there are more and more applications of modern technologies such as ICT, IoT or AI/ML in different areas of the economy [4,5]. Because of the fact that there is currently little research on the evaluation of information usefulness efficiency on websites in terms of sustainability, the authors of the article decided to cite the literature review of the research and concepts related as closely as possible to the issues raised in the work.

Interpersonal communication is the basis of existence and one of the most basic and oldest social processes that determines the existence and functioning of the world [6,7]. In the social sciences and humanities, communication is seen as a contact with people and a manifestation of mutual interactions, whose purpose is to share knowledge and information, as well as maintaining the social context needed to exchange thoughts, skills, feelings and ideas [8–10]. These processes take place by means of assigning and receiving the meaning of specific behaviors and symbols formed by words, images, gestures, sounds or touch. By communicating with each other, people receive and transmit information through individual senses, such as: eyesight, hearing, smell, touch or taste [11]. In business and organization, communication is a process that plays a significant role in the implementation of basic management functions, serves the purpose of providing information and mutual communication between the organization's stakeholders and is the basis for building relationships between the company and the environment [12,13]. It is especially important to understand the form, content and meaning of the message between the sender and the recipient, thanks to which the main functions of the organization's activities are satisfied, such as, among others: informing, planning, organizing, controlling and motivating [14–16]. In turn, in marketing, communication is a system of actions and means by which the company transfers various information to the market and tries to shape the behavior of both internal and external recipients. Marketing communication involves the coordination of promotional activities and other marketing activities in order to communicate with customers, which takes place by receiving and transmitting specific content or information [17,18]. One of the most popular, relatively cheap and quick-to-function communication channels used on a large scale in marketing communication are websites and internet services based on electronic media. They also perform a basic function according to the assumptions of the communication model in a hypermedia computing environment, which combines the possibilities of the mass communication model with the model of individualized communication, and also introduces a new quality of the process to marketing communication. This model presents a new meaning of the message, which is characterized by multimedia, the content and form of the message changing qualitatively, and the relationships and communications between marketing entities taking place interactively [19,20].

Effectiveness is a concept that has many meanings and various interpretations in the sciences of economics and management. One of the most frequently used approaches is efficiency or economy, which is the result of the activity of a business entity or specific project and the result of the relation between the obtained effects and the incurred costs. This effectiveness can be estimated before and after the activity starts, and the inputs can be expressed in terms of resources or costs [21–23]. Another popular approach is effectiveness or organizational effectiveness, which means the ability of a business entity or enterprise to adapt currently and strategically to changes in the environment as well as productive and economical use of resources to achieve the adopted goals [22,24,25]. Regardless of how different definitions of effectiveness are understood and interpreted, the general concept of effective communication is understood to mean the receipt of a message in the same sense as the intention of the sender, that is as the realization of a cognitive goal [26,27]. The task of effective communication is the most adequate transfer

of widely understood information; that is, the ability to fulfill the intention of the act of communication. Adequacy refers here to the appropriate time, function, social reach and the content of the act of communication [28]. Effective communication between people depends, among other things, on similarities in communication skills and attitudes, degree and type of education, social experiences or culture of the sender and receiver [27]. On the other hand, to define organizational communication as effective, it should meet the following conditions: it should be based on business goals, rely on a clear set of expected results, create a pleasant climate, influence attitudes and focus on transforming information first into understanding and then into action [29,30].

Information is a concept that has a very large number of definitions and various interpretations among others due to its original character. For the purposes of analyzing the communication process, the concept of information should be understood as content expressed in linguistic and/or non-linguistic signs that means something to someone [31]. In turn, from the point of view of economics and management sciences and in the context of effective communication, it can be said that information is data that have been interpreted by its recipient or recipients and used for a specific purpose. Data are understood here as all kinds of facts, numbers and symbols that have not yet been analyzed and properly prepared [32]. According to P. Sienkiewicz, information is a set of facts, events or features of specific objects (things, processes, systems) contained in a message (statement), presented and given in such a form (figure) that allows the recipient to respond to the situation and take appropriate mental or physical action [33]. On the other hand, Wiener believes that information is a certain content, the source of which is the outside world, and the process of obtaining it is related to the adaptation of people to this world [34]. As can be seen in the above definitions, the concepts of data, message and content are essential elements in the process of informing. However, there are significant differences between informing and communicating, related inter alia with different goals of both processes, its participants or mutually occurring relations. Therefore, according to D. Weiss, informing concerns the transmission and reception of structured data, while the purpose of communication is the exchange of information aimed at changing someone's consciousness [35,36]. In turn, A. Bartoli believes that only the sender of the message plays an active role in informing, while in the process of communication there is interaction between the participants; besides, it is an act, a subject and means of communicating information at the same time [37]. Features of information are selected aspects that describe it in more detail and include the following three characteristics: quality, value and usefulness. The information quality consists of appropriate features that information should have, so that its quality is at a sufficiently high level. The most often desired quality features of information include: timeliness, accuracy, veracity, adequacy, completeness, readability, etc. [32,38,39]. The information value usually means a certain feature that determines the measure of its suitability, but this feature is also referred to as valuableness, usefulness, importance of information or utility value [40]. According to A. Charkiewicz, the information value is also a combination of various features related to its quality and usefulness in terms of a specific recipient and decisions made by him [41]. Usefulness in the information dimension is related to the qualitative theory of information, which was first described by M. Mazur, and according to which the utility of the information concept determines its quality (inter alia accuracy, authenticity, etc.), amount (appropriate range of time and flowing frequency), and relationship with tasks (validity of the subject) [42]. According to P. Sienkiewicz, information usefulness is also related to the probability of achieving the intended goal for the taken action. Therefore, if the action is taken together with the information received, and the goal is achieved to a greater extent than it would have been before obtaining it, it can be said that the information was useful. Therefore, the effect of the taken actions must differ significantly before and after obtaining specific information [33]. According to Bogdan Stefanowicz in one of the most synthetic approaches presenting the useful information, it is said that this information should have the right content and be delivered at the right time and in the right form [43]. The information usefulness collected on the website is a number of different criteria that

should be characterized by information content that is available, current or understandable to recipients [38,39]. The evaluation criteria of information usefulness for their suitability for a user may be features such as: accuracy, veracity, timeliness, completeness, reliability, adequacy, form, frequency of use, scope, coherence, source, time horizon, etc. [38,44,45].

Usability in the context of digital products is a scientific discipline dealing with the ergonomics and functionality of interactive devices and electronic applications, among others in terms of the ease and convenience of using websites and internet applications. Web usability, according to the ISO 9241-11 standard, defines the extent to which the website can be used by specified users to achieve specified goals in a specified context of use [46]. According to J. Nielsen, one of the best-known experts, the usability of an IT product is determined by such components as ease of learning, effectiveness of achieving goals in working tasks, ease of remembering acquired skills, system tolerance for errors and level of user satisfaction understood as a pleasure felt with system use [47]. In Nielsen's opinion, usability is also a quality attribute which evaluates how easy to use user interfaces are and refers to methods of improving ease and pleasure of use during the design process [48]. In turn, another of the known practitioners of designing useful websites, namely S. Krug, calls to not make users unnecessarily think while using digital products. According to him, usability means the certainty that something works well and a person with average skills or experience can use it as intended, without being frustrated. In Krug's opinion, useful things are characterized by such features as helpfulness, ease of learning, ease of remembering, effectiveness, efficiency, and being desirable and delightful [49]. Another approach for understanding information in the context of its usefulness in information systems are different concepts related to technical usability of these systems. Therefore, for end users, such aspects as perceived usefulness, perceived ease of use and usability of computer systems are important. According to F.D. Davis, the perceived usefulness is the degree to which a person believes that using a particular system would enhance her performance [50]. This type of usefulness has been confirmed by many researchers as a reliable and effective indicator to use for various information technologies by users with different levels of knowledge and experience. However, according to S.A. Gahtani, the perceived ease of use is the degree to which a person believes that using a particular system will not result in additional costs associated with its operation [51]. This type of usefulness describes the extent to which something new is not perceived as difficult to understand in study or practical use. In addition, as stated, E.M. Rogers perceived ease of use to be considered as the degree to which consumers perceive a new product or service as a better than its alternatives [52]. However, according to J. Nielsen, the usability of a computer system is the extent to which the system can be used by specified users to achieve specific purposes, consistent with the rules of effectiveness, efficiency and satisfaction in a specified context of use [53]. In practice, usability is a field of knowledge dedicated to the convenience and ergonomics of using computer systems, and in particular of Internet sites. The web service is useful when the first visit attracts the attention of visitors, and further browsing allows intuitive use of its resources [49,54].

Evaluation of information usefulness efficiency was treated by the authors of this article in the context of its economic efficiency evaluation, that is as a result of the relation between the obtained effects and incurred expenses. This is due to the fact that, on the one hand, access to the desired information enables the fulfillment of various information needs (income, effects, etc.), and on the other hand, actually getting to the right information is usually associated with incurring various related charges (costs, expenses, etc.). The literature on the subject points out that information has the potential to create effects or specific revenues, which is now reflected in its treatment as the fifth resource, as it meets the conditions imposed on resources in general, such as work, ground, capital or organization. Moreover, information as a resource has specific properties, such as the possibility of any use to achieve specific goals, having value and the requirement to incur costs to obtain them, being a mobile and non-consumable resource, manifesting the synergy effect, property of duplication and easy copying without leaving a sign of this treatment, or being an

experimental good and a source of profit [55–57]. On the other hand, information is also characterized by the possibility of generating costs, which is especially noticeable during its acquisition, storage, processing, sending and sharing with recipients. This is related to the involvement of appropriate specialists, taking someone's time, and using appropriate resources; that is, incurring specific financial, time and personnel costs. This is particularly evident in the case of media information markets, where most often the fixed costs of generating and preparing information are high (e.g., film production), while the variable costs of information reproduction are usually low (e.g., duplicating copies of film discs). Therefore, any information valuation should be carried out on the basis of its value, not just the cost of production [58]. Moreover, in order to obtain information that is more reliable, accurate and meeting the relevant quality requirements than the standard, it is necessary to incur higher costs, spend more time and put in more effort [55–57]. Other costs related to the use of information include psychological and cognitive barriers, such as: lack of appropriate knowledge to handle information, information overload, problems with remembering information, switching costs, costs of paying attention or information asymmetry [59].

The study presented in this article makes a significant contribution to the existing literature. It is one of the first studies on the analysis and evaluation of information usefulness efficiency applied to websites, using a combination of various types of quantitative and qualitative methods in research and analysis. The following four methods were used in the study: internet survey, usability testing, heuristic analysis and the DEA method. The article fills the research gap in the discussion on the possibility and applicability of using the DEA method on efficiency evaluation in a situation, where the role of decision-making units (DMUs) was given to people (respondents of the survey), and not machines, devices or institutions, as is usually practiced.

The article is structured as follows. In the first section, the literature review of the research and concepts related to the issues raised in the article on the evaluation of information usefulness efficiency on websites in terms of sustainability was reviewed. The second section characterizes the research problem, the research procedure, the research entity, the research object and thematic scope as well as the methods used in the research. The third section describes the individual stages of the research procedure, presents graphically obtained results from the preliminary data analysis carried out on the group of respondents and the main data analysis using the DEA method, and also carries out a detailed interpretation of the presented data. The fourth section makes a general interpretation of the results obtained from the study in terms of the evaluation of information usefulness efficiency on websites, summarizes the research carried out and draws conclusions for the future.

## 2. Materials and Methods

The research problem of the article is the analysis and evaluation of information usefulness efficiency applied to selected information and shopping websites with the use of selected methods. The evaluation of information usefulness efficiency was focused mainly on available informational content and various forms of information presentation and visualization, such as text, graphics, images, pictures, movies and information graphics. In addition, attention was also paid to knowledge increase aspects, cognitive aspects and user experience (UX) aspects. The selected research problem was prepared and developed on the basis of quantitative research (internet survey) and qualitative research using the usability testing and the heuristic analysis. Analysis of the results was carried out with the use of the DEA method.

The research entity survey conducted in May 2021 used a 34-person group of respondents, which was selected for the study by the targeted selection method and represented people with secondary and university education. The sample size was considered as statistically representative due to the specificity of the study related to the website's usability evaluation. All respondents were students; most of them graduated from some form of higher education (52%), a smaller fraction graduated from high school (40%), and the others

graduated from technical high school (8%). The vast majority of the respondents were citizens of Polish nationality (90%), and the others (10%) were citizens of other countries. All respondents represented two different age groups of young people aged 18–22 years old (65%) and 23–26 years old (35%). Among the respondents, the majority were women (57%) and the remainder were men (43%). From the answers obtained from the respondents, it can be concluded that exactly everyone (100%) uses the Internet several times a day. The most popular form of communication using the Internet among respondents were mobile devices (83%) and stationary devices such as laptops (57%); the use of desktop computers (44%) and tablet devices (4%) were reported significantly less.

The research objects were five different Polish-language internet services with the possibility of content reading and browsing, as well as online shopping. The websites included in the study, in terms of analysis and evaluation, were fully functional software products used to transmit and receive information content in various forms, scope and functionality. For the study, services with informative articles were selected based on the following aspects: the one selected topic, various forms of information presentation in the article, the time needed to read the textual content and view the multimedia content in the article, and the length of the article's total content counted by the number of screens to scroll. Selected websites were characterized by various forms of information content presentation on the one specified topic, such as: textual content combined with images, pictures, movies, or infographics; full product specification in the form of textual content with a picture gallery; full product specification in the form of textual and multimedia content with software interactions; full product specification and the possibility of making online purchases and suggestions of sample products on the selected topic.

The thematic scope of the research was a group of electronic devices such as smartwatches, whose popularity in society in recent years is much higher than traditional watches and still growing. The smartwatch is a wearable computer, in the form of a watch with a touch screen and the size of a wristwatch, that meets all the functions of a traditional electronic watch and additionally has some smartphone functions and telemetry functions. Smartwatches most often operate based on mobile operating systems, are equipped with various types of wireless communication, and may have various additional functions, such as a digital camera, accelerometer, thermometer, pedometer, heart rate monitor, altimeter, barometer, compass, GPS receiver, MP3 player and more [60].

The research procedure of analysis and evaluation of information usefulness efficiency applied to the selected information and shopping websites consisted of taking the following steps:

1. Creation of the survey, conducting the survey on selected websites and collecting data from respondents using the usability testing and heuristic analysis;
2. Preliminary data analysis using normalization and construction of a hierarchical structure of criteria, which contain the list of eight groups of criteria related to different aspects of information usefulness, thematically assigned main criteria and obtained values of final results;
3. Main data analysis using the DEA method and data interpretation for main criteria within the CCR-I and the BCC-I model;
4. Drawing out conclusions from the analysis.

The usability testing is one of the most popular UX qualitative research methods, used for usability evaluation and based largely on the user-oriented design approach. This method is used primarily to assess the functionality and usability of websites [61]. Usability tests, as opposed to group tests, are usually carried out on individual users and rely on the practical use of selected functions of a website. During the performance of specific tasks, participants are asked to pay attention to what they see, do and feel, and then describe their impressions orally or in writing. The purpose of the research is to check the correct functioning of the website and to detect areas where users have problems, and then to provide recommendations for improvement [62].

The heuristic analysis is one of the UX expert research methods based on a group assessment made by specialists in a selected field, the so-called experts. These methods use the opinions and assessments of various people (e.g., experts, professionals and non-professionals) involved in solving a given problem, finding facts and relationships between them and formulating their own uninhibited judgments and proposals for solutions. Heuristic analysis deals with the study of creative thinking processes and formulating recommendations, which application allows for more effective problem solving [63]. The use of heuristic analysis to evaluate website usability usually consists of determining the degree of its compliance with recognized design principles, the so-called heuristics, UX guidelines, requirements or other evaluation criteria [48].

The data envelopment analysis method (DEA) is a linear mathematical programming technique that is used for the evaluation of the effectiveness (performance or efficiency) of a group of complex entities, referred to as decision-making units (DMUs). The DEA is one of the most widely applied non-parametric methodologies used to study frontier efficiency, ever since its introduction in 1978 by Charnes, Cooper, and Rhodes (acronym: CCR), that has grown into a powerful mathematical and linear programming technique [64,65]. The DEA method, as a non-parametric method, was created to overcome the limitations of various disadvantages of parametric methods, which means that it does not require the presentation of a functional relationship between inputs and outputs. The subject of the analysis of this method is efficiency or productivity; how DMUs transform their inputs into outputs. This method determines the most effective unit among the respondents, and the results of the others are referred to by creating a ranking of all units and demonstrating a leader worth following (the so-called benchmark). One of the main goals of DEA analysis is to improve the efficiency of ineffective DMUs, which, in relation to the reference unit, is referred to as the projection at the limit of production possibilities. As the type of set of units is not strictly defined here, any units capable of transforming inputs into outputs can be included in the analysis, and therefore units such as service, manufacturing, commercial, public sector or non-profit organizations can be analyzed [66,67]. However, the set of decision units to the analysis must be carefully selected in order to make meaningful comparisons. Therefore, the group of examined units should have a finite number, be fairly homogeneous, pursue the same goal and operate under the same market conditions [68]. The overall assessment of the productivity level for individual DMUs in the DEA method is measured as the quotient of the weighted sum of inputs (costs) to the weighted sum of outputs (revenues), where the result is a pointer in the range 0 to 1 [65,69]. In the DEA method, many models are distinguished, according to the orientation criterion and the scale effects criterion. The two basic and most commonly used models include the CCR and BCC models, which can be additionally input- or effect-oriented. In the CCR model, in which an assumption of constant returns to scale is made, the relative efficiency of a given unit is the same for input and output orientation, therefore CCR-I and CCR-O have the same result. In turn, the input-oriented BCC-I model is the first and most popular modification of the basic CCR-I model, which in turn has an impact on the method of estimating effectiveness. The BCC-I model is a model that assumes the existence of variable returns to scale (VRS), thanks to which it is possible to recognize whether the ineffectiveness of a given object results from the waste of inputs (the so-called pure technical ineffectiveness) or from operating in the non-optimal area of economies of scale (the so-called scale ineffectiveness). It may also be seen that the object is ineffective both technically and in terms of scale, which demonstrates the presence of so-called global technical ineffectiveness [70–73]. The DEA method has been widely used, researched and developed by scientists and practitioners all over the world for over 40 years since its inception in a variety of areas and types of units, such as schools, hospitals, universities, banks, agriculture, transportation, courts, companies, cities, regions and countries [65,66,74,75].

## 3. Results

### *3.1. The Survey*

In the first stage of the research procedure, in order to collect data from respondents, an electronic survey was created using the free of charge Google Forms online survey system [76]. The survey study was based on the evaluation of selected criteria and performing simple successive tasks, which were performed in a network environment using an internet browser application and selected internet information and shopping services. All of the tasks were evaluated by respondents on a slightly extended Likert scale for values from 0 (lack of or lowest rating) to 5 (highest rating), based on the level of satisfaction and usability fulfillment of specific qualitative and impression criteria for content on selected internet services [77].

### *3.2. The Preliminary Data Analysis and Presentation of the Survey Results*

In the second stage of the research procedure, preliminary data analysis was performed for a specific research problem. For this purpose, eight groups of criteria, related to different aspects of information usefulness, were built. The created groups of criteria were selected thematic areas of analysis and evaluation of information usefulness, and they related to the content and impressions of the articles, published on the analyzed websites, as part of the following aspects: informational, information presentation, knowledge increase, cognitive, user experience (UX) and economic effectiveness. Then, a list of thematically related main criteria was assigned to each of the groups of criteria, which were additionally divided into criteria with the feature of income (effect) or cost (input). The total number of groups for the criteria was eight and was selected on the basis of the analyses results of the effectiveness evaluation models in the context of the overall assessment of quality or level of provided services, which were carried out by other researchers [78–80]. Furthermore, in this stage, assigning cost-income features to the criteria was related to the need for further analysis and evaluation of the information usefulness efficiency using the DEA method. In addition, it was assumed that the income criteria (outputs) were a kind of web article usefulness property which the recipient experienced after reading the content of the article on the website, thanks to which he was potentially satisfied with the article as an informative product and he was able to obtain additional values for himself, e.g., information, knowledge, wisdom, etc. In turn, the cost criteria (inputs) were a kind of web article usefulness property related to the article as an informative product and incorporating all costs of its production, storage on the website and its further distribution. The number of individual income criteria within the selected groups of criteria varied and ranged from a minimum of two to a maximum of five main criteria. The number of individual cost criteria, as in the case of the income criteria, was also varied and ranged from a minimum of three to a maximum of seven main criteria. The condition for selecting a certain number of income and cost criteria within one group of criteria was the fulfillment of the determining assumption that the product of the number of income and cost criteria must be smaller than the total number of respondents who took part in the survey [81–83].

As part of the second stage, the results of the data analysis carried out for a specific research problem were presented. Exceptionally in this stage and in order to clearly show the results obtained in the study, the data from individual respondents were averaged to one value and then normalized for comparison purposes. Symbols of the main criteria (MC-01-O, . . . , MC-16-O and MC-01-I, . . . , MC-15-I), a list of names of individual main criteria, a profitable (output) or costly (input) type of criterion feature and values obtained from the survey after preliminary data analysis in the context of five analyzed websites (Site-1, Site-2, Site-3, Site-4, Site-5) are presented in the following Table 1.

**Table 1.** Structure of each group of criteria and assigned main criteria with obtained results from the survey (source: self-study).

| Symbol | Short Name of Criterion | Criterion Feature | Data from Survey Study Thematic Websites | | | | |
|---|---|---|---|---|---|---|---|
| | **Aspects of Informational, Information Presentation, Knowledge Increase, Cognitive, UX and Economic Effectiveness Information Usefulness** | | **Site-1** | **Site-2** | **Site-3** | **Site-4** | **Site-5** |
| | **Group I. Informational aspects in the content of the article** | | | | | | |
| MC-01-O | The occurrence diversity of multiple-meaning information in the content of the article | Output | 0.39 | 0.55 | 0.57 | 0.46 | 0.69 |
| MC-02-O | The usefulness of the entire content of the article in the future | Output | 0.58 | 0.71 | 0.74 | 0.63 | 0.72 |
| MC-01-I | The timeliness of textual and graphic content on the website | Input | 0.75 | 0.81 | 0.83 | 0.79 | 0.90 |
| MC-02-I | The substantive quality of textual and graphic content on the website | Input | 0.77 | 0.83 | 0.80 | 0.74 | 0.89 |
| MC-03-I | The availability of the entire textual and graphic content on the website | Input | 0.78 | 0.76 | 0.77 | 0.75 | 0.90 |
| MC-04-I | The informational completeness of textual and graphic content on the website | Input | 0.77 | 0.78 | 0.78 | 0.74 | 0.86 |
| MC-05-I | The matching amount of text content to amount of graphic content on the website | Input | 0.84 | 0.86 | 0.91 | 0.58 | 0.82 |
| | **Group II. Information presentation aspects in the content of the article** | | | | | | |
| MC-03-O | The ease and reading comfort of textual and graphic content of the article | Output | 0.78 | 0.76 | 0.77 | 0.79 | 0.85 |
| MC-04-O | The level/amount occurrence of multiple-meaning knowledge in the content of the article | Output | 0.44 | 0.52 | 0.57 | 0.52 | 0.63 |
| MC-06-I | The presentation attractiveness of the textual content of the article | Input | 0.63 | 0.65 | 0.74 | 0.66 | 0.94 |
| MC-07-I | The presentation attractiveness of the graphic content of the article | Input | 0.56 | 0.64 | 0.72 | 0.75 | 0.97 |
| MC-08-I | The quality of the information presentation forms for textual and graphic content in the article | Input | 0.72 | 0.69 | 0.75 | 0.62 | 0.91 |
| MC-03-I | The availability of the entire textual and graphic content on the website | Input | 0.78 | 0.76 | 0.77 | 0.75 | 0.90 |
| MC-09-I | The presentation aesthetics of textual and graphic content on the website | Input | 0.63 | 0.58 | 0.71 | 0.69 | 0.97 |
| MC-04-I | The informational completeness of textual and graphic content on the website | Input | 0.77 | 0.78 | 0.78 | 0.74 | 0.86 |
| MC-05-C | The matching amount of text content to amount of graphic content on the website | Input | 0.84 | 0.86 | 0.91 | 0.58 | 0.82 |
| | **Group III. Knowledge increase aspects in the content of the article** | | | | | | |
| MC-04-O | The level/amount occurrence of multipl- meaning knowledge in the content of the article | Output | 0.44 | 0.52 | 0.57 | 0.52 | 0.63 |
| MC-05-O | The amount of knowledge acquired on the selected topic from the article | Output | 0.56 | 0.66 | 0.70 | 0.54 | 0.74 |
| MC-06-O | The quality of knowledge acquired on the selected topic from the article | Output | 0.61 | 0.71 | 0.70 | 0.64 | 0.79 |
| MC-04-I | The informational completeness of textual and graphic content on the website | Input | 0.77 | 0.78 | 0.78 | 0.74 | 0.86 |
| MC-10-I | The amount of knowledge contained in the article on the selected topic | Input | 0.68 | 0.76 | 0.78 | 0.61 | 0.79 |
| MC-11-I | The quality of knowledge contained in the article on the selected topic | Input | 0.73 | 0.78 | 0.78 | 0.63 | 0.82 |
| | **Group IV. Cognitive aspects of the article's content message** | | | | | | |
| MC-07-O | The level of concentration/attention while reading the article | Output | 0.63 | 0.64 | 0.67 | 0.58 | 0.77 |
| MC-08-O | The level of remembered information from the entire article | Output | 0.71 | 0.68 | 0.70 | 0.63 | 0.77 |
| MC-09-O | The level of acquired new information from the entire article | Output | 0.50 | 0.67 | 0.66 | 0.57 | 0.70 |
| MC-10-O | The level of cognitive fatigue and exhaustion after reading/browsing the article | Output | 0.66 | 0.57 | 0.59 | 0.61 | 0.80 |
| MC-12-I | The intelligibility of textual content in the article | Input | 0.84 | 0.86 | 0.86 | 0.79 | 0.88 |
| MC-13-I | The intelligibility of graphic content in the article | Input | 0.84 | 0.76 | 0.80 | 0.82 | 0.91 |
| MC-14-I | The total length of the article on the website | Input | 0.75 | 0.61 | 0.78 | 0.73 | 0.90 |
| MC-15-I | The number of elements on the website distracting from proper access to the information contained in the article | Input | 0.75 | 0.57 | 0.46 | 0.70 | 0.74 |
| | **Group V. UX aspects of the article in terms of textual content on the website** | | | | | | |
| MC-03-O | The ease and reading comfort of textual and graphic content of the article | Output | 0.78 | 0.76 | 0.77 | 0.79 | 0.85 |
| MC-11-O | The usability of user interfaces used on the website | Output | 0.78 | 0.67 | 0.70 | 0.68 | 0.84 |
| MC-12-O | The interaction attractiveness of user interfaces used on the website | Output | 0.67 | 0.68 | 0.67 | 0.61 | 0.87 |
| MC-14-I | The total length of the article on the website | Input | 0.75 | 0.61 | 0.78 | 0.73 | 0.90 |
| MC-15-I | The number of elements on the website distracting from proper access to the information contained in the article | Input | 0.75 | 0.57 | 0.46 | 0.70 | 0.74 |
| | **Group VI. UX aspects of the article in terms of graphic content on the website** | | | | | | |
| MC-03-O | The ease and reading comfort of textual and graphic content of the article | Output | 0.78 | 0.76 | 0.77 | 0.79 | 0.85 |
| MC-11-O | The usability of user interfaces used on the website | Output | 0.78 | 0.67 | 0.70 | 0.68 | 0.84 |
| MC-12-O | The interaction attractiveness of user interfaces used on the website | Output | 0.67 | 0.68 | 0.67 | 0.61 | 0.87 |
| MC-07-I | The presentation attractiveness of graphic content of the article | Input | 0.56 | 0.64 | 0.72 | 0.75 | 0.97 |
| MC-09-I | The presentation aesthetics of textual and graphic content on the website | Input | 0.63 | 0.58 | 0.71 | 0.69 | 0.97 |
| | **Group VII. UX aspects of the article in terms of emotions on the website** | | | | | | |
| MC-13-O | Types of feelings and emotions accompanying while reading the article and content | Output | 0.63 | 0.62 | 0.70 | 0.58 | 0.76 |
| MC-14-O | The intensity of the feelings and emotions associated with reading the article and content | Output | 0.50 | 0.56 | 0.63 | 0.53 | 0.70 |
| MC-03-O | The ease and reading comfort of textual and graphic content of the article | Output | 0.78 | 0.76 | 0.77 | 0.79 | 0.85 |
| MC-06-I | The presentation attractiveness of the textual content of the article | Input | 0.63 | 0.65 | 0.74 | 0.66 | 0.94 |
| MC-08-I | The quality of the information presentation forms for textual and graphic content in the article | Input | 0.72 | 0.69 | 0.75 | 0.62 | 0.91 |
| | **Group VIII. Economic effectiveness aspects of the article** | | | | | | |
| MC-15-O | The effectiveness of the article's informational transfer | Output | 0.76 | 0.76 | 0.74 | 0.69 | 0.81 |
| MC-16-O | The performance of gaining new information on a selected topic in the article | Output | 0.68 | 0.68 | 0.72 | 0.67 | 0.81 |
| MC-14-I | The total length of the article on the website | Input | 0.75 | 0.61 | 0.78 | 0.73 | 0.90 |
| MC-05-I | The matching amount of text content to amount of graphic content on the website | Input | 0.84 | 0.86 | 0.91 | 0.58 | 0.82 |
| MC-15-I | The number of elements on the website distracting from proper access to the information contained in the article | Input | 0.75 | 0.57 | 0.46 | 0.70 | 0.74 |

### *3.3. The Main Data Analysis*

In the third stage of the research procedure, and as a result of the conducted preliminary data analysis, the properly prepared results were obtained, which the authors of the article decided to interpret in two different ways. The first way of interpretation was the comparison of the results within individual websites, and to determine which of the five examined websites and, represented by them, which forms of content presentation and experiences from applied information usefulness were the most effective, using the input-oriented CCR-I model with assumption of constant returns to scale. The second way of interpretation was the comparison of the results within individual websites and to determine which of the five examined websites and, represented by them, which forms of content presentation and experiences from applied information usefulness were the most effective, using the input-oriented BCC-I model with assumption of variable returns to scale. In the CCR-I model, the lowest possible level of inputs is searched, at which it is possible to achieve effective results for the object under the assumption that output variables increase proportionally with the input variables. Meanwhile, in the BCC-I model, the lowest possible level of inputs is searched, at which it is possible to achieve effective results for the object under the assumption that proportional change of the inputs does not necessarily lead to a proportional change of the outputs [84,85]. Therefore, in the processes of main data analysis and interpretation for both objectives set in the study, the DEA method was used.

The main data analysis obtained in the study for individual main criteria consisted of selecting appropriate data sources from each respondent separately, and then calculating the total efficiency level of selected websites using the DEA method within two different models oriented at the inputs analysis; that is, the CCR-I constant returns to scale model and the BCC-I variable returns to scale model. In the context of the performed analyses using the DEA method, each of the respondents was treated as a separate decision-making unit (DMU). Calculations and results related to the application of the DEA method were performed with the use of the MaxDEA 8 computer program [86].

### *3.4. The First Method of Data Interpretation and Presentation of the Results*

The first method of data interpretation was the analysis of selected websites for each group of criteria using the CCR-I model of the DEA method in terms of cumulative values for individual main criteria and within each respondent. The sum of the values obtained in this way was the value of information usefulness efficiency for one selected website and within one selected thematic group of criteria. This method of data analysis was supposed to show the impact of all main criteria values within one specified group of criteria on a group efficiency assessment of individual websites, and then the possibility of creating a group ranking of websites. Similar operations were performed for each of the eight thematic groups of criteria, and then the final efficiency assessment for individual websites was calculated and their final ranking was created. The final ranking of websites was to demonstrate their order from the highest- to the lowest-rated according to respondents, in terms of the efficiency level of eight different aspects of information usefulness and applied in selected information and shopping websites.

The results obtained from the main data analysis using the CCR-I model of the DEA method for the values of information usefulness efficiency are presented in the following Table 2 and in Figure 1.

**Table 2.** The final ranking of websites divided into groups for the values of information usefulness efficiency after main data analysis using the CCR-I model of the DEA method (source: self-study).

| Ranking Position | Thematic Websites and Results from Data Analysis Using the CCR-I Model of the DEA Method Name of the Group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Group I. Informational Aspects in the Content of the Article | Group II. Information Presentation Aspects in the Content of the Article | Group III. Knowledge Increase Aspects in the Content of the Article | Group IV. Cognitive Aspects of the Article's Content Message | Group V. UX Aspects of the Article in Terms of Textual Content on the Website | Group VI. UX Aspects of the Article in Terms of Graphic Content on the Website | Group VII. UX Aspects of the Article in Terms of Emotions on the Website | Group VIII. Economic Effectiveness Aspects of the Article |
| 1 | Site-5 (194,789) | Site-5 (209,000) | Site-5 (175,259) | Site-5 (197,158) | Site-5 (193,000) | Site-5 (208,000) | Site-5 (212,782) | Site-5 (180,000) |
| 2 | Site-3 (183,513) | Site-3 (180,061) | Site-3 (136,085) | Site-2 (184,866) | Site-4 (155,989) | Site-4 (141,167) | Site-3 (133,833) | Site-3 (160,667) |
| 3 | Site-2 (172,250) | Site-2 (161,833) | Site-2 (135,365) | Site-4 (183,987) | Site-1 (135,167) | Site-3 (124,500) | Site-4 (132,030) | Site-2 (150,616) |
| 4 | Site-4 (146,500) | Site-4 (160,111) | Site-4 (114,288) | Site-3 (173,009) | Site-2 (129,699) | Site-2 (107,167) | Site-2 (123,996) | Site-4 (144,510) |
| 5 | Site-1 (138,373) | Site-1 (156,750) | Site-1 (109,699) | Site-1 (163,750) | Site-3 (127,833) | Site-1 (104,133) | Site-1 (113,779) | Site-1 (139,000) |
| Sum | 835,425 (92.54%) | 867,755 (96.12%) | 670,696 (74.29%) | 902,770 (100.00%) | 741,688 (82.16%) | 684,967 (75.87%) | 716,420 (79.36%) | 774,793 (85.82%) |

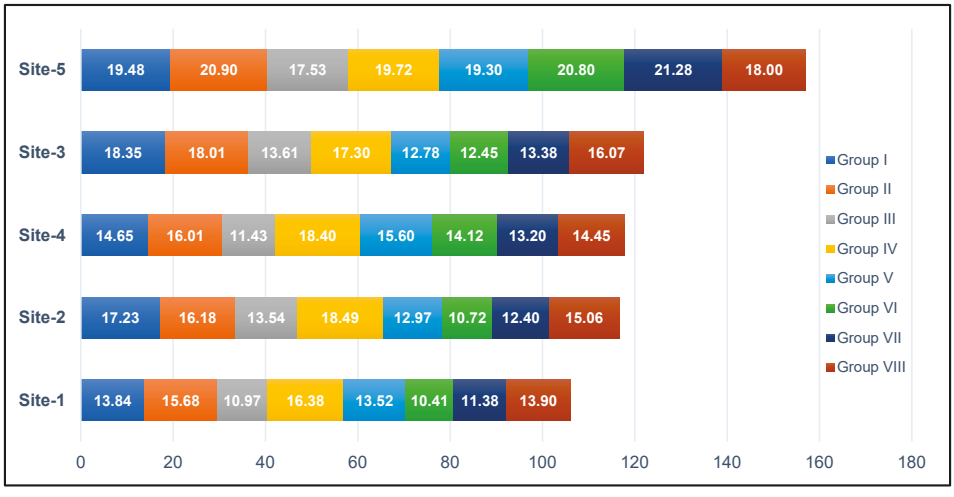


**Figure 1.** The final ranking of websites from the highest- to the lowest-rated, divided into groups for the values of information usefulness efficiency after main data analysis using the CCR-I model of the DEA method (source: self-study).

As follows from the first data analysis using the CCR-I model of the DEA method and based on the results presented in Figure 1, all of the evaluated information and shopping websites were characterized by a relatively high level of information usefulness efficiency. The range of obtained values for individual services varied in the range from 68% to 100%, the ideal rating value, obtained by the best-rated website in the opinion of the respondents. The best website in the ranking in terms of the information usefulness efficiency level turned out to be website 5 (Site-5), which obtained the summary evaluation result of all groups of criteria at the level of 15,699 points (100%), and at the same time it was recognized as a pattern (the so-called benchmark) for other services. This website was characterized by a one-page style and textual content combined with attractive and large-size images, and a full product specification as well as spectacular interaction and user experience opportunities. The second place, with a score of 12,195 points (78%) was taken by website 3

(Site-3), which was characterized by a two-column style and textual content combined with images, movies and infographics. The third place in the ranking was taken by website 4 (Site-4), with a score of 11,786 points (75%), characterized by textual content combined with large-size images, a picture gallery, full product specification, online shopping options and the possibility of comparing similar products. Website 2 (Site-2) was in fourth position, with a slightly lower score at the level of 116.58 points (74%), which was characterized by a two-column style and very extensive textual content combined with images and the possibility of making online purchases for selected models of smartwatch devices in one of the popular online shops. Website 1 (Site-1) turned out to be the last in the ranking, with a score on the level of 10,607 points (68%), which obtained the lowest scores in almost all groups of criteria (except for group 5) and was characterized by a one-column style and advisory textual content combined with images and the possibility of making online purchases for selected models of smartwatch devices in one of the popular auction services.

As part of the obtained data and on the basis of the results presented in Table 2, the second area of analysis and interpretation within the CCR-I model was the summary evaluation of the efficiency level for the individual eight groups of criteria. As was the case with the ranking of individual websites, all of the evaluated groups of criteria were also characterized by a relatively high level of effectiveness. The range of obtained values for individual groups of criteria varied in the range from 74 to 100%, the ideal rating value, obtained by the best-rated group in the opinion of the respondents. The best thematic group in the ranking in terms of the efficiency level turned out to be group 4 (Group 4), which obtained the summary evaluation result within all analyzed websites at the level of 90.28 points (100%), and at the same time it was recognized as a pattern (the so-called benchmark) for other groups of criteria. This group concerned a total of eight criteria (four inputs and four outputs) related to "Cognitive aspects of the article's content message", and its result means that, in this group, the most effective results were achieved with proportionally the lowest level of costs. Of the groups, those that obtained slightly worse efficiency results, with 83–87 points (92–97%), were group 1 (Group 1—Informational aspects in the content of the article) and group 2 (Group 2—Information presentation aspects in the content of the article). The efficiency level of 71–78 points (about 80–86%) was obtained by the following three groups: group 7 (Group 7—UX aspects of the article in terms of emotions on the website), group 5 (Group 5—UX aspects of the article in terms of textual content on the website) and group 8 (Group 8—Economic effectiveness aspects of the article). The lowest efficiency level, with 67–69 points (74–76%), was obtained by the following two groups: group 3 (Group 3—Knowledge increase aspects in the content of the article) and group 6 (Group 6—UX aspects of the article in terms of graphic content on the website).

### *3.5. The Second Method of Data Interpretation and Presentation of the Results*

The second method of data interpretation was also an analysis of selected websites for each group of criteria, but using the BCC-I model of the DEA method in terms of cumulative values for individual main criteria and within each respondent. The sum of the values obtained in this way was also the value of information usefulness efficiency for one selected website and within one selected thematic group of criteria. Analogously to the first case, this method of data analysis was supposed to show the impact of all main criteria values within one specified group of criteria on a group efficiency assessment of individual websites, and then the possibility of creating a group ranking of websites. Similar operations were performed for each of the eight thematic groups of criteria, and then the final efficiency assessment for individual websites was calculated and their final ranking was created. The final ranking of websites was to demonstrate their order from the highest- to the lowest-rated according to respondents, in terms of the efficiency level of eight different aspects of information usefulness and applied in selected information and shopping websites.

The results obtained from the main data analysis using the BCC-I model of the DEA method for the values of information usefulness efficiency are presented in the following Table 3 and in Figure 2.

**Table 3.** The final ranking of websites divided into groups for the values of information usefulness efficiency after main data analysis using the BCC-I model of the DEA method (source: self-study).

| Ranking Position | Thematic Websites and Results from Data Analysis Using the BCC-I Model of the DEA Method Name of the Group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Group I. Informational Aspects in the Content of the Article | Group II. Information Presentation Aspects in the Content of the Article | Group III. Knowledge Increase Aspects in the Content of the Article | Group IV. Cognitive Aspects of the Article's Content Message | Group V. UX Aspects of the Article in Terms of Textual Content on the Website | Group VI. UX Aspects of the Article in Terms of Graphic Content on the Website | Group VII. UX Aspects of the Article in Terms of Emotions on the Website | Group VIII. Economic Effectiveness Aspects of the Article |
| 1 | Site-3 (215,000) | Site-5 (225,000) | Site-5 (200,333) | Site-5 (210,000) | Site-5 (203,333) | Site-5 (220,000) | Site-5 (218,333) | Site-5 (208,333) |
| 2 | Site-5 (213,333) | Site-3 (210,000) | Site-2 (164,167) | Site-2 (199,702) | Site-4 (172,361) | Site-4 (158,333) | Site-4 (152,833) | Site-3 (201,667) |
| 3 | Site-2 (200,000) | Site-2 (195,000) | Site-3 (150,833) | Site-4 (198,823) | Site-1 (150,833) | Site-3 (140,000) | Site-2 (148,167) | Site-4 (190,801) |
| 4 | Site-4 (190,000) | Site-4 (190,000) | Site-4 (138,333) | Site-3 (193,333) | Site-2 (143,417) | Site-2 (125,833) | Site-3 (145,000) | Site-2 (185,786) |
| 5 | Site-1 (183,750) | Site-1 (180,000) | Site-1 (133,333) | Site-1 (185,000) | Site-3 (143,333) | Site-1 (114,000) | Site-1 (137,500) | Site-1 (175,000) |
| Sum | 1,002,083 (100.00%) | 1,000,000 (99.79%) | 786,999 (78.54%) | 986,858 (98.48%) | 813,277 (81.16%) | 758,166 (75.66%) | 801,833 (80.02%) | 961,587 (95.96%) |

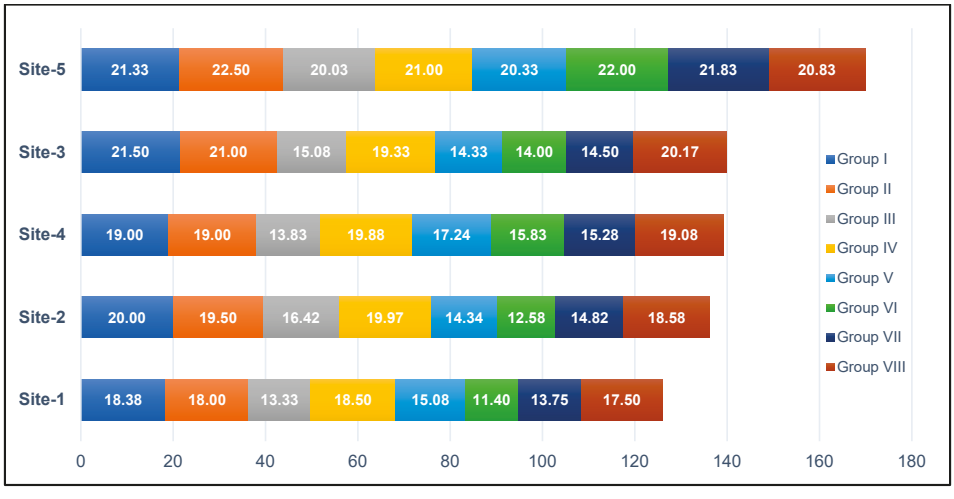


**Figure 2.** The final ranking of websites from the highest- to the lowest-rated, divided into groups for the values of information usefulness efficiency after main data analysis using the BCC-I model of the DEA method (source: self-study).

As follows from the second data analysis using the BCC-I model of the DEA method and based on the results presented in Figure 2, all of the evaluated information and shopping websites were characterized by a relatively higher level of information usefulness efficiency than in the case of the CCR-I model. The range of obtained values for individual services varied in the range from 74 to 100%, the ideal rating value, obtained by the best-rated website in the opinion of the respondents. The best website in the ranking in terms of the information usefulness efficiency level turned out to be, again, website 5 (Site-5), which obtained the summary evaluation result of all groups of criteria at the level of 16,987 points

(100%), and at the same time it was recognized as a pattern (the so-called benchmark) for other services. The second place, with a score of 13,992 points (82%), was taken again by website 3 (Site-3), which was only slightly ahead of the third site in the ranking, website 4 (Site-4), which obtained the score of 139,15 points (82%). Website 2 (Site-2) was in fourth position once again with a slightly lower score of 136,21 points (80%). The last in the ranking turned out to be, again, website 1 (Site-1), with a score at of 12,594 points (74%), which obtained the lowest scores in almost all groups of criteria once more (except for group number 5).

As part of the obtained data and on the basis of the results presented in Table 3, the second area of analysis and interpretation within the BCC-I model was the summary evaluation of the efficiency level for the individual eight groups of criteria. As was the case with the ranking of individual websites, also all of the evaluated groups of criteria were characterized by a relatively high level of effectiveness. The range of obtained values for individual groups of criteria varied in the range from 75 to 100%, the ideal rating value, obtained by the best-rated group in the opinion of the respondents. The best thematic group in the ranking in terms of the efficiency level was group 1 in this instance (Group 1), which obtained the summary evaluation result within all analyzed websites at the level of 100.20 points (100%), and at the same time it was recognized as a pattern (the so-called benchmark) for other groups of criteria. This group concerned a total of seven criteria (five inputs and two outputs) related to "Informational aspects in the content of the article", and its result means that, in this group, the most effective results were achieved with not necessarily the lowest level of costs proportionally. Three groups obtained marginally worse efficiency results of 96–100 points (95–99%): group 8 (Group 8—Economic effectiveness aspects of the article), group 4 (Group 4—Cognitive aspects of the article's content message) and group 2 (Group 2—Information presentation aspects in the content of the article). The efficiency level of 80–82 points (80–82%) was again obtained by the following two groups: group 7 (Group 7—UX aspects of the article in terms of emotions on the website) and group 5 (Group 5—UX aspects of the article in terms of textual content on the website). The lowest efficiency level of 75–78 points (75–78%) belonged to the following two groups: group 6 (Group 6—UX aspects of the article in terms of graphic content on the website) and group 3 (Group 3—Knowledge increase aspects in the content of the article).

## 4. Conclusions

The conducted research of analysis and evaluation of information usefulness efficiency, applied to selected information and shopping websites, showed significant differences in the respondents' perception of the information usefulness efficiency level in terms of various analyzed aspects. One of the goals of the research was to show that the information usefulness efficiency and available content on websites is important for recipients and potential buyers, which has been positively proved. Various types of websites selected for the study in terms of methods of content communication and attractive subject matter of websites for the respondents resulted in the results of the research turned out to be current, interesting and practical. Moreover, the application of a combination of various types of quantitative and qualitative methods in research and analysis mean that the results obtained can be regarded as realistic and useful in different areas and applications.

Regarding the results from the first data analysis in terms of the ranking of websites selected for research, it can be concluded that, regardless of the two different models of scale effects for the DEA method used in the calculations, the overall ranking of websites from the most to the least effective is identical for both CCR-I and BCC-I models. This confirms the unequivocal perception and evaluation of the respondents regarding the level of quality and efficiency of individual websites. The result values of the efficiency levels between the weakest and the best service for both models fluctuated in very similar ranges from approx. 70 to 100%. The differences that existed were mainly due to the slightly higher values achieved in the case of the BCC-I model, which means that in this particular model the level of achieved efficiency was higher for all analyzed websites. Regardless of

the analyzed models, the service with the highest level of efficiency (benchmark—100%) according to the respondents was the one-page style website 5 (Site-5), which represents content in the form of visualization intended for advertising websites, where the main emphasis is on the presentation of the product, description of its specifications, showing off its functionality in the best possible way and helpful information for making the purchase.

Regarding the results from the second data analysis in terms of the ranking of eight criteria groups and related main criteria selected for research, it can be concluded that there was a greater diversity in this area in the obtained results for the CCR-I and BCC-I models. For each of the models, the obtained results were completely different for the rankings of quality and efficiency level of various aspects of information usefulness perceived by the respondents within the surveyed websites. This is indirectly due to the different methods of calculating efficiency by each of the models, in one case assuming the proportionality of the increase in effects along with costs or, in the second case, in the absence of this dependency, which in turn may highlight the various causes of the dependencies between inputs and outputs. Regarding the received data, the highest values of the total efficiency obtained for each group of criteria are variable in most groups of criteria for both models. The effect of this is completely different rankings of individual groups of criteria within the CCR-I and BCC-I models, which in turn also influences a different significance assessment of criteria groups and related main criteria among the respondents. Depending on the analyzed models, the groups of criteria with the highest efficiency level (over 90%) according to the respondents were: cognitive aspects (benchmark for CCR-I model and BCC-I model), informational aspects (CCR-I model and benchmark for BCC-I model), information presentation aspects (CCR-I model and BCC-I model) and economic effectiveness aspects (BCC-I model).

In conclusion, it can be said that the DEA method used in the study has proven effective in practical data analysis, allowed for performing calculations and data analysis both in terms of creating the ranking of the analyzed websites and criteria groups, and thus also for the appropriate data interpretation in terms of information usefulness efficiency evaluation. Moreover, it must be admitted that the DEA method has proven successful in efficiency evaluation, even in a situation where the role of decision-making units (DMUs) was given to people (respondents), and not machines, devices or institutions, as is usually practiced. Therefore, further research of information usefulness efficiency on websites should be conducted towards more in-depth efficiency analysis, both using criteria for evaluating websites and individual respondents, as well as results analyzing using different variants of the DEA method and other data analysis methods, such as various types of multi-criteria methods, e.g., AHP/ANP, SAW, SMART or TOPSIS.

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# 360° Retail Business Analytics by Adopting Hybrid Machine Learning and a Business Intelligence Approach

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**Abstract:** Business owners and managers need strategic information to plan and execute their decisions regarding business operations. They work in a cyclic plan of execution and evaluation. In order to run this cycle smoothly, they need a mechanism that should access the entire business performance. The sole purpose of this study is to assist them through applied research framework-based analysis to obtain effective results. The backbone of the purposed framework is a hybrid mechanism that comprises business intelligence (BI) and machine learning (ML) to support 360-degree organization-wide analysis. BI modeling gives descriptive and diagnostic analysis via interactive reports with quick ad hoc analysis which can be performed by executives and managers. ML modeling predicts the performance and highlights the potential customers, products, and time intervals. The whole mechanism is resource-efficient and automated once it binds with the operational data pipeline and presented results in a highly efficient manner. Data analysis is far more efficient when it is applied to the right data at the right time and presents the insights to the right stakeholders in a friendly, usable environment. The results are beneficial to viewing the past, current, and future performance with self-explanatory graphical interpretation. In the proposed system, a clear performance view is possible by utilizing the sales transaction data. By exploring the hidden patterns of sales facts, the impact of the business dimensions is evaluated and presented on a dynamically filtered dashboard.

**Keywords:** business intelligence; digital revolution; sustainable business model; data warehousing; artificial intelligence; B2C; B2B

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## 1. Introduction

In recent years, business intelligence has drastically changed business operations by providing a smart cloud computing-based solution to enhance the working capacity and expand the business on a large scale, such as using knowledge performance indicators (KPIs) to enhance the performance of Nike's company with conversion into analytical reports. One study showed how KPIs are designed smartly to have a direct impact on overall performance management [1]. The core objective of business intelligence services is to view the past performance, diagnose the decision mistakes, and predict and forecast the future demands, benefits, and the best plan based on business facts and figures. By keeping in mind the past, present, and future direction of a business, warehousing business

intelligence (BI) and predictive artificial intelligence (AI) solutions are the best tools for designing flexible and powerful computing applications [2]. The authors of [3] studied how enterprises across the globe are now using big data analytics cloud solutions for their businesses to gain a competitive edge and the strategic planning and development for future demands.

The major challenges in big data analytics and business intelligence are unrefined BI strategies, the right business measures and performance scaling, and the adoption of self-service cross-department analytics [4]. Companies are using customer relationship management (CRM) and the decision support system (DSS) to analyze and develop intelligent and smart business solutions, moving from a product- to customer-centric approach to revise business strategies and high-valued performance metrics adoption [5].

Recently, the customer 360° view term was induced in BI, which comprises the broader view of a business with the help of dynamic filtering and querying responsive dashboards. The process of BI mainly consists of four phases which are business policy and operation framing, data extraction, transformation, and loading, data and machine modeling by applying BI and AI techniques, and at last, presenting the results visually by applying data mining and statistical techniques. Broadly speaking, there are four types of businesses in terms of scale, which are wholesale, business-to-consumer (B2C) retail, business-to-business (B2B) production and manufacturing, direct-to-consumer (D2C) deals and marketing, and facilitators in drop shipping. To acquire the intelligent systems for a specific business, the cost, quality, and access are the core factors in terms of business concerns [6].

To address these issues, software and platforms as services based on cloud computing yield easy access and cost-effective solutions for the end users. The primary concern of business professionals is to lead and expand a business using business intelligence smart applications and big data analytics by exploring why, what, which, where, and how business performance indicators could be evaluated to maintain and increase sales, products, employees, and customers. For effective business solutions, business management faces data management, performance evaluation, and smart business plan issues to smartly manage and lead a business and gain a competitive advantage. With the development of big data analytics and cloud computing solutions, businesses are utilizing their services to reduce costs and provide fast access, quick results, and reliable BI solutions. Customer relationship management, customer experience, departmental business data, quality work in operational systems, and knowledge performance indicators are the major factors driving the best solutions [7].

Data management applications based on database technologies are used in different departments such as administration, accounts, human resources (HR), sales, marketing, and customer care services. These departments produce departmental data such as account details, employee details, product manufacturing, stock and supplier details, transactions, payments, shipment details, customer-related information, and feedback via CRM apps and marketing details. With the advancement of eCommerce businesses, the method of doing business is now very smooth and flexible. Online customers can approach e-business easily and select, order, and track products via social media and eCommerce websites. Business owners know the worth of e-channels and try to facilitate eCommerce websites, mobile apps, and social media. These channels are producing big data as the result of both sides' data management operations. Data entries from administrative operators market products publicly and aggregate customers' information, orders, and reviews. Management with database management apps for day-to-day transactions is not a big issue, but big data analytics is a complex process that requires many resources. For a proactive approach to lead a business, the BI set-up must view different aspects of the past, current, and future performance perspectives.

The actual usage of BI is for utilizing data to support decision making with compelling and interactive data visualization, such as with the Qlik View BI tool [8]. To turn the raw data into knowledge and analytical insights into strategy making, the systematic process is followed with advanced BI tools. At the same time, when designing the data

warehouse, the first knowledge performance indicators describe what to evaluate and the performance scales. In the second step, information source documents are prepared in which abstract detailed information is maintained. The third step matrix documents are prepared to map the information from the source to the target desired analytical attributes using transforming, cleaning, and preprocessing techniques. These documents keep the sources attributes, technical constraints, and target mapping. All these documents are maintained with log files to maintain the versions and for the team's distribution. All source information is gathered via extraction transformation loading (ETL) or an ELT mechanism and placed in the staging area to avoid data loss. These data are then stored in a warehouse scheme for further processing. Mainly, two approaches are used to design and construct a warehouse first: top to bottom, which starts from a complete warehouse and goes to to data marts, and the second is bottom to top, which combines data marts with the data warehouse for incremental development. For small types of business, the bottom-to-top approach is usually used. After collecting business requirements, the warehouse schema is designed, which can be of four types: (1) a start schema, (2) snowflake schema, (3) galaxy schema, or (4) clustered galaxy schema.

Each design has its pros and cons. Usually, the choice of design is based on storage and time constraints. BI is the systematic process that holds the data and business needs and implements a data collection mechanism, ensuring data quality and implementing data marts and data lakes with ETL and ELT to put data into the warehouse [9]. The BI warehousing provides a descriptive framework to view the business performance in terms of business dimensions in a detailed manner using data warehousing, which involves extraction, transformation, and loading to collect relevant business data from operational systems and external sources and preprocessing and data modeling under a relational schema to make them usable for relational online analytical processing (ROLAP) and multidimensional online analytical processing (MOLAP), which filter the data using business dimensions such as time, geo-graphs, products and HR, and a data visualization process in which ad hoc reporting is performed to view and explore the business performance as well as the impact of business features. On the other hand, machine learning (ML) allows for supporting the decision makers with helpful trained models which capture the data trends, acting as a magic box to answer the queries with probability. ML offers multiple analytics (personalized recommendations, sales, demand forecasting, and customer behavior prediction) in eCommerce [10].

ML offers capturing data trends such as customer segmentation, sales forecasting, and product recommendation systems. For predictive analysis to see the future based on past and current business data, strategy makers set up various questions. In [11], the authors performed predictive analysis to predict the sales in weekly collected data.

In [12], the authors proposed an ensemble approach by combining S-ARIMA, vector auto regressor, and long short-term memory (LSTM) for demand forecasting of monthly product distributor orders with some external features such as weather, campaign, and holidays. In [13], the author implemented a model to manage chain stores via BI modeling and presented a dashboard to report on the managers and strategy makers for effective decision making. The proposed model considers the KPIs and divides the dashboard reports for different business layers to support the supply chain and, ultimately, the impact on sales. For practical customer and sales data usage in a retail business, the author of [14] developed a framework under the BI tool and quickly communicated with a chat bot using point of sale (POS) transitional data. The author [15] studied the impact of business intelligence and analytics for retailing intelligent data insights. They used 25 global retailers' online databases and web source datasets and analyzed the retailer activities in different phases.

The authors of [16] presented a profit-based forecasting model for shoe multi-seasonal retail data. They evaluated ML models with 10 parts via cross-validation and real-time demand values and used the mean absolute percentage error. In retail chains, the authors of [17] applied a forecasting (special calendar days as features) framework on a centralized

food bakery to predict the product facility in 100 stores on a daily basis. In [18], the authors evaluated the customer engagement data for the telecom sector in terms of social demography and services used by the customer. Segmenting in similar customer traits and then predicting the expected behavior were the main concerns in their study. In [19], the authors applied a data mining approach on an electronic sales dataset (mixed B2B and B2C) for a complete online business process from customer analysis (by customer segmentation via k-means clustering), product analysis (by association mining via the Apriori method), and predicting customer behavior outcomes (by the decision tree method).

The authors implemented an ML model on time series data of B2C Amazon quarterly sales data in 2019 in [20]. After data transformation, three models were applied (Holt winters exponential smoothing, automotive regression integrated moving average (ARIMA), and ANN auto regression), and they compared the accuracy of the three models by evaluating the mean absolute percentage error (MAPE) and root mean squared error (RMSE), as well as other metrics for the implemented models. The seasonal ARIMA was best in the projection of revenue.

In [21], a comparison of two powerful ML algorithms (XGBoost and LSTM) to predict the sales for retail products is performed. The authors used online analytical processing (OLAP) methods to analyze the sales measures on a multi-dimensional data model which contained sales transactions, customers, and item information [22]. The outcome of their analysis was a web dashboard which showed the sales trends for the given dimensions.

In [23], the author implemented a model to manage chain stores via BI modeling and presented a dashboard to report to the managers and strategy makers for effective decision making. In [24], a data warehouse monitoring framework is presented in various applications for effective results and integration with management pipelines. In [25], the authors identified the main KPIs, such as the net income, rate of investment, details, equity, and gross margin, as well as their implementation with machine learning and presented the results on a dashboard.

As discussed above, the intelligent BI and AI mixture for a business provides a smoother platform for dealing with day-to-day operational management and making better decisions for a business. This research primarily focuses on business to consumers, in which the retail and wholesale types target business subdomains. This research will be conducted on utility product industries to add valuable business insights. The following are the core research questions that are going to be addressed in this article:

- What is the sales performance in terms of the date and time dimension?
- What is the sales performance in terms of the product selection dimension?
- How can business knowledge communicate with a central visual data platform for a business stakeholder to view the performance, operations, and strategic planning?
- What is customer behavior in business, and what are the reasons for these insights?
- How many business dimensions are dependent and impact on sales performance?
- How can we make more accurate analytical models to find impactful business insights?
- Which business are dimensional features highly impactful to driving a business strategy?

Retail business sales performance can be evaluated using BI techniques for efficient sales views in various business dimensions and effective strategies. A light and flexible warehouse schema needs to be designed by keeping in mind the business type, analytical needs, and transnational data produced. The main concerns of a retail business are to evaluate the sales so that the appropriate action can be taken. Therefore, the proposed framework is based on a hybrid cloud solution which mainly consists of warehousing business intelligence, which provides statistical analysis about the past and current views of a business and predictive artificial intelligence to forecast the business plans. The dateset used in this study was taken from the UCI repository, having 541,909 data entries of transactions by different customers from 2010 to 2011. By utilizing this data, BI techniques were applied to fulfill the analytical research objectives. Compared with existing techniques, this will provide a lighter weight, less errors, and a centralized and comprehensive view of

a business at a low cost and with fast access and dynamic business analysis. The leading business intelligence solutions are the cloud-based data pipelines with deep data analytics as well as data visualization.

The rest of the paper is formatted as follows. Section 2 describes the system model, while the results are discussed in Section 3. In Section 4, the conclusions and future works are discussed.

## 2. Materials and Methods

The business intelligence techniques under cloud computing and big data processing are the core ones to drive the insights from data. In recent years, various cloud services have offered making decision support systems from data collection to dynamic dashboards by Watson IBM, Qlik View, Microsoft Power BI, Tableau, Oracle NetSuite, Amazon Redshift, and Google Data Studio. The proposed methodology is based on a customer 360° view with four dimensions and an advanced business analytical dashboard to drive smart business insights. The core components are data sources, ETL, data consumers, a processing module, and an analytical dashboard. The figure below demonstrates the smart application framework, consisting of the following:

- Business data sources;
- The process of extraction, transformation, and loading;
- Relational warehouse and machine learning data modeling;
- Descriptive BI analytics;
- Diagnostic performance modeling;
- Prescriptive planning modeling;
- Predictive AI analytics;
- A dynamic central dashboard for ad hoc queries and a customer 360° view.

Finding the business insights from data is a systematic process which contains multiple layers and processes to drive the actionable results for business strategic development. Data are the core components, which are collected from operational management and point-of-sale systems, CRM systems, as well as social media marketing channels, which are combined into a centralized data repository. Figure 1 depicts the layers of the smart analytical system.

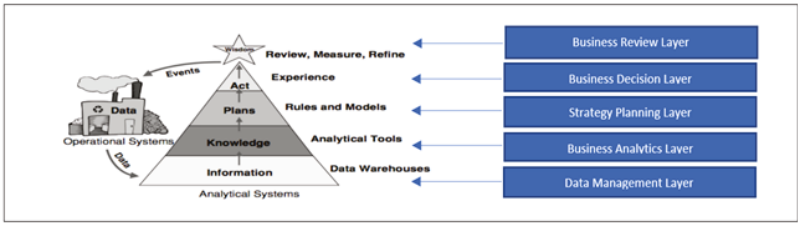


**Figure 1.** The business operation and analytical system mapper for understanding the actual business needs to feed into analytical system development.

Data sources are diverse and may produce different types of data stored in file formats, such as how department management system data are stored in SQL and Excel or CSV files which contain customer data, HR data, store data, financial data, sales, and marketing data from local sources. Customer data can also be collected from social media and mobile apps, which are used to engage and retain customers for a long time. These data are used in the warehousing and predictive data modeling after ETL processing. The output of this process is the refined form of data repositories, which are further used in data modeling for the descriptive diagnostic business intelligence (DD-BI) phase and PP-AI phase. This DD-BI phase uses statistical techniques to explore the data relations and interpret the results in the form of graphs. The PP-AI phase uses machine learning predictive and diagnostic techniques to predict the future outcomes with time, customer, and business demographics

graphs. The final phase is the dashboard analytical phase, which interprets the results in the form of dynamic visuals with the help of BI cloud solutions. The dashboard will give the smart insights of a business for each department as well for the business owners.

The process flow for the proposed research framework is given in Figure 2, showing the abstract flow of the analytical techniques. First, the sales data was collected from the UCI repository, and the initial data was preprocessed to clean it and remove duplicates and irrelevant data entries. For the comprehensive sales analysis, we derived some date and time features from the invoice dates. After that, we constructed a schema design and the ML's needed data. This involved two main components: one was machine learning, and the second was warehousing. The work for these two components was performed in parallel. For the DD-BI phase, one subprocess was compiled. With the help of power BI, the complete development was performed for data loading, relational design, and interactive data reporting. Similarly, for the predictive forecasting machine learning (FP-ML) phase, a second subprocess was compiled with Anaconda Jupyter Notebook to prepare the trained test datasets and the ML modeling and evaluation. The results were compiled on the dashboard. In the next subsections, the complete dataset description and all working components are described.

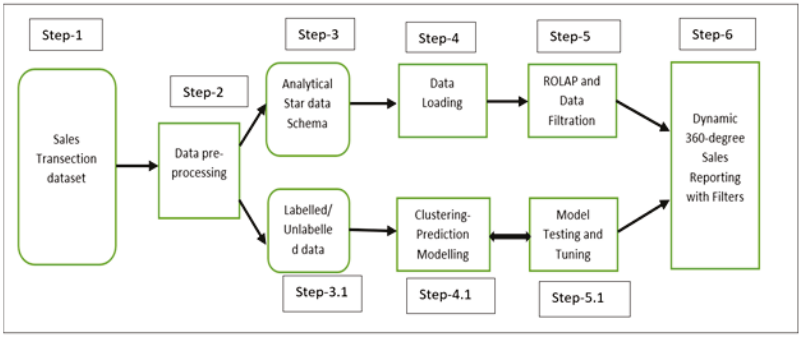


**Figure 2.** Sales analysis process flow to find the performance insights using warehousing and machine learning algorithms.

The proposed research model has two phases which are based on business intelligence data warehousing and machine learning solutions. To fulfill the research objectives, how these phases will sort out the issues and provide a comprehensive assistive solution for better and more friendly insights is shown in the technical flow diagram.

After applying this model, the final analytical report outcomes address the business objectives with graphical interpretation. In the figure, we can see the analytical solutions of hidden business insights.

A deeper view of the research framework in terms of development and its core techniques are discussed here. As the proposed methodology consists of BI and AI development with deep analytics, using big data analytics and web applications enabled us to present the quick results and effective business analytics for business professionals. The proposed research design provides the BI solution for a business to view the performance and employ friendly and accurate assistance to make future decisions in terms of the product pipeline, customer relationship management, and core business dimensions for strategy development to lead and manage a business in quick, productive, and efficient ways, as shown in Figure 3.

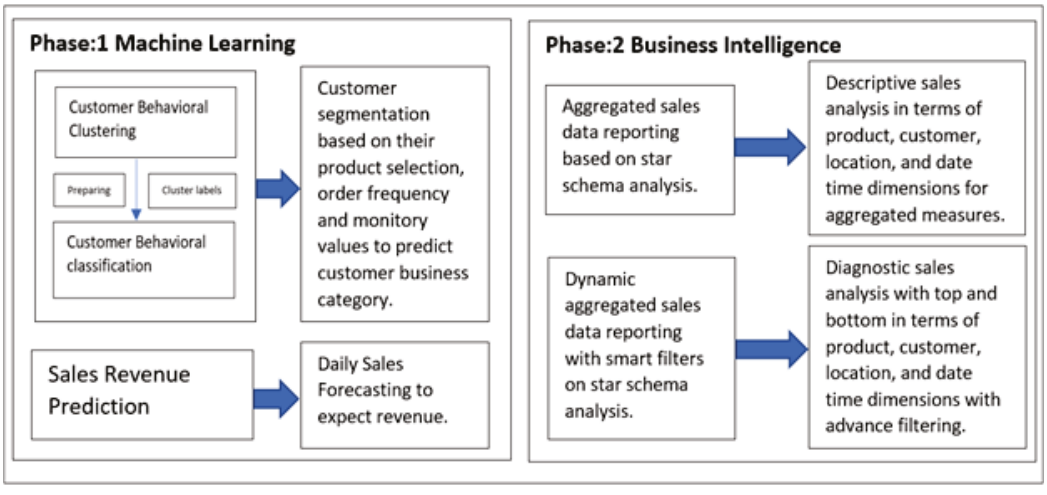


**Figure 3.** Proposed model's ML-BI technical flow for retail data analysis in 360 degrees to answer business analytical questions.

*2.1. Designing Knowledge Performance Indicators*

The data analytics process begins from business process framing and conversion into the smart metrics needed in performance evaluation, decision making, and strategy building. Designing KPIs is not a straightforward process, as it needs a thorough understanding of a busienss's set-up, sales channels, entire environment, and polices. As the dataset used in this study was taken from the UCI repository, having eight lakhs of data entries of transection by different customers from 2009 to 2011, by utilizing this data, business intelligence techniques were applied to fulfill the analytical research objectives.

Being a business stakeholder, one has to be concerned about business performance and expansion plans to compete in a market. This research focuses on business performance indicators and customer relationship management by targeting the retail business level. The following are the core business questions which explain the problem statement regarding this research proposal:

- Which business information (product, management, and customer features) does one need to decide the better plans for a business?
- How can business performance indicators be used to carefully choose and make an impact on a strategy with smart intelligent dashboards to take a competitive edge in the market?
- Can one make smart and intelligent business decisions without visual business insights which are based on facts and figures?
- Is there any proper mechanism for capturing a customer's dynamic behavior which is necessary for a strategy planning?
- How can operational systems link with cloud BI solutions to make live contact with business events and performance for control management?

Business strategy and planning development, which are addressed in this proposal, are designed for B2C businesses. For business managers and owners, a proactive approach leads one's business on a high scale. Therefore, some problems are mentioned in retail and wholesale businesses in different departments to find the operational and planning efficiency and effectiveness.

To formalize the business problems into detailed analytical objective points, knowledge performance indicators are the best way to describe them easily. The ultimate objective of this study is to answer these KPIs by exploring the sales data and applying ML-BI techniques. These KPIs are dependent on given business information, as the less-studied

data contains sales transnational data. Therefore, the following KPIs are the defined goals which will be met at the end of analytical experimentation and data result reporting:

- What is the customer behavior (similarities in buying) in product selection?
- What will be the expected category of customers in product selection?
- What are the total sales measures (revenue, sold quantity, customers, products, orders, and canceled quantity)?
- How much are total dimension values (location, customers, products, date time)?
- What is the total sales revenue for location-wise order placement (maximum and minimum revenue locations)?
- What is the relation of products with date time (frequently in date hierarchy)?
- What is the relation of products with customers (location wise products orders)?
- What is the relation of products with customers and date time (smart data filters to view measures)?
- What is total sales revenue customer-wise (frequent and infrequent customers)?
- What is total sales revenue product-wise (frequently and infrequently sold products)?
- What is the total sales revenue year-wise (maximum and minimum revenue time frames)?
- What are the prices of products with the maximum revenue generation?
- What are the sales and quantity distribution among all orders?
- What are the sales and quantity distribution among weekends and weekdays?
- How many orders were placed year- and month-wise?
- What is the average of the sales revenue in terms of top customers, products, country, and months?
- Which are the top and bottom customers in terms of maximum revenue?
- Which are the top and bottom customers in terms of sold quantity?
- Which are the top and bottom customers in terms of order booking?
- Which are the top and bottom customers in terms of maximum orders quarterly and monthly?
- Which are the top and bottom customers with the maximum revenue generation location-wise?
- Which are the top and bottom customers having the maximum product orders location-wise?
- Which are the top customers for every month with the maximum revenue generation?
- What are the similar customers in product ordering (segmentation and category prediction)?
- What is the relation of customers with date time (frequently in date hierarchy)?
- What is the relation of customers with order products ( location-wise products order and features)?
- Which are the top and bottom products in terms of sales revenue generation?
- Which are the top and bottom products in terms of sold quantity?
- Which are the top and bottom products in terms of order booking?
- Which are the top and bottom quarters and months in terms of sales revenue?
- Which are the top and bottom quarters and months in terms of sold quantity?
- Which are the top and bottom quarters and months in terms of order booking?
- What is the relation of quarters and months with customer engagement (frequently in date hierarchy)?
- What is the relation of quarters and months with order products (location-wise products order and features)?
- What are expected sales revenue in near future based on daily sales?
- How much was contributed to the total sales revenue by the top and bottom customers with the maximum sales revenue?
- Which are the top and bottom products with the maximum sales location-wise?
- Which are the top and bottom products with the maximum sold quantities location-wise?

- Which are the top and bottom products with the maximum sales month-wise?
- What is the difference between the quantity sold, canceled quantity, and total sales semester-wise?
- What is the difference between the quantity sold, canceled quantity, and total sales quarter-wise?
- What is the difference between the quantity sold, canceled quantity, and total sales month-wise?
- What is the difference between the quantity sold, canceled quantity, and total sales in terms of the week of a month?
- What is the difference between the quantity sold, canceled quantity, and total sales in a month by day?
- Which are the order's quantity and sales revenue in terms of the maximum sales revenue generation?
- Which are the product's quantity and sales revenue in terms of the maximum sales revenue generation?
- What is expected of one month's sales revenue minimum, maximum, and trend lines?
- What are the expected sales revenue minimum, maximum, and trend lines over two months?
- What is the sales revenue distribution among locations having orders returned?
- What is the sales revenue distribution among product prices having orders returned?
- Which is the top sales revenue generated by a product's sales revenue with orders returned?
- Which is the top sold product's revenue with orders returned?
- Which is the most frequent product revenue when orders are returned?
- What is the relation between the sold quantity and total sales for the highest-revenue products?
- What is the relation between the sold quantity canceled quantity for the highest-revenue products?
- What is the relation between the sold quantity and total sales for the most sold products?
- What is the relation between the sold quantity and canceled quantity for the most sold products?
- How many orders are canceled and returned (order, quantity, price)?
- What is the relation of invoice orders with customers location and products)?
- What are the observation and frequency of invoices in date time hierarchy?

These need to be used to deeply analyze the relationships of relational sales attributes to find the hidden insights so that improvements can be made in weak areas. For the hidden picture of business data, this is the best problem-framing technique for mapping the research objectives. In addition, these KPIs will be useful in the evaluation of the proposed analytical techniques.

### *2.2. Dataset Description*

Data are the hub of analysis, and they can be in any file format, local or global source of data, and type of data such as text, sound, or visuals. The textual type of data is mainly used for analysis specifically in the banking sector and business industries. These data are produced everywhere with the help of web and mobile applications from the client and administration sides to complete the needed tasks. In this research, online retail sales transactional data will be used to conduct research experiments for B2C and B2B businesses. Most of the transactions were made by a UK-based, registered, non-store internet retailer between 1 December 2010 and 9 December 2011. In this multinational data collection process, 541,909 entries were collected from the following countries, given as percentages; the United Kingdom (88.9%), Germany (2.3%), France (2.1%), the EIRE (1.8%), Spain (0.6%), the Netherlands (0.6%), Belgium (0.5%), Switzerland (0.5%), Portugal (0.4%),

and Australia (0.3%). The following data columns were used in the data collection phase and also described in Figure 4:

- InvoiceNo: The invoice number is a nominal, six-digit integral number issued to each transaction specifically. If this code begins with the letter "c", then a cancellation has occurred.
- StockCode: The product (item) code is a nominal, five-digit integral number issued specifically to each individual product.
- Description: The product (item) name, which is nominal.
- Quantity: The number of each product (item) in a single transaction, which is numeric.
- InvoiceDate: The invoice date and time is numeric and shows when each transaction was created, both in terms of day and time.
- UnitPrice: The unit price is the numeric product price per unit in GBP.
- CustomerID: The customer number is a nominal, five-digit integral number uniquely assigned to each customer.
- Country: The country name is the nominal name of the country where each customer resides.

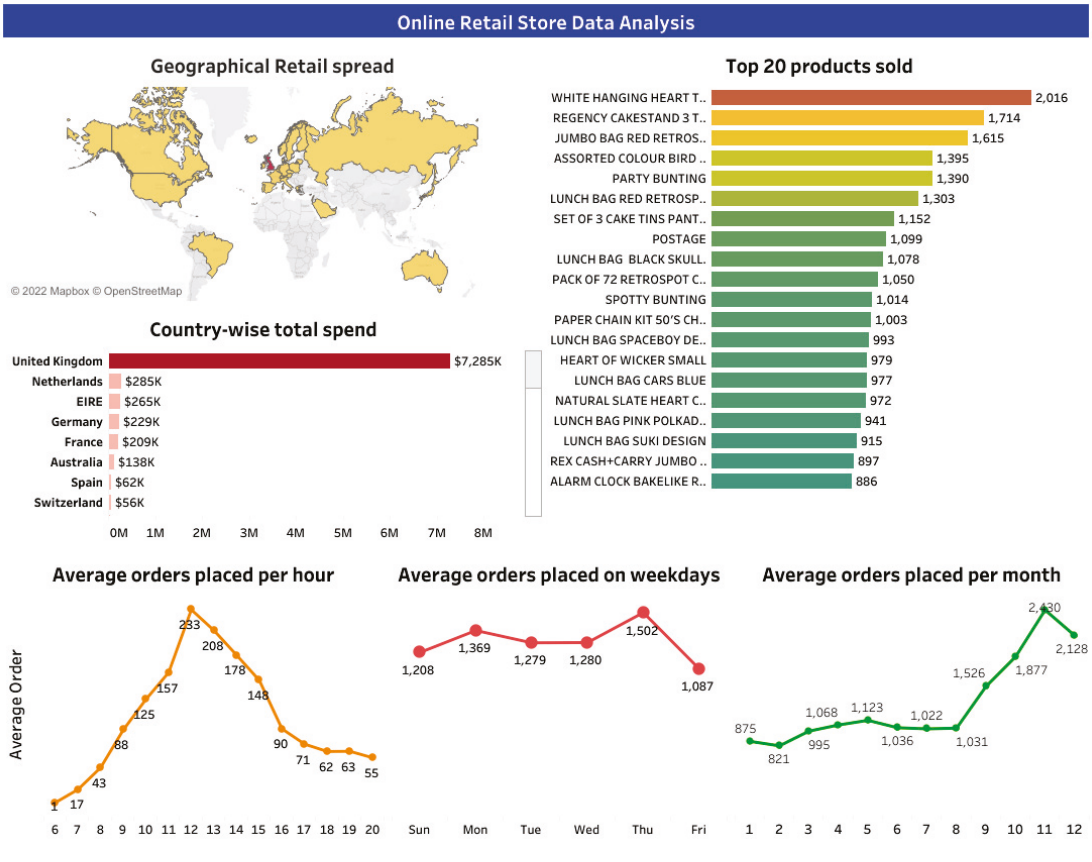


**Figure 4.** Data analysis of online store.

For the detailed dimensional analysis provided, the features were not enough, so we derived some more features from the date and time column to conduct overall fact measurements and paired-fact measurement analysis.

### *2.3. BI Data Modeling*

Business intelligence-based application demands structured warehousing data models, which are used for the development of data marts, data lakes, and complete warehouses. Raw data are collected from multiple sources, which consist of different file formats such as SQL from operational systems, Excel, and Word reports from management reporting systems. In this study, online retail data are used to prepare a data model with the help of Python scripting to first prepare dimensional data in different Excel sheets and then prepare a warehousing schema with power BI. As shown in Figure 5, the proposed schema data model contained four dimensions and one fact table to measure the revenue, sold quantity, and number of orders.

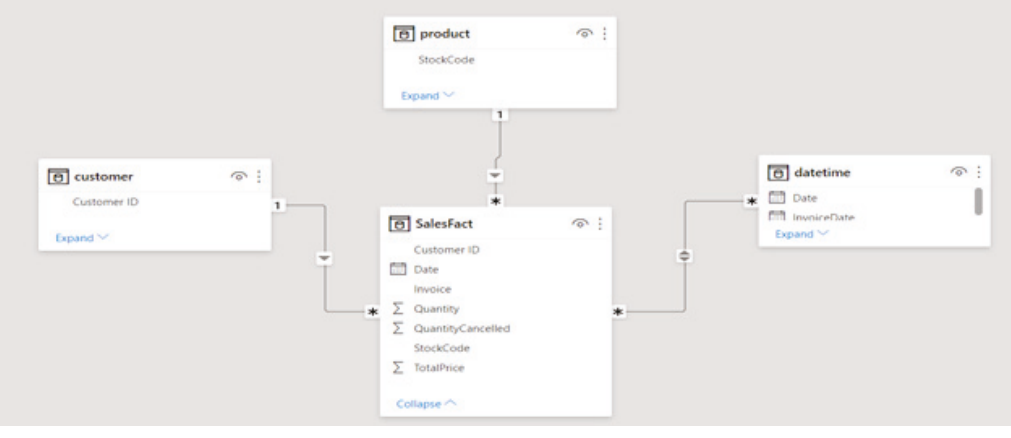


**Figure 5.** Data warehousing analytical schema to support ad hoc queries and data reporting.

This is the dimensional star schema model which contains three business dimensions—customers, product, and date and time—and one fact sales table connected with all dimensions. These are extremely helpful for ad hoc analysis and how these dimensions are having an impact on sales growth.

### *2.4. ML Data Modeling*

Machine learning-based applications demand featured data models which are divided into training and testing data to train the ML model using supervised or unsupervised algorithms according to the data attributes and business goals. Usually, Excel, CSV, TSV, and SQL data files are used, from which features are extracted and set as dependent or independent variables for predicting forecasting. In this study, after collection and preprocessing, we prepared the data for unsupervised learning to create similar bought product- and customer-based clusters on unlabeled (product category and customer category) data. Therefore, we first arranged the data for products sold and customer orders. To prepare the data for forecasting, we just picked two features from the given data, which were the invoice date and total sales.

Similarly, for customer classification, the customer-driven features were based on product selection and their participation in sales transactions. In the first segment, the products totaled five buckets, as in order transactions, and they were labeled as customer category buckets, which totaled 11, as well the customer minimum, maximum, mean, and sum values contributed in their sales orders. This customer oriented-data will be used in the FP-ML phase for customer classification.

2.4.1. Descriptive Diagnostic Business Intelligence

The deeper analysis provides relevant and accurate insights about the data, which drives actionable results. DD-BI is the first parallel phase and highlights the past and current states of the data by exploration, detection, and association techniques. Experimenting with clustering and association techniques to explore the data by segmentation and dimensionality reduction highlights the customers, products, deviated sales, demand behavior, and aggregated business impact. This phase consists of descriptive and diagnostic analysis, which will be performed on BI data models. To describe the patterns in the data, initial visualization will be performed to know the associations, correlations, and deviations to find and identify the positive and negative factors.

Here, we describe the basic static data measures to overview the data values. The total unique customers, products, orders, canceled orders, quantity sold, and total revenue show the basic descriptive analysis. To diagnose the sales and their dependency on the product, customer, location, and date and time, multiple types of filters were implemented to view the measures in 360°. These analytical reports were on the completely self-descriptive properties implemented with power BI. Stakeholders can easily find the sales with on-demand business questions and design the strategy based on these stats. This is the flow which shows how descriptive and diagnostic analysis will be performed to find the sales KPIs.

2.4.2. Predictive Forecasting Machine Learning

Proactiveness is the key to attain success in the corporate world while managing any enterprise business to gain a competitive edge in the industry. FP-ML is the second parallel phase to view and decide in advance on the future outcomes which will be faced. This involves first segmenting the ordered products and customer segments based on product clusters with K-mean and principle component analysis. Clustering will be used to prepare the customer-oriented data that will lead to classifying the customers into various categories regarding sales contribution. This mechanism is explained in the ML data modeling section. Forecasting analysis will be performed using ML data models to forecast the performance, behavior, engagement, and demands related to the business domain. To view the future demands, a predictive ML technique by ensemble for ARIMA, forecasting models with Python scripting, and a power BI automated tool are used to determine what suitable action will be best in future to lead the business from the front in terms of decision support systems.

This flow shows how the patterned mining of products in sales orders and customer behavior prediction will be performed with K-means clustering and classifying customer categories with multiple multi-class enabled algorithms. To predict the sales in near future, ARIMA will be applied to find the sales trends.

This proposed methodology contains a BI-ML hybrid framework for effective sales analytics for online retail businesses. As our research objects mainly concern sales facts, which are needed for sales managers and owners to facilitate customers directly, this is dual process uncovers the sales insights from the past to the future as well as user-friendly interpretations. In the next section, the complete implementation is given, which shows both phases and each step of experimentation. As explained in Figure 6, the abstract view of the proposed model which uses BI and ML effectively to view the retail sales yields the KPIs with the help of interactive charts on retail data. In Figure 6C, the analytical BI model and ML model data are shown. Similarly, Figure 6A,B shows how dimensional OLAP analysis will be performed for the descriptive and diagnostic models. The results of these two phases are presented as reports. These reports are highly beneficial in performance analysis, strategy making, and inductive decisions. The real output from this analytical model provides a self-service BI solution for effective sales analysis for performance monitoring.

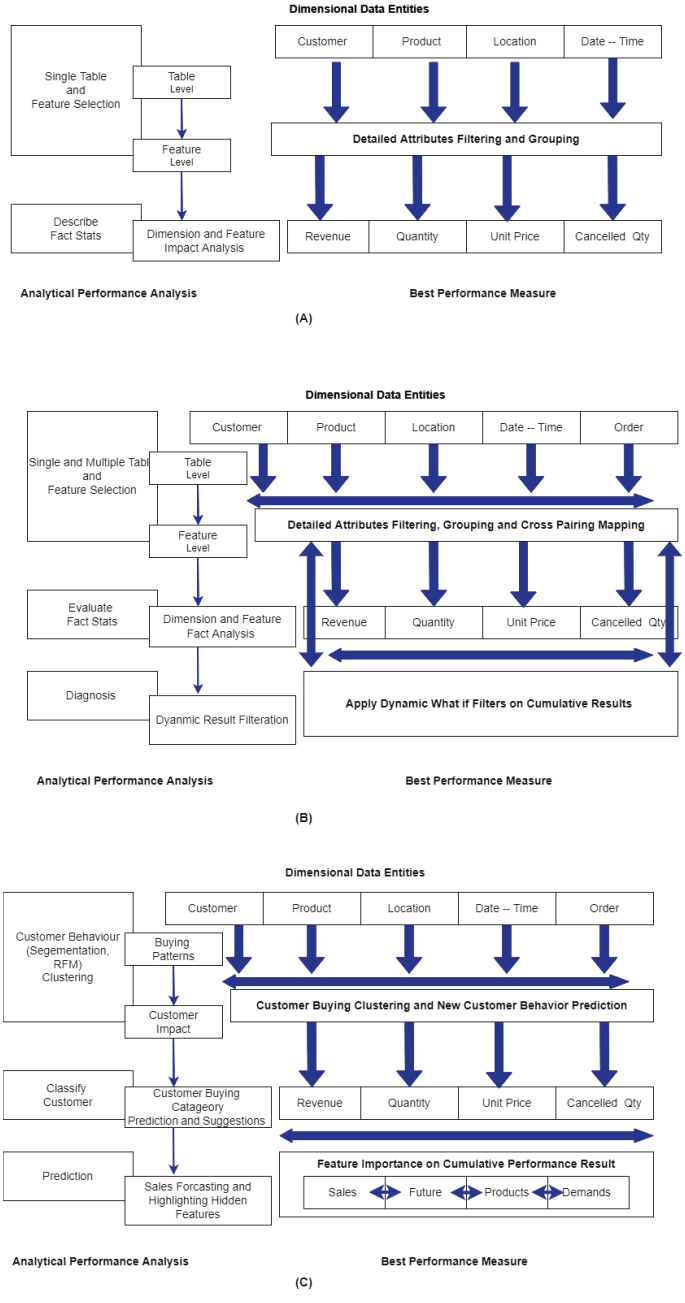


**Figure 6.** (**A**) Warehousing descriptive data analysis to know the past overall business performance. (**B**) Warehousing diagnostic data analysis to know the past business performance with dynamic filtration and feature importance. (**C**) Machine learning predictive data analysis to predict the future business performance with customer segments and sales forecasting.

## 3. Results and Discussion

As the proposed model contains two phases and subprocesses to develop the analytical system to evaluate business performance with possible aspects and determine the data features' importance and dependencies, they were first presented in ML clustering and classification model evaluation. These results were the final outputs of both the ML and BI phases after implementation. They describe the customer clustering (Figures 7 and 8) and classification algorithm evaluations, which show the ML algorithm's accuracy on the data, given in Table 1. Gradient boosting and the voting classifier performed better in the classification task. With the help of power BI, the implemented analytical reports described the data insights with and without smart filters to meet the business KPIs for the concerned research objectives. The following are the results, which show the performance of the hidden facts.


**Figure 7.** Clusters of chosen products by similar customers to show behavior in multiple orders.

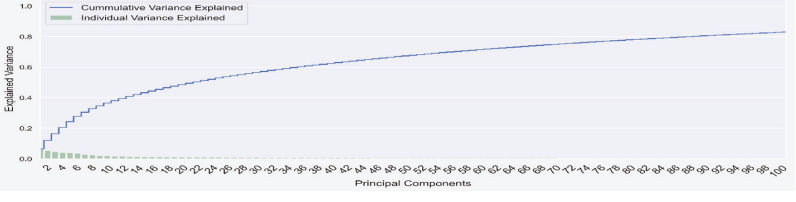


**Figure 8.** Product-based clusters' difference in the results of principle component analysis to determine the variance of clusters.

**Table 1.** ML classification model scores.

| Algorithm | Accuracy Score |
|---|---|
| SVC | 75.92% |
| Logistic Regression | 94.93% |
| KNN | 84.23% |
| DT | 89.76% |
| Random Forest | 94.56% |
| AdaBoost | 59.59% |
| Gradient Boosting | 95.39% |
| Voting Classifier | 95.30% |

Applying multiple variants of predictive algorithms to classify the customer behavior will help to see the similar customers and their buying trends.

On the other hand, RFM analysis was performed to find the best potential customers, which is very valuable technique when having low customer and sales figures. Recency is known as the number of days from the last purchase in the analysis data, the frequency is simply how frequent customers are purchasing a product, and monetary is the customer's total individual contribution to the overall sales revenue.

The customers having the lowest recency rate and high frequency and monitory values are the best potential customers which are important for sales revenue because in less time, they became the most frequent customers and yielded more revenue, as shown in Figure 9.

| Customer ID | recency | frequency | monetary | r_quartile | f_quartile | m_quartile | RFM_Score |
|---|---|---|---|---|---|---|---|
| **18102.0** | 0 | 145 | 580987.04 | 1 | 1 | 1 | 111 |
| **17450.0** | 8 | 51 | 244784.25 | 1 | 1 | 1 | 111 |
| **13694.0** | 3 | 143 | 195640.69 | 1 | 1 | 1 | 111 |
| **17511.0** | 2 | 60 | 172132.87 | 1 | 1 | 1 | 111 |
| **16684.0** | 4 | 55 | 147142.77 | 1 | 1 | 1 | 111 |
| **15061.0** | 3 | 127 | 126389.02 | 1 | 1 | 1 | 111 |
| **17949.0** | 1 | 118 | 117314.08 | 1 | 1 | 1 | 111 |
| **15311.0** | 0 | 208 | 114966.42 | 1 | 1 | 1 | 111 |
| **13089.0** | 2 | 203 | 113416.91 | 1 | 1 | 1 | 111 |
| **12931.0** | 21 | 57 | 92347.34 | 1 | 1 | 1 | 111 |

**Figure 9.** Customer recency, frequency, and monitoring values after RFM analysis and computing.

The forecasting results were better, forecasting a two-month sales forecast as shown in Figures 10–15. The sales daily trends, ARIMA modeling, fitted model stats, and forecasting values are displayed. Due to some shortcomings in data length, the results were not up to the mark but showed a clear view of the sales for the next two months in the results of daily seasonality.

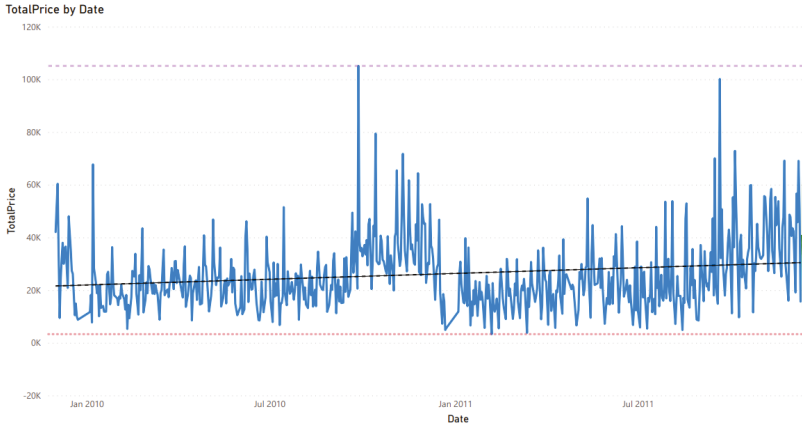


**Figure 10.** Sales values with day-to-day transactions by invoice date.

SARIMAX Results

| | | | |
|---|---|---|---|
| Dep. Variable: | TotalPrice | No. Observations: | 374 |
| Model: | SARIMAX(1, 0, 1)×(1, 1, 1, 30) | Log Likelihood | -3545.487 |
| Date: | Sat, 01 May 2021 | AIC | 7100.973 |
| Time: | 16:22:17 | BIC | 7119.688 |
| Sample: | 12-01-2010 - 12-09-2011 | HQIC | 7108.453 |
| Covariance Type: | opg | | |

| | coef | std err | z | P>\|z\| | [0.025 | 0.975] |
|---|---|---|---|---|---|---|
| ar.L1 | 0.2633 | 0.222 | 1.185 | 0.236 | -0.172 | 0.699 |
| ma.L1 | 0.2300 | 0.207 | 1.111 | 0.266 | -0.176 | 0.636 |
| ar.S.L30 | -0.2132 | 0.121 | -1.765 | 0.078 | -0.450 | 0.024 |
| ma.S.L30 | -0.7000 | 0.084 | -8.335 | 0.000 | -0.865 | -0.535 |
| sigma2 | 6.538e+08 | 5.52e-11 | 1.18e+19 | 0.000 | 6.54e+08 | 6.54e+08 |

| | | | |
|---|---|---|---|
| Ljung-Box (L1) (Q): | 2.32 | Jarque-Bera (JB): | 10.78 |
| Prob(Q): | 0.13 | Prob(JB): | 0.00 |
| Heteroskedasticity (H): | 3.08 | Skew: | 0.04 |
| Prob(H) (two-sided): | 0.00 | Kurtosis: | 3.91 |

**Figure 11.** Sales forecasting behavior summaries.

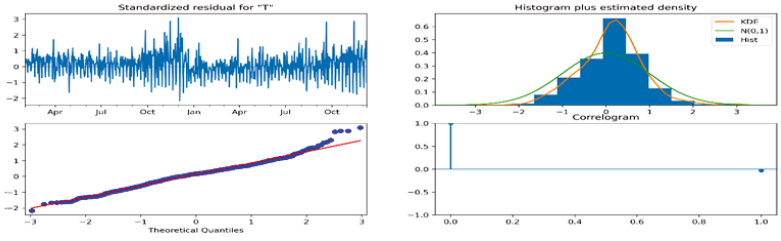


**Figure 12.** Sales forecasting model with summary visuals to show the model's training fit.

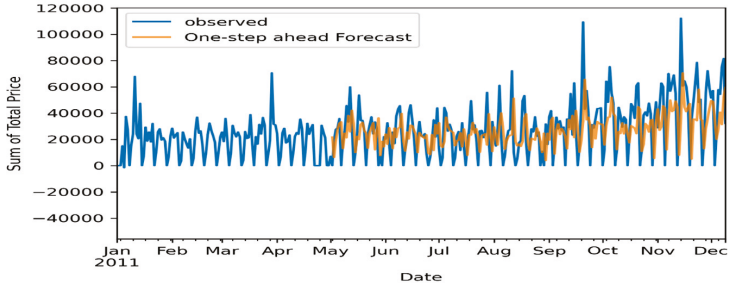


**Figure 13.** Sales forecasting model validation of existing dates to show the model's training fit.

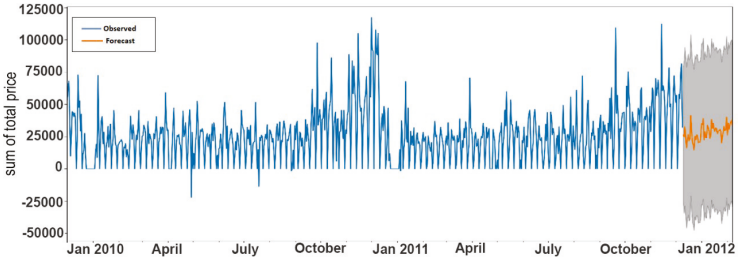


**Figure 14.** ARIMA mean sales forecasting of two months to forecast future sales

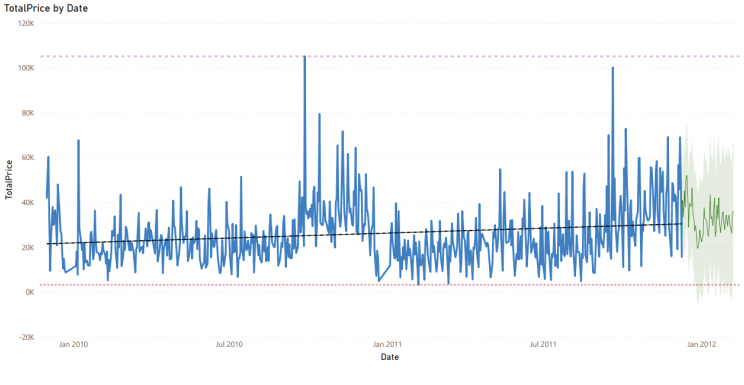


**Figure 15.** Automatic forecast using power BI sales forecasting (with minimum, trend, and maximum values) for two months to forecast future sales.

The overall results were compiled on an interactive dashboard to show the data insights statically as well dynamic reporting with multiple ad hoc filters. Here, we only

presented two reports for the sake of simplicity. There were 14 dynamic data reports are made which demonstrated the 360-degree view of sales.

We viewed the data patterns with the smart filtering approach presented with power BI data modeling and detailed data reporting to answer the business questions. We can see in Figure 16 the sales overview with respect to the location, customers, date and time, and product values. By applying multiple filters, we could view the data insights in 360°.

Similarly, an extension the generic sales performance for the order characteristics, such as how many orders were placed in a specific price range of products, a comparison of revenue on weekends and working days, and having multiple options in the date and time hierarchy in terms of years, semesters, quarters, months, and weeks, is shown in Figure 17.

Customers always play vital role, and in this report, we had no rich features about the customers, so we could only explore customer IDs against the facts measured for multiple dimensional values.

The next angle was products which also had features with fewer dimensions, so we could just explore the product type (extracted from the description) for high and low products for other dimensions and against the measurements.

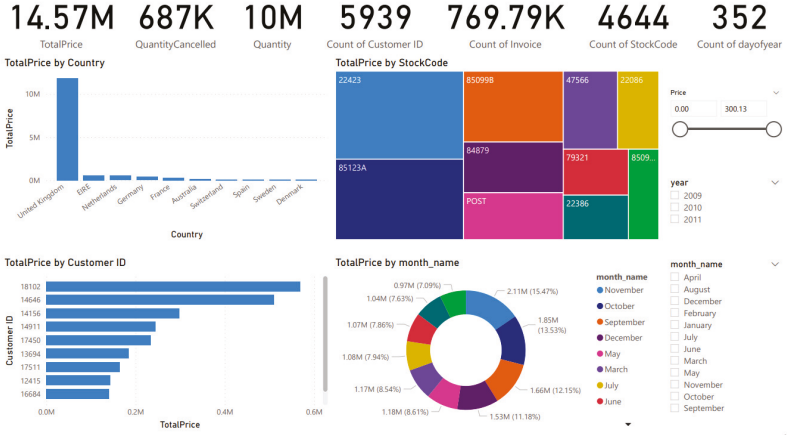


**Figure 16.** Sales performance overview with respect to highest revenue for products, date and time, and location.

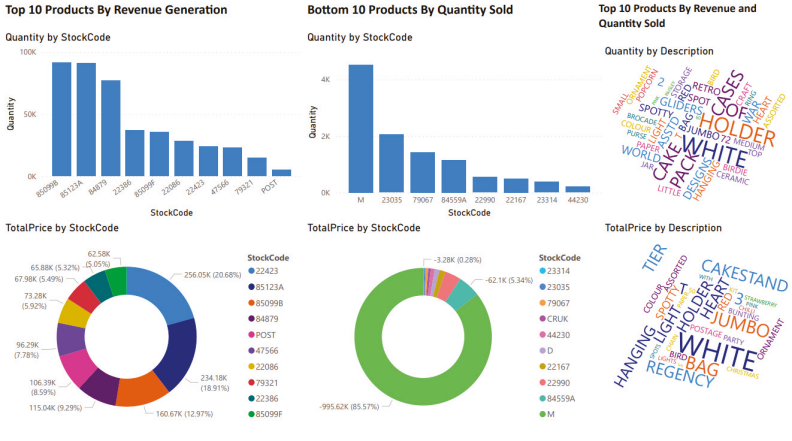


**Figure 17.** Product analysis with respect to highest revenue for products, date and time, and location.

The most important dimension in this study was the time data, which gave more rich features (derived from the date) and had multiple scenarios for the evaluation of the facts. Using smart filters, the 360-degree analysis was possible for all of the data. We similarly extended the generic sales performance for order characteristics such as how many orders were placed within a specific price range of products, a comparison of revenue on the weekends and working days, and multiple options in the date and time hierarchy in terms of years, semesters, quarters, months, and weeks.

The order analysis for products and customers showed the quantity of products sold and sales revenue with the order characteristics. With smart filters, viewing the data with multiple factors was very informative and helpful to answering the short- and long-term performance-monitoring questions. The cancellation order analysis for products and customers was summarized. Quality results are totally dependent on the given data and applied analytical framework, as discussed above regarding the results for ML and BI. All the statistical graphs showed the hidden insights as well the analytical framework evaluation. Every section of the charts was cross-filtering enabled, which showed the business insights in a detailed manner. The interactive reports were summarized on a sales dashboard for specific dimensions and are shareable with associated sales persons and stakeholders.

## 4. Conclusions

Business intelligence is a growing technology that uses data and computational analytical techniques to find business insights. Business owners and management are facing data management, customer relationship management, customer experience, departmental business data, operational system quality, and KPI issues to smartly manage their businesses and gain competitive advantages. The proposed framework is based on a hybrid solution that mainly consists of warehousing and ML empowered with BI data reporting, which provides statistical, ranking, and dimensional analysis of the past and current views of a business and a predictive view to forecasting a business's performance. These analytical sales reports are user-friendly, easily shareable across departments, and very useful in performance monitoring and for designing the best strategies. Users can utilize smart filters to obtain fully dynamic and versatile business insights that can truly answer analytical questions. This is purely a self-service business intelligence model implementation with ML and effective data reporting. The overall process is very efficient from data loading to processing, schema design, pattern computation, and data reporting, as well sharing with stakeholders to view the performance quickly. The smart framework comprises the sales metrics with respect to different dimensions that are very helpful for designing business strategies. Compared with existing techniques, this will provide a lightweight, centralized, and comprehensive view of a business with less errors, a low cost, and fast access with dynamic business analysis.

*Future Work*

As the dataset under consideration belongs to online retail, which has customer-based features, no shipping or payment information was given in the detailed product information, and any supplier information was not provided. The proposed approach will give more interesting and needed insights if the data are enriched with more detailed information. This study can be further extended with more inter-department and external source data such as product reviews and demands to evaluate the overall growth, dependent areas, and future goals and strategies.

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# Biometrics Innovation and Payment Sector Perception

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**Abstract:** This paper presents an analysis of innovations in the biometrics market, which have started to play a very important role in personal identification and identification systems. The aim of the study was to analyze current customs and opinions regarding payment methods, as well as to identify threats and opportunities for new biometric solutions in this area. First, the history of the biometrics market is presented. Acceptance patterns of new technologies are explored and modified. The authors used literature reviews, qualitative research (focus groups), and quantitative research (questionnaire survey) as methods. The main value and importance of biometrics is the uniqueness of biometric patterns (e.g., face, fingerprint, iris, etc.), which takes the security of these systems to a new level. The results of the quantitative study based on the qualitative survey show positive verification of the hypothesized reasons; e.g., importantly, that the age of potential users of biometric payments influences the fear about personal data. Fear of losing personal data affects the perceived safety of biometric payments. Perceived security has a very strong influence on attitudes towards biometric payments, which is the strongest predictor of behavioral intention to use biometric payments.

**Keywords:** market research; biometrics; security; biometrics market; biometrics perception; structural equation modeling

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## 1. Introduction

### *1.1. Introduction to Biometrics*

Biometrics is the field that deals with measuring the characteristics of living organisms, including humans of course, but also animals and plants. At the basis of the application of biometrics in the field of authentication and identification lies a number of characteristics of living organisms, which allow the unambiguous distinction of an individual against the population. When choosing a particular biometric trait, we should be guided by the following criteria:

- Universality (almost every individual in the population has the trait);
- Unambiguity/uniqueness (the feature is highly distinguishable in the group);
- Persistence/variation over time (the trait does not degenerate over time);
- Technical feasibility of acquiring (the trait can be read fairly easily);
- Acceptability (cultural, religious concerns, sense of comfort and hygiene).

Biometric traits can be divided into physical/physiological and behavioral ones. Relating to the structure of individual parts of the body, e.g., iris patterns of the eye, the shape of a hand or ear, a fingerprint, face geometry or the shape of our veins, are the physiological features. Behavioral traits are developed and established during the maturation process of the individual and are related to their behavior, e.g., the way they walk, brain wave P300 (since brain waves have been proved to be unique enough across individuals to be used as

biometrics), their handwritten signature (keystroking), or the characteristics of their voice (although sometimes the dual nature of this biometric is referred to). An example of a combination of both types of traits can be found in Figure 1.

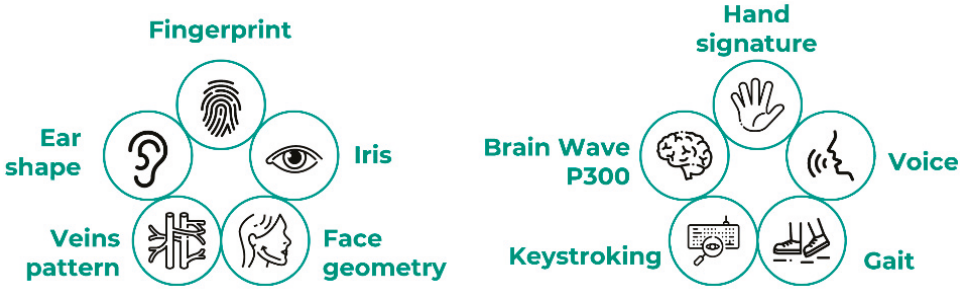


**Figure 1.** Physiological (**left**) and behavioral (**right**) biometric traits (adapted from [1]).

Biometric security in the modern sense was born in the 19th century, thanks to the innovations of administrators, anthropologists, and French detectives [2]. The first known research publication on automated biometric recognition was Mitchell Trauring's 1963 paper [3] in the journal *Nature* on fingerprint matching. The development of automated biometric systems based on other features, such as voice, face, and signature, also began in the 1960s. Subsequently, biometric systems based on features such as hand geometry and iris were developed. In this sense, almost 70 years have passed since the first paper on automated biometric recognition was published [4]. In Figure 2 there is a timeline of the development of the fingerprint; other biometric traits were investigated in quite similar timeframes in the 19th century.

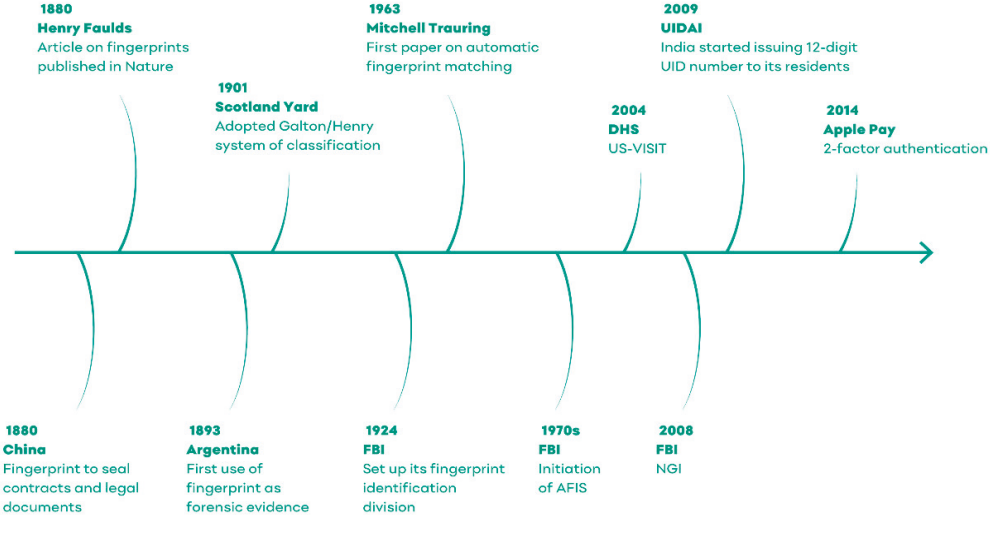


**Figure 2.** Some major milestones in the history of fingerprint recognition (see [4]).

Each biometric trait has its advantages, disadvantages, and limitations and these should be considered while selecting it for a given usage scenario. Due to the aforementioned characteristics of biometric traits, especially uniqueness, time invariability, and unambiguity, they should be considered as sensitive data and protected on multiple levels. The theft of raw biometric data can be used by an adversary to impersonate the victim and consequently gain unauthorized access or commit theft. The European Union, in its General

Data Protection Regulation (GDPR), has addressed this issue and defined biometric data as particularly sensitive and has assigned to it the need for special protection [5]. Keeping the above in mind, raw biometric data should be treated with special care, which means primarily reducing its processing to a minimum. A fundamental solution to this issue is the use of so-called one-way processing [6], which generates from a sample of raw biometric data a template/profile/code that is an imprint of that data. Such a code still has individual properties and can be compared with others, so the idea of using biometrics is preserved. However, it is not possible to reconstruct the original biometric data only on its basis. This approach also protects the user in case the code database is leaked, because its use in a transformed form is negligible—similar to the case of password hashes. An example of iris encoding according to Daugman's solution [7] can be found in Figure 3.

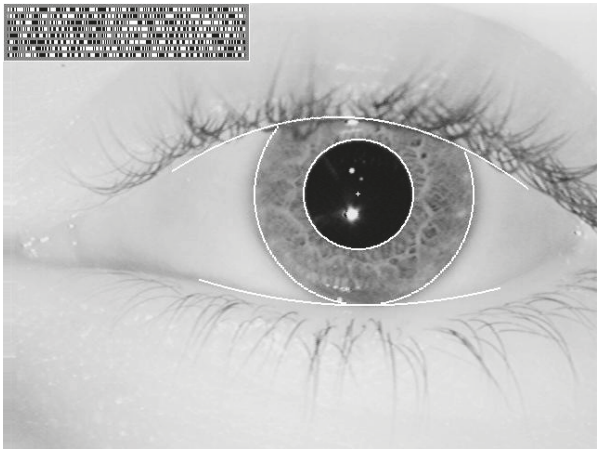

**Figure 3.** Iris code and accompanying iris pattern. Source: https://www.cl.cam.ac.uk/~jgd1000/iris_recognition.html (accessed on 14 April 2022), based on [7].

Referring to palmprints, biometric template protection methods, such as cancelable biometrics and a biometric cryptosystem, are essential to avoid direct disclosure of original palmprint features [8]. To strengthen user security, an approach based on so-called *cancelable biometrics* can also be used [9] in different types of biometrics. This solution is based on the ability to create multiple biometric identities from a single source data and to manage these identities. In a particular case, we can delete a given biometric identity and create another one based on its raw data. Such an application can be particularly useful when the database of the system in which the identity was used has been leaked or when we have a reasonable suspicion that someone is trying to impersonate that identity. When using the approach of cancelable biometrics, we usually need an additional source of external information beyond the biometrics itself so that we can modify the identity accordingly and combine it with biometric data. Such information can be, for example, a string of characters entered by the user, such as a password or PIN. Another existing method of template protection (used in palmprint biometrics) is a *palmprint cryptosystem*, which is the merging of biometrics and cryptography, which attempts to deploy biometrics as the authenticator of cryptographic applications, in which biometric features are claimed to be protected [8].

No matter how much effort is put into securing biometric data, at some point an adversary will manage to gain possession of it and try to use it to impersonate a legitimate user. This type of action is called a presentation attack, and the defense is presentation attack detection (PAD).

To counter such forgery attempts, liveness tests [10] are used, which are the basis of biometrics applications. A general scheme of how a biometrics-based security system works is shown in Figure 4. Liveness tests are designed to detect attempts to replace artificial

objects—simulating real biometric features, including stolen biometrics converted into fake samples—photos, masks, recordings, etc. Any security system based on biometrics should place great emphasis on liveness testing and enforce high detection of substitution attacks. However, this is not an easy task as adversaries have increasingly more modern methods of defrauding at their disposal and are often extremely determined in demonstrating system weaknesses.

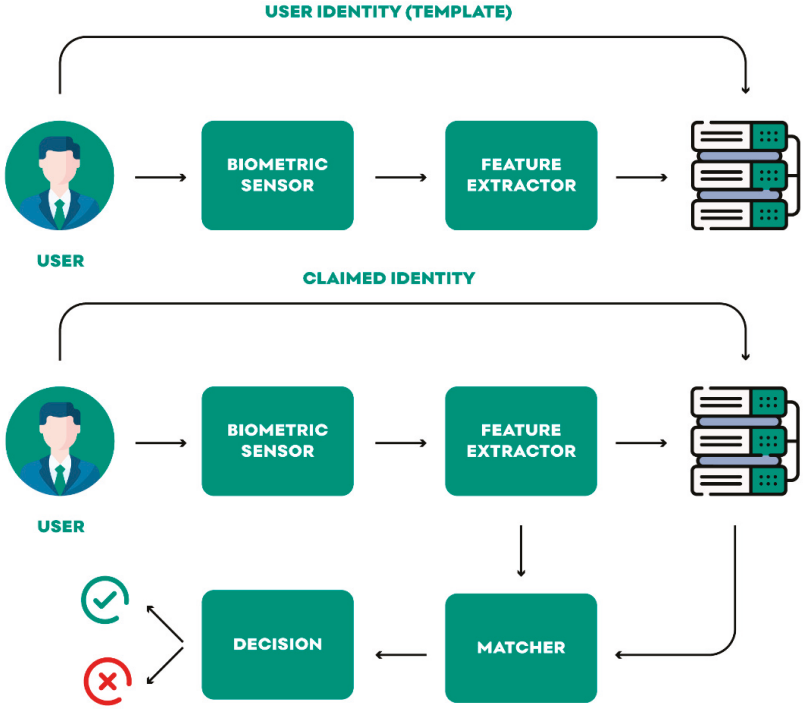


**Figure 4.** Biometric enrollment and verification. The enrollment phase produces an association between a biometric characteristic and its identity. In the verification phase, an enrolled user claims an identity, which the system verifies on the basis of the user's biometric feature set [10].

Applications of biometric solutions can be found in many fields, the most noteworthy being:

- Authentication (1:1);
- Identification (1:N);
- Access control (entry/exit registration);
- Continuous verification (real-time monitoring of biometric parameters);
- Biometric link (e.g., link between a person and an identity document).

Some of the abovementioned applications have already been addressed earlier and will be described in more detail later in this article. However, now we would like to focus on the last two applications that undeniably distinguish biometrics from other security solutions.

Biometrics, in contrast to standard authentication or authorization mechanisms (e.g., based on the knowledge factor–password or PIN or based on the possession factor–hardware token) allows the introduction of continuous verification of the identity of the person using the system [11]. Thanks to the transparent collection of such biometric data as in the rhythm of typing (keystroking), the way a touch screen is used, or the continuous analysis of the image from a camera, the system is able to verify, on an ongoing basis, whether an authorized person is still using its resources [12]. None of the standard mecha-

nisms based on passwords or hardware keys provides such ease and efficiency of real-time verification while maintaining a high level of usability.

The second specific application of biometrics mentioned is the ability to create a biometric link between the person to whom the identity document has been issued and the person who is currently using it [13]. This is another layer of security that allows us to link an individual to a specific identity document through biometric characteristics. Without the biometric layer, we would only be able to verify that the data inside the chip of the identity document is consistent with the printed data or manually confirm the similarity of the photo with the person who holds the identity document. By using biometrics, we can not only verify the integrity of the data in the physical and electronic layers, but also apply an algorithm that authenticates biometric features and compares the biometrics of the person holding the document with the pattern recorded inside the electronic layer of the document. This solution will significantly reduce the effectiveness of counterfeiting identity documents and the use of documents by people to whom the documents have not been issued. Finally, let us look at iris biometry. The first smartphone with an LED, which allows for the scanning of the iris of the eye, has appeared on the market (so far only in Japan) as a form of camera protection. The Arrows NX F-04G phone by Fujitsu is sold by the Japanese telecommunication operator DOCOMO. The innovative LED is manufactured by OSRAM [14].

### *1.2. Market of Biometrics*

Market forecasts indicate that the biometric systems market will be worth nearly USD 33 billion by 2022 [15]. The global biometrics market value will rise from USD 33 billion in 2019 to USD 65.3 billion in 2024 [16]. According to analyst firm Global Markets In-sights, the biometrics-based security solutions market will be worth USD 50 billion by 2024 [17]. From a total value of USD 23.4 billion in 2018, the global biometrics technology market is expected to reach USD 71.6 billion by 2024 [18]. By 2024, healthcare applications will register a compound annual growth rate (CAGR) of 26.3%, airport and seaport applications 25.8%, financial services 25.1%, and government services 23.3%. Retail, gaming, and hospitality applications will also see CAGR growth of 23% and 22.8%, respectively [18]. For information on stocks of companies using biometrics, see [19] (p. 3). Figure 5 represents the rise of worldwide biometric technologies market (Figure 5) [20].

The prominent key players in the biometric system industry are: SA (France), NEC Corporation (Japan), Fujitsu Ltd. (Japan), BIO-Key International, Inc. (U.S.), Precise Biometrics AB (Sweden), Secunet Security Networks AG (Germany), Thales SA (France), Aware, Inc. (U.S.), Cognitec Systems GmbH (Germany), and Cross Match Technologies (U.S.), among others [21].

Nearly six in ten people polled in the United States cited some hesitation or concern with biometric authentication. The top concerns among those polled by Statista included concerns about data and that the technology is too easy to fool. Biometric authentication includes fingerprints, face recognition, iris scanners, and any voice recognition. The government end-user sector is currently leading the market. It captured a significant market share of around 48% in 2018 [22]. North America leads the global biometrics market in 2018 with a market share of around 30%, which is followed by Asia-Pacific and Europe. In North America, the requirements of biometrics are higher because of the rise in the demand for developed security precautions and tourist administration after the 9/11 attacks. In North America, the biometrics market has witnessed strong growth over the years, especially in law enforcement, forensics, and government activities. Biometric passports became compulsory for issuance of foreign passports as of 2016 in the U.S. One of the strongest laws regarding biometrics exists in Illinois, named the Biometric Information Privacy Act (BIPA), which forbids companies from collecting information without prior consent from an individual. The Asia-Pacific is also a speedily evolving region. The existence of developing economies such as India, China, South Korea, Japan, Malaysia, Singapore, and Australia, which are displaying increased acceptance of biometrics, is no

doubt driving market growth [23]. Compound annual growth rate (CAGR) of the global biometric market is shown in Figure 6.

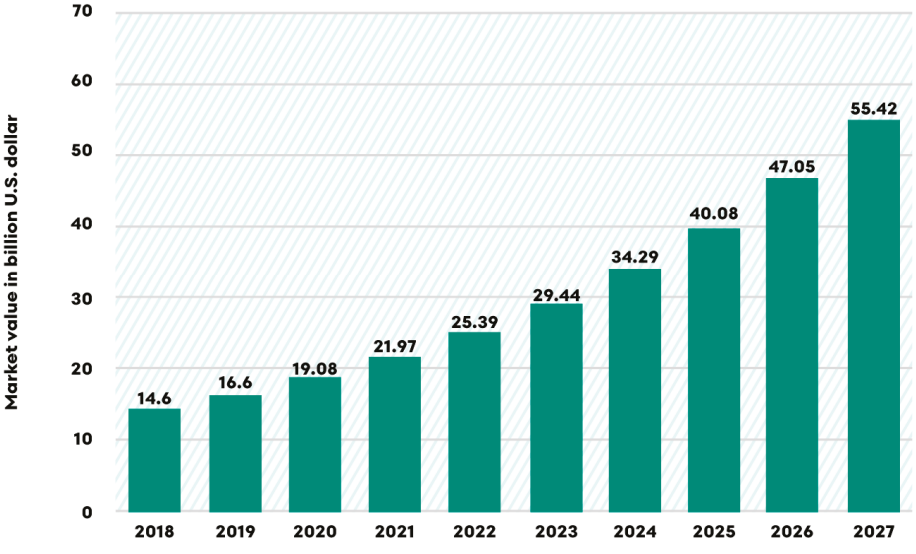


**Figure 5.** Worldwide biometric technologies market, source: [20].

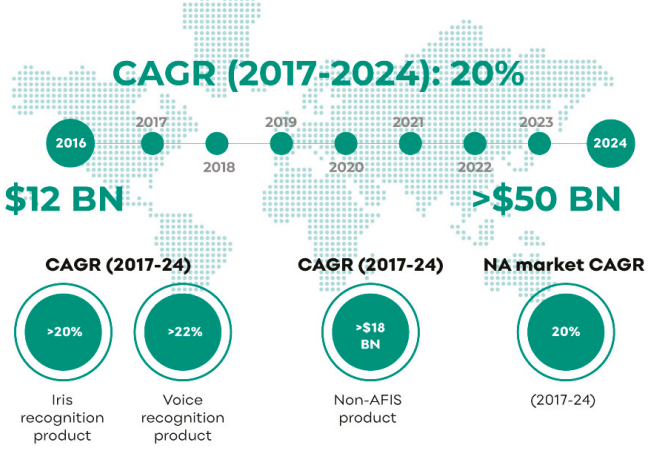


**Figure 6.** Biometric market growth, source: [24].

### *1.3. Biometrics in Poland*

The development of biometric technologies and popularization of their use in Poland has been very dynamic, as shown by numerous studies and reports. Poland is a receptive market for technological innovations, where large numbers of companies implement and experiment with the latest applications of biometrics.

A study by Visa [25] shows that as much as 62% of the surveyed Polish consumers declared their willingness to use biometrics instead of a password to verify payments. Consumers in Poland appreciate that thanks to biometrics, they do not have to remember passwords or codes: 73% of the surveyed consumers thought that using biometric data was faster than passwords and 76% thought it was easier, while 92% of Polish consumers

who took part in the survey believed that fingerprint recognition was the safest form of payment authentication. According to the report *Global TMT Predictions 2018* [15] prepared by Deloitte, by the end of the year 29% of smartphone users will verify their identity by fingerprint, and 42% of all mobile devices will be equipped with a fingerprint reader. Currently, one in four (25%) participants of the Mastercard 2019 survey [26] uses biometrics (not only for authentication and payment), but if they had the option, they would use it every second (50%). Forty-seven percent of Polish e-consumers would prefer biometric authentication for card payments, both online and in physical stores. Those who indicated preference for this method would most willingly use the technology of fingerprint recognition, iris scan, voice recognition, or facial features analysis. Confirmation of a transaction with a fingerprint was considered safe by every fourth respondent (75%) in the Mastercard study. This was a higher result than in the case of one-time codes (66%). More than half of the respondents considered the technology of facial features recognition (54%) or other kinds of biometrics (53%) was safe.

The Polish payment market is developing very dynamically and is one of the most modern in Europe. In general, it is a society that relies on cashless payments [27].

A survey conducted by Ping Identity [17] shows that 92% of companies believe that the use of biometric methods is a very effective way to authenticate people and increase the security of data stored in company resources. It found 86% of the respondents thought that biometrics allowed for good security as access to information is stored in the cloud. However, currently only 28% of companies use biometric systems in their local infrastructure and 22% use them to secure access to applications and data stored in the cloud.

In 2019 MasterCard conducted research in the context of Polish consumers' attitudes towards online shopping, taking into account upcoming changes in e-commerce payments. The result of this work was a report called "Safe e-commerce". The authors prove that biometrics will become a standard for confirming identity in payments. Moreover, more than 75% of the respondents believed that strong online card payment authentication, which came into force in mid-September 2019, was needed, which clearly sets a new trend in banking [28].

Therefore, there is a need to popularize authorization mechanisms such as biometrics, which are a convenient and effective way to confirm identity [28]. Similar conclusions were drawn in the results of research conducted by MasterCard in 2019.

At the same time, the authors of [28] observed that technologies such as biometrics, e-identity services or cashless payments are not something extraordinary for the respondents, but rather a desirable direction of development and providing greater convenience and usability of digital banking systems. The respondents showed great confidence in financial institutions and entrusted their data and money to them, so it is up to them to ensure the highest possible protection of consumers' identity and accumulated assets.

PayEye (https://payeye.com/, accessed on 2 October 2020) is a Polish fintech that introduced the world's first such secure, convenient, and complete payment based system, for both payment acceptance and user identification, using iris biometrics. By combining technology with science, PayEye has created a whole, independent, and secure ecosystem, which consists of proprietary, innovative eyePOS terminals, an electronic wallet for users, algorithms which convert the iris into a biometric pattern and, in the future, also solutions for e-commerce.

### *1.4. Literature Review of Technology Acceptance Models*

As mentioned previously in the paper, biometrics play a crucial role in many innovative systems. Each innovation is subject to the implementation process and as a result is or is not accepted by market participants. Many researchers emphasize that diffusion is a social process that occurs among people in response to learning about an innovation such as a new evidence-based approach for extending or improving health care. In its classical formulation, diffusion involves an innovation that is communicated through cer-

tain channels over time among the members of a social system [29,30]. Market practice aspects and research paradigms known as the diffusion of innovation (DOI) [31] can be applicable into the complex context of biometrics identification processes and its usage in payment systems.

Innovative biometric systems that incorporate biometric payments are rapidly becoming an important part of information technology (IT) and information systems (IS). The literature indicates that biometrics is becoming the standard of modern life, as commercial and governmental entities are rapidly adopting technology that promises increased security and better identification [32] (p. 314). Theoretical frameworks for technology acceptance are IS theories that model how users accept and use a particular technology. These theories suggest that when users are introduced to a new technology, many factors influence their decision about how and when they will use it [33].

It has been noted in the literature that the acceptance and use of information technology has been one of the priority issues in the research of information systems and practice since the late 1980s [34,35]. Building on the theory of reasoned action (TRA) formulated earlier by Fishbein and Ajzen [36], Davis [37] developed the technology acceptance model (TAM) and introduced it to the IS field. TRA has its roots in social psychology and attempts to explain why individuals engage in consciously intended behavior. In TAM, a user's motivation to adopt a new technology can be explained by three constructs: perceived ease of use (PEU), perceived usefulness (PU), and attitude towards using the system [38].

IS and IT are becoming increasingly complex and crucial for business operations, thus making the issue of acceptance an important challenge in IT implementation [33]. Many models and theories have been introduced that examine the acceptance and use of information systems from past to present. The unified theory of acceptance and use of technology (UTAUT) is a model that explains the use of technology by 70% of society. It is also used to estimate the probability of success of a new technology and to evaluate the adoption of various technologies [39,40].

In the study of Venkatesh et al. [39], UTAUT comprises of four main factors. These are performance expectancy, social influence, effort expectancy, and facilitating conditions. In addition, UTAUT includes four intermediate individual variables, gender, age, experience, and voluntariness of use, which predict the relationship between primary factors and behavioral intention and use behavior. According to UTAUT, there are determining factors that directly affect intention or use in models combined within the UTAUT framework. These determining factors are called performance expectancy (PE), social influence (SI), effort expectancy (EE), and facilitating conditions (FC). According to the literature review, the FC are empirically identified as the direct determinant of adopting the behavior. These factors play a prominent role as direct determinants of user acceptance and usage behavior [40].

Part of this complexity of the acceptance issue in biometrics, especially in the context of payments, is the issue of security and privacy. Langenderfer and Linnhoff [32] in their work analyze the costs and shed light on how biometrics can negatively affect consumers. The authors point out that the rapid development of biometric authentication technology represents a double-edged sword for consumers. On the one hand, increased use of biometrics is likely to reduce identity theft, improve consumer convenience by eliminating or reducing the use of passwords, and lower prices by reducing fraud costs for retailers. On the other hand, while overall security is likely to be enhanced, security breaches will be more costly and require significantly more effort to remedy.

The level of security perception in the context of biometrics, as a matter of the individual characteristics, is strongly connected with the privacy issue. A wealth of existing theoretical work has suggested that privacy levels, along with privacy perceptions, regulation behaviors, and information disclosure, are inherently context-dependent and vary across situations [41,42]. As Masur [41] (p. 312) points out, "privacy is a subjective perception resulting from the characteristics of the environment in which an individual happens to be at a given time".

It is also important to emphasize that research in IS has investigated the differences in levels of privacy concerns and their impact on a number of dependent variables such as willingness to provide information and intention to transact online [42–44]. Smith et al. [45], in their interdisciplinary review of privacy research, summarized existing privacy research into the antecedent–privacy concern–outcome (APCO) framework of information privacy, with privacy concerns as the central element, accompanied by antecedents and outcomes. Scientists also suggest that further research on the identification of the factors that contribute to privacy concerns is essential.

Several antecedents of privacy concerns have been found by Li [46] in the process of systematically reviewing existing empirical studies on privacy. The list of factors contains: (a) individual factors (demographics, personality traits, knowledge and experience, self-efficacy), (b) social factors (e.g., social norms), (c) organizational factors (privacy policies, website informativeness, company reputation), (d) macro-environmental factors (culture, regulatory structures), and (e) information contingencies (information sensitivity, type of information) [43,46,47]. Li [46] points out that for some factors (e.g., privacy experiences having a positive impact on privacy concerns), results have been cross-validated across studies, while for others (e.g., internet use and fluency and the big five personality traits), results have been inconsistent. Therefore, the researchers indicate that it is essential to conduct further research to examine the impact of different antecedents on privacy concerns [42].

Drawing on elements of DOI, the technology acceptance model (TAM), and a unified theory of acceptance and use of technology (UTAUT) along with the trust−privacy research field, Miltgen et al. [33] proposed an integrated approach that is both theoretically and empirically grounded. Their study examines individual acceptance of biometric identification techniques in a voluntary environment, measuring the intention to accept and further recommend the technology resulting from a carefully selected set of variables (Figure 7).

Research [33] confirms that the influence of known technology acceptance variables, such as compatibility, perceived usefulness, and facilitating conditions, on the acceptance of biometric systems and subsequent recommendations. Second, antecedent factors such as privacy concerns, trust in technology, and innovation also prove to be influential. Third, if not innovation, the most important factors explaining the acceptance and recommendation of biometric systems do not come from traditional adoption models (TAM, DOI, and UTAUT) but from the trust and privacy literature (trust in technology and perceived risk).

Miltgen et al. [33] in their paper pointed out that there are many other external factors that may influence responses that should be considered and investigated in the future, such as: 'security perceptions of users of biometric systems', 'consumer characteristics', 'situational factors', 'product characteristics', and 'previous experiences'. The authors suggest that additional future research should investigate these 'other' factors and their impact on consumers' behavioral intentions to accept new technologies in general and biometrics in particular.

On the basis of literature studies (both scientific literature and a review of journals, magazines, market reports), a research gap was identified. This gap concerns the need for further exploration of consumer attitudes towards biometrics, with particular emphasis on the use of iris biometrics in payment systems.

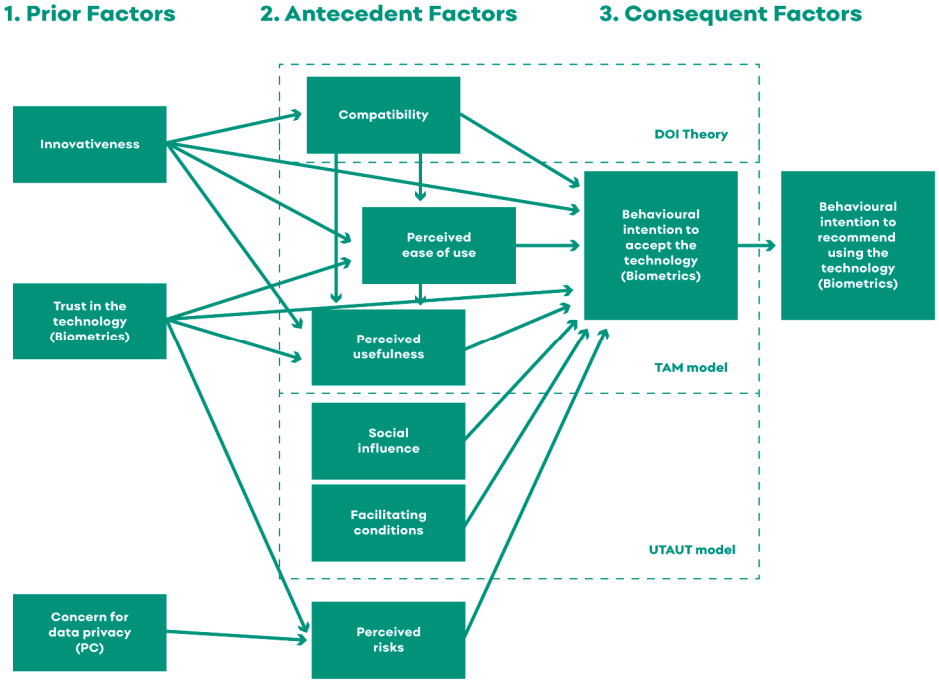


**Figure 7.** Determinants of end-user acceptance of biometrics, integrated approach model—see [33] (p. 106).

## 2. Materials and Methods

### *2.1. Methodology of the Qualitative Research*

After reviewing the literature, we decided to use a qualitative research method to explore the research topic from the perspective of a defined scientific gap.

The aim of the study was to analyze current customs and opinions regarding payment methods, as well as to identify threats and opportunities for new biometric solutions in this area. Based on the process of studying literature, as well as the author's own observations regarding the biometric market and its participants, we were able to formulate research questions:

- What is the current situation referring to payment solutions and its image in the minds of customers?
- What is the image and opinion of biometrics from the perspective of its usage in payment systems?

As a method of qualitative studies, we chose the FGI (focus group interview)—a well-known technique for collecting data in social sciences, which consists of conducting collective in-depth (semi-structured) intelligence in groups of 4–9 people (depending on the research area and organizational capabilities). We decided to focus on the newest form of biometric usage, which is iris-based biometrics (for now only available in Poland as a pilot project). We decided to choose this particular case because of its innovative nature and the effect of fresh opinions. A total of 4 focus groups meetings were conducted (November−December 2019), the shortest of which lasted 2.5 h and the longest almost 4 h. The participants were of different age groups, from different localities (both residents of small towns and big cities), and of different ages (the youngest was 17 and the oldest 74).

Focus I—4 women and 5 men predominate in focus groups;
Focus II—3 women and 3 men;

Focus III—5 women;
Focus IV—4 women and 3 men.

In conclusion, the gender differences in the focus studies conducted were as follows: 16 women and 11 men, for a total of 27 people. They were from different professions and lifestyles—high school students, housewives, secretarial managers, accountants, office workers (4 participants), sales, lawyers, entrepreneurs (3 participants were from businesses). All groups were surveyed without showing any type of biometric devices (no biometric payment tools).

According to the focus group participants, there were no apparent flaws in the current payment system (notably, this generation uses a card and a smartphone). There was enthusiasm about using smartphones as a payment option, especially among the younger generation. All participants stressed that biometric solutions are associated with risks of data leakage, health risks, "data hacking", etc. The visualization of the most frequent word used in relation to eye biometrics during the focus research, marked by emotion, was definitely the word "fear".

After the focus study, without the demonstration of a biometric device (iris-based), two focus studies with the demonstration of an identification device were conducted. After observing the first set of focus groups, we decided to divide the subsequent groups according to gender categories, as we noticed that due to the stereotype of a wider knowledge of technological issues in the male group, women kept their opinions to themselves and were not very open to sharing their thoughts. Due to this, the first meeting was a women-only meeting. These women represented different ages and professional categories:

- Economics student—master's degree;
- Employee of a creative agency;
- So-called housewife, however, conducting business;
- Accountant;
- Cashier;
- Management student;
- Bachelor's degree/at the same time waitress;
- Administrative employee of a small company (staff).

The age gap of the participants of the study (focus group) was 21–56 years old.

The first phase of the study looked similar to previous audio meetings: the issues of making payments, stressors, annoying and unpleasant payments were discussed (mainly queue times, breathing on the back of other customers, and lack of hygiene, whether using cash or card, "system jams", "internet crashes", and similar problems).

Participants declared that they mostly paid by card (plastic or smartphone) or cash. Another element of discussion was biometrics and their approaches to the use of biometric solutions in payments. In this area, there was a fairly strong element of doubt about biometric solutions, with survey participants associating them with gaining access to their accounts, and therefore lack of security surveillance, the possibility of copying fingerprints, and more than half of the survey participants stated (which was also important in this part) that they did not use biometric features at all and usually paid by card or cash, and used a code to identify themselves on their laptop or smartphone.

In the next part of the study, biometric equipment was presented. After a brief presentation, participants were encouraged to "encode" their eye on the device, which they were rather reluctant to do and even stressed about whether something could happen to their eyes.

In the next round, participants were able to check how the equipment recognized their iris. This step was welcomed more positively, although it must be said it was not met with great enthusiasm.

The final element was a discussion of other possible uses of the equipment. It is worth noting that participants strongly emphasized the health aspect—concerns were raised about the impact of eye scanning on health.

After the study, which took place with a female group, only male participants were intentionally invited to the second meeting. The format of the second focus group (except for different participants) was identical to the format of the stages (including the presentation of the device) in the female group. A total of eight participants, aged 21–54, representing different professions and industries took part in the second study:

- Aviation/own business;
- Film production;
- Economics student;
- Management student/bank employee;
- Management representative;
- Marketing director in a large international production and trading company;
- Construction worker;
- Rock musician.

There were noticeable differences in the observations in this male group compared to the female group, the most important being:

- No strong emphasis on health and hygiene aspects;
- No problem with searching for their wallet, phone, card in their pockets (for objective reasons) as aspects of everyday life.

### *2.2. Methodology of the Quantitative Research*

A survey was conducted in order to verify and extend the main results of the qualitative research and the observed dependencies. A questionnaire was prepared during a brainstorming session based on the results of qualitative research and the authors' own observations. A pilot survey was used to verify this model. The sample size was planned for a minimum of two hundred respondents, and social platforms were selected as the distribution channel for the questionnaire. For the pilot study, the respondents were not selected randomly, but the aim was to find representatives of working age for the sample. A list of analyzed items in the questionnaire is presented in the Appendix A of Table A1.

The statistical analysis was based on measures of dependence between the variables: mainly on the correlation matrix, and also on cross tables, e.g., for binary variables. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were used for the groups of questionnaire items, and for the variables grouped by EFA, a reliability analysis was performed using the Cronbach's alpha coefficient. Dependencies between constructs based on a linear correlation matrix were analyzed using path analysis within a structural equation model (SEM) to verify the significance of direct and indirect causality.

Due to the indicated research area, on which the research presented in this article focuses (biometric innovations in the payment sector), the model of hypothetical dependencies was based on the analysis of literature studies, including the presented UTAUT model, as well as qualitative research conducted by researchers. Such research procedures made it possible to derive and consequently define a new, proprietary model of hypothetical dependencies, which is presented in Figure 8. Our own observations and conducted qualitative research on the perception of biometric payments using the iris of the eye (BP) allowed us to prepare a set of hypotheses that lead to the acceptance model of BP verified in this study. The observation about the strong influence of consumer age on BP acceptance is due to the fact that age is the main exogenous variable in the first stages of diffusion of this type of innovation. Thus, age is not only an impact moderator, but also a primary predictor. The main target variable is the behavioral intention to accept and use BP (but not yet recommend BP due to the novelty of the technology), as described in the literature models.

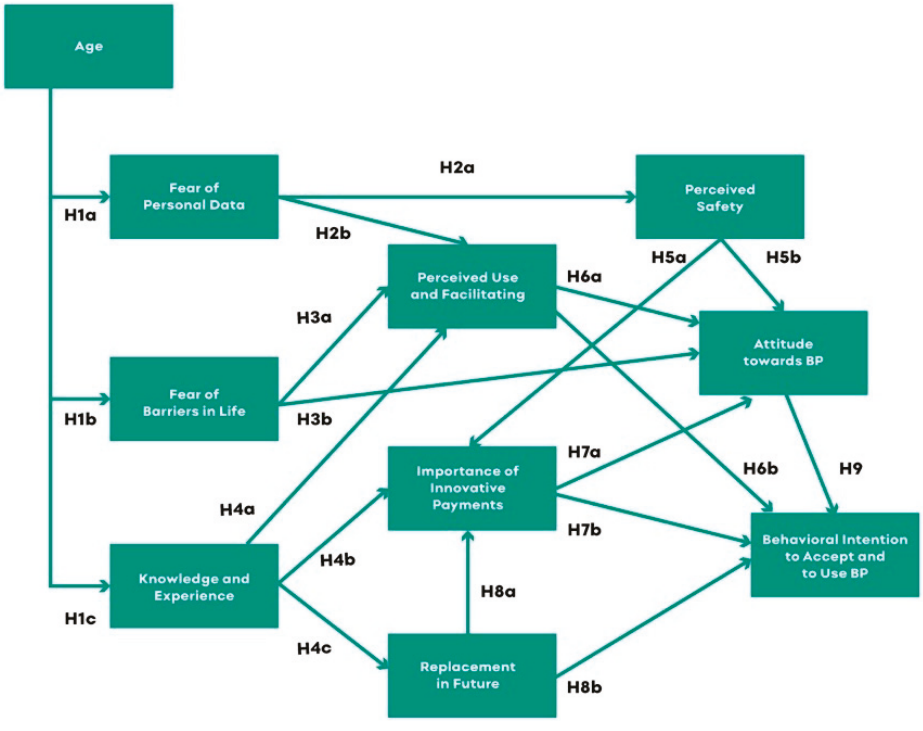


**Figure 8.** A Model of the verified hypotheses of dependencies and characteristics measured in qualitative research: model of behavioral intention to accept BP.

During the process of discussion, we formulated direct causes between variables, marked with arrows in Figure 8. The directions of the relationships between the variables of the model are presented in Table 1 together with the content of the hypotheses.

**Table 1.** Set of hypotheses in verified model.

| Symbol of Hypothesis | Content of Hypothesis |
|---|---|
| H1a | The higher the age of the respondents, the greater their fear of using personal data in BP systems |
| H1b | The higher the age of the respondents, the greater their fear of barriers in life with BP |
| H1c | The higher the age of the respondents, the greater their knowledge and experience (also in BP area) |
| H2a | Fear about personal data has a direct negative effect on perceived safety |
| H2b | The higher the respondents' concerns about personal data, the worse their perception of use and facilitating conditions of BP |
| H3a | Fear of barriers in life has a direct negative effect on perceived use and facilitating conditions |
| H3b | Fear of barriers in life has a direct negative effect on attitude towards BP |
| H4a | Knowledge and experience has a direct positive effect on perceived use and facilitating conditions |

**Table 1.** *Cont.*

| Symbol of Hypothesis | Content of Hypothesis |
|---|---|
| H4b | Knowledge and experience has a direct positive effect on importance of innovative payments |
| H4c | Knowledge and experience has a direct positive effect on replacement in future |
| H5a | Perceived safety has a direct positive effect on importance of innovative payments |
| H5b | Perceived safety has a direct positive effect on attitude towards BP |
| H6a | Perceived use and facilitating conditions variable has a direct positive effect on attitude towards BP |
| H6b | Perceived use and facilitating conditions variable has a direct positive effect on behavioral intention to accept and to use BP |
| H7a | Importance of innovative payments has a direct positive effect on attitude towards BP |
| H7b | Importance of innovative payments has a direct positive effect on behavioral intention to accept and to use BP |
| H8a | Replacement in future has a direct positive effect on importance of innovative payments |
| H8b | Replacement in future has a direct positive effect on behavioral intention to accept and to use BP |
| H9 | Attitude towards BP has a direct positive effect on behavioral intention to accept and to use BP |

The measurements of variables were constructed from questions presented in the Appendix A of Table A1. Predicted behavioral intention to accept and to use BP was measured as the sum of binary items numbered 18 and 19a–19d from Table A1. Three variables are measured with only one question:

(1) Self-reported perceived safety (item 9) was understood as the inverse of perceived risks from the model shown in Figure 7;
(2) Self-reported attitude towards BP (item 8) was understood as one of the main mediators predicting behavioral intention to accept and to use BP, rather shaped by other predictors and not initially trust (component of the model) presented in Figure 7;
(3) Replacement in future (item 20) was a stated belief about payments that may also be shaped by unmeasured science fiction in literature and films.

The three variables from the UTAUT model (perceived ease of use, perceived usefulness, and facilitating conditions) were considered during the preparation of the questionnaire as combining into a single latent variable called perceived use and facilitating conditions, measured as the sum of items 21–26 from Table A1. Importance of innovative payments was measured by the sum of items 3 and 4; not only biometric payments in their initial use in society (in real shops), but also mobile payments (e.g., codes generated in banking applications used mainly online in online shops), contrasting with traditional cash payments and the very popular card payments. Fear about personal data was measured as the sum of items 10–12 from Table A1 and is understood as concern about data privacy from Figure 7. Fear of barriers in life was measured as the sum of items 13–17, understood as social problems (the inverse of social influence from the UTAUT model or social incompatibility used as inverse in the DOI theory shown in Figure 7). Knowledge and experience was measured as the sum of binary items 5 and 7a–7d and shows respondents' acquired knowledge of BP. By constructing the model shown in Figure 8, discussing what is cause and what is effect, the direction of the hypotheses shown in Table 1 was decided. Comparing Figure 8 with the model shown in Figure 7, the only thing missing from the

model in Figure 8 is the perceived innovativeness of biometrics, but this was evident for payments. Statistical software Statistica 13.3 [48] was used to analyze the collected survey data to assess the measurement of latent variables and to verify the hypotheses.

## 3. Results

### *3.1. Qualitative Research*

From a consumer's perspective, biometric authentication offers many advantages. Once enrolled in a biometric system, the customer is instantly untroubled by the fraudulent use of their credit cards. Payments can be easily made without carrying any cash or other forms of identifiers and in this case the only thing required is their fingerprints. They can be certain that if their car or computer is stolen, it will be worthless to all except the most sophisticated thieves since access is biometrically controlled; in consequence this leads to a decrease in the impetus for theft. The bothersome task of remembering passwords could be considered a thing of the past.

As the general conclusions of the preliminary qualitative studies carried out, we point out the skeptical approach to biometric solutions in payment systems.

It is necessary in the future to indicate market concerns about novelties, but to seek innovation to assuage numerous consumer concerns about the introduction of biometric applications with important implications for marketing communication associations with nature, simplicity, and naturalness. There is a need to promote biometric solutions in the educational form.

### *3.2. Quantitative Research*

Continuing with the qualitative research, results were collected from the questionnaire. Most analyses (EFA, CFA, reliability analysis, SEM) were based on a linear correlation matrix where most values are significantly different from zero (hard to publish because of matrix size, but available upon request from the corresponding author). The number of observations was 200, which is not a very large number to verify such complex hypothesis models. The age of the respondents was the only objective variable analyzed, the others being subjective or behavioral variables. The mean age was 28.7 years, and the standard deviation was 9.2. The respondents were rather young people: the minimum age was 17 years, and the maximum was 61 years, so the sample included representatives of almost the entire working age range.

Factor analysis of variables with Likert-type response scales confirmed the three measurement scales for fear concerning personal data, fear of barriers in life, and perceived use and facilitating conditions developed from the questionnaire items in Table A1; e.g., the EFA scree plot reduced the dimensions to three and the CFA fit was rather good.

Following the strict methodology of Song et al. [49–52], before proceeding to testing the hypotheses H1–H9, we checked the reliability of scales and measurement items.

### *3.3. Reliability and Validity*

As a measure of reliability, that is, the internal consistency of the measurement items of the survey, we used Cronbach's alphas, as given in Table 2. All the values were above the threshold 0.7 (the minimum value was 0.830); that is, the scale may be regarded as reliable.

**Table 2.** The internal consistency of the measurement items.

| Construct | Cronbach's Alpha | Variable | Standardized Factor Loading | SMC | AVE | Composite Reliability |
|---|---|---|---|---|---|---|
| Fear about personal data | 0.879 | Q10 | 0.877 | 0.687 | 0.761 | 0.905 |
| | | Q11 | 0.910 | 0.731 | | |
| | | Q12 | 0.828 | 0.538 | | |
| Fear of barriers in life | 0.829 | Q13 | 0.681 | 0.492 | 0.569 | 0.868 |
| | | Q14 | 0.780 | 0.439 | | |
| | | Q15 | 0.678 | 0.411 | | |
| | | Q16 | 0.851 | 0.546 | | |
| | | Q17 | 0.767 | 0.500 | | |
| Perceived use and facilitating conditions | 0.879 | Q21 | 0.708 | 0.473 | 0.627 | 0.909 |
| | | Q22 | 0.837 | 0.649 | | |
| | | Q23 | 0.782 | 0.567 | | |
| | | Q24 | 0.793 | 0.532 | | |
| | | Q25 | 0.775 | 0.481 | | |
| | | Q26 | 0.848 | 0.606 | | |

We also investigated the correspondence between the constructs and their operationalization. This constitutes four components: analysis of unidimensionality, convergent validity, discriminant validity, and nomological validity.

To investigate the unidimensionality of the scale, we performed CFA to examine whether the indicators were assigned to the constructs adequately. Using the maximum likelihood method of estimation, we obtained a satisfactory result, including fit indices, presented in Table 3. As chi-square/d.f., it should range between 1 and 5, so our result fitted well within that. GFI and AGFI should exceed 0.9; the latter in our research was a bit below this threshold. RMSEA should range between 0.05 and 0.08, and the value for our research fitted well. SRMR, which should be below 0.08, equaled 0.054 and was below the threshold. Incremental fit indices, NFI (normed fit index), IFI (incremental fit index), TLI (Tucker–Lewis index), and CFI (comparative fit index) were above the threshold of 0.9 apart from NFI, which is slightly below. Overall, we regard the result of this investigation as satisfactory to accept the unidimensionality of the scale.

**Table 3.** Goodness of Fit Test.

| Category of Index | Measure | Value |
|---|---|---|
| Absolute fit indices | Chi-square | 152.381 |
| | d.f. | 74 |
| | Chi-square/d.f. | 2.059 |
| | GFI | 0.905 |
| | AGFI | 0.863 |
| | RMSEA | 0.071 |
| | SRMR | 0.054 |
| Incremental fit indices | NFI | 0.894 |
| | IFI | 0.948 |
| | TLI | 0.930 |
| | CFI | 0.942 |

As for convergent validity, which we present in Table 4, standardized factor loadings should be above a 0.5 threshold, and all were well above this (the minimum was equal to 0.678), while AVE (average variance expected) should also be above 0.5, and within our research all values were above this. Thus, we may conclude that the convergent validity is acceptable.

**Table 4.** Correlation matrix of the constructs.

| Construct | AVE | F1 | F2 | PU |
|---|---|---|---|---|
| Fear about personal data (F1) | 0.761 | 1 | | |
| Fear of barriers in life (F2) | 0.569 | 0.456 *** | 1 | |
| Perceived use and facilitating conditions (PU) | 0.627 | −0.020 | 0.095 | 1 |

Note: *** $p < 0.001$.

For discriminant validity, we calculated the correlation coefficients between constructs (presented in Table 4). Squares of those values should not exceed the minimum AVE. The only statistically significant coefficient of correlation, 0.456, was low enough and its square (0.208) was much lower than the minimum AVE (0.569). Thus, discriminant validity is satisfactory.

Nomological validity refers to possible collinearity and mutual dependencies of constructs. As the highest correlation coefficient was not too high, we did not expect this effect; still, we calculated variance inflation factors (VIF) to check whether they were below the commonly used threshold of 10. All values were well below it (between 1 and 2); thus, we conclude that the nomological validity of our research is acceptable.

The reliability coefficient for behavioral intention to accept and to use BP was 0.719 and was sufficient—the Kuder-Richardson Formula 20 (KR-20) for binary variables is equivalent to Cronbach's alpha). However, the reliability of the knowledge and experience measure was insufficient as the KR-20 was equal to 0.419 for the sum of items 5 and 7a–7d from Table A1 and 0.489 for the sum of items 5–6 (overall experience with BP). A new research question arises: is it possible to combine two characteristics (1) knowledge and (2) experience into one variable? Inferences about knowledge and experience may be distorted by random measurement error; also, the reliability of importance of innovative payments measurement was insufficient: KR-20 was equal to 0.448, so conclusions about this variable may be biased by random error.

The hypotheses in Table 1 were verified in a structural equation model, and its parameters together with the conclusions regarding the hypotheses are presented in Table 5. The fit of this model was not sufficient (SRMR = 0.176, RMSEA = 0.175, GFI = 0.843, AGFI = 0.668, NFI = 0.650, CFI = 0.670), so this complex model should be improved or simplified. However, the estimated parameters and their *p*-values when tested equal to zero are reason to make preliminary inferences about the hypotheses that make up the model shown in Figure 8.

Most of the hypotheses have been positively verified (*p*-value less than 0.05), some of them forming a cause and effect sequence: e.g., age had a positive effect on fear about personal data. Fear about personal data had a negative effect on perceived safety. Perceived safety had a very strong positive effect on attitude towards BP, which was the strongest predictor having a positive effect on behavioral intention to accept and to use BP. Hypotheses in which the *p*-value of the estimated parameter was very close to the significance level of 0.05 were classified as "almost verified". Three hypotheses were rejected due to the insignificance of the parameter estimate (not significantly different from zero). The rejection of H3a is very interesting because the sign of the estimated parameter was opposite to the hypothesized one—a reason to investigate the relationship between the measured variables. Positive verification of the hypotheses can also provide a basis for recommendations on how to manage BP to gain greater acceptance and use in society, alleviating various concerns and balancing them with utility and facilitating conditions.

**Table 5.** Estimated SEM parameters, their *p*-values, and conclusions about hypotheses.

| Symbol of Hypothesis | Parameter Estimate | *p*-Value (Rounded to 3 Digits) | Conclusion about Hypothesis |
|---|---|---|---|
| H1a | 0.323 | 0.000 | Verified |
| H1b | 0.171 | 0.013 | Verified |
| H1c | −0.083 | 0.237 | Rejected |
| H2a | −0.241 | 0.000 | Verified |
| H2b | −0.067 | 0.319 | Rejected |
| H3a | 0.175 | 0.008 | Rejected because of positive value |
| H3b | −0.124 | 0.020 | Verified |
| H4a | 0.258 | 0.000 | Verified |
| H4b | 0.348 | 0.000 | Verified |
| H4c | 0.262 | 0.000 | Verified |
| H5a | 0.126 | 0.053 | Almost verified |
| H5b | 0.589 | 0.000 | Verified |
| H6a | 0.205 | 0.000 | Verified |
| H6b | 0.116 | 0.052 | Almost verified |
| H7a | 0.149 | 0.005 | Verified |
| H7b | 0.200 | 0.001 | Verified |
| H8a | 0.052 | 0.445 | Rejected |
| H8b | 0.179 | 0.002 | Verified |
| H9 | 0.395 | 0.000 | Verified |

## 4. Discussion and Conclusions

Respondents have begun to understand the need to use biometrics, trust it more, and appreciate the benefits it brings. It can be inferred from the responses that users feel the need to increase the level of security. The most common indications were greater use of biometrics, such as fingerprints and iris scans. Such solutions inspire confidence in respondents, regardless of their age and experience in e-banking. This was indicated by both younger and older people. Based on some of the interviews, there is also an image of a person for whom convenience is definitely more important than security. Such a person would gladly give up, for example, confirming actions with SMS codes. This opens the path for the popularization of biometric solutions [53]. However, the connection to new emotional aspects of BP is similar to the connection of psychological aspects to TAM and UTAUT, as presented in work of Koufaris [54] on online shopping.

Reading the results of recent studies in the BP sector shows a similar importance of the attitude variable, shaped by other predictor variables, such as in the study of behavioral intention to use BP reviewed by Moriuchi [55]. Such an important role is played by the attitude variable in the presentation of the research conducted by Rosén et al. [56]. In the research model used by Zhang and Kang [57], perceived usefulness plays a similar role as a mediator in predicting intention to use BP, but also safety is very important, as are concern for personal information and perceived safety in the research model reviewed in this article. The inverse of safety (perceived risk) also plays an important role in the BP model verified by Liu and Tu [58]. In the work of Hizam et al. [59], social influence and perceived system quality are added to TAM as predictors—good functioning of BP systems is also measured by perceived user conditions and facilitation, as well as fear of barriers in the model verified in this paper.

Our study has many limitations to generalize the results—the sample is only from Poland and is rather too small to verify such a complex model of behavioral intention to use BP. New analyses could be conducted on the basis of this data, e.g., investigating the influence of gender on emotional variables such as fear about personal data or perceived safety, or their moderating role in predicting intention to use BP. Future research is planned on a more representative random sample of working-age members of the public (average age is likely to be much higher), with a minimum number of respondents of one thousand. The complex model will also be simplified, and some analysis should be applied so that

the model with direct and indirect causes is better suited to predicting intention to use BP. The main results of this pilot study should be verified in new analyses. The measurement of some constructs (especially without sufficient reliability) could be improved by using measurement scales tested in the literature. Biometric data is so important that consumers are very often unsure whether they can terminate their agreed use of BP and remove their own data from the consumer database. Compared to other technologies, biometrics combines technological innovation with biology and is even similar to medical technologies. Fear about personal data as one of the important variables can be the basis of a cluster analysis of potential consumers using BP, carried out to place the BP market in the BP-open part of society. Conspiracy mentality [60] should also be measured as one of the reasons for avoiding BP. Well measured general openness (or curiosity) to new and innovative technologies could also be added to the models. The research procedure made it possible to derive and define a new, proprietary model of hypothetical dependencies, which is presented in the paper, that along with the analysis and systematization of knowledge of the biometric market, as well as undertaking innovative research in the field of the payments market using biometrics, should be considered the main contribution of this article.

**Author Contributions:** Conceptualization, B.M.-G., C.K. and W.W.; methodology, C.K. and B.M.-G.; software, C.K.; validation, C.K.; formal analysis, C.K. and B.M.-G.; investigation, B.M.-G., A.A. and W.W.; resources, B.M.-G., W.W. and A.A.; data curation, B.M.-G., A.A. and C.K.; writing—original draft preparation, W.W., B.M.-G. and C.K.; writing—review and editing, B.M.-G., W.W., A.A., K.C.-P. and C.K.; visualization, B.M.-G., A.A. and C.K.; supervision, B.M.-G.; project administration, K.C.-P. and B.M.-G.; funding acquisition, B.M.-G. All authors have read and agreed to the published version of the manuscript.

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## Appendix A

**Table A1.** Questionnaire items used in quantitative analysis.

| | No. Question | Answering |
|---|---|---|
| 1. | How important are these payment methods in your daily purchases? [cash] | 5 point Likert-type scale |
| 2. | How important are these payment methods in your daily purchases? [card] | 5 point Likert-type scale |
| 3. | How important are these payment methods in your daily purchases? [mobile] | 5 point Likert-type scale |
| 4. | How important are these payment methods in your daily purchases? [biometric] | 5 point Likert-type scale |
| 5. | Do you what biometric payment is? | yes/no |
| 6. | Have you ever used biometric payments? | yes/no |
| 7. | What kind of biometric payments have you used [a: finger, b: face, c: eye, d: voice]? | selection |

**Table A1.** *Cont.*

| | No. Question | Answering |
|---|---|---|
| 8. | What is your attitude towards biometric payments? | 5 point Likert-type scale |
| 9. | Do you think biometric payments are safe? | 5 point Likert-type scale |
| 10. | What are your main concerns about biometric payments? [how data is stored] | 5 point Likert-type scale |
| 11. | What are your main concerns about biometric payments? [how data is used] | 5 point Likert-type scale |
| 12. | What are your main concerns about biometric payments? [possibility of personal data theft] | 5 point Likert-type scale |
| 13. | What are your main concerns about biometric payments? [lack of legal regulations] | 5 point Likert-type scale |
| 14. | What are your main concerns about biometric payments? [technological errors (e.g., data not detected)] | 5 point Likert-type scale |
| 15. | What are your main concerns about biometric payments? [low number of sites accepting biometric payments] | 5 point Likert-type scale |
| 16. | What are your main concerns about biometric payments? [lack of knowledge about biometric payments] | 5 point Likert-type scale |
| 17. | What are your main concerns about biometric payments? [discomfort with using biometric data in public] | 5 point Likert-type scale |
| 18. | Would you like to use biometric payments on a daily basis? | yes/no |
| 19. | What kind of biometric payment system would you like to use? [a: finger, b: face, c: eye, d: voice]? | selection |
| 20. | Do you think biometric payments will replace current payment methods? | 4 point Likert-type scale |
| 21. | Which of these factors do you think are driving the use of biometric payments? [security] | 5 point Likert-type scale |
| 22. | Which of these factors do you think are driving the use of biometric payments? [ease of use] | 5 point Likert-type scale |
| 23. | Which of these factors do you think are driving the use of biometric payments? [no need to remember passwords and pin numbers/no] | 5 point Likert-type scale |
| 24. | Which of these factors do you think are driving the use of biometric payments? [it is not possible to lose the identification method] | 5 point Likert-type scale |
| 25. | Which of these factors do you think are driving the use of biometric payments? [environmental friendliness] | 5 point Likert-type scale |
| 26. | Which of these factors do you think are driving the use of biometric payments? [speed of service] | 5 point Likert-type scale |
| Demographics | | |
| 27. | Age | number |
| 28. | Gender [female, male, other, not to show] | selection |
| 29. | Education [primary, secondary, vocational, tertiary, higher] | selection |
| 30. | Occupational status [working, jobless, student, retired] | selection |
| 31. | Monthly household income per person (approximate net amount) | number |

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# Exploration of Lean Management Methods Used in Shared Services Centers, Drivers and Barriers to Process Selection for Improvements in the Light of Risk Management and ESG Reporting

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**Abstract:** This paper aims to study how processes are selected for improvements in shared services centers (SSCs), and if the risk management aspect is considered during process improvements. Lean management has become a highly regarded platform for process improvement within organizations with the focus being on waste reduction and value added at the customer level. As a leading destination of SSCs, Poland has been seen implementing this approach since at least 2015 with the main benefit being cost reduction. This philosophy opens the door to identifying potential waste reduction and ongoing efficiencies of processes that have been migrated to SSCs. With the identification of the research need, firstly, a targeted literature review on tools and models of process selection for improvements was performed. The second step entails in-depth interviews with lean management experts, surveys with detailed questions in the area of lean management implementation, and finally a case study on measurements of testing the effectiveness of applying lean management methodology. The findings present drivers and barriers to selecting of processes subject to lean management. Although lean management activities are strongly supported by risk management experts, there is no synergy between the two streams causing the need for further research in SSCs.

**Keywords:** lean management; shared services center; risk management; process automation; sustainable management; COVID-19

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## 1. Introduction

Lean management can positively affect the performance of an organization in terms of quality, delivery, and other economic improvements. However, it is necessary to create the organizational culture required for the effective implementation and continuation of lean management. The Cultural Web, developed by Gerry Johnson and Kevan Scholes in 1992, helps to provide a look at an organization's culture and its changes [1]. The biggest challenge related to implementing and maintaining lean management is identifying an organizational culture infrastructure that will allow this system to function well in other corporate areas. Continuous improvement is the primary goal of kaizen, the Japanese concept of management, which is an integral part of lean management. It is expected that all staff members will stop working when any non-compliance is encountered and, together with their supervisor, suggest an improvement to correct the non-compliance. Kaizen can be used in everyday life, not only during working hours, and the improvement should be gradual and constant, as we all strive for excellence [1]. This life-style philosophy applied at an organization level helps the business to strive for optimal performance, using the full potential of our resources, i.e., employees. The primary goal of kaizen is to create a permanent habit of improving the organization [2]. By building foundations, kaizen aims

to develop a learning enterprise that engages both management and employees, thereby achieving common goals and establishing value. If such an environment is created, improvement is a way of life, employees demonstrate pride in their work, exhibit continuous growth of their skill sets and are empowered to solve problems at every level [3].

Evolution is a natural method for improvement. Every single concept can be improved and expanded to the current needs. Figure 1 shows how different concepts evolved to create Lean Six Sigma, the most mature concept of lean thinking nowadays.

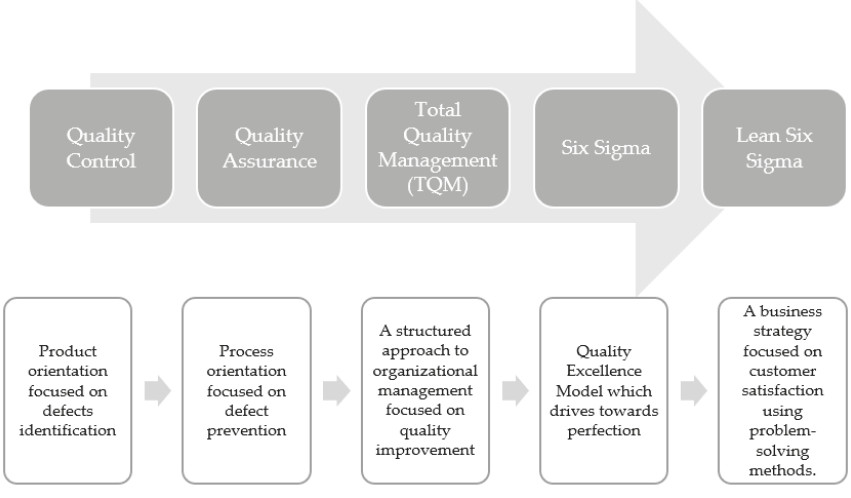


**Figure 1.** Evolution of Lean Six Sigma.

The quality control concept can be treated as the basis for further definitions, evolving into quality assurance. Perfection was the main driver to define the TQM concept, which is strongly focused on continuous improvement. The question is how TQM evolved into the Six Sigma methodology. Setting a new performance standard using tools that were part of the total quality management concepts is the leading indicator of the Six Sigma methodology [4]. The current commonly used term is Lean Six Sigma (LSS). This combined approach of lean management and Six Sigma is the most mature methodology driving process excellence for many experts. Lean management is focused on waste reduction while Six Sigma continuously improves quality. Less emphasis on the statistical analysis requirements included in the Six Sigma methodology and more focus on lean approaches is the easiest way to define what is, in reality, the LSS methodology. Consequently, the LSS methodology focuses on waste reduction, with less emphasis on reducing variation [4].

Continuous improvement drives both concepts, as shown in Figure 2. In the past, companies started their journey with lean management or Six Sigma, depending on their goals and strategy. Because the ultimate ending point for both concepts is continuous improvement, LSS was an expected step for the evolution and ultimate concept to build an efficient organization [5].

Lean Six Sigma can be described as "doing quality quickly," which may initially seem counter-intuitive [6] because intuition suggests that the faster a process goes, the more likely it is for mistakes to occur. Lean Six Sigma works not by speeding up the workers or machines but by reducing the unnecessary waiting time between value-added steps [7].

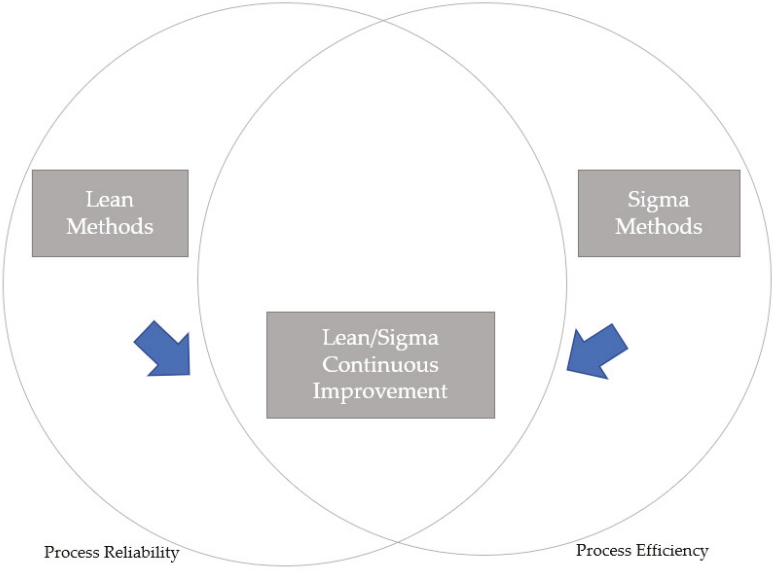


**Figure 2.** Lean vs. Six Sigma starting points adapted from: [5].

In principle, all lean management concepts commonly used in an industry also apply to service organizations. The challenge is to be creative enough, to use them most effectively and to adapt industry value streams to customer expectations [8]. It should be noted that Lean Six Sigma concept can be extremely powerful in improving the quality and speed of all types of "transactional" processes, including sales (quotations/pricing/order processing), marketing, and financial, administrative and human resources [5], i.e., in the real scope of standard SSC.

Utilizing a third-party to perform various tasks and/or services, is a business practice that has been in existence for centuries, even dating back to Rome for tax collection [9]. Officially, the concept of outsourcing was first proposed by Adam Smith in 1776 in *The Wealth of Nations* [10]. Labor division and specialization critically influence productivity optimization due to increased cooperation between groups of employees and the promotion of individual efficiency [11].

Over the last 20 years, outsourcing for businesses has grown from the traditional outsourcing of facilities management to outsourcing more administrative support functions, such as information technology, finance, accounting, and human resources. In these cases, a business will choose to transfer functions to an outside entity rather than performing internally, most often for efficiency and financial benefits. [12]. As Henry Ford suggested, "if there is a thing that we cannot do more efficiently, cheaper or better than a competition, there is no point in doing it further—we should hire the one who does it better than we do" [13].

SSCs are in some ways similar to outsourcing in that they are separate entities, but the existing units are not liquidated. Only certain activities and processes separate from these units are transferred and consolidated in the centers. The SSC differs from outsourcing primarily in that the tasks are not outsourced, but are carried out by a specially established unit that remains within the structures and under the parent company's control. An SSC operates as a business with full responsibility for managing their costs, quality, and timeliness of services and has organizational independence, utilizing contractual arrangements (known as service-level agreement—SLA) with their internal customers to define the type, scope, and price of the provided services. Moreover, an SSC provides well-defined process- or knowledge-based services for more than one unit of a company (e.g., division, business unit), with their own dedicated resources [14].

SSCs are a viable alternative to outsourcing, reengineering, organizational restructuring, and other related "solutions" for costing and building service performance. Innovative structures, strategies, and solutions to complex business problems result from rapid technological progress and the pursuit of global performance standards [14]. Increasingly complex and costly support services within the organization are prime candidates for reducing costs and building efficiency. The modern market and the development of the outsourcing industry have made lean management popular, not only in production but also in the area of SSCs created to outsource functions such as IT, accounting, and HR, as presented in Table 1.

**Table 1.** Traditional functions moved to SSCs adapted from: [14–16].

| Finance | HR | IT |
|---|---|---|
| General ledger<br>Liabilities<br>Receivables<br>Taxes<br>Purchasing<br>Customer Service<br>Cash management<br>Internal audit<br>Insurance<br>Treasury | Processing of salaries<br>Payroll administration<br>Administration of benefits<br>Training and further education<br>Relocation services | Standards<br>Technology/development<br>Application development<br>Application maintenance<br>Telecommunications<br>Purchase of hardware and software |

As continuous improvement is an essential element of any successful business strategy, lean management is an excellent guide to building an effective and solid organization that is constantly evolving, identifying real problems, and solving them. Regardless of the improvement scale, the goal remains the same: better use of the organization's resources to create optimal value for customers and other key stakeholders.

Lean management is focused on bringing value to customers by reducing inefficiencies. Lean Six Sigma is a method that relies on a collaborative team effort to improve performance by systematically removing waste and reducing variation [6]. Managing risk contributes to the improvement of management systems leading to improved performance, encouragement of innovation, and achievement of objectives [17]. Every rework and control may be treated as potential waste. Considering that, lean management should strongly impact the risk management process, where controls are implemented as risk responses. If this dependency can be verified, additional question is about reporting perspective.

In previous studies, the scholars unanimously state the critical necessity (mandatory character) for integrating risk analysis during lean management process redesign [18–32], but so far, the relationship between lean management and risk management has not been analyzed in greater detail. At this research stage, this paper aims to study how processes are selected for improvements in SSCs, and if the risk management aspect is considered during process improvements. With the identification of this research need, the following hypotheses are offered and tested:

**Hypothesis 1 (H1):** *The risk management aspect is not considered during process selection for improvements.*

**Hypothesis 2 (H2):** *There is no sufficient cooperation between risk management and lean management teams enabling the full use of risk reduction opportunities.*

While the literature provides models that can be used, a lack of specific guidelines, especially considering the risk management aspect, has been recognized. It is believed that this current study contributes valuable empirical insights. When discussing lean management in SSCs, insufficient attention is paid to the right choice of processes. In the last decade, the focus was on the expected benefits, ignoring the adaptation difficulties of lean management to shared services centers processes. Additionally, the lack of suffi-

cient empirical research reveals the marginalization of potential possibilities for building synergies between lean management and risk management.

On top of that, from the reporting perspective, the role of Environmental, Social, and Governance (ESG) plays a significant role. The demand for transparency on sustainable and socially responsible practices is rising. The terms "ESG" and "sustainability" are used interchangeably, especially when it comes to benchmarking and disclosing data. Sustainability is an umbrella term for corporate responsibility and many green concepts. ESG has become the preferred term for investors and the capital markets.

In Poland, as of 2018, approximately 300 Polish companies are required to submit non-financial statements together with a report on their activities. The provisions on non-financial reporting apply only to large companies, which are public interest entities (PIE), employing more than 500 employees and meeting one of the two financial conditions: PLN 85 million in total assets on the balance sheet at the end of the financial year or PLN 170 million in net revenues from the sale of goods and products for the financial year [33]. On 24 February 2022, the EU Competitiveness Council adopted the so-called general approach to the draft directive on corporate sustainability reporting (CSR). The new directive replaces the existing EU regulations on disclosing non-financial information and expands the catalog of entities required to report. The member states propose a significant deadline extension for transposing the directive. In the first term, the new provisions would apply only to those entities that already report non-financial information (i.e., large public-interest entities with more than 500 employees). In the second term—all other large entities, i.e., meeting any two of the three criteria (balance sheet total over EUR 20 million, net income over EUR 40 million, number of employees over 250), regardless of whether they are public interest entities or not. In the third term—all small and medium-sized listed companies. The directive's scope will also cover large capital groups [34].

It is in every company's interest to address environmental, social, and governance risks and opportunities adequately because the costs to repair damages can be higher than preventative measures and proactive ESG risk management. Evidence shows that companies that fully integrate ESG and are accountable to stakeholders and transparent are better positioned for long-term success. The financial sector is mainstreaming ESG, and its integration in finance is expected to accelerate further [35].

Integrating ESG in risk management is an essential step on a sustainability journey. Being aware of ESG risks and handling these adequately is fundamental to running a business and pursuing operational excellence. Mapping and prioritizing ESG risks, for example, by filling out a materiality matrix and managing this over time is important.

While the demand and practice of ESG reporting have increased, there still lies a considerable knowledge gap between ESG information and supply, which results from several factors like varying ESG reporting standards and frameworks, nonmandatory reporting regimes, and steep costs to collect and report data.

To meet the research objectives, this article is organized as follows. Section 2 presents the research methodology on procedures and methods utilized. Section 3 presents results:

1. Based on a review of Polish and international literature, the principles of selecting lean management processes were analyzed.
2. Expert interviews conducted in the first half of April 2021 constituted the basis for preliminary considerations of the drivers and barriers to selecting lean management processes.
3. Surveys were sent to the SSC audience working in lean management area in October 2021 to examine lean management implementation.
4. Case study on measurements of testing the effectiveness of applying lean management methodology helped formulate conclusions and future directions for the research.

Section 4 discusses empirical findings contributed by the analysis, and Section 5 contains conclusions and future direction for this research.

## 2. Research Methods

This study is exploratory research, conducted on an issue that has not been previously investigated in Poland within shared services centers. It is descriptive and analytic from the viewpoint of the exploratory objective, including two steps. The first step entails targeted reviewing the existing literature, followed by empirical research covering expert interviews, surveys and case study. Both steps are explained further below.

To evaluate current trends, the targeted literature review [36] was conducted using Web of Science database to identify the most popular approaches for the selection of processes subject to lean management. The search strategy applied included specific keywords: "process selection for improvements" and keywords associated with organization (e.g., shared services, BPO—Business Process Outsourcing, SSC). The search was limited to studies published within the last 12 years (2010–2022). No language restriction was applied to the search but only studies with an abstract written in English and full text in English and Polish were eligible for inclusion. All retrieved articles were reviewed by a researcher, and those considered irrelevant were removed. The remaining articles were further assessed to identify those studies that met the eligibility criteria. A quality check was conducted on a sample of the selected articles/abstracts by a second researcher, and a full-text review was conducted to determine relevance to the eligibility criteria. The literature search identified 387 records through the selected database. All records were screened and 370 were excluded based on the eligibility criteria. A full-text analysis was conducted on the remaining 17 articles and resulted in the exclusion of 8 articles that did not meet the eligibility criteria. For completeness check purposes additional verification of available literature was conducted using Google where additional 6 articles reviewed. A total of 15 references were included in the qualitative analysis.

To learn the context of the drivers and barriers in the selection of processes subject to lean management, individual interviews were conducted with experts [37] certified at the minimum level of Green Belt in the area of lean management. There are four types of certification: White, Yellow, Green, and Black Belt. An expert with a Green Belt has extensive business experience and comprehensive knowledge of processes. In contrast, an expert with a Black Belt is fluent in the methodology of the DMAIC improvement cycle (define, measure, analysis, improve, control), mastering a wide range of tools and a unique way of working. Experts were selected based on their professional experience in SSC distributed across international capital groups, providing services to at least 20 internal entities and employing at least 100 employees. It was also crucial to have professional qualifications at the minimum Green Belt level. The interviews were conducted in a video conversation, mainly due to the COVID-19 pandemic situation. Each interview lasted approximately 60 min and was partially structured. The three interviewees did not know the questions beforehand. Through guiding or refining the questions, essential information was obtained to understand the context. As the interviewees cited examples from their practice and some of the information was insightful, it made it possible to understand the principles not previously described for selecting processes subject to lean management.

Three research questions were formulated:

1. What criteria must the process meet to apply the lean management concept?
2. Which of the processes are most often not considered regarding applying the lean management concept due to the high probability of failure?
3. Are the process risk analysis and the risk response analyzed before applying lean management tools?

Qualitative analysis of the interviews was performed using the QDA Miner Lite software. As a result of the coding process, four main categories were distinguished and specific codes were assigned. The software was then used to analyze the frequency of the codes in the statement, and after summarizing the data for the codes, the results for the categories were obtained. Analysis of the frequency of codes allowed us to determine which categories were most frequently discussed by experts. Further analyses were mainly devoted to "process selection" since they were most closely related to the research questions.

The remaining categories were considered less important in the context of the research questions. The "risk analysis" category was also distinguished because, in the authors' opinion, it brings important research questions that will be the subject of further analysis.

The next step was designing the survey, a quantitative method of research [38], which was created based on interviews with experts. It was developed taking into account two sets: companies that implemented the Lean methodology and companies that did not. In relation to companies that have implemented the lean methodology, the intention was to understand:

1. The measurements of the effects of applying lean management.
2. The priorities are taken into account during process selection.
3. The relationship between lean management and process automation.
4. The approach took in risk management during the work on process modeling after applying the lean management methodology.
5. The effects of applying lean management in the SSC as an element of a business strategy.

In the second set of companies, a survey was closed after confirming that the company does not implement lean management. The online questionnaire performed in the MS Forms application ran online between 17 October 2021 and 31 October 2021. This format was chosen because online questionnaires present numerous advantages in terms of cost, time, easiness of administration, data organization, and analysis [38]. The data file with the answers obtained was downloaded in MS Excel format. The first section of the questionnaire addressed respondents whose companies had already implemented Lean tools. The second section of the questionnaire consisted of generic questions aiming at characterizing the respondents and the companies.

The questions asked in the questionnaire were translated into qualitative variables (nominal and ordinal) and quantitative variables containing Likert-type scale questions from 1 to 5, and the lean management implementation was measured. The study of companies was grouped in terms of the role performed by the respondent, size of the company (number of internal entities and number of employees), years of lean implementation, phase of lean progress, and the scope of services. Based on these groups, statistical tests were carried out to verify any standardization or differentiation.

Quantitative data analysis was performed using descriptive statistics to summarize the information collected, followed by inferential statistical techniques based on the graphical presentation of data [38]. The statistical analysis was completed using Microsoft Excel and Statistica application.

The population of the present study consisted of companies operating in Poland, with SSCs that were created as part of an international capital groups, providing services to at least 20 internal entities and employing at least 100 employees. Firstly, based significantly on annual research executed by ABSL on Business Services Sector in Poland [39], 128 companies were defined as a population meeting research criteria. Additional search on the Internet (LinkedIn social medium) allowed to collect a list of firms' representatives for the study. They were selected based on position related to one of the keywords "lean management," "process excellence," or "continuous improvement." The survey was fully anonymous, and made available to selected people in a private message on LinkedIn. Considering population size: 128 companies in scope for the research, confidence level: 90% and maximum error: 5%, sample size was defined as 87. In total, 90 questionnaires were sent out successfully, and 23 with answers were collected (a percentage of 25%). Even though the return of the questionnaires was low, the research results obtained with different methods are complementary, and the results of the questionnaire were additionally confirmed by the case study method. However, the conclusions from this research cannot become the basis for generalization. The main limitation of the research itself was the size and selection of the research sample based on willingness to participate in the research. This is also the reason why this survey will be repeated in the future. In addition, the authors plan to create a new survey focused on the risk management perspective to have comparable results from two sides: lean management and risk management.

The last stage in the research cycle was preparing a case study [38,40] for a selected SSC. Case study is an in-depth research of processes in their real environment. The selection of cases is subordinated to the presentation of the research subject. It is intended to contribute to a better understanding of the reality that is the subject of the study. A crucial matter in question was how to examine the measurement of testing effectiveness of lean management in practice. To answer this research question, a deliberate case selection was made. The selected SSC was established in 2011. Currently, their team consists of over 200 people. They provide business services in finance, accounting, purchasing, tax, internal control, law, and human resources and support companies based in Europe, India, Africa, and the Middle East. Lean Management in the capital group has been used for decades and in the SSC area for over five years. A field study was conducted to collect data, and while staying in the company's seat, access to two project cards carried out in 2020 was obtained. On their basis, a pattern was selected, which was then subjected to further analysis.

## 3. Results

### *3.1. Targetet Literature Review*

To further the research purpose, this study performed a targeted review using the methodological approach explained in Section 2. Based on the review of the 15 articles sorted by publication year, it was found that the approach in area of selection process for lean improvements has evolved progressively over the years.

Assuming that lean management aims to eliminate errors, and thus waste, a problem-based approach can be suggested. This problem must be significant, visible, and understandable to employees; otherwise, the employees will not see the need to change. The problem cannot be too broad because a large problem that must be overcome in the first stages carries a high risk of failure, which may discourage employees from further actions in a scenario where the problem cannot be solved. In such a case, it is worth dividing such a problem into more minor elements and initiating improvement [41]. From this perspective, selecting an area subject to lean management requires selecting an appropriate method, which may not be easy due to the multitude of options. According to other authors, the implementation should start with value stream mapping (VSM) [8,42], which may indicate the redundancy of some processes. Value stream management includes the process of measuring, understanding, and improving, as well as managing the flow and interaction of all related tasks to keep the costs, service, quality of products, and services of the company as competitive as possible. More importantly, value stream management sets the stage for implementing lean management transformation across the enterprise. The basic value stream management tool is of course VSM [8]. The basis of this approach is to go to the *gemba* (workplace) and define the current state as an "as is" process map. Then, the future state or process should be determined. The gap between the two maps indicates the actions that need to be taken to move from the present state to the future. After improvements are introduced and the process stabilizes, new maps of the present and future state are generated, and the cycle begins. However, the initially defined future state is never reached. Through successive cycles, one strives for the ideal vision of a lean process [8]. Another comprehensive approach to process transformation using the lean management and VSM concepts may be the hierarchical transformation framework, which, at the first stage, involves taking a step back and viewing from a broad perspective (gain the big picture) to apply lean management [43–45].

Methods of selection and adoption of improvement initiatives in today's competitive environment and with a confusingly large number of improvement programs to chose from, are rarely structured, and the selection criteria are inconsistent. Much literature discusses the perspective for decision making and defines management ideas as fads or fashions. As a result, the adoption of management fashion is complex and strongly influenced by the power of fashion setters. Existence of the management fashion phenomenon was confirmed and its better understanding using the case of improvement initiatives was provided [46].

There is no doubt that the choice of lean management tools and methods is extensive. In addition, not only should tools and methods be defined but also the processes for which they will be applied should be listed. There is no clarity about the order in which the lean tools are implemented. Many experts believe an organization should start with a methodology known as 5S (Sort, Straighten, Shine, Standardize, Sustain), which helps to create a more organized environment and serves as a solid foundation for further lean tools to be implemented [47,48]. 5S is certainly useful and encouraged for all lean endeavors and can progress naturally to the next step of an organization identifying value and where to prioritize their efforts.

In the area of SSC operations, a process-based view of the organization's activities may be of crucial importance. The processes transferred to an SSC, although in the center itself they can be called an end-to-end (E2E) process, are often part of a much larger, engaging process that is also undergoing the transformation of owners from companies supported by the centers. Actions should be taken to improve processes if their assessment is unsatisfactory. The first method is to select the processes for improvement based on the extent to which they generate value for the customer. Only those processes that create high value should be continuously improved [49].

Where E2E focuses on an entire process, organizations may also choose to analyze particular projects, resources and portfolio using project portfolio selection (PPS) [50]. It is to be noted that this tactic becomes increasingly complicated as organizational size and the number of potential projects increases which has often led to complicated ways of managing portfolios.

The lean solution to PPS is an information technology (IT) derived value-based management approach. Failure rate is inherently higher for more complex implementations which contradicts the lean approach. With this solution, a business can assess the potential for process improvement within projects by utilizing IT to reduce complexities. First a catalog of non-value added (NVA) activities that can be used in management control and governance procedures for the systematic identification of process inefficiencies is provided. Next, by breaking down processes to the level of atomic activities, it can be shown that minimizing NVA activities provides a systematic means to mitigate process inefficiencies. A significant observation is that different NVA activities may impact process performance to varying degrees. Consequently, line items in the request for proposals should be weighted accordingly, contrary to the common practice of treating all line items equally [51,52].

A slightly different approach may be to identify and isolate those essential processes, not only in the opinion of customers and shareholders but also in the critical factors of the company's success. Pareto analysis accomplishes just that. The basic principle of this technique is that all processes are contending for resources (input) each with an outcome of varying benefits (output). Processes can be selected for lean management based on the analysis performed to derive value closest to the maximum benefit [49]. There is a belief that 20% of processes involve 80% of resources and, at the same time, that about 20% of operations performed in the process generate about 80% of the results of the process [49]. Think of what an organization could do if they had the tools to analyze and reprioritize their resources for maximum results.

With the continuing proliferation of decision methods and their variants, it is crucial to have an understanding of their comparative value. Decision-making is the act of choosing between two or more options. However, there may not always be a "correct'" decision among the available choices. Multi-criteria decision-making (or MCDM) is the most well-known model of decision-making. Its basic working principle is the same [53]: selection of criteria, selection of alternatives, selection of aggregation methods, and selection of alternatives based on weights or outranking. MCDM methods are widely used in many fields and disciplines and were inspiration to create many various models [54–62], which are built systematically by incorporating all related decision criteria with suitable tools required to select improvement alternatives. Generally the developed models used to prioritize the problem scope and select the solutions from various options, because it can

be challenging for organizations to select the most appropriate improvement projects from a pool of many potential project ideas.

The lack of a strategic approach to the selection of processes subject to lean management may result in a lack of effects and a departure from this concept. It is worth highlighting that in the area of services for which lean management method was applied, results may not be as spectacular as in a production environment. Colloquially called myopia, it is a persistent focus on the here and now at the cost of a more or less uncertain future. Since people create the organization, we find the short-sightedness of people in the organization [63]. In addition, the improper implementation of the lean concept can lead to adverse effects, such as simple rationalization, a loss of quality, employee stress, decreased motivation, superficial staff reduction, and an increase in the demand for professional forces, while neglecting the problems of employees with lower qualifications [64]. There is no doubt, however, that continuous improvement should serve the implementation of the company's strategy and not only short-term benefits.

Based on above analysis it is possible to conclude that there is significant amount of offered tools and methods which could be utilized for process improvement selection. However, it should be emphasized that the application of these models in the case of processes transferred to shared service centers has not been studied in greater detail, and none of these models has been tested in such conditions. The conclusions from this research cannot become the basis for generalization. The main limitation of the research itself was the size and selection of the research sample based on willingness to participate in the research.

### *3.2. Expert Interviews*

Based on the conducted expert interviews, it was agreed that to choose a process for applying lean management principles, it is necessary to have knowledge of the principle and appropriate people resources who perform a given process. Observation, active collection of information, and visualization of this process are inseparable elements that must occur before the actual work begins. From a practical point of view, it is also essential that the process remains unchanged over a specific period of time and awareness of the boundaries of the process exist in the company. Processes can be viewed broadly or narrowly, but the optimal approach, suggested by the experts, is the end-to-end analysis of processes, although this is not always possible, especially in SSCs.

During interviews, it was confirmed that the strategic goal to which the organization aims in selecting processes should be guided and that process optimization should move within this strategic goal. Unfortunately, organizations are usually driven by the need of the moment and the occurrence of dissatisfaction on the part of the beneficiary. Additionally, the results of internal control are often a factor in the fact that a given process is analyzed at all.

Thinking only about the potential savings may miss the chance of effective implementation of lean management. It seems that to be able to apply lean management tools to all processes and see these benefits, it is necessary to develop an organizational culture and commit to continuous improvement of processes with the correct presentation of results. It is essential to share ideas so that everyone can use them to see if the same or a similar improvement can be introduced in their work, which will result in savings.

Based on the conducted interviews, significant problems with the inventory of processes were also indicated. The organization's unawareness of the number of processes, their owners, and measures of a given process (key performance indicator—KPI) destroys the strategic approach to selecting processes subject to the lean management concept.

Processes cannot be changed, if it's in no one's interest. People involved in the process often take bottom-up initiatives, but if no one in the organization cares about the process itself, it is likely not to be optimized. Support from middle management to the highest level is critical, especially when implementing optimization solutions. If there is no such support, then continuously operational work, ongoing performance of tasks, and an attempt to keep up with deadlines will be more important than improvements. In addition, employees

often become content with completing work in the manner it has historically been done (especially seasoned employees). It is often not until leaders empower their employees that process improvement and change is sought.

Processes that do not happen in a particular system are also a challenge.

There is also a lean trap in the lack of a strategic approach, especially in organizations that introduce automation solutions. It manifests itself in the fact that such automation must concern stable and repeatable processes, and in practice, waste or ineffectiveness of the process is automated.

Experts were also asked about the use of risk analysis in process optimization projects. In terms of supporting tools, FMEA (failure modes and effects analysis) was mainly used, which allows one to track and build weights of how a change may prevent one from detecting a potential error in a structured way. As a result of the research, it was confirmed that although the lean concept included such risk analysis in the work on process optimization, praxis excluded this approach. Some focus on the process and involving people from a given process narrowed the possibility of including risk analysis in process optimization. Even if risks were identified within the project, there was no support from the risk manager to make a proper assessment, and often, such departments did not exist at all within the SSC.

Based on the results of the performed expert interview, it is possible to conclude on the drivers and barriers in the selection of processes for improvements summarized in the Table 2.

**Table 2.** Factors determining the selection of processes.

| Factors Favoring the Choice of Processes | Factors Making Process Selection Difficult |
|---|---|
| Availability of resources: the people who carry out this process and are knowledgeable about it. | Data availability: processes completely outside the system where it is difficult to collect measurable data. |
| Process stability: the process should not change over time. | Existence of the process: the process either does not exist or is so diverse that it is difficult to establish the core of the process and operationalize it. |
| Awareness of process boundaries: definition of the beginning and end of the process. | Inventory of processes: lack of knowledge about the number of processes or it is impossible to systematically approach their optimization. |
| Existence of an actual problem: dissatisfied customer or unfavorable internal control. | Stakeholder support: no real management commitment and no one at the top. |
| Organizational culture: organization's openness to changes, even at the cost of breaking down silos. | Strategy: no strategic approach to process selection. |
| Repeatability of processes: high repeatability of processes can generate the greatest savings potential. | |

An important finding coming from the expert interview phase is connected with risk management. It can be defined as a lack of cooperation between lean management, and risk management teams manifested in no further actions in identified and remodeled risks.

### *3.3. Surveys*

Bearing in mind the multidimensionality of the concept of lean management, in the shared survey, for systematization purposes, authors presented general understanding of this concept for the purposes of the survey. The reason for the need of systematization is coming from the discussion with experts working in SSCs which pointed out, based on their experiences, that research should not be limited only for lean management and cover much more advanced and broader concept of Lean Six Sigma. As a result, following clarification was added to the survey, directly in the introduction: "A company operating according to the principles of lean management is a company focused on creating maximum value for the client using minimal resources, which is possible thanks to perfectly organized

processes, which are in turn the result of using the talents of people at every level of the organization and minimizing waste. Lean Six Sigma (LSS) derives directly from the combination of Lean and Six Sigma methodologies, giving greater benefits than when used separately. Lean Six Sigma is an evidence-based and data-driven improvement philosophy that prevents product defects from arising by detecting them and continuously improving processes. Ensures customer satisfaction and focuses on the end result (end product) reducing process variability, waste and cycle time, while promoting the use of standardization and workflow, thus creating a competitive advantage." In addition, authors decided to add to the survey's introduction, clarification around Shared Services Center (SSC) versus Global Business Services (GBS): "In the Shared Services Center (SSC) model an independent entity is separated from the organization and responsible for providing services to other units. The Global Business Services (GBS) model is based on creating a global, integrated and centrally managed organization that provides comprehensive end-to-end services. For the purposes of the survey, GBS is defined as the last, most advanced step on the SSC organization maturity scale."

Specifically for the survey, a key issue in this study was to identify drivers to process selection for improvements in the companies where lean management or Lean Six Sigma is implemented.

To do that, first few questions were focused on general information about the lean management approach. The most important information needed for further analysis was the confirmation around lean implementation. This specific section of the questionnaire was addressed only to companies that practice the lean philosophy (96%, where lean management is 52% and Lean Six Sigma is 44%). Almost all respondents confirmed that they use this methodology for between 1 and 3 years (68%) or more than 5 years (23%). The levels of lean management implementation were varied. A significant proportion of the responses confirmed that almost all organizations analyzed at least identified processes in the scope of the SSC (19%), created value stream maps for them (18%), created a standard process (16%), and implemented a culture of continuous improvement (16%). This specific set of questions helped to understand how mature and advanced lean management is in the shared services center structures.

The next set of questions was focused on the main purpose of the research and looked at hypothesis confirmation or rejection. Based on the survey responses, main drivers to process selection for improvements were, among others, the biggest expected benefits from improving the efficiency of the process (as a relation of the obtained effects to the expenditure incurred)—27%, and the effectiveness of the process (as a relation between the adequacy of the obtained result of the completed activity with the goal specified for this activity)—21%. Respondents reported also that potential reduction of the number of processes without value added (14%) is driving lean improvements. Respondents did not mention high-risk-related processes, which is driving the initial conclusion that this factor is not taken into account during selection. In addition, through the structure of the survey, authors were investigating who is decision-maker on the process selection for further improvements to better understand the process itself and the ownership behind. Based on the survey, it was concluded that the processes were designated for improvement with the lean management method based on the decisions of the management (31%), the assessment performed by dedicated experts (25%), and the profitability assessment of the processes (17%). Respondents were asked if tools and models that the organization uses were diversified and provided the following responses: scoring model, customer satisfaction surveys, KPIs, benchmarking, end-to-end process analysis, and value stream mapping (VSM).

Measuring effectiveness of implementation was also in the area of research because the Authors wanted explicitly to analyze how crucial specific risk measurements factors are at this stage. The most important measures for assessing the effectiveness of lean management reported by the respondents involved in lean management activities were:

1. Time reduction (22%).

2. Creation of a standard process (19%).
3. Cost reduction (15%).
4. Quality improvement (14%).
5. Number of potential automation opportunities (12%)

Only 5% of respondents reported a reduction of operational risk and a decrease in control activities: 4%. It is a significant finding coming from this research, especially for risk management and ESG (Environmental, social, and governance) reporting. Despite the enormous pressure on international organizations, none of the respondents indicated the possibility of reporting lean management effects in ESG reporting.

The last layer of the survey was focused on the organizational structure of the lean team to gain an understanding of potential dependencies and relations with other structures in the organization. Based on respondents' responses, the team responsible for lean management is organized mainly as a separate team (50%), or there is an independent expert in the organization (27%). Specifically asking about process risks and mitigating controls discussion when streamlining processes using the Lean Management method, 68% of respondents confirmed that it is taking place, and it is discussed with a representative of the Internal Controls Team (47%) or Risk Management Team (13%). In almost 40% of responses, no Risk Management/Internal Controls representative is taking part in the discussion, the knowledge of people in the team and their general understanding of risk is used. This initial result is giving new light on the organization of the process itself and how proper cooperation should look like to build proper synergy between lean management and risk management team. In terms of risk assessment during the improvement process using the lean management method, 70% of respondents confirmed that risks and mitigating controls were discussed and 53% of respondents indicated that a representative of the internal control or risk management team participated in the process improvement. After the process transformation, risk analysis was not executed in 55% of responses and the risk matrix was updated less often than once a month for more than 50% of responses. All these conclusions raised additional questions and require more in-depth analysis via additional surveys and case studies from a risk-management perspective.

The second part of the questionnaire characterizes the sample distributed by the following components presented in the Table 3.

**Table 3.** Summary of the respondents and the companies characteristics.

| Component | Respondents' Responses |
|---|---|
| Employing entity | 82% reported they belong to SSC organization. |
| Location of employing entity | Most of the respondents represent Poznań (38%), Warszawa (33%) and Kraków (10%). |
| Organizational level of the position in the company | Most of the respondents represent Directorial level (27%), Managerial level (27%) and Leader level (23%). |
| Size of the company: number of internal units | Analyzed SSCs support 20–50 units—82%, 50–100 units—9%, more than 100 units—9%. |
| Size of the company: number of employees | Analyzed SSCs employ 100–300 people—55%, 301–1000 people—36%, more than 1000 people 9% |
| Scope of services (top 10 ranking) | Purchase to Pay (PTP), Oder to Cash (OTC), Treasury/Cash and Banking, Taxes, Procurement, Internal Controls, Customer Service, Corporate functions, Application development and maintenance, Internal Audit. |

Based on the results of the conducted surveys, it is possible to conclude that no risk management factors were considered as drivers to process selection for improvements. In addition, significant differentiation was identified in the area of models used for the

selection of processes. Potentially the barrier to building synergy can be the placement of the lean management and risk management teams in the organizational structure because, based on this empirical research, in almost 40% of responses, no risk management/internal controls representative is taking part in the discussion. The knowledge of people in the team and their general understanding of risk is used. It is important to highlight that this research shows only one perspective because respondents represent a lean management team. Further discussion should take place with representatives of the risk management stream.

### *3.4. Case Study*

The analyzed entity supported over 50 internal units in the field of processing receivables, liabilities, payments, operations on the general ledger, and other corporate functions. The scale of the overall processes that were significantly transferred to this entity was still small, as processes such as customer service or purchasing remained outside the SSC. Taking this into account, the scope of the lean management application was limited, mainly due to the lack of responsibility for the entire process. From an efficiency perspective, it is clear that the definition of the standard process (29%) and cost reduction (29%) were the two main measurements used to assess process transformation (Figure 3), which confirmed the conclusions found based on the surveys. Defects reduction (14%), process delays reduction (14%), and process digitalization (14%) were also mentioned as measurements showing whether lean management was implemented successfully.

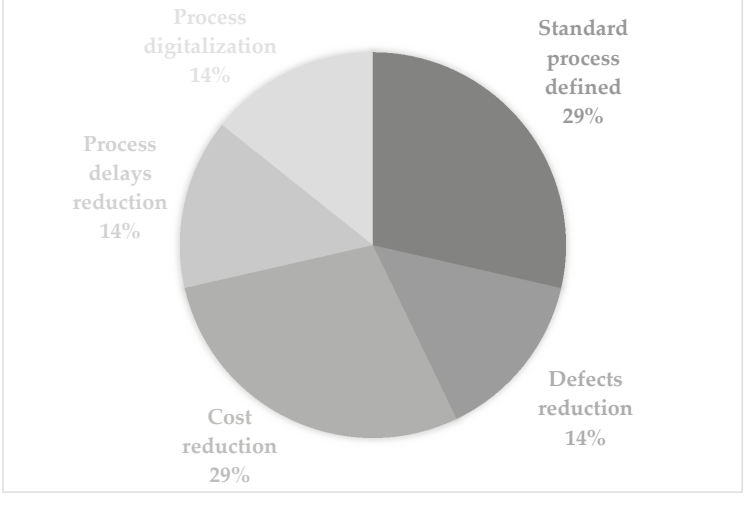


**Figure 3.** Measurement of benefits in the SSC using lean management.

It can be concluded that the results of the case study identifies and confirms the same benefits measured by SSC in the area of process improvements as results of the survey.

## 4. Discussion

The received results from targeted literature review and empirical research confirmed hypotheses H1 and H2 and proved that the risk management aspect is not considered during process selection for improvements, and there is no sufficient cooperation between risk management and lean management teams enabling the full use of risk reduction opportunities. In this initial stage of research, in this paper, to achieve the synergy between lean management and risk management teams, the authors offer a systemic implementation of both concepts highlighting the need for proper placement of both teams or their representatives in the organizational structure. The future is unknown, but alternative

future outcomes can be identified, assuming that the chances of possible alternatives are known [65,66]. The risk should be assessed and proper actions should be taken to respond to the risk. One possible response can be the implementation of control activities, which connect risk management to lean management, as control activities are often treated as waste due to the assumption that a perfect process should eliminate errors and, simultaneously, control activities.

It should be noted that outsourcing for cost savings is something that is still heavily exercised today. The COVID-19 pandemic brought new importance to outsourcing because organizations of all sizes and industries have started using this process of engaging a third party, either locally or internationally, to handle certain business activities for them at a lower cost. The use of remote teams, virtual assistants, and the ability to work from anywhere in the world has made business more accessible, faster, and cheaper. Outsourcing allows a business to streamline practices by focusing on an improved outcome with less resources; a main goal of lean management.

For shared services organizations, best practices have been challenged during the pandemic and changes focusing on better performance were expected by clients. The new standard for shared services includes operational practices that were previously thought impossible since they required physical attendance in the office. To understand the challenges and responses of organizations to the COVID-19 pandemic, in 2020, Deloitte conducted more than 40 in-depth interviews with GBS, SSC, and business process outsourcing (BPO) organizations [67].

Figure 4 presents an examination of traditional service delivery practices versus the new standard, which could be defined only because of the COVID-19 pandemic's challenges to conventional logic.


**Figure 4.** New standard evolution for shared services due to the COVID-19 pandemic [67].

Working from home (WFH), offering complex process delivery, and ensuring proper security are the biggest challenges affecting organizations worldwide.

In recent decades, large office spaces were created in the best locations of city centers to ensure good communication routes and increase the flexibility of working hours. Physical proximity was treated as a standard that should not be challenged. Teams can cooperate and build relationships, and supervisors can directly observe people's performances. No one was interested in challenging this current state because organizations traditionally believed physical proximity was critical to achieving goals and effectively executing more complex tasks. Many companies with highly face-to-face-intensive processes, such as

month-end close and financial planning and analysis, shifted and performed them virtually, demonstrating that face-to-face interactions may not always be required for effective process performance. Work that previously required proximity transitioned effectively to a virtual environment during the pandemic, breaking down conventional wisdom in this area. This has expanded opportunities in terms of the potential scope delivered through shared services and outsourcing delivery models. The same approach could be applied to lean management, with the main focus on repeatable and transactional processes, which are migrated to the SSCs. By default, more complex and less repeatable processes would not be considered during process redesigning using lean management tools. Considering the results of Deloitte's research in 2020, a massive transformation of complex processes can be expected. Now, new obstacles need to be considered in how lean management is approached. COVID-19 has drastically altered the typical the working environment which may require us to alter our way of thinking how to approach lean management. Older approaches may not be as effective, etc. We need to be agile not only with internal business processes but also with our thinking and acceptance of external factors.

Data security and lack of direct oversight strongly increase doubt in the new standard. How is it possible to ensure that all important data is well secured? Is a VPN enough for a secure connection? How is it possible to ensure that employees are not sharing sensitive information? Shared services organizations had to quickly adapt to support the data and security needs coming from the new remote work requirements. For companies in financial services, insurance, and healthcare with significant PII (personal identifiable information) or PHI (protected health information), the risk and data security represent the greatest challenges. As reported by Deloitte, to succeed in these difficult conditions, these organizations implemented short-term technology solutions to address potential security concerns and secure sensitive data, which include the following [67]:

- The ability to remotely lock down an employee's computer;
- Camera recognition on devices to prevent picture taking by onlookers;
- Voice recognition for customers;
- Privacy screens.

Currently, the global development of economic relations is characterized by two key features: digitalization and multipolarity. Due to the emergence of a new growth pole in developing countries under the conditions of the digital economy, for the first time in the modern history of the world economy, it could be stated that its multipolarity stimulates the reduction of countries' inequalities rather than an increase [68], and thus contributes to the implementation of the Sustainable Development Goals (particularly SDG 10 [69]). Sustainable management is now more critical than ever because it should be driven in a beneficial manner to present and future generations. Environmental, social, and governance (ESG) metrics are widely used to measure the firms' social performance. The scope of non-financial information reported by enterprises includes issues related to sustainable development, business responsibility, natural environment, social affairs and remediation, ethics, human capital, and health. This additional qualitative information provides insight into the company's internal and external policies, vision and values, risk management, and future prospects [70]. The introduction of non-financial reporting obligations is nothing new. According to Directive 2013/34/EU, enterprises classified as public interest entities have been obliged to disclose information on environmental, social, and employment-related issues, including protecting human rights, combating fraud and corruption, and respecting the principle of diversity management. This directive was amended by Directive 2014/95/EU of the European Parliament and the Council regarding disclosure of non-financial and diversity information by certain large companies and groups [71]. Authors' intention is to highlight that lean management activities could be recognized as a part of ESG reporting, especially in area of risk management under Governance pillar as it is the internal system of practices, controls, and procedures a company adopts in order to govern itself, make effective decisions, comply with the law, and meet the needs of external stakeholders [35]. In addition, operational risks arise from external events or

imperfect and unfruitful internal systems, people, and processes. Digitalization strongly affects all management practices, shedding light on exceptional thinking and non-standard approaches. Cyber risks are a type of operational risks and are constantly evolving due to new technologies and the rapid development of computer information systems [72]. It is mentioned here because the COVID-19 pandemic strongly changed the perception of cyber risk definitions and treatment, what can impact the future research.

## 5. Conclusions, Implications and Future Directions

The risk management aspect is not considered during process selection for improvements, and there is no sufficient cooperation between risk management and lean management teams enabling the full use of risk reduction opportunities. The qualitative and quantitative treatment of the obtained results shows that the analysis of only one perspective: lean management is not sufficient to conclude entirely on the final results of this research. Further studies are necessary to fully understand the organizational impact of the lean and risk management relationship.

In the lean management approach, control itself can indicate the existence of inefficiencies or errors in the process. The process should be built in such a way as to avoid making a mistake, and the organization should be committed to improving and streamlining the process, but not at the expense of making errors. Optimization itself would be teams working together, combining efforts in the framework of risk management and lean management. They have similar goals (minimization of errors) but perceive the process from a different angle. It is worth noting that not all risks should be controlled, particularly those related to minor processes. However, to be able to assess it, an entire process inventory is required. The scope of risk management also plays an important role, focusing on material risks and those potentially significant in terms of the company's overarching goals.

The presented article highlights the context of the selection of lean management processes implemented in SSCs, defining the future research direction. Based on targeted literature review models and tools proposed by researchers were presented and discussed. Expert interviews helped to define preliminary considerations of the drivers and barriers to selecting lean management processes. A deeper analysis was necessary to examine how SSCs implemented lean management, not only from an organizational perspective but also in terms of the extent and scope of implementation. The results of the survey shed new light on this subject because the answers received were provided by people working in the lean management sector. This discussion should take place with the risk management teams working in the SSC in question. Lean management impacts not only risk management process, but also ESG reporting, in the area of governance. This is the reason why future direction of the research will be focused on following aspects:

1. Lean Risk Management approach.
2. Lean management reporting as a part of ESG reporting in the area of risk management.

It should also be pointed out that the conclusions from this research cannot become the basis for generalization; they only serve as concepts that should be taken into account when designing research that deepens understanding of the phenomenon. The main limitation of the research itself was the size and selection of the research sample based on willingness to participate in the research. The practical aspect of this part of the research is related to the usefulness of this knowledge for decision makers in the organization. People involved in lean management organizations and management staff can design activities in such a way as to implement lean management more effectively or at least avoid the practical pitfalls associated with it. Upon analyzing the statements, one could ask exploratory questions. One of them could refer to the short-sightedness of management in creating lean management structures, as described by one of the interviewees.

Conclusions based on empirical research allow for the conclusion that an SSC is often created to reduce costs; only in the long term can the potential benefits of standardization, automation, and building effective and efficient processes be noticed. Often, however, in

the pursuit of cost reduction and the desire to achieve short-term benefits, these types of organizations do not focus sufficiently on a long-term strategy.

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# FabLabs: The Road to Distributed and Sustainable Technological Training through Digital Manufacturing

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**Abstract:** The fast expansion of digital culture has fostered the creation of makerspaces such as fabrication laboratories (FabLabs) that, thanks to their flexibility and their use of open source tools, strengthen the sense of community and produce true transformations within those communities. Despite their relevance, few studies focus on the characterization of these environments. This paper presents the results of the FabLab Global Survey, aimed at understanding the characteristics of FabLabs through the visions of their managers, or "FabManagers". The results show an enormous diversity of approaches within the FabLab movement that cannot be extrapolated to a single characteristic element, but that allow its global compression. Their properties reveal them as transforming elements that eliminate technological and cultural barriers, empowering user communities and optimizing learning processes regarding digital technology. FabLab activities allow not only economic and industrial development thanks to innovative projects, but also a digital technology approach for young students and the inclusion of minorities at risk, thus eliminating old cultural and social barriers.

**Keywords:** fablabs; digital manufacturing; sustainability; digital culture; open source; maker culture; collaborative ecologies

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## 1. Introduction

In the last decade, the processes of design, production and manufacturing have changed with the incursion of new technologies and strengthening concepts such as digital manufacturing, open innovation and Industry 4.0. This change has brought a new industrial revolution, where the popularization of knowledge and the productive elements and even the relationship between the user and manufacturing have changed. This change is also cultural and social since the user can achieve greater ease of access to information and the necessary technology and is no longer a mere consumer of products and services without the capacity to make actual decisions about them or the knowledge or technology to alter the industrial process or operation. Consumers can go on to become "prosumers", a term coined in the early 1990s by Alvin Toffler in his book *The Third Wave* [1]—becoming producers and consumers of products without, in some cases, these being marketed or participating in the economy. This new democratization of industrial processes has been fueled by a proliferation of spaces and environments where users can acquire complex knowledge about digital technologies and modern manufacturing through social learning and the development of technologically advanced projects. The strong social interaction that occurs in these environments is conducive to learning and acquiring complex skills to carry out projects, in many cases solving the knowledge barrier and popularizing these digital manufacturing processes by providing a new tool for economic development and equal opportunities to achieve, finally, technological empowerment.

Within maker environments, the novelty of the movement and the significant expansion of FabLabs have aroused considerable interest in this type of collaborative initiative. Led by some standard features, including open technological knowledge and access to

advanced technology and its strong international network structure, the FabLab is shown as a strong actor, with the ability to alter its environmental influence. Its effect depends on the properties of the laboratory, however, including the characteristics of the users who participate in it, and the attributes of FabLab that are included. Despite its strong social relevance, there is little information about the general properties of such environments in the literature.

Fabrication laboratories (FabLabs) are an integral part of "communities and spaces with more or less open to the public levels, with objectives and targets agreed by its members in which, through learning processes, production, prototyping, design, and manufacturing, both tangible and intangible assets, complex two-way exchanges of information are produced, knowledge, technology, skills and resources among users, users and society and between users and industry" that constitute the new wave of collaborative ecologies [2,3] into which elements such as makerspaces, hackerspaces, living-labs or co-workings also fall, highlighted by its origin and its capacity as an international organization.

A FabLab is a strong social space offering affordable and accessible manufactured tools and is sometimes conceived as an appropriate platform to begin the prototyping and development processes of any object [4]. They emerged in the 2000s at the Massachusetts Institute of Technology (MIT) from Professor Neil Gershenfeld's subject [5,6], called "How to Make (Almost) Anything". Thanks to the creation of this first FabLab, Professor Gershenfeld's students could realize their designs, popularizing digital manufacturing and making the subject successful.

After this initial FabLab, fabrication laboratories were globally involved in a dramatic increase from 45 laboratories in 2010—a time that coincided with the popularization of digital production elements such as the 3D printer Rep-Rap—to over 1000 in just seven years. The first FabLabs, together with the creation of the FabLab in Boston, were established in Costa Rica, Ghana, India and Norway, with a strong interest in local development, but with notable differences in their main orientations.

Each FabLab is as different as their users' interests or projects, but they share some characteristics that differentiate them from other similar ecologies. One of the primary and most common attributes of FabLabs involves rules from the "FabLab Charter". These rules can be summarized in several ideas [7]: The FabLab must consider themselves a community resource and, consequently, leave some time in the week for public access. They must have a standard set of tools that give them the capacity to work and carry out projects and processes that allow projects to be shared between the different laboratories, giving them a network awareness that makes the laboratory an integral part of a larger network. They must respect the open source philosophy in their activities and projects and must consider the commercial initiatives carried out by their users as possible initiatives for incubation in a FabLab, but which must subsequently be developed as an external element.

An awareness of global integration allows FabLabs to exchange knowledge, promoting interconnections between different laboratories that make up the FabLab Network [7] thanks to elements such as the FabAcademy program and the various gurus therein formed. Other elements are the expansion of FabLabs, regional FabLabs networks and the involvement of the FabLab Foundation, regional and interregional FabLab meetings, creating documents and web portals of the laboratories, the development of collaborative projects between different FabLabs and, mainly, by creating a learning environment that fosters collaboration and interaction between users locally and internationally [8]. Thus, and through one of the critical aspects of the FabLab ideology, the learning and documentation of the projects carried out are prioritized, making them replicable in any other laboratory where it is possible to use the same instruments, generating a global knowledge environment in that ideas and projects transcend regional borders thanks to new technologies, receiving the support and improvements of a worldwide community and facilitating access to knowledge and complex techniques even for users without specific training.

It is necessary to note that, despite the importance of digital skills in today's changing world and the existence of multiple elements that bring these skills to citizens, many

non-experts see difficulties in accessing this maker culture, understood as an amateur and professional movement that includes the use of digital manufacturing technology and software with traditional manufacturing methods to create or customize objects [9]. Immersed in this maker culture and despite its popularity, FabLabs still have the problem that any advanced technology has for general users: the difficulty of use. Despite the growing popularity of this technology, users express a lack of skills and/or essential experience necessary for the design or use of the various techniques involved in digital manufacturing; there is a high level of complexity in the action and overall management required, for example, for the use of 3D design software or a favorite 3D printer that, despite interfaces and systems, have relatively simple operations. This lack of skills, many self-perceived by users, is a barrier for entry to digital manufacturing processes, the related technology and maker environments in general. This difficulty is usually solved only through actual access to the technology offered in these places or through the occasional workshops or training activities in the maker areas. The substantial impairment that requires access to this basic knowledge in digital manufacturing is overcome by working in the community, group learning and medium- and long-term project development to achieve the involvement of users in actions aimed for children and adults. In this respect, the projects in makerspaces in general, and the FabLab in particular, often act as transformations of the population in which they find themselves, working directly in their development, as a union or open to the community generation of non-expert users actively evolving learning, as demonstrated in FabLab Genk [9].

Innovation processes are also not beyond the capability of showing makerspaces to alter and improve the social and economic community in which are established directly. As an example, programs to promote development, such as ERUDITE, for the design and construction of services that improve the digital innovation in rural and urban environments, have been used in Slovenia; creation and tuning included two FabLabs (in Ptuj and Ribnica) with the aim of stimulating innovation and entrepreneurship by improving the economic and social conditions of nearby communities. These two laboratories were involved in the community–technical aspects of digital manufacturing through training, from primary school to university levels, in long-term programs adapted to local issues. The access of citizens to entrepreneurship was enhanced by generation communities working in the laboratories, and the process of co-creation next to the open innovation processes in the public sector was strengthened, improving transparency [10].

The participation of citizens in the programs developed in the FabLab also includes the realization of technologically advanced research projects through citizen science. In these programs, users become nodes of research in the development and use of many useful information devices, which is difficult to achieve otherwise. These programs, such as the Smart Citizen program conducted by FabLab Barcelona [11] or the MicroMascotas program mentored by César Laboratories in Etopía (FabLab Zaragoza) [12], include the massive participation of citizens, users and non-users of the FabLab; organizers, data collection tools and technological developments are made at very low cost, often by users themselves with open instructions. Through open calls, and thanks to the participation of various public entities, FabLabs realize incredible projects that are proposed, designed and led by citizens who, despite not having the means or the necessary knowledge, benefit from the participation of other users who perform tasks of high complexity. The Servet experimental stratosphere project, also developed in the Cesar laboratory in Etopía (FabLab Zaragoza), is a good demonstration of this [13]. This new wave of citizen involvement helps transform the cities from passive elements that are "product in, trash out" to living elements that generate knowledge, i.e., "data in, data out". Here, the usual waste, technology and information are included in a fundamental element of sustainability that turns cities in the next model to FabCity, where information technologies redefine the use of the towns to obtain a new productive, economic and social dimension [11].

Socially, and despite the various programs that they develop, FabLabs embody many of the social stereotypes of the cultural environment in which they are included. Classically,

despite great social advances in equality, technology has been dominated by males, in the so-called "gender gap". Excluding natural gender equality and maintaining a strong differentiation is strengthened by social customs that make up the established roles, from the linguistic construction itself to the assumption of different cultural values. This classic "gender gap" seems also to be reflected in the distribution of users in FabLabs, where some studies show slightly higher female participation of 25% [14], far from equal participation. It is obviously not possible to generalize from these figures due to the diversity of FabLabs as cultural spaces and the variety of orientations, themes and projects which makes it impossible to extrapolate, as rightly noted by the authors of the study mentioned. The multiplicity of FabLab types scattered throughout the world promotes differences in the gender distribution of their users; countries such as Brazil have shown a greater elimination of differences in the participation of the genders, approaching parity [15]. Indeed, FabLabs reflect the differentiation that society sets, and despite the egalitarian mentality of these cultural environments, the existence of multiple programs for female empowerment and their inclusion in both the maker environment and in the FabLabs themselves, the ever-growing presence of women in FabLabs in technical roles and as FabLab managers and the impact on education and training programs open to egalitarian goals, laboratories are still far from achieving the equality pursued. An example of the type of program developed in the FabLab initiative is the Poderosas program in FabLab León [16], which aims to encourage female commitment to technology and digital manufacturing, improving self-confidence through exclusive programming activities for girls. These types of programs activate the curiosity of young users, enhancing their willingness to join higher education related to science and technology, where the male presence is classically predominant.

Despite all these efforts, the most significant gender differences among participating users in a FabLab can be found in laboratories dedicated to carrying out high-tech projects because, presumably, more cultural and economic factors limit access to resources themselves. These differences are probably due to the FabLab dependence on some institutions, where the difference is palpable, including variations due to the environment (industrial, artistic, academic, etc.) or the central themes of the laboratory (architecture, electronics, art, design, etc.) due to gender differences, since they are usually not at all limitations of access or use to users of any condition [17].

It can be argued, therefore, that FabLabs are not spaces that contribute to gender differences or discrimination, but even being influenced by their socio-economic background and cultural tradition, they constitute a hope, thanks to the widespread use of technology and the implementation of specific programs of empowerment and outstanding contributions to social equality in education, as well as their strong, open and participatory character [17].

In addition to the development of activities of inclusion and gender equality, several FabLabs are involved in programs aimed at social inclusion, equal opportunities or improving future opportunities for young people through training and skill development in technology and digital manufacturing. Some of these programs have strong support from foundations such as the Orange Foundation in "The Solidarity Program FabLab", an international program aimed at young people between 12 and 25 years. This program, in which several countries in Europe, the Middle East and Africa participate, works with local authorities and a collaboration of FabManagers [18]. As an example, in addition to supporting 19 FabLabs in France, the 2015 program selected nine international social projects for further development [19]:

- Two projects in Spain: one proposed by the "Social Technology Foundation" in Barcelona, with the aim of creating objects for the sick, and another proposed by the association "Friends in Madrid", which seeks the inclusion of young people with Asperger's syndrome in digital creation in the FabLab.
- FabLab Trojmiastro in Poland included a project to improve access to digital technology in isolated rural settings.
- In Senegal, the "Ker Thiossane" association was supported by the Orange Foundation to improve the popularization of electronics among young people.

- In Cairo, the Egypt FabLab received support to create a network of mini-FabLab laboratories in five other cities.

The program also financed the creation of four new FabLabs, whose job was geared to solidarity and development as proposed by the "Old Market Alliance Hall" association in Slovakia, the "Jeunes et Sciences" association in the Tunisia project, FabLab Madagascar presented by the "SOS Village d'Enfants Madagascar" and the FabLab association in Mauritania presented by the "Mauritius Telecom Foundation". In its 2018 edition, there were 61 projects in this program [20].

"The Solidarity FabLab Program" Challenge #Imake4MyCity, used digital technology in 2017 to offer participants aged between 12 and 25 years without formal qualifications in digital manufacturing the opportunity to show their creative potential. The challenge, endowed with three prizes of EUR 15,000 and in which more than 60 laboratories and associations were included, focused participants' attention on the adaptation of inclusive sport under the title "Sport for All", while in 2018, its focus was on creating a digital solution to reinvent the city of the future (Foundation Orange, 2017) [18].

The Orange Foundation also develops the "FabLabs Social" project in Spain within the "Solidarity FabLabs" program. The "FabLabs Social" program is a training program around digital fabrication aimed at improving the active and participatory social inclusion and employability of young people in vulnerable situations. "Breakers, Fabricate a New World" includes a program that aims to stimulate the learning of technological skills related to digital manufacturing, together with other transversal competences such as teamwork and social skills through a combination of digital innovation, the use of digital production in learning environments and social facilitation. The program is distributed in three annual calls and developed in FabLabs including FabLab Sevilla, FabLab Valencia, FabLab Leon, Tinkerers FabLab Castelldefels and Open Space MakeSpace Bilbao or Madrid, among other maker venues. This program has the support of Federation of Organizations with Projects and Flooring Assisted (FEPA) and BJ-Adaptations, as among its objectives it aims to include young people in care and guardianship who are disabled or problematic and at risk in the social sphere [18].

FabLab Bohol [21] is another case study, where the implementation of learning programs in the local population seeks the economic and social transformation of a rural area by improving the educational training of local entrepreneurs. These contextualized innovation programs are proposed as a solution to economic poverty and lack of industrialization in the rural regions and have a substantial impact on social and economic trends in the area.

It is clear that knowledge and training in new skills are powerful tools for economic and social development. Digital manufacturing in maker environments has a healthy positive relationship with education, as their conditions are ideal for acquiring skills in new technologies. There are numerous examples documented in the literature in which, through these learning environments, imagination, creativity and interaction between humans and technology [22–25] are improved, converting FabLabs into real laboratories for exploring and exceeding individual limits in creation, art, science and engineering [26–28]. By providing experience and knowledge, they also achieve improved self-esteem, motivation and, of course, fun [29]. Learning theories such as constructivism involve learning processes through direct experimental contact that are developed in the FabLab. Previous constructivist experiences include the constructionist Learning Laboratory, designed by Stager and Papert in the Maine Youth Centre with the idea of fostering an environment where knowledge is generated through the act of "doing" itself, showing the pillars of learning that take place in these collaborative environments even in challenging conditions [30].

In recent years, the scientific literature has offered particularly important evidence of the contribution of digital manufacturing to the development of new digital skills. This application of digital production, including immersion FabLabs in educational environments, is not limited to higher education, where knowledge of the target users could be closer than expected to develop such complex skills, but includes settings such as elementary schools or libraries. Digital manufacturing, and specifically the FabLab, provides the necessary

characteristics for the profound transformation that the teaching–learning process should consist of in its openness to current and future society. This incursion into the training field both occurs in the official curriculum and is unofficially protected by carrying out exercise and recreational additional activities carried in embedded laboratories and their own educational institutions, such as from laboratories supported by public/private funds and externally to the educational institution, but within collaboration. These projects are of particular interest in the education of children which increases investment in technology, science, engineering, art and math (STEAM), and it is of great importance in preparing students for future society. In this way, the elements of digital manufacturing are part of school educational projects at early ages, as in the "Arcángel: D" project developed by the Arcángel Primary School with the collaboration of the FabLab Media Lab Prado [31] or MAkey Project with the aim of understanding the role of makerspaces in developing young children's digital literacy and creativity [32–35].

The introduction of FabLabs in training programs also allows educational innovation. Some educational programs include innovative experiences such as using deliverable-based learning (DBL) in FabLab Faces in the Sorocaba Engineering School of São Paulo, Brazil, where students are encouraged to think about what final product they want from their job, learning in its design and constructing a path of knowledge that leads them to their ultimate goal. To strengthen social and economic development, they must be accompanied by a cultural event to be built for new generations in a way that relies on today's adults. This cultural development implies the generalization of digital culture, but the educational objective collides head-on with the social reality in many regions. The addition of digital manufacturing activities and collaborations with FabLab educational programs contributes to the creation of a digital culture for the future and improved equal opportunities in society.

It is not only in purely educational environments that the elements of digital culture have a place. Typical librarian ideals are not so far from the collaborative ecology models close to the FabLab environment, especially if we consider factors such as free access to information, openness and freedom. This conventional approach seems to be reinforced by increasingly documented cases of FabLabs, makerspaces or hackerspaces linked to libraries. Since the opening of Fayetteville Free Library FabLab in 2010, by Lauren Britton [7], the number of these collaborations has increased rapidly, reaching 109 three years later, as identified in John Burke's study [36]. In addition to this common ideology, the digital manufacturing environments share involvement in educational training with FabLabs by including experimental learning and communities of practice and improving self-efficacy through social education, even becoming elements of strong social transformation through the empowerment of the cities and individuals involved [37].

Thus, and considering the development of culturally more distant regions from urban centers, and regions with less technological capacity, mobile laboratories are an interesting case. These laboratories represent the approach of digital technology to rural or remote environments. The first mobile FabLab was established in 2007 at the Center for Bits and Atoms (CBA) at MIT, followed by the laboratory used by the Council for Scientific and Industrial Research (CSIR) in South Africa in 2009 and MC2 STEM High School Cleveland Metropolitan School District in Ohio in 2010 [38]. One of the cases documented is the FryskLab, a mobile laboratory in Friesland (Netherlands) housed in an old bookmobile, which in 2012 was the first mobile FabLab in Europe [7], developed through an initiative of Bibliotheekservice Fryslan (BSF) (the Friesland Library Service). Its objective was to bring training and access to equipment and knowledge closer to regions that did not have a nearby laboratory, including training programs and the dissemination of digital manufacturing culture, even in primary and secondary education. Despite the limitation of space, it offers typical FabLab machines: 3D printers and scanners, laser and vinyl cutters, hardware such as Arduino boards and several open source portable computers. It is not the only mobile FabLab in Europe. In July 2018, there were 159 officially registered FabLabs in FabLabs.io. In France, we find the Nomad Lab, designed by ENSGSI School in 2012–2013

in order to remove the barriers to the creation and innovation of small and medium-sized enterprises in rural areas, improving their economic development [38].

The contribution of FabLab regional development is one of the inherent cultural and nature elements applicable to their integration in the regions where they are established. Thanks to FabLab's own characteristics, which combine the use of digital manufacturing equipment with a high technological component, and the processes of social interaction and knowledge exchange, it is possible to confirm that FabLabs are suitable environments for generating open innovation processes. These processes, along with the facilitation of access to the skills and knowledge of digital manufacturing for non-expert users, democratize manufacturing previously reserved for highly industrial environments. FabLabs constitute a real opportunity for economic development and help in preventing social exclusion and unemployment, features especially relevant in developing countries, by promoting creativity and technological entrepreneurship from knowledge, addressing concepts of the collaborative economy. This situation has been taken advantage of by different regional governments in different parts of the world where, through actions that include the participation of FabLabs as facilitators, programs are carried out aimed at improving innovation and entrepreneurship for local development, constituting a new paradigm of technological inclusion through collaborative development [21,39].

Do all FabLab show the same properties, however? Do they all have the same characteristics and could they be implemented in the same way in any community or region? FabLabs are diverse in their features and conditions, but according to a standard general structure based on the FabLab Charter, they should have common aspects. Using the limited literature on the subject, this paper seeks to identify the main characteristics of the digital manufacturing laboratories linked to the FabLab movement and tries to characterize their main processes and activities in order to establish a basis for further development and research.

## 2. Materials and Methods

Considering the conception of the FabLab movement more deeply, we created an instrument to obtain information, developed as a questionnaire addressed to the managers of the various existing FabLabs. A focus group consisting of FabManagers and technologists helped identify the most relevant concepts related to the movement, allowing the following dimensions of interest or relevance to be defined:

- Descriptive aspect of basic characteristics;
- Perception dimension of digital manufacturing;
- Economic aspect;
- Social aspect;
- Dimension linked to innovation and technological development;
- Aspects related to documentation and knowledge sharing.

Based on these dimensions and validation by the Delphi method, we proceeded to design the questionnaire with the following general structure in which the different aspects are included:

- Part I: Description of FabLab;
- Block II: Innovation Processes and Documentation;
- Block III: Business Model Description;
- Block IV: Internal View.

After this initial process, we began implementation in November 2015. An online questionnaire was created to assess the laboratories, through the questionnaire platform of the University of Cantabria, based on the open source Lime Survey software [40]. The questionnaire was translated into French and English for international application, as alternative languages to Spanish.

*Participants*

To select sample sizes and obtain contact information, we used the www.fablabs.io (accessed on 1 March 2022) website. This website contains an updated list of registered FabLabs, organized by country, and it is possible to download a data file in JavaScript Object Notation (JSON) format light text for exchanging structured data which, once adequately converted, makes work through any data manager practical and straightforward.

The list of data included 516 laboratories on the date of receipt of questionnaire responses (December 2015), of which contact information of only 473 laboratories was available. Once the initial report was refined, 445 fabrication laboratories were finally contacted through email, informing them about the research and inviting them to participate through a direct link in their language (Spanish, English or French). Once the universe was defined, to determine the appropriate sample size, a confidence interval of 95% was established by setting the sample size needed for a margin of error of 10%. We consider 80 effective responses as an equal conservative ratio of 50%. In our case, after completion of the acceptance period units, representing 124 replies with the above values, a margin of error close to 7.5% was obtained, substantially below the 10% of our initial approach, as seen in Table 1.

**Table 1.** Research data table.

| | |
|---|---|
| Universe considered | 445 |
| Total answers | 124 |
| Margin of error (confidence interval 95%) | 7.5% |
| Response rate | 27.86% |

The high participation in the questionnaire, superior to that of previous studies, allows us to propose an important general overview of the characteristics of this phenomenon. The descriptive analysis of the information generated through the FabLab Global Survey reveals a great diversity in the participating digital manufacturing spaces. The typology of their activities, the diversity of their users and business models, the ability to carry out projects and the other features queried account for this variety, but, above all, this variety allows us to access a significant amount of relevant information that is difficult to access in any other way and will permit subsequent studies.

As shown in Figure 1, laboratory participants in FabLab Global Survey come from all over the world, with the response obtained from European and Latin American FabLabs being especially significant.

**Figure 1.** Distribution by country.

## 3. Results

The most notable results are discussed below, divided into their physical, social, economic and other distinctive features.

### *3.1. Expansion*

One of the main characteristics of the FabLab movement is its fast expansion. The evolution of the number of laboratories registered in www.fablabs.io (accessed on 1 March 2022) shows a sharp growth curve from 3 registered FabLabs in 2003 to 678 registered FabLabs in mid-2016. Of those nearly 700 labs, more than 200 were registered in that last year. In July 2018, there were over 1300. This growth rate was also observed in the results of the questionnaire, by analyzing the start dates of the participants.

#### 3.1.1. Start of Laboratory Activities

Since their birth in the early 2000s, the number of FabLabs has not stopped growing, although this growth was discreet at the beginning. These growth rates were endorsed in the questionnaire responses. Most of the laboratories that responded originate from the year 2010.

The diversity of fabrication laboratories is as wide as the number of laboratories in different continents. Laboratories generally do not behave as isolated cells, and their activities are committed to the environment in which they are included through the generation of various ecologies [2]. That is why one of the goals in developing this research instrument was to strengthen the primary and essential characteristics of the different laboratories in their environment, to achieve a general characterization, but with a different univocal classification according to exclusive intent features. There are many factors that determine these differentiating features, including financing, internal structure and process management, the involvement of own or external personnel, the interests developed by laboratory users, the objectives included in a lab's creation or even the relations of the laboratories with other entities and communities. These are, therefore, aspects that make up the particular traits of each laboratory, influencing their activities and affecting their development.

#### 3.1.2. Useful Surface

The variety of laboratories is also seen in their active surface areas, where answers ranged from 8500 $m^2$ or 3200 $m^2$ in some laboratories, in contrast to the smaller surface areas of modest laboratories, such as the 30 $m^2$ indicated by FabLab Shibuya Tokyo or FabLab Lima in Peru. Sixty-three percent of laboratories participating in digital manufacturing reported possessing a smaller surface area than 250 $m^2$.

Despite the apparent relationship, we can confirm the existence of a significant correlation between the available surface in a FabLab and annually available laboratory budget (rho = 0.459, $p < 0.001$). Similarly, we can say that there are significant correlations between the budget, the number of registered users (rho = 0.279, $p < 0.05$) and the number of current users (rho = 0.318, $p < 0.01$). Similarly, there are correlations between the physical area size of the FabLab, the number of registered users (rho = 0.243, $p < 0.05$) and the number of current users (rho = 0.284, $p < 0.05$), as shown in Table 2.

**Table 2.** Correlation between surface area, budget and number of users.

| | Surface (SUPER) | Budget (PRESU) | Current Users (CRURUSER) |
|---|---|---|---|
| Rho Spearman | 0.243 * | 0.279 * | 0.566 ** |
| Sig. (2 tails) | 0.042 | 0.023 | 0.000 |

* Significance at level 0.05 (2 tails). ** Significance at level 0.01 (2 tails).

#### 3.1.3. Tools and Equipment

While the existence of laboratories has been commonly associated with the development of digital fabrication by popularizing typical tools such as 3D printers and laser cutters [41–44], it is no less valid that some of that equipment, when it is intensely used, reaches acquisition and maintenance costs that are not compatible with the budgets of some laboratories. In addition, although FabFoundation recommends a specific list of items for a FabLab, the reality seems to indicate that not all laboratories have the equipment suggested.

In our questionnaire, we used an item for the evaluation of the equipment present in the different participating laboratories without evaluating the concrete models or trademarks chosen. The results offered no surprises beyond logic; thanks to the increasingly accessible cost of digital manufacturing processes, all laboratories had 3D printers. A large majority also had laser cutters or CNC machines. These items have higher costs associated with consumables and the facilities required for their implementation and maintenance. The questionnaire also allowed providing other equipment that did not appear in the relationship initially indicated. Some laboratories indicated that they had 3D scanning elements (12% of laboratories) in their facilities and elements of sewing and embroidery (9% of the participating laboratories), as seen in Figure 2.

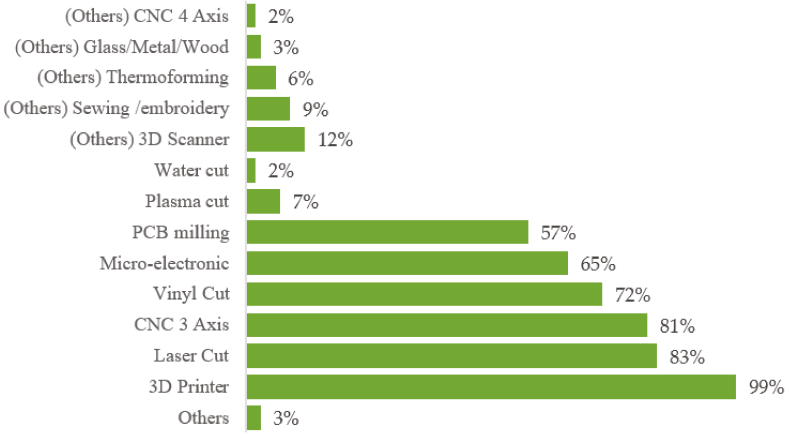


**Figure 2.** Common tools in FabLabs.

3.1.4. Relevant Activities in the Laboratory

Fabrication laboratories present activities as diverse as the different interests of their users. In this sense, a community can develop different interests from another, based on the relevance or quantity of the activities developed. Through the FabLab Global Survey, it was intended to obtain information on the predominant interests in a general way. The option of indicating other interests not included in the range of options provided was also presented (Figure 3).

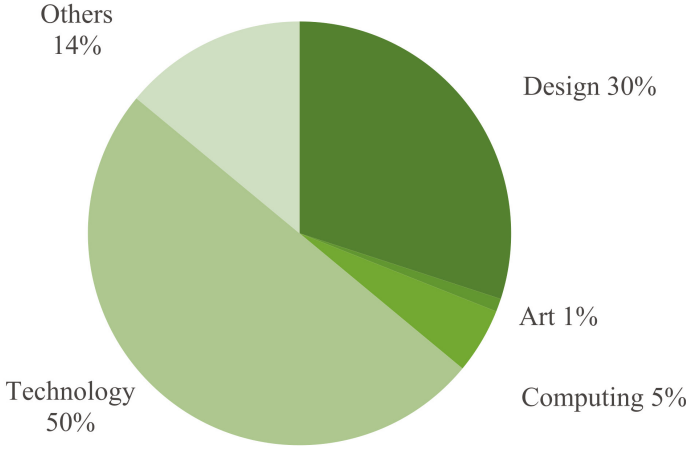


**Figure 3.** Distribution of main interests in the FabLab.

The main interests developed in FabLabs are activities related to technology (50% of the participating laboratories) and design (30%), although there is a growing interest in developing activities relating to education (9.6%) and medical/biological activities (2.24%) that were included in the Others section (Figure 4). Another aspect is the relevance of artistic activities recorded for 18% of the laboratories in a second preference.

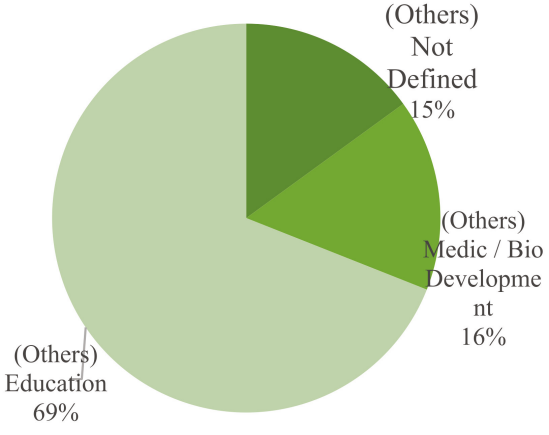


**Figure 4.** Distribution of relevant interests indicated in the "other" section.

3.1.5. Personnel

Another characteristic of some FabLabs is the presence of employees and professionals with specific dedication to the management of the equipment present in the laboratory. The presence of employees is not a constant feature in FabLabs, and labor dependency (e.g., salaried employees of external institution laboratory) was not a direct objective of this study. Thus, even though one of the main objectives in a FabLab is to train users to develop the necessary skills to carry out their own projects using the equipment available, we observed the presence of professional staff in charge of the facility in a large majority of laboratories. To obtain information concerning the types of employees present in the FabLabs, a specific multiple-choice question that allowed participants to indicate the number of employees and also select the type of employees was made available by offering the following as options: Employees of the Institution that Houses the FabLab, University Employees, FabLab Employees, Users and Volunteers.

The responses were grouped into seven main groups: laboratories whose employees solely depend on the university to which they belong or with which it maintains relations; FabLabs whose employees, in addition to the above, include external employees—not on the staff of the university; laboratories depending on users and volunteers; dependent employees of the institution that houses the laboratory; other types of personnel, foreign or belonging to a university; employees and volunteers or users (it should be noted that in some cases, laboratories participating in digital manufacturing correspond to mixed development centers in which, in addition to the dependence on an external entity, the participation of a university is added and open to the general public, which explains the variety in the composition of the laboratory personnel); and laboratories whose staff is independent of any institution.

In the latter group, it is interesting to note how 18% (as seen in Figure 5) of laboratories maintain their operations with users and volunteers, without the presence of specific employees, keeping a clear independence and assuming a spirit of working that is closer to the roots of FabLab movement in which support is from the laboratory users, based on suitable communication and documentation processes.

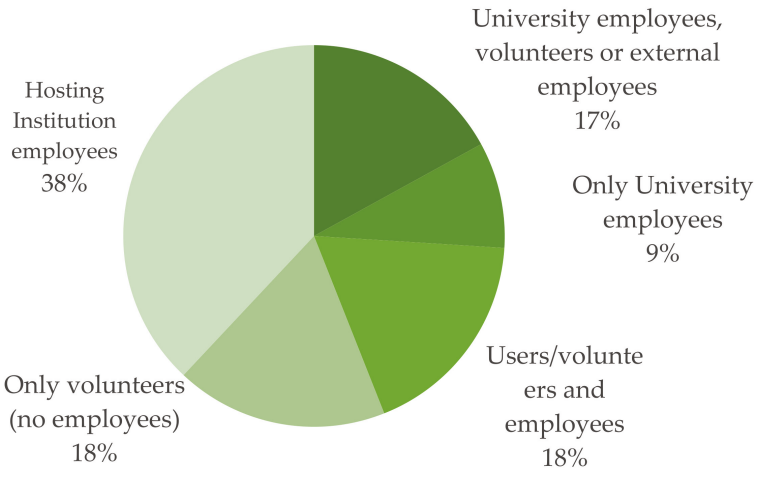


**Figure 5.** Distribution of laboratories according to groups of personnel typologies.

Analyzing the information provided directly, it is interesting to note that only 36% (Table 3) of the laboratories have their own separate staff, i.e., FabLabs that have their own employees and/or users and volunteers, compared with 63% of laboratories with external institution dependent personnel.

**Table 3.** Distribution by type of laboratory personnel.

| | |
|---|---|
| Laboratory personnel of the institution that houses the laboratory | 40% |
| Laboratories with staff from the university to which the laboratory belongs | 41% |
| Laboratory personnel not directly dependent on the laboratory | 64% |
| Laboratory personnel | 46% |
| Laboratories comprising volunteer staff and lab users | 78% |
| Dependent laboratory personnel | 86% |
| Laboratories exclusively dependent on laboratory personnel | 36% |

3.1.6. Established Relationships with Other Communities and with External Entities

Digital fabrication laboratories, to be involved in the maker movement, dynamically and openly present activities that usually take advantage of their social characteristics for establishing relationships with other organizations and stakeholders in their environment. In this research, it was relevant to analyze the capacity of interrelationships between diverse communities of users with characteristics linked to digital manufacturing. We established a multiple-choice question for this, in which participating laboratories were allowed to indicate the communities with which they had maintained some type of collaborative relationship in the development of activities (Figure 6).

The results obtained in this section show a high tendency to establish collaborative relationships with co-working spaces and makerspaces. It is also important to note a large number of laboratories (12%) that have not established any partnership with other entities, as seen in Figure 6.

On the other hand, communities formed in digital manufacturing laboratories are also active in collaboration with other external development activities and projects of different entities. Proof of this is that only 3% of the responses claimed not to have established any kind of partnership with another entity, while 63% indicated having found some sort of relationship with universities, and 66% (Figure 7) indicated having formed partnerships with entrepreneurs and small companies.

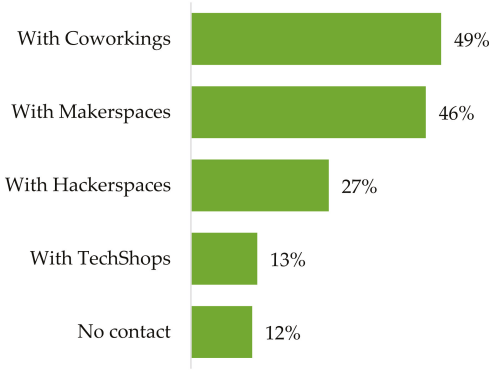


**Figure 6.** Laboratories that have established relationships with a community.

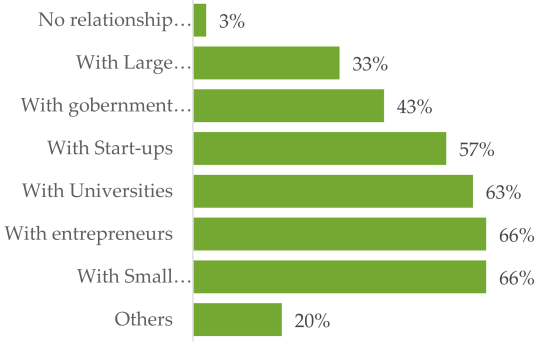


**Figure 7.** Laboratories that have established relationships with companies and other entities.

### *3.2. Social Aspect*

Another intrinsic characteristic of digital fabrication laboratories, and mostly responsible for the activities that they develop, is the type of users. This was initially conditioned by the facilities and the activities carried out, also in planning the opening of the laboratory, and although sometimes not maintained after the initial idea, in others it is set as their own hallmark. As is clear from this study, a FabLab not only makes machines available, but also consists of the community of users who use them, the relationships and knowledge exchange that it develops through the implementation of projects and interaction with other laboratories.

#### 3.2.1. Targeted Users, and Current Users

One of the fundamental aspects of creating a FabLab is planning the type of user to which the laboratory is directed. This affects not only the activities carried out, but also fundraising, project development and the ultimate goal of the laboratory.

Two multiple-choice questions were included in the questionnaire in which participants were allowed to choose between different types of users typically present in the FabLab (students, researchers, companies and general) and allowed an open response by providing other types of potential users already offered. Analyzing the target audience of the creation of a digital fabrication laboratory, it was possible to observe the active involvement of the FabLab general character of openness in that 15% of the participating laboratories provided laboratory services to the general public (Table 4). The initial involvement of laboratories with students is also noteworthy, as the inclusion of this category is evident in 75% of the participants.

**Table 4.** Distribution by objective user typology.

| | |
|---|---|
| General public | 15% |
| Only students | 9% |
| Students and general public | 12% |
| Students, general public, researchers, and companies | 24% |
| Students and researchers | 9% |
| Students and companies | 4% |
| Students, researchers and companies | 4% |
| Students, researchers and general public | 6% |
| Students, companies and general public | 7% |
| Other/not defined | 7% |

Business activity also acquires remarkable values by being present in the selection of 42% of the participating laboratories, although, and as it was logical to expect, this was not among the exclusive objectives. An exclusive dedication to the student population, without including other user typologies, was important (9% of the participants) in the specific typology of manufacturing laboratories: those dedicated exclusively to training or the provision of services for the student community.

Only 51.6% of participating digital manufacturing laboratories currently include the user type originally planned, however. Laboratories exclusively dedicated to the public comprised 3% of the participants, while maintaining similar values, 71%, to those outlined about those established by this category within the chosen among others. Dedication to students exclusively, indicated by 10% of participants, seems to maintain the distribution between the values initially identified by the participants when planning users, reaching 62% of cases selected in this category.

For current users, business, again, is not an exclusive category, but is among regular users of the laboratories in 42% of situations, demonstrating a possible excess of optimism when considering the interaction of business planning for the creation of fabrication laboratories, as seen in Table 5.

**Table 5.** Distribution by current user typology.

| | |
|---|---|
| General public | 3% |
| Students | 10% |
| Students and general public | 19% |
| Researchers and companies | 1% |
| Students and researchers | 4% |
| Students and companies | 1% |
| Students, researchers, companies and general public | 17% |
| Students, researchers and general public | 11% |
| Students, companies and general public | 15% |
| Students, researchers and companies | 4% |
| Companies and general public | 5% |
| Researchers and general public | 1% |
| Other/not defined | 9% |

#### 3.2.2. Registered Users and Regular Users

One of the usual difficulties in describing the business models used by digital manufacturing laboratories is mainly due to the different types of monetizing through possible membership and the existence of several organizational forms. From university-type laboratories, in which the manufacturing processes are produced for free to payment-for-use typologies, but for which there are no registered users, there is a wide range of different types. In our study, we analyzed the relationship between registered users and active users, considering those with a regular presence in the laboratory as active.

Analyzing the individualized information, the ratio of regular users to registered users for each laboratory was calculated and four large clusters were established: laboratories

in which less than half of the users are registered, laboratories in which more than half of the users are registered, laboratories in which there are more regular users than registered users or in which registration is not needed and laboratories in which information was not available. The differences in everyday registered users may correspond to the effect of potential differences in methods of membership, different types of access, the impact of organizing various open events with free access or segmentation in customer type.

The two groups with a lower ratio of users to registered users demonstrate the difficulty for fabrication laboratories of maintaining an active link with all users. Despite this, bonding is usually high, social application has been proven and the theoretical development is demonstrated by noting that only 28% have less than 50% registered users (Figure 8).

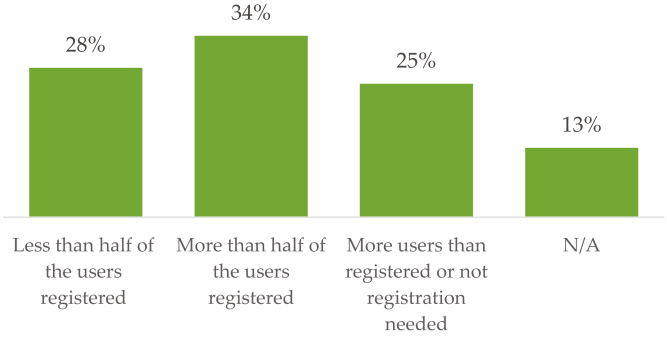


**Figure 8.** Usual over registered user ratio.

### 3.2.3. User Profile

Finally, for the evaluation of the user profile, we used a question of type ranking in which the participants had to order the different optional profiles provided according to the real users of the laboratory. Responses were grouped according to the first two profiles of the questionnaire. In this way, the majority of user profiles were engineers (19% of laboratories chose this option in first or second place) and designers (19%), followed by all those related to architecture (14%) and amateur users (13%). It is important to note that only 8% of laboratories reported students or researchers as their main users (Figure 9).

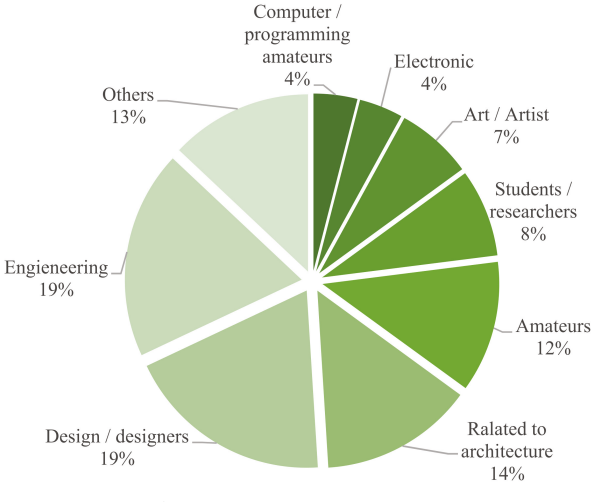


**Figure 9.** User profile.

### *3.3. Economic Aspects*

#### 3.3.1. Economic Sustainability

Once the social reality of the FabLabs was demonstrated, the next aspect to be considered was the operating model and the characteristic typologies associated with the business model to guarantee sustainability. We understood economic sustainability as the ability of the laboratory to carry out its activities without interruption and continuously over time, without problems. It is an objective to be achieved from the adoption of a business model or, in some cases, insurance to be under the economic protection of an institution providing a particular service. As previously mentioned, one of the biggest difficulties that laboratories face is the costs of purchasing and maintaining equipment. Although basic equipment, such as a 3D printer, is a small investment and even, in some cases, built into the FabLab itself, this also includes other equipment such as laser cutters or CNC machines, which involve a high outlay, high maintenance costs for intensive use and even the adaptation of the facilities to their technical characteristics. All this, together with the common expenses and supplies, presents a difficulty for the development of FabLab activities.

In the section in question, we discuss the key economic issues associated with financing the activities of FabLabs, considering the diversity of budgets, the main source of income and business patterns and analyzing their characteristics as associated with the innovation and value proposition that a FabLab offers to its users and the community.

#### 3.3.2. Annual Budget of Digital Manufacturing Laboratories

Budget is one of the conditioning factors of the activities developed in a FabLab. In our questionnaire, one of the open response questions was assigned to budget determination; although it was not mandatory, it did obtain a high response rate, enough to be considered in this study. The responses were grouped in significant quantity intervals for the analysis of the information related to the budget thus obtained, after adapting to a single type of currency applying the appropriate change.

It is interesting to note that 14% of the FabLabs had a meager annual budget, with amounts equal to or less than EUR 5000. Do not forget that for the development of the activities it is necessary to have a properly conditioned room and not only the equipment, but also the necessary consumables. On the other hand, it is also striking to note that 70% of laboratories have an annual budget of more than EUR 10,000 per year.

The diversity of budgets is obviously as varied as the laboratories themselves, but it is possible to group laboratories into budget ranges that include significant margins relative to the activities that can be developed in them. Based on this distribution, the most characteristic budget range was between EUR 10,001 and 25,000 per year (Figure 10).

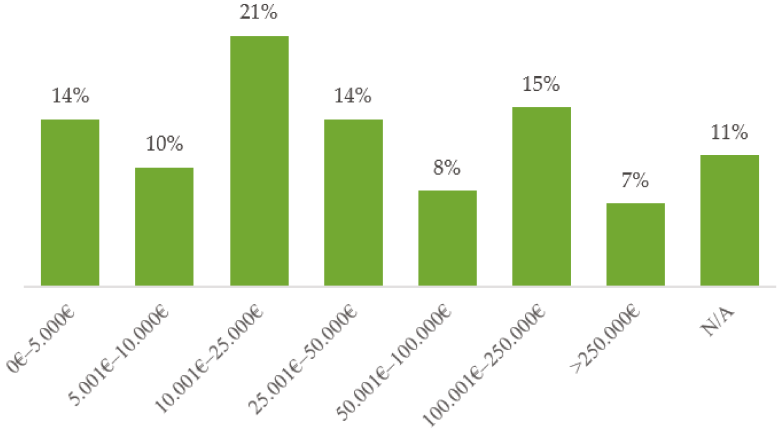


**Figure 10.** Distribution of laboratories in annual budget intervals.

3.3.3. Main Sources of Income

Once it is known what the typical budget of a laboratory is, it becomes important to identify the main source of that budget. The questionnaire provided options for respondents to rate on a five-point Likert scale. Research has demonstrated repeatedly that funding is rarely based on a single source, and so respondents were asked to indicate the relevance of a number of financing options in their annual budget.

The majority of funding sources were valued with an average score of 3.4 out of 5 points and considered an important source of funding (ratings equal to or greater than 4) in 52% of cases. In addition, the source of financing is shown as the main funding (considered as the main funding source when the valuation of the rest of the options is low—scores equal to or less than 3) and the valuation of the financing from the users is high (scores equal to or greater than 4) in 18.8% of the cases and exclusive (considered exclusive when the rest of the options adopt the lowest possible value) in 7% of the cases, allowing the conclusion that the contribution of the users does not represent the only form of financing in most of the laboratories (Figure 11).

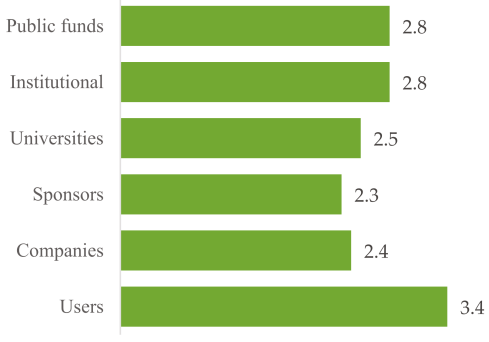


**Figure 11.** Mean values of the relevance of the different sources of income.

Laboratories whose fundraising is based on public institutions, universities or public funds were about 26% of the participants (25.8%), and only 10.6% of these cases reported any of these funding sources as exclusive sources (valuing with minimal other funding sources).

The responses show that 1.18% of laboratories received their funding exclusively from private funds or sponsorship from private companies, and 27% of laboratories reported funding sources mostly associated with the contributions of their users, external companies or sponsors (scoring less than or equal to 3 points for the contribution of public entities, universities or institutions) (Table 6). Only 14.1% of the participating laboratories reported exclusive financing from private initiatives, understood as funding from companies, sponsors or their own users (values equal to or greater than 4 points) rather than financing of public or institutional origin from universities, institutions or public funds (valued, in this case, with the lowest possible score).

**Table 6.** Sources of financing outstanding.

| | |
|---|---|
| Exclusively from users | 7% |
| Exclusively from public funds (universities, institutions and public funds) | 10.6% |
| Exclusively from private funds (including the contribution of users) | 14.1% |
| Exclusively from public or private funds, without user contribution | 17.6% |
| Mainly from users | 18.8% |
| Mainly from public funds | 25.8% |
| Mainly from private funds (not including the contribution of users) | 1.1% |
| Mainly from private funds (including the contribution of users) | 27% |

As noted, users are a significant source of funding for digital manufacturing in laboratories, being present as an essential factor in 52.9% of cases. Only 17.6% of participants declared funding from the contribution of public or private funds from universities, institutions, federal funds, direct funding or financing companies through sponsorship agreements without user involvement. Finally, the importance of funding sources from federal funds is evident, as 25.8% of cases were financed mainly from public funds, and the difficulty of maintaining laboratories based solely on funding from users is shown in that only 7% of participants were financed mainly by users.

#### 3.3.4. Types of Institutions Housing the FabLab: Dependence and Independence of Institutions

The funding sources noted in the previous section show the dependence of most laboratories on institutions that provide appropriate stability. In this regard, the FabLab Global Survey included a question about the nature of the institutions that house the laboratories.

The decision to impose greater accuracy in determining the host institution among the possible entities in public or educational (universities, educational institutions, institutions dedicated to research or dependent on government or public institutions in general) was adopted based on the multiple examples of these relationships that can be seen in the different active FabLabs; however, to avoid making the mistake of not covering all possibilities, an open option was added to allow participants to indicate the type of entity that housed them. Most FabLabs were strongly dependent on host institutions (57% of the participating laboratories), leaving a significant 37% of laboratories with no direct relationship with any hosting institution and for which, therefore, matters relating to the space in which activities occur, supplies and equipment are a direct charge of the laboratory developing digital manufacturing.

In more detail, universities (no distinction between public universities or private universities) typically host the digital manufacturing laboratories, at 31%. Education entities, including universities of any type, non-university educational institutions and entities based on research, generally provide the framework for most FabLabs (52%). Only 3% of respondents said they relied on government institutions, showing, perhaps, the low involvement of non-public educational institutions in this kind of social movement. As envisaged in the development of the issue, some of the participating laboratories did not identify with the categories provided, and their responses were included in "Other." These laboratories (2% of respondents) said they were hosted by non-governmental/non-profit organizations or private foundations (Table 7).

**Table 7.** FabLab dependence.

| | |
|---|---|
| Independent FabLab | 37% |
| FabLab dependent on a university | 31% |
| FabLab dependent on an educational institution | 17% |
| FabLab dependent on an entity based on research | 4% |
| FabLab dependent on a government institution | 3% |
| Others | 2% |
| Ns/Nc | 6% |

#### 3.3.5. Business Model: Innovation vs. Service

Although the number of activities undertaken in FabLabs is varied, and a source of technological and educational innovation, the need for sizing was raised through a continuum. To do this, and based on the classical differentiation between the most basic business of the models, we proceeded to classify them into two different types: activities organized from the laboratory performing these acts as a service or activities purely innovative [45]. For this, a matter in which participants were invited to a position in a continuum divided into five positions whose ends were precisely the poles above was established. Thus, the

participants could indicate, using the choice in the scale, their basic typology according to both parameters.

As shown in Figure 12, we found a balance between the two main types of general model (the average score was 2.97 points) with a slight tendency to business models based on innovation versus a service delivery model. In this respect, there was, importantly, a comparable number of FabLabs whose model was essentially the provision of service (31% of participants) versus participants whose model was essentially innovation (32% of participants).

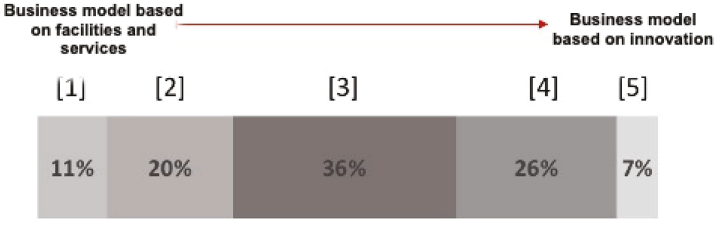


**Figure 12.** Business model.

3.3.6. Business Model

Economic sustainability of FabLabs is one of the main problems in the maintenance and continuity of the laboratories. Some studies have classified their activities to establish patterns that fit with business models. In our case, and in order to identify the patterns shown by FabLabs, FabManagers could choose between the following typologies (Figure 13):

- Techno-tourism. A business pattern characterized by the attendance of non-regular users who are traveling and visiting different communities and technology development centers.
- Co-X. Digital manufacturing laboratories combine their activities with the presence of collaborative work environments not directly related to the development of their activities, complementing or offering their services.
- Access to gurus. Knowledge is one of the main values in digital manufacturing laboratories. In this business pattern, the knowledge of experts becomes the main value proposition, and their expertise becomes the main contribution, providing consultancy or advisory services to users.
- Prototype shop. Technological capabilities coupled with strong experience and knowledge can be displayed as factors added to the prototype development service. In this particular pattern, digital fabrication laboratories provide their tangible and intangible resources for the development of basic models of temporary products by users or external customers.
- Access fees. A business pattern that bases its income on charging a recurring fee to its users for regular access to the laboratory and its services.
- Member of an institution. In this pattern, the FabLab is embedded within a larger institution to provide a service, which promotes all or most of its activities.
- Access to infrastructure and equipment. The technological capacity of laboratories is based on the existence of specific equipment for digital manufacturing. The business model based on access to infrastructure and equipment includes the possibility that both regular users and external users make use of these capabilities independently of the activities carried out in the laboratory. The central value proposition provided in this pattern resides in the equipment and infrastructure present in the FabLab and the services offered through its use.
- Educational activities. Since the beginning of the FabLab movement, the actions of FabLabs as digital manufacturing laboratories have been strongly linked to training and educational activities as sources of essential knowledge exchange. Through this

pattern of business, laboratories focus their model on educational events or related educational activities carried out by other institutions or by the FabLab itself.

- Other. In this research, we tried to include and group the most common patterns, but we were aware that the variety of models of existing business could be as wide as the number of laboratories that exist, so participants were allowed to briefly describe their patterns.

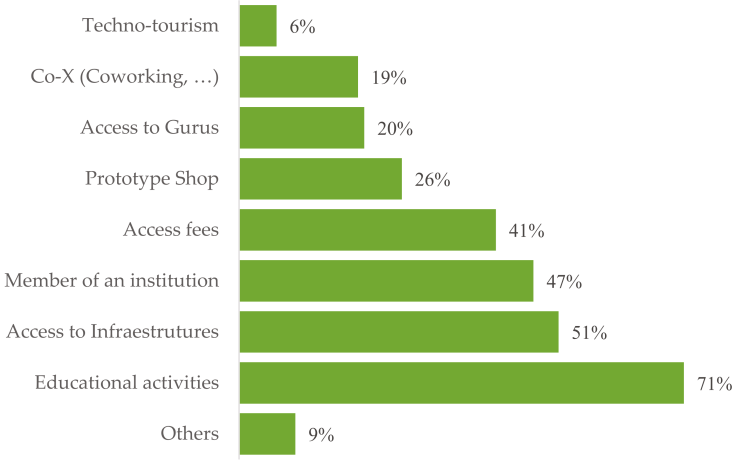


**Figure 13.** Distribution of FabLabs depending on the type of business model.

3.3.7. Main Value Proposition Offered

If the business model of a FabLab is trying to establish a pattern of income generation, the value proposition is the greatest asset that the laboratory offers to its participants. To develop this analysis, we considered the existence of several value propositions mentioned throughout the literature:

- Access to FabLab Network. Developing collaborative projects jointly with the laboratories that constitute the international FabLab Network provides, for each particular FabLab, access to a vast knowledge distributed in every corner of the planet and allows expansion of the project to infinite possibilities. Interaction with the FabLab Network can be via any FabLab Network node for information exchange or advice. In this case, the assessment of participants reduces the importance of access to the FabLab Network as a value proposition compared to other options presented in the questionnaire, since only 44% of the laboratories considered it an essential asset, with an average overall rating of 3.22 out of 5 points. The low consideration of the access to the FabLab Network by 33% of the laboratories is remarkable.
- Access to FabLab knowledge. The FabLab is made up of a community of users, and as has been argued in previous sections, in reality, the FabLab is the community of users. This community of users is characterized by a common interest that acts as a unifying factor but in itself possesses a high level of knowledge in certain skills at a higher level than would be expected. This knowledge, which not only comes from formal education but also, on many occasions, has been forged in the course of the common activities of the laboratory itself, can be considered as another asset when its application to user projects is an aspect valued as such by the participants in the project and represents the most common intangible asset of digital fabrication laboratories, valued as highly important in 88% of the participating laboratories with an average rating of 4.19 out of 5 points.
- Access to the FabLab's experts. In the FabLabs there are users with more advanced knowledge than the rest of the community who could be called experts, from the

FabManagers themselves to other users whose training or job profiles allow a superior knowledge in some technical or technological aspects. Often, these experts' knowledge, advice and collaboration become the true value proposition of the FabLab. Experts who have been trained through the Fab Academy Program, with some years of experience added to their previous knowledge of technological matters, are called Fab Gurus. Access to an expert who is part of FabLab as a value proposition obtained a high score of 4.07 out of 5 points and is considered a very important value proposition for 78% of the participating laboratories.

- Access to FabLab infrastructure. The equipment needed in manufacturing processes has high acquisition costs and is difficult to handle. Users can access this technologically advanced equipment at an affordable price per use. The learning curve for its utilization is mitigated by learning via Do It With Others (DIWO) processes, and training courses are regularly offered. The presence of complex equipment, which otherwise could involve disbursements of hundreds or thousands of dollars and would involve a steep learning process, implies a true value proposition in itself. Access to FabLab infrastructure received the highest mean score—4.38 out of 5 points—and was considered a highly relevant value proposition for 86% of the participating laboratories (Figure 14).

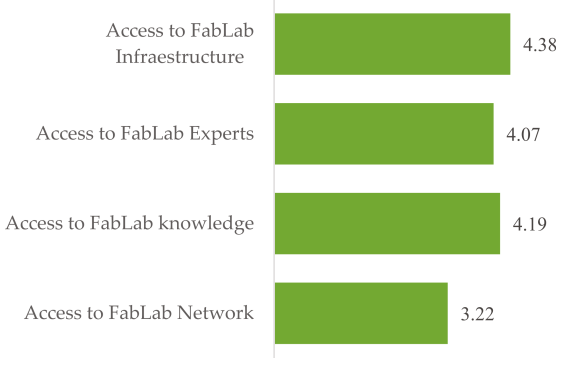


**Figure 14.** Average valuation of value propositions.

### *3.4. Distinctive Features*

Once the physical, social and economic conditions laboratories are identified, we focus on their distinguishing characteristics, among which are the ability to promote entrepreneurship (through fast prototyping, level of innovation, collaboration with other entities, or due to independence in project development), the training offered and the public documentation of projects undertaken to conclude with their contribution to the community.

#### 3.4.1. Entrepreneurship and Fast Prototyping

The FabLab can serve as a vivarium for business development, improving products and processes or generating prototypes that constitute the minimum viable product of a commercial initiative. Among the FabLab Global Survey participants, 22.9% had witnessed the creation of a new commercial initiative, stressing the importance of these processes.

The economic sustainability of these laboratories is, however, even today, an added difficulty for their own characteristics, causing many of them to depend in one way or another on the entity that hosts them. This kind of dependence could well place a limitation on the development of projects by establishing clear preferences in their choice, skewing the typology of their development or limiting the involvement of the laboratory in certain types of activities.

Answers provided by the participants show a high perception of the contribution of the FabLab as a factor in the development of entrepreneurial culture (73% of respondents rated

their agreement with a 4 or 5 out of 5). A positive impact is noted on the contribution of the close ecologies to the FabLab, as positive factors in the development of entrepreneurial culture (73% of respondents rated their agreement with a 4 or 5 out of 5). The perception of fast prototyping as a contribution is also highly considered (90% of respondents rated it with 4 or above out of 5 as seen in Table 8), probably due to involvement in innovation processes.

**Table 8.** Perception of the contribution of FabLabs.

| | Low | High |
|---|---|---|
| Entrepreneurship | 26% | 73% |
| Fast prototyping | 10% | 90% |

The FabLab Global Survey evaluated the perception of independence in carrying out different projects. The participants were asked to indicate the perceived independence of the realization of the FabLab projects on a 1 to 5 scale, with 1 meaning a null independence, and therefore a full dependence, and 5 meaning a complete independence. It is important to consider that while a large percentage of laboratories are dependent on institutions to ensure sustainability, 68% of laboratories indicated a high level of independence, and 52% of the participants indicated a level of absolute independence (Figure 15).

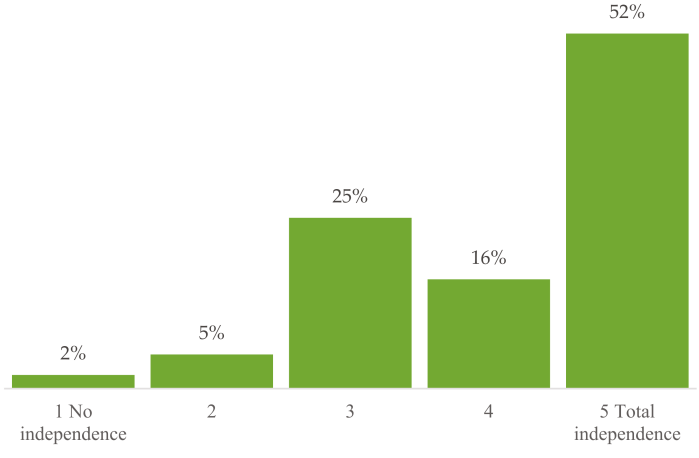


**Figure 15.** Distribution of laboratories according to declared independence.

3.4.2. Development of Joint Projects with Other Institutions and Groups

In the FabLab Global Survey, the participants were asked about the realization of joint projects with certain typical institutions in the FabLab environment. Among the participating laboratories, 43.5% had jointly carried out projects with external industries, although only 9.4% of the participants had carried out more than 10 projects. Twenty-four percent of participants reported having developed projects with sponsors, but only one participant carried out more than 10 projects. On the other hand, 45.9% of the participants indicated that they had carried out projects with research entities, although only 8.2% of the participants had completed more than 10 projects of this type. While 48.2% of the laboratories had carried out projects in collaboration with universities, only 1.18% of the laboratories developed more than 10 projects of this type. The projects carried out with students were the most common collaborative projects, present in 68.2% of the cases, where 34% of the participants exceeded 10 projects of this type and 15.3% had developed 100 projects. Only 24.7% of the laboratories had carried out joint projects with other laboratories in the FabLab Network, and only 3.5% had realized 10 projects (Figures 16 and 17). Among the participating laboratories, 55.3% had developed projects

jointly with startups, and 7% had developed 10 of these. As a reference, 62.4% of FabLabs had carried out projects without the need for external support, with 17.6% of participants exceeding 10 projects (Table 9).

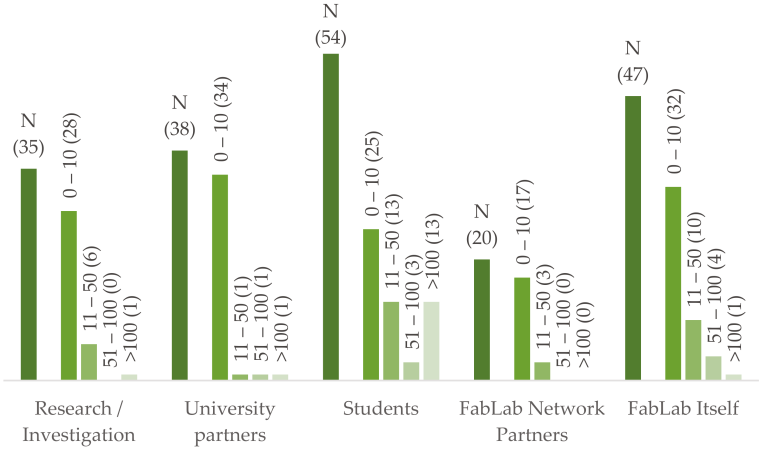


**Figure 16.** Distribution of number of projects developed.

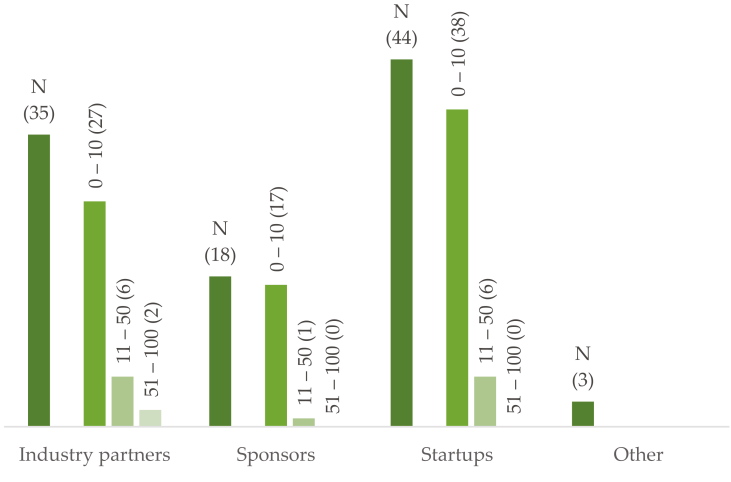


**Figure 17.** Distribution of number of projects developed (industrial section).

**Table 9.** Distribution of FabLabs that have developed collaborative projects.

| | |
|---|---|
| With industry | 43.53% |
| With sponsors | 24.71% |
| With research entities | 45.88% |
| With universities | 48.23% |
| With the FabLab Network | 24.7% |
| With students | 68.23% |
| With startups | 55.29% |
| By the FabLab (no collaboration) | 62.35% |

3.4.3. Level of Innovation, the Percentage of Innovation Projects Developed Jointly

The projects developed in the environment of FabLabs are adjusted to multiple and different interests and objectives and, therefore, tend to be varied despite their common

ground in digital manufacturing. One of the interests of this research was identifying the contribution of the projects carried out in the laboratories to innovation, for which an item was included in the FabLab Global Survey where participants were asked about the approximate percentage of projects carried out dedicated to innovation for research and development for industrial companies or small businesses. The results reveal that 27.8% of the laboratories had a high percentage of projects linked with innovation—more than 50% of the projects—with 11.8% of the cases considered as a very high level—more than 75% of the projects. By contrast, 40% of the laboratories reported a very low level of projects linked to innovation—less than 25% of projects dedicated to innovation. A meager 7% of the laboratories reported no projects linked to innovation (Figure 18).

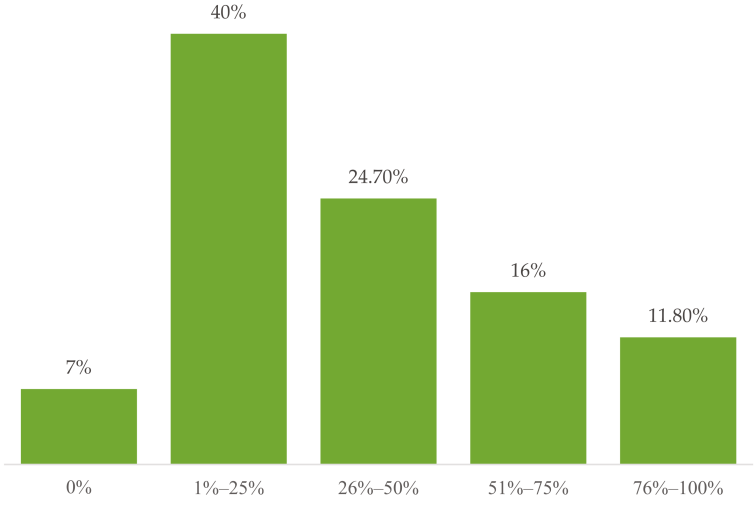


**Figure 18.** Percentage of projects related to innovation.

The communities that emerge within a FabLab often share the point of view of one of the key roles present in their daily lives: the FabManager. The FabManager is, along with the rest of the technical staff, the soul of the laboratory. They know the function of all available material—some of the machinery has even been created by them or with their essential collaboration—and participate in all processes that are taking place in the laboratory, in most cases being a fundamental part of them. It is thus interesting to hear their opinion of aspects such as the contribution of the FabLab to entrepreneurship development, the process of project documentation or the training of users.

#### 3.4.4. Documentation

Another important aspect to consider in this section involves the internal processes associated with public FabLab project documentation. As suggested by the FabLab Charter [2,8,40], a FabLab has a responsibility to disseminate the knowledge generated in the projects through its public documentation. Project documentation is an added difficulty in development since it involves time and resources, rarely available in digital manufacturing laboratories. This feature is not exclusive to FabLabs, as it is shared with the culture of the maker movement.

Documentation seems to be perceived as an obstacle and represents a serious difficulty in the development of projects; however, a common platform for the documentation process has not been established (although some joint initiatives from within the network of FabLabs have been developed and there are some attempts to standardize the documentation process), and relatively few laboratories make the public documentation process a priority using an online platform. Several items were included in FabLab Global Survey

concerning the documentation process, from the items designed to assess the perception of documentation to items that were intended to determine who is ultimately responsible for the documentation process and items that evaluate the actual percentage of documented projects. Most of the participants expressed the great importance of project documentation as one of the main benefits of FabLab (68% of participants) and also the difficulty that it represents (53% participants), as seen in Table 10.

**Table 10.** Distribution according to the degree of agreement with the statements regarding the documentation.

| | 5 | 4 | 3 | 2 | 1 | High | Low |
|---|---|---|---|---|---|---|---|
| As an advantage | 40% | 28% | 20% | 11% | 1% | 68% | 32% |
| As a difficulty | 22% | 31% | 24% | 19% | 3% | 53% | 46% |

When asked about the importance of documentation in their own FabLab in particular, 65% of participants reported a high or very high importance and 18% admitted a relatively low importance. Although 68% of respondents considered the public documentation of projects as one of the great strengths of the FabLab, 51% recognized it as one of its great difficulties (Figure 19).

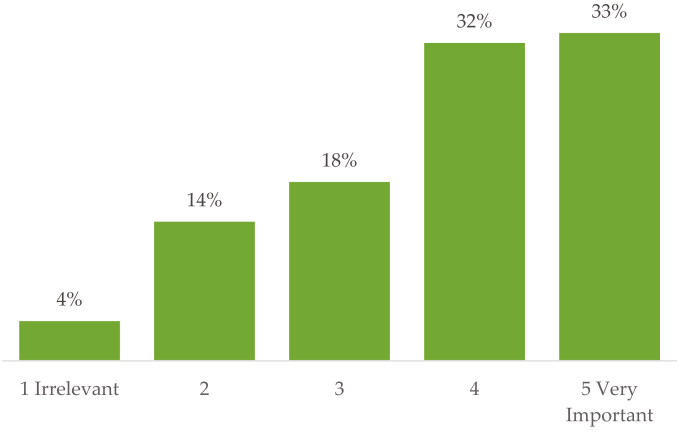


**Figure 19.** Evaluation of the importance of the documentation processes for the FabLab.

If we focus on the actual percentage of publicly documented projects, 39% of the laboratories showed a high rate of documented projects (more than 50% of the projects documented) while only 6% assumed a very high rate (more than 75% of projects). The difficulty associated with project documentation seems to be the reason for the high number of laboratories with a low rate of documented projects, demonstrated by 36% of participants having more than 25% of projects documented and 8% of laboratories without any projects documented. It is interesting to note that 35% of the participating laboratories that indicated public documentation of projects was important had a documentation rate lower than 50% (Figure 20).

An item was included to identify who was responsible for project documentation. Participants noted the person responsible for documenting from a multiple choice offered. Twenty-four percent of respondents indicated that there was no fixed role in charge of documentation, and 82% reported any of the project members as usually responsible for documentation, with the project leader being responsible for 9% of cases. Four percent of the participants indicated that there was a specific user or member in the laboratory responsible for project documentation, and 11% identified the Fab Manager as responsible for such documentation. Two percent of respondents indicated that all members and users

of the laboratory were responsible for the documentation process equally, and in 4% of cases, that responsibility fell on other actors such as a community manager or the client themselves (Figure 21).

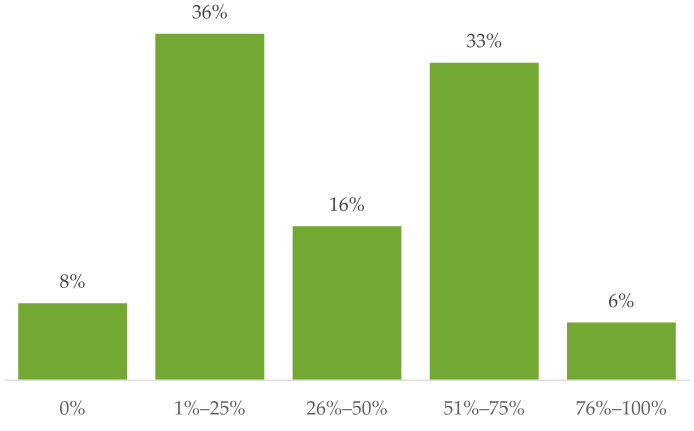


**Figure 20.** Distribution by percentage ranges of documented projects.

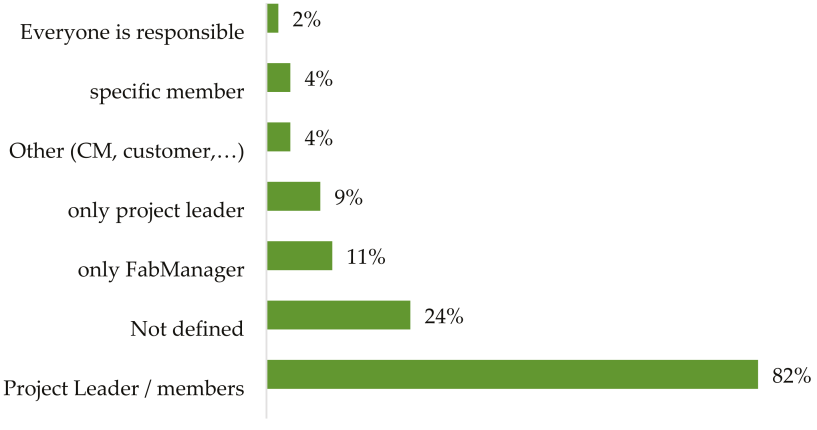


**Figure 21.** Responsibility for project documentation.

3.4.5. Education

Knowledge sharing is one of the main advantages of FabLabs. In the FabLab Global Survey, items were included to evaluate perceptions about FabLab contributions to training in new digital fabrication technologies, including the 3D design and open hardware platforms. The results revealed certain differences in processes associated with training each of the above aspects. For open hardware development platforms, the majority opinion was that the FabLab provides adequate training (74%) in these technologies and, although values are subtly lower, the perception of training in additive manufacturing and 3D technology training (69% and 61%, respectively, as seen in Table 11) was similar. We must not forget that, although the open hardware platforms and the communities associated with their use have democratized and simplified previously unthinkable processes for the ordinary user, they require high knowledge of aspects as diverse as electronics or programming projects.

**Table 11.** Perception of FabLab training.

| | Low | High |
|---|---|---|
| Additive manufacturing | 31% | 69% |
| 3D design | 39% | 61% |
| Open hardware platforms | 26% | 74% |

3.4.6. FabLab Contribution to Users and the Community

Digital fabrication laboratories provide a framework for social relationships where there is an exchange of knowledge about technological aspects. This exchange of knowledge takes shape through the FabLab activities. These activities were divided into four main processes that try to include, in a generic way, the most common aspects of the interaction and implementation of value proposals.

A FabLab Global Survey item aimed to obtain information about the real contribution that FabLab makes to its users through a question in which the participants evaluated different proposals from 1 to 5 and in which it was possible to add new options in case those suggested do not apply.

In our survey, the possible contributions are as follows:

- Education and learning. FabLabs are a true learning community where their users, regardless of the existence of a guru or not, learn by doing and watching what others do. They learn to overcome their difficulties with the support of the community, interact in finding solutions and discover aspects that otherwise would have required a complex journey through regulated education. It is an informal, competitive and dynamic learning-centered interest and is based on project learning. FabLab's contribution of education and learning to its users was valued very highly by the participants—a score of 4.4 out of 5 points—and was considered of very high relevance in 87% of the cases. Only 4% of cases considered this contribution as low in importance (Figure 22).
- Research. Open innovation processes include research elements set out in FabLabs. In some cases, this research is conducted jointly with other entities to become a true development laboratory. This type of activity was evaluated as of intermediate importance by participants—obtaining a value of 3 out of 5 points—and considered relevant in the possible contributions of the laboratory in 44% of cases. Twenty-four percent of participants felt that FabLab did not contribute to these processes for its users.
- Development. In this section, we distinguish the application of processes to product development as part of the non-specific standard innovation process and included in the dynamics of the existing systems in FabLab. In this respect, 65% of FabManagers considered the contribution FabLab makes to their development processes (3.8 points out of 5) as being of high importance.
- Prototyping. The innovation processes carried out in FabLabs emphasize the application of technology, and they own digital manufacturing processes to develop new projects or products that meet diverse needs. This development takes place through prototyping and knowledge sharing. Eighty-one percent of laboratories assigned high scores (4.2 out of 5 points on average) for the FabLab contribution to their users in prototyping, describing its importance as very high.

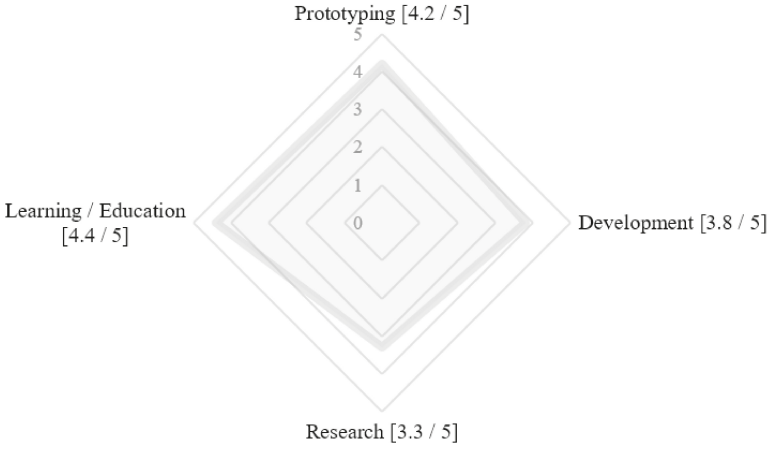


**Figure 22.** Average valuation of the main contributions of a FabLab.

## 4. Discussion

Given the results, from a technical point of view, the FabLab appears to be the ideal environment to bring the possibilities offered by current technologies to the public [45,46]. Cutting-edge and accessible technology (3D printers, laser cutters, CNC machines or free hardware development platforms) coexist with the tools of a traditional workshop, all at the service of FabLab users. From a social point of view, openness is evident to all users regardless of their knowledge and skills [47].

This diversity in user profiles brings about other benefits, such as the creation of multidisciplinary working groups that can undertake major projects that individually could not be performed. Similarly, the diversity in training promotes another characteristic: knowledge transfer among peers. It is evident that the combination of technical elements with their social vocation makes these ecologies ideal environments for the development of activities that promote the reduction not only of the digital gap but also other differences related to gender, culture or role.

As mentioned, many of the projects developed in the FabLab must overcome, sometimes, user training barriers, and the technological and logistic difficulties of a region, providing solutions that equal conditions between regions far from urban environments, contributing to economic and social development by ensuring sustainability [48]. Emphasizing the central idea, through these and other programs, FabLabs show their ability to alter and improve social and economic conditions and feed economic and technological development in societies through project implementation and user training.

From an economic point of view, even though the FabLab movement is still looking for a business model to ensure its survival, it is noted that the decision to implement a FabLab should not be based only on economic reasons, but should also consider that the central element is the community, and equipment is a mere excuse to enhance interaction between FabLab users. We can therefore say that the FabLab function as a "tiers-lieu" or "third" [49], that is, a different space from home or workplace that fosters remote informal relationships and fast prototyping capabilities, coupled with the opening to other organizations. It allows the development of germ activities for future business projects. As stated in the FabLab Charter, its policy of sharing resources and information is not incompatible with the possibility of developing business projects that will continue outside the FabLab. A FabLab offers a friendly community to develop prototypes before going to market, which succeeds in reducing an environment of exclusion and underdevelopment.

On the other hand, dedication to training is not simply a means of economic support for a FabLab, but also a means of knowledge transfer and bridging the digital gap. Documentation is a basic tool for disseminating knowledge and increasing cohesion in

the FabLab Network. Training activities and public processes of project documentation constitute a strong tool for improving the conditions of the communities in which FabLabs are established.

The FabLab movement, with its characteristics of openness and closeness to the public, is not exempt from criticism [50]. The FabLab can be seen in many different ways: from a mere bourgeois pastime or training space technology to the catalyst for a new industrial revolution, by enhancing a revival of the arts in combination with technology and science. From this perspective, the FabLab can be considered a "counter-context" [51]: a showcase for the confluence of different currents and theories. Its open, democratic, decentralized nature is not without risk and can attract people 3 with strong ideologies, distorting its essence of being an open and free-ideology place [51].

Today, the main criticism facing FabLabs involves the difference between their speech and the reality they face. Laboratories cannot escape the reality in which they are immersed, which can lead to severe contradictions. These contradictions include the search for a sustainable operation that is altered by the fact that local suppliers cannot compete with offerings from Asiatic companies to induce a strong technological consumerism; generation needs users—another form of consumerism with the kit concept emergence, which as a substitute for pure DIY is empty of content and the maker movement [52]. Another contradiction is the generation of prototypes as a mere excuse to gain skills, misrepresenting the fact of creating something useful as an end in itself, which also can be seen as mismanagement of resources [50]. Thus, some of the critics see a distance from the FabLab environment concept of critical making, which aims to "reduce the gap between physical and conceptual creative exploration" [53] and is divided into three phases: seeking information and relevant technologies, design and prototype development, and the last iterative process of reflection and prototype connection with the initial objective.

## 5. Conclusions

Currently, the cost reduction of technological components and the greater use of open tools give users unimaginable design and creation capabilities. The FabLab, born to bring digital manufacturing possibilities to the public, offers new opportunities to users and enhances the transmission of knowledge without gender or role distinctions. Its adaptability makes a FabLab the ideal environment to accommodate most situations, including lack of space or limited resources. Thus, we find FabLabs not only in industrial and educational environments, but also in public libraries and places far away from industrial or urban centers, thanks, for example, to mobile FabLabs or small local groups. The imagination and the abilities of its users, along with access to relatively simple materials such as self-replicating tools, a 3D printer or recycled materials, can lead to the creation of a FabLab anywhere in the world. The implantation of these laboratories has been beneficial for the development of communities, helping the popularization of technology among groups of users previously far from it, due to its complexity, increasing resources and population capacities and even reducing the gender gap that culturally accompanies the technical aspects.

Actually, a FabLab's essence is the community that composes it: a community of knowledge exchange, of joint learning, of evolution and development and of innovation, in which complex interaction processes develop naturally, allowing a flow of information of incalculable value. These processes include not only user-to-user proximity-based interactions, but also distance interactions, thanks to the international network or, even, to interactions with companies and startups. Collaboration with other communities, such as makers or co-working spaces, and between FabLabs and small companies, entrepreneurs and universities is frequent.

Despite rapid expansion and the existence of common standards, the relative novelty of the FabLab movement and its particular diversity makes it difficult to identify the main characteristics of these laboratories, generating a strong information gap in the scientific literature to date. In order to understand this approach and to provide a basis for further

studies, the authors developed the "FabLab Global Survey" instrument whose results are presented in this study in their physical, social and economic aspects, with special emphasis on the characteristics related to education, project documentation and entrepreneurship that define the FabLab movement.

The results confirm that, despite having similar characteristics, the wide variety of existing FabLabs makes it difficult to establish broad common characteristic patterns for classification. The number of FabLabs is higher every day, showing a significant increase year by year. It is easy to see how every month there are more laboratories registered in fablabs.io, which constitutes an informal list of existing FabLabs. There we found types from modest laboratories with little equipment to spaces with high budgets and the potential for project development. FabLabs share the use of specific basic technologies—3D printers, laser cutters and CNC machines—as general characteristics, but the wide variety of environments implies the typological diversity of their main users and the fundamental themes of the projects developed. The richness of these labs lies in this variety of environments and users, given that together with their ability to adapt, they are fundamental elements to ensure the popularization of digital skills in their communities. As has been shown, the interaction of the manufacturing laboratories and their communities is beneficial not only for their cultural and technological evolution, but also for their industrial and economic progress. Together with the rapid prototyping capacity offered by FabLabs, the empowerment of the user community fosters the development of innovative projects in which industries and small and medium-sized enterprises can be involved. In this way, the data show that a large number of FabLab participants in the "FabLab Global Survey" maintain relationships with a high innovative component with companies and organizations in their community, making clear the relevance of these environments as catalysts of economic activity and generators of wealth.

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*Article*

# Business Model Disclosure in the Reporting of Public Companies—An Empirical Study

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**Abstract:** Traditional financial reporting primarily discloses information about assets, equity, liabilities and financial situation of an enterprise. Simultaneously, socio-economic changes are prompting enterprises to implement business reporting towards disclosing activities for sustainable development and information about the business model in non-financial reporting. Shaping of an enterprise's business model is carried out in the spirit of sustainable development, which is beginning to dominate the strategies of many large enterprises. At the same time, the concept of the business model and its reporting have still not been characterized in detail or standardized, which limits transparency and the usefulness of information. These phenomena provided an incentive to undertake the research on the business model reporting. The overall goal of this study is to expand research on disclosures about the business model in the corporate reporting of Polish listed companies, as well as to indicate the degree and directions of development of this subject against the background of the accounting system. The study also addresses the epistemological goal by entering the discussion on reporting about the business model. The research uses the financial statement content analysis method and the statistical method (Spearman's correlation). The scope of disclosures about the business model are examined in integrated reports, consolidated reports, management reports, non-financial data reports and CSR reports of Polish companies listed on the stock market. This information is examined according to its four main components: inputs, business activities, outputs and outcomes. The correlation between the number of audited disclosures and selected economic and similar parameters characterizing enterprises (total assets, performance, board, EBITda, equity and liabilities) is also studied. The research reveals that entities preparing an integrated report demonstrate a greater number of disclosures of business model components in selected economic categories than entities that do not prepare such a report. Thus, the companies preparing an integrated report follow the mainstream of stakeholder theory, opting for a more descriptive reporting approach, accessible to a wider group of users. Moreover, business model information is often reported in a highly random manner. Simultaneously, descriptive forms of business model disclosure prevail over numerical ones, although not to a large degree. The findings also confirm that there is a positive correlation between the detail of disclosures about the business model and selected economic parameters of an enterprise (the strongest with total assets, board and EBITda). Thus, it becomes possible to recognize that large enterprises with a strong and stable structure of assets follow specific, more detailed reporting patterns aimed at sustainable development of reporting. At the same time, they are more likely to expand the scope of disclosures compared to smaller enterprises. This investigation responds to the interest of enterprises and other stakeholders in the reporting spectrum by increasing market information efficiency and transparency. Findings can also be used by standards setters, while providing new rules and regulations.

**Keywords:** business model; disclosure; non-financial information; economic parameter; reporting; accounting

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## 1. Introduction

The primary objective of business reporting is to disclose information about the economic results of business activity. An equally important objective is to communicate about the broadly understood activity of enterprises, also in the field of sustainable development. All this is carried out to meet the increasingly sophisticated but also selective needs of an increasing group of enterprises' reporting stakeholders. According to the theory of legitimacy, an enterprise must take into account the requirements of a wider group of users, that is not only investors but also society in general. The scope of information requirements among stakeholders interested in such information is also growing. In this context, there are also changes in the perception of the company, especially its impact on the local economy, community, environment and sustainable development. From a position of one of many elements in the goods and services delivery process, enterprises are becoming significant organisms that may shape their environment. This assumption is in line with the theory of sustainable development. However, the relation also works in the opposite direction.

The guiding purpose of business reporting is to disclose companies' underlying business model [1] and its relations with other elements of various systems (economic, social, environmental and others). The business model (BM) represents the path taken by a company to create value [2]. Research on disclosures about the BM in reporting is justified because it contributes to the understanding of the process of creating value and of the company's implementation of sustainable development. The development of these disclosures results in increased diversity and simultaneously forces actions to improve their quality and usability. At the same time, the BM is a kind of tool for communicating with stakeholders, through which various pieces of information can be announced, reconciling the needs of the many interested groups that may affect the operation of the enterprise, which is in line with modern economic theories, including stakeholder theory [3] and legitimacy theory [4].

The presented topic is highly relevant given the global move towards increasing corporate responsibility. The public is interested in holding businesses accountable, an aspect which the article relates to by focusing on reporting related to business models as a way of communicating business issues and value to all stakeholders. The significance of the study is to focus on showing the tightening relationship between the BM concept and accounting, the specificity of its reflection in company reports and to highlight aspects of its use for creating a company's image. Information on the BM has been examined according to its four main components: inputs, business activities, outputs and outcomes.

Another important research gap is the lack of in-depth research on the disclosure of BM elements, especially in European countries. Poland seems to be a relevant example since it is classified as early adopter country, being on the initial step of the development of integrated reporting, business model reporting and, generally speaking, non-financial reporting. We therefore enrich the emerging literature on integrated reporting by offering empirical evidence on the disclosures about the BM in Polish companies. In order to fill the above gap, this study aims to investigate the number of disclosures regarding companies' BM and the relationships with variables characterizing enterprises such as total assets, performance, board, earnings before interest and taxes (EBITda), equity and liabilities. For this purpose, analysis was conducted of integrated reports, consolidated reports, management reports, non-financial data reports and CSR reports for 2017–2019 from companies in the energy, fuel, mining, telecommunications and banking sectors listed on the Polish stock market (WIG 20).

The following research methods were used in the study: literature studies, critical information analysis, statistical methods (descriptive statistics, Spearman's rank correlation coefficient), deduction and synthesis.

The work contributes to the development of the theory and practice of the field of finance by identifying and filling the gap in information about the components of the business model in different reports and the relationship of the BM with other dimensions

characterizing an enterprise. As a result, the authors fill an important research gap relating to the debate around the concept of the BM in the area of accounting, especially in the area of non-financial and integrated reporting, which are the pillars of sustainable development reporting. For scholars, this study provides an opportunity to further analyse the trends in integrated thinking and its role in business strategies that combine sustainability, governance and the BM. This study contributes also to the literature by enhancing the understanding of business model reporting practices.

The study also makes a significant contribution to

- A better understanding of the BM relationship with the values that characterize an enterprise from the point of view of sustainable development throughout the entire value chain of the company;
- Laying the foundations for further research on the development of new business models supporting the sustainable development of enterprises.

The study contributes to the discussion on the amount of information published by enterprises. The authors argue that information about the BM is needed, and a greater amount of information published increases research opportunities and shapes good corporate reporting habits, including in terms of environmental protection, for both employees and other market participants. Nowadays, enterprises should disclose how sustainability practices have been integrated into their business strategy, in particular how value has been created over time. Research into different areas of reporting contributes to popularizing the transparency of reporting information, as well as increasing activities promoting sustainable development among enterprises. Companies should offer a comprehensive picture of the social, environmental and economic issues which influence the sustainability of business models. In the literature on understanding a stakeholder's information needs about sustainability issues, an important element is integrated reporting. This should also be reflected in the legal regulations regarding integrated reporting. A valid framework may be particularly beneficial for improving the quality of inherently subjective information such as information about the business model. These activities can increase the potential of integrated reporting in promoting positive changes in communicating about the business model as well as about sustainability [5]. At the same time, according to the authors' knowledge, no one has conducted the research presented in this study before.

The above justifies that presented findings have strong implications for the development of accounting literature and practice, as well as for the development of integrated business reports for transparent demonstration of business intentions and practice.

The remainder of this paper is organized as follows. The section on the theoretical background explains the evolution of the business model concept, presents the basic definitions of the business model, and provides key business model components. The next part of this section relates to analogous research on the business model as reflected in corporate reporting for the development of hypotheses. The following section on research design describes the research sample and data selection process. It defines the research method and main variables. The subsequent section presents the empirical outcomes, while the discussion section presents an analysis of the results with reference to the outcomes of other studies. The last section includes research limitations, a general summary and directions for future research.

## 2. Theoretical Framework and Hypotheses Development

### *2.1. Business Model and Corporate Reporting*

The concept of a business model is evolving. Today, it is widely used as a description of activities (including strategic activities) of an entity through elements such as value creation, competitive advantage and firm performance [6,7]. The evolution of the BM is also visible in its definition layer [8–12].

The BM strives to holistically present an enterprise's operations, illustrating the process of creating value and its delivery to customers, as well as capturing this value for the enterprise [13]. The BM is therefore of particular importance in supporting balanced and

sustainable development as it helps describe, analyse, manage and communicate a firm's proposition regarding sustainable value for customers and all stakeholders, how it creates and delivers this value, and how it creates economic value by preserving or regenerating natural, social and economic capital beyond its organizational boundaries [14]. Companies at various stages of development should build and adapt their BMs in order to maintain their ability to create value for stakeholders [15].

The BM consists of specific components that may be presented in various classifications [16,17]. These components, by creating a natural network of related BM elements, enable it to be structured, but most importantly, they often depict the path and tools for creating or losing value in the course of business operations. One such classification, indicated by IIRC, points to four main elements of BM: key inputs (1), key activities (2), outputs (3) and outcomes (4). The enterprise, through the use of key inputs (1), capital and other resources), across its key business activities (2), transforms inputs into outputs (3), key products and services; by-products, emissions, and others) to finally obtain internal and external positive and negative outcomes (4). Outcomes (reputation, employee morale, revenue, cash flows, environmental effects, customer satisfaction, reduction of value, and others), in the short-, medium-, and long-term, generate or decrease value for the organization and for its closer and further environment. Therefore, the BM concept has a financial dimension [18], which directs the research process towards accounting [19], although some researchers question whether there is a need to report on the BM at all [6].

Economic information is largely provided by the accounting system. Increased interest in business models is therefore a determinant as well as simultaneously a result of the development of accounting and its adjustment to changing reporting expectations.

The need for enterprises to report certain additional information to external stakeholders is still not fully theoretically justified [20]. However, the need to extend traditional financial statements with additional information is firmly embedded in theories trying to explain management board decisions in the field of information policy, including in particular stakeholder theory, institutional theory and legitimacy theory. The stakeholder theory, promoted by E. Freeman [21], states that an important element of shaping the relationship of a company with its stakeholders is informing them effectively about the achievements in all areas of the business, as all stakeholders claim the right to decide about the company's matters. All stakeholders also have the right to be informed about how the company affects them, even if they cannot directly influence its business. As result, in this theory, the dominant goal of an enterprise in the form of profit maximization is supplemented with the co-dominant goal of maximizing the social welfare and satisfaction of various stakeholder groups. In this context, it is necessary to maintain balanced relations between various groups of external stakeholders [21] (p. 274).

Essentially, stakeholder theory accepts that different stakeholder groups will have different views about how an organisation should conduct its operations; there will be various social contracts 'negotiated' with different stakeholder groups, rather than one contract with society in general. Whilst implied within legitimacy theory, stakeholder theory explicitly refers to issues of stakeholder power and how a stakeholder's relative power impacts their ability to 'coerce' the organisation into complying with the stakeholder's expectations. According to the stakeholder theory, managers need to balance and mitigate conflicts of interest between shareholders and other stakeholders, which results in the necessity to extend financial disclosure with material nonfinancial information, includiincludeng the BM [3]. However, it is also important to maintain a balance and a uniform disclosure line in order to avoid information chaos and maintain transparency. As a result, it can be concluded that stakeholder theory underlies the development of reporting, including about the BM.

According to legitimacy theory, society expects an organization to develop its activities in a manner consistent with its beliefs. The enterprise must therefore also take into account the demands of society, not just investors, as well as undertake various kinds of activities aimed at social acceptance of its implemented mission, strategy and operational activities.

According to this theory, institutions with high social and environmental commitment should be more likely to disclose information on these topics [22].

Institutional theory is important in research on the development of corporate reporting. In relation to this theory [23], organizations engage with a comprehensive system of political, financial, educational, cultural and economic institutions that exert institutional pressure on them. This theory treats the enterprise as an open system that changes in response to social and institutional processes taking place in its environment, legitimizing its actions [22]. Its relationship with information disclosure is that it shows how organizations perceive and respond to changing social and institutional pressures and expectations. In response to the increase in these expectations, the reporting area, including the BM and sustainable development, is also developing. Institutional theory strengthens the system of values on which the assumptions of the theory of legitimacy are based, and the stakeholder theory leads to changes in the system of these values. Legitimacy theory looks at society as a whole, whereas stakeholder theory recognizes that some groups within society are more powerful than others. We posit that the mentioned theories, which are of value in studies into BM reporting, focus upon distinct perspectives of the same issue. The overarching goal of reporting in the context of stakeholder theory and institutional theory is to indicate how successful a firm's business model is [9]. While the combination of elements of these three theories in research on BM reporting emphasizes the importance of this area. Conflicts and problems appear on the line—goals and intentions of the enterprise—needs of stakeholders, compliance with legal regulations and standards, and the occurring tendencies to increase disclosures about the enterprise.

Communication by enterprises to stakeholders contains certain information about the enterprise. Examples include the following: environmental aspects (CSR), corporate governance, and risk management [24–30], and many other non-financial areas, inter alia intangible assets and intellectual capital [13]. The narrow approach to reporting drew attention to the dynamics of processes and the ability of entities to integrate, create, and transform internal and external competences to respond to the changing environment [2]. These in turn reflect in the design of BM and its reporting.

Despite the influence of action-intentionalism, the usefulness of reporting in the process of communicating about the BM is emphasized by many researchers and institutions [9,16]. Additionally, there is a mention of the term "Business Model Disclosure", which aims to provide information on a BM that is not supplied through traditional financial reports [31].

The development of the reporting spectrum has resulted in initiatives that attempt to integrate it to achieve consistency while maintaining the principle of true and fair views [32]. On 9 December 2013, the International Integrated Reporting Council issued recommendations on the Integrated Reporting Framework, which was the first international attempt to consolidate business reporting [10]. From this perspective, integrated reporting provides "a process founded on integrated thinking that results in a periodic integrated report by an organization about value creation over time and related communications" [10]. It takes the form of an integrated report which is "concise communication about how an organization's strategy, governance, performance and prospects, in the context of its external environment, lead to the creation of value in the short, medium and long term" [10]. The initiators' intention to clearly separate such a report was to focus on many aspects (financial, ecological, human) originally presented in multiple reports accompanying financial reports, and to concentrate largely on non-financial information [33–36]. This may also be recognized as a reflection of following the mainstream of stakeholder theory and increasing its role in shaping corporate reporting. Integrated reporting that combines financial and non-financial information into one document is a significant evolutionary step towards creating an advanced sustainability reporting tool [37].

As a result of the development of integrated reporting, reporting is moving away from a traditional, synthetic system, supplemented only with selective verbal description, in the direction of extended information on the process of creating value. However, the premise of

integrated reporting is always to present companies' business models in a holistic way [1]. Given the considerable diversity of practical approaches, the authors suggest considering integrated reporting from a broader perspective, which covers various reports (financial, CSR, non-financial and integrated reports).

Consequently, the International Accounting Standards Board (IASB) and International Integrated Reporting Council (IIRC) indicate that communication about the BM is one of the stages of reporting evolution, which resulted, for instance, in the integrated report [31]. Simultaneously, due to the lack of specific guidelines, BM disclosures is "inconsistent, incomparable, and incomplete" and takes the form of a boilerplate; rather generalised [16,38].

Approximately only 40% of reporting on the BM provided in-depth and detailed information about the issue, and only 8% of BM disclosures combined these data with reporting on the strategy and business risks [16]. Moreover, the current state of research on the BM is not advanced from the perspective of implementing the information and the reporting function of accounting. Studies on business models are not extensive [1,39], while researchers emphasise the need to strengthen these studies, both in the epistemological and empirical layers [40,41]. This is directly related to the fact that enterprises today often create value in a complex manner that cannot be demonstrated solely on the basis of traditional financial reporting based on assets or cash flows. Page's research [38] showed a high degree of generalisation of the presented disclosures of the BM. However, Lai et al. [31] obtained opposite results in European early adopters. These researchers revealed that the entities disclose the BM in a broad and detailed way (inputs, business activity, outputs and outcomes), including information about six different forms of capital presented in an extensive and balanced manner. Importantly, these studies showed a predominance of the descriptive nature of reporting, while the quantitative dimension was significantly limited. Malola and Maroun [42] show that companies with higher quality integrated reports are those that invest in complementing their integrated reports with a sustainability report and have their disclosures externally assured.

Bearing in mind the current, fragmentary research results of other researchers, the authors identified a research gap in the form of a lack of in-depth research on BM disclosures, particularly in European early adopter countries. This gap also focuses on the development of BM disclosure provided by listed companies and its relations with a specific set of components, as well as the observation of these relations' trends over a longer period of time. This seems to be especially interesting from the perspective of initial research on the relationship between BM and accounting.

### *2.2. Business Model Reporting in Selected Companies*

Given the short implementation period, it should be emphasized that empirical research into integrated reporting, particularly into BM disclosures in corporate reporting, is very rare [43,44]. It is difficult to clearly distinguish the sectors in which these studies dominate, but certain foundations and results can be taken from much broader environmental reporting, including CSR, which is strongly developed in energy, fuel, mining, high-technology and banking sector. The companies representing these sectors must meet the expectations of many different groups of stakeholders, in particular: society, local governments and communities, organizations and bodies for environmental protection, as well as the additional legal regulations and environmental requirements. They not only undertake numerous social and environmental activities but must also report on them. These activities are inseparable from the assumptions of stakeholder theory and legitimacy theory. They are also a way of building a positive image for the company within the society.

Few studies examine BM disclosures in mining entities. Evidence from the UK indicates that these companies present a selective and soft approach to sustainability in the context of mandatory disclosure about the BM. Researchers indicate that entities present the full value chain in the reporting process (mining operations, processing and sales), and there is a tendency to introduce their own indicators dedicated to the environmental dimension [45]. Each entity uses a different approach to disclose information [46],

which can be interpreted as a significant degree of individualisation of reporting processes being implemented.

The issues of environmental impact and relations with the local community as well as working conditions are discussed quite often. However, initiatives in other areas are overlooked. Topics such as the use of raw materials or information on waste are ignored or marginally presented; in turn, human rights, recruitment and training are only demonstrated in a descriptive way [47]. Perez and Sachez [46] indicated that the biggest entities in the mining industry produced more comprehensive and sophisticated reports. Additionally, research has confirmed the reluctance to disclose a wide spectrum of information beyond the particulars required by legal regulations [48,49]. Therefore, it can be considered that the quality and scope of disclosures are strongly determined by the applicable reporting standards, which underlines the important influence of institutional theory.

Further, research from the UK listed entities operating in high-technology industries, and their BM disclosures in the strategic report indicated that only a few companies use the BM to emphasize the process of creating and capturing value. Moreover, the BM is often not clearly distinguished and poorly illustrates the interactions among its components [50]. The scope of disclosed information in integrated reports may also be affected by the financial performance of entities [32]. Enterprises with lower financial performance tend to produce longer, more complex and less readable reports [51]. The purpose of such a behaviour may be to "window-dress" real causes and divert the attention of stakeholders towards soft discretionary disclosures [52].

The results of empirical research on integrated reports in Poland are also few and in the early stages of development. These reports are prepared by a few entities listed on the Warsaw Stock Exchange (in the years 2013–2016, there were only 12 entities and less than 30 reports) [53]. Despite these limitations, studies confirmed the descriptive nature of these reports and the predominance of presenting non-financial content over financial content. The BM in the reporting of Polish enterprises is not subject to explicit and broad distinction. Moreover, only a few enterprises used the boilerplate structure indicated by IIRC, although they tried to refer to almost all components of the BM, but in a non-uniform manner [54]. Despite this, many BM elements are disclosed. Moreover, the areas of disclosure are significantly random, and as a result, there is no clear combination of these components and no indication of the path of value creation [55]. Certainly, this limits the cognitive function that the BM should fulfil. The Polish enterprises focused on the following BM components: objectives and strategy, presentation of capital in accordance with the IIRC concept, products, labour-related matters, waste, and emissions and the results of operations which were reflected by disclosing the key performance indicators (KPIs) [54–56]. This subject underwent a minor transformation, as prior research indicated that the entities had focused on the presentation of objectives and strategies, although they did not include the subject of value creation, relations with customers or other stakeholders [57]. Reporting on capital as a component of the BM is also developing [54,56]. However, throughout these years, the incompleteness, inconsistency, the dispersive nature of the information presented and even misunderstanding the essence of the BM were still emphasized.

Based on the above-mentioned research, it should be noted that entities may experience trials and errors in the process of integrated reporting as it is a relatively new concept, and the process of full presentation of all elements of a BM can take several years to be fully developed [58]. Relying on institutional theory [23], it can be noticed that the reporting patterns of enterprises are adjusted to existing regulations, although the process is not clear. It should be noted, however, that the reason may be the level of detail of these regulations. This occurs in Poland, where the regulations on disclosure of the BM are very general. Garcia-Sánchez et al. [59] also described the impact of national cultural systems on integrated reporting, while Frías-Aceituno et al. [60] analysed the impact of legal systems on integrated reporting. Research carried out in South Africa provides empirical evidence for the impact of the regulatory environment on integrated reporting [61]. The gap between

current company reporting practices and integrated reporting framework requirements was also studied [61,62].

On the other hand, looking at this process from a broader perspective [63], organizations try to change management behaviour and disclose more information highlighting efforts to adhere to socially acceptable norms and values in order to change stakeholder views. External incentives applied to the perception of the principles of sustainable development cause organizations belonging to the same industry to follow the industry leader's reporting patterns so as to gain greater legitimacy from the public. Such practices favour the process of institutionalizing reporting practices, especially in sectors that are particularly socially vulnerable.

One can conclude that the above-described phenomena occur in companies that prepare integrated reports; however, it can also be inferred that the situation is much more complicated in companies that do not prepare such reports. Based on the assumptions of institutional theory, it can be assumed that more detailed legal regulations and additional reporting standards extend the reporting horizon. This also applies to the BM and its embedding in integrated reporting. The above justifies the advancement of the first research hypothesis:

**Hypothesis 1 (H1).** *It is assumed that enterprises that prepare integrated reports provide more detailed disclosures about their activities and business model compared to enterprises that do not prepare such reports.*

The BM is often depicted in graphic form [55,62]. Some authors believe that in order to present the holistic and multi-faceted dimensions of a BM, information about it must be conveyed through a story that can be expressed in various forms. The purpose of such a solution is, on the one hand, to legitimize various economic, social and environmental activities conducted by an enterprise, and at the same time, to satisfy the needs of a very diverse group of stakeholders. Many additional elements, covering company background, non-financial and forward-looking information, are largely reported in a narrative form [13]. Companies also use diagrams to illustrate their BM in a descriptive form and to distinguish how they create value. According to researchers, BM components are an indistinct factor in determining differences between business models, but when combined they present the path leading to value creation [64]. Perhaps the use of diagrams and illustrations, as well as their presentation in interactive form on websites is the reason why researchers indicate limited numbers of integrated reports [54]. The intention of the presented study was to compare the two groups of information: financial (numerical) and non-financial. With the aim of expanding the results of existing studies, the following hypothesis was advanced:

**Hypothesis 2 (H2).** *It is assumed that enterprises which use integrated reporting tend to disclose more descriptive information about selected non-financial components of their business model than financial (numerical) information.*

### *2.3. Reporting on Business Model and Economic Parameters of Enterprises*

The academic literature presents different studies on the relationship between disclosures and selected economic parameters of an enterprise. These studies do not relate specifically to disclosures about the BM but to the selected economic parameters as well as to many different characteristics (i.e., market attributes). Hence, they form a backdrop to our study. Ohlson [65] examined the differences in compliance of book values and profits between two groups of firms using the developed valuation model. More transparent disclosures increase the overall reliability of financial statements, which increases decision-making usability for investors. This view is in line with theoretical assumptions that suggest that higher quality disclosures resulting in higher information precision have a greater impact on share prices. Assuming that the errors in the measurement of book values cause the regression coefficients to be oriented towards zero, it can be expected that such coefficients decrease as the transparency of disclosures decrease. Verrecchia [66] shows that

the coefficient that measures the market's response to a disclosure is a growing function of the quality (precision) of disclosure. Clearer, and therefore higher quality, disclosures enable investors to better interpret the consequences of aggregated approaches. Research also suggests that investors find more detailed and transparent disclosures more useful in decision-making [65]. Jensen and Berg [67] examined country-based characteristics impacting the decisions of companies to publish integrated reports. Rivera-Arrubla et al. [68] analysed the influence of company-level determinants (i.e., GRI application level, publication of the report on the IIRC website and length of the report, industry and auditor type, external assurance of the report,) on disclosures in integrated reports.

Research carried out by Dratwińska-Kania [69] on a group of investment funds in Poland confirms the correlation between the level of transparency on the condition of the investment fund operations account and selected characteristic features for a selected group of funds (e.g., a change in the value of participation units). The literature indicates that profitable enterprises voluntarily show more detailed environmental disclosures so as to promote their activities [70,71]. The same applies to their BM. In turn, Cowen et al. [72] and Patten [73] found no relationship between profit and disclosed information, while Roberts [71] found links between disclosures of social and environmental data and good financial results, measured by return on capital.

Considering the taxonomy of BM components used in the literature, it was found that increasing disclosures about specific components increases the quality and development of reporting on the BM [31]. On this basis, we assume that larger, more developed companies reveal more details about their business model, also to fulfil legitimization processes. The parameters that characterize these enterprises are board members, total assets, equity, performance, EBITda and liabilities). To this end, another detailed hypothesis is advanced:

**Hypothesis 3 (H3).** *It is assumed that there are positive correlations between the amount of disclosed information about the business model and the results achieved for specific economic parameters that characterize the enterprise.*

The overall goal of the study is to expand research on disclosures about the BM in corporate reporting, as well as to indicate the degree and directions of development of this subject against the background of the accounting system.

The detailed aim is to investigate the number of disclosures on selected components of the BM, as well as the division of this information into financial (numerical) and non-financial (descriptive) form. The second detailed aim is to examine the correlation between the business model's components and selected company's parameters including total assets, performance, board, earnings before interest and taxes (EBITda), equity and liabilities.

## 3. Materials and Methods

To attain the indicated goals and verify the hypotheses, the study covered financial statements and similar reports for 2017, 2018 and 2019 (96 observations), issued by 32 randomly selected enterprises from 5 selected industries (listed on the Warsaw Stock Exchange, on the following indices: WIG-Energy, WIG-Fuels, WIG-Mining, WIG-Telecommunications and WIG-Banks). The types of reports covered by the study are presented in Table 1.

Within the group of 32 companies, only 9 issued an integrated report. It should be emphasized that the relatively small research sample is conditioned by the small number of enterprises that currently publish information about their BM. Information on the BM is derived from different reports, as there is no single unified reporting concept regarding this issue; however, authors tried to focus on integrated reports.

**Table 1.** Types of reports examined in the field of disclosures about the business model in the companies studied.

| Industry | Enterprise Name | Type of Report |
|---|---|---|
| Energetics | ENEA | CR, MR, N-FR |
| Energetics | Tauron | IR, MR |
| Energetics | Kogeneracja | CR, MR |
| Energetics | Zepak | CR, MR |
| Energetics | Polenergia | CR, MR, CSR |
| Energetics | PGE | IR, CR, MR |
| Energetics | Energa | CR, MR, CSR |
| Energetics | MLSystem | CR, MR |
| Energetics | Będzin | CR, MR |
| Mining | Bogdanka | IR, CR, MR |
| Mining | JSW | CR, MR, N-FR |
| Mining | KGHM | IR, CR, MR, N-FR |
| Fuel | Lotos | IR, CR, MR |
| Fuel | Orlen | IR, CR, MR |
| Fuel | PGNIG | CR, MR, N-FR |
| Fuel | SKOTAN | CR, MR, N-FR |
| Fuel | UNIMOT | CR, MR |
| Telecommunications | Orange | IR, CR |
| Telecommunications | Netia | CR, N-FR |
| Telecommunications | Cyfrowy Polsat | MR, N-FR |
| Banks | INGBSK | IR, CR, MR, N-FR |
| Banks | Getin Holding | CR, MR |
| Banks | Getin Noble | CR, MR, N-FR |
| Banks | BOS | CR, MR, CSR |
| Banks | Alior | CR, MR, N-FR |
| Banks | Millenium | CR, MR, N-FR |

Explanation: Integrated Report (IR); Consolidated report (CR); Management report (MR); Non-financial data report (N-FR); Corporate Social Responsibility Report (CSR).

This study complements and extends the research carried out by Dratwińska-Kania et al. [74]. With the aim of selecting a representation of IR adopters, the research sample was gathered from the official Integrated Reporting Example Database, which includes companies from the Polish "IR Reporters", the WIG Index 30 (30 companies) and the Respect Index (31 companies).

The industry comparison made by the authors showed that the largest number of companies that prepare integrated reports belong to the aforementioned five industry sectors: WIG-Energy, WIG-Fuels, WIG-Mining, WIG-Telecommunications and WIG-Banks. In addition, the authors chose the sectors WIG-Energy, WIG-Fuels and WIG-Mining because environment–enterprise relationships are visible in every section of the value chain, which is why these companies have particularly strongly developed reporting on corporate social responsibility (CSR). Energy, fuel and mining companies are required to conduct sustainable activities aimed at maintaining the sustainability of land, air and water resources, meeting the expectations of various stakeholder groups. Enterprises from these industries perform tasks in line with many environmental regulations, consisting of the implementation of activities for the benefit of society and the environment, financed from own resources. By preparing CSR environmental reports and engaging the media, such firms help to raise social awareness, and thus, such activities are inseparable from the assumptions of stakeholder theory. The use of CSR reporting on the BM in such companies leads to believe that the business models in these companies will be more sophisticated and advanced, which enhances the credibility of the research results obtained.

Enterprises from the telecommunications industry were included in the research sample, as the transformations of the BM in this sector are particularly profound due to the rapid development of new technologies and high competitiveness among service providers. These enterprises need to create appropriate security systems related to cyberspace. An

appropriate BM enables understanding of business logic and the infrastructure necessary to operationalize this concept [41].

Banks are a type of organization, which, due to the diversification of the research group, can make the results more attractive and enriched. Banks are public trust institutions and are subject to specific regulatory requirements and consequently the detail and quality of reporting in such institutions is very high and more evolved than in other sectors. The findings presented by Mechelli et al. [75] imply that companies belonging to the financial services sector, due to their high public accountability and strong interaction with customers, present the most strategy-related disclosure. Results provided by Zijl et al. [76] also confirm that banks provide the most information on their strategy and that they dominate in the ranking in terms of providing social strategy and economic strategy disclosure. However, the degree of environmental disclosure was a little lower, which is understandable given these companies' specialization. To counter this, banks may inform stakeholders about funding clean energy projects [76], their use of natural resources or other ecological activities. On the other hand, studies by Ungerer [77] and Sukhari and De Villiers [78] showed that companies from the energy and mining sectors made more disclosure about strategy than banks. Moreover, results presented by Mohammad [79] demonstrate that banks provide little holistic, integrated information on the economic, environmental and social aspects of business without this being linked to financial information. Therefore, it can be concluded that banks fulfil the assumptions of the stakeholder theory, even though they selectively pursue reporting objectives.

The studied relationship between the amount of information about the BM disclosed as part of the adopted components and selected economic parameters comprised two levels of analysis: performing a manual content analysis and a multivariate statistical analysis. The study consisted of gathering information disclosed by selected enterprises under the four main components of the BM. For this purpose, the disclosure map proposed by CIMA and IIRC [7,13] was used, according to which the BM consists of 4 components:

1. Inputs, which include the following capitals: financial, manufactured, human, intellectual, natural, social and relationship.
2. Business activities, which include such categories as: planning, design, production, training, research and development, innovation and relationship management.
3. Outputs (output effects), including key products, key services, waste and other by-products.
4. Outcomes, including such categories as: customer satisfaction, profit/loss, shareholder return, asset consumption, employment creation, employee development and commitment, improvement of living standards, environmental impact, licenses/certificates and contribution to the local economy.

As part of the indicated components, 26 detailed disclosures were identified in 2017, 2018 and 2019. In the first stage of the analysis, the total number of disclosures (financial and non-financial) about the BM for each company was examined. The descriptive form of the specified disclosures was also studied in this stage of the research. For each of the selected descriptive parameters, the following points were given: 1, when the information was disclosed, and 0, when there were no such disclosures. As a result, the maximum number of points that could be awarded for an enterprise was 52 for one year (26 descriptive disclosures and 26 financial disclosures) and 156 in total for all the years analysed. The research was based on content analysis, an empirically important research tool in the field of social and environmental reporting, intellectual capital reporting and integrated reporting [80,81].

The purpose of this stage was to compare the disclosures of companies that prepare a non-financial report and those that do not. The second stage of the study was to collect information on individual components of the BM in total values and to separate out only the financial information. The purpose of this part of the research, apart from presenting disclosures about the BM, was to compare the published disclosures about financial and non-financial information.

As part of the study on the interdependence of specific BM components, the correlation between the sum of disclosures about the BM in selected components for the studied enterprises and selected economic parameters achieved by these entities for 2017, 2018 and 2019 were examined. The analysed economic parameters included board (number of members), total assets, equity, performance, EBITda and liabilities.

The board has greater motivation to increase the value of an enterprise because it increases the value of the assets they manage and allows them to achieve management goals. Donnelly and Mulcahy [82] reported clear evidence that voluntary disclosure increases with the number of non-executive directors on the board. Firms that have a non-executive chairman make greater voluntary disclosures than other firms. Samaha, Khlif and Hussainey [83] came to a similar conclusion in their research and found that board size has a significant positive effect on voluntary disclosure. The presence of a larger number of board members who take care of the interests of various stakeholder groups should stimulate an increase in the disclosure of information. This is in line with stakeholder theory that requires a higher level of disclosure, indicating the compliance of the objectives of various stakeholders. Such an assumption is consistent with research by Manes-Rossi [84], who examined the presence of external members on boards. The effect of board characteristics on integrated reporting quality according to the agency theory approach was researched by Vitolla et al. [85]. The findings, based on a sample of 134 international firms, show a positive relationship between the size, independence, diversity and activity of a board, and the quality of integrated reporting. Gandía [86] highlights how a board made up of a larger number of members favours the effectiveness and efficiency of such functions, consequently increasing both the level of transparency of the company and the disclosure of information by top management.

However, a few researchers found an inverse relationship [87,88]. Empirical findings from Pearson correlation analysis show that there is a negative correlation between board size (proxied as the number of board members) and the level of corporate environmental disclosure among the selected firms [87].

Firm size is considered as an important factor to determine the levels of disclosures [89]. There is a correlation between the size of the enterprise and the scope of its disclosures. This is also confirmed by agency theory, which suggests that "big firms have higher agency costs than small firms". To reduce this agency cost, large firms adopt more extensive and comprehensive disclosures [90]. The size of an enterprise can be measured by the size of assets (total assets) as well as equity. Performance and EBITda are measures of assessing an enterprise's profitability. It is assumed that profitable enterprises have an incentive to present themselves in a better light and in a more detailed manner than less profitable ones in order to raise capital on the best available terms.

Enterprises with a high level of liabilities have increased disclosure needs to meet the security of lenders and confirm their ability to generate further debt.

Statistical correlation analysis in the presented study was based on Spearman's. The arguments for using this coefficient were the small sample size (32 companies) and the fact that qualitative and quantitative data were compared. As the data are cross-sectional, it is possible to unambiguously organize them from the smallest to the largest and assign ranks. In the case of two or more identical values, the standard tied ranks are used. Notably, for the analysis tool adopted, the study does not analyse curvilinear dependencies which would require a coefficient that takes into account the lack of monotonicity of the variables [91], pp. 742–746.

Nevertheless, in addition to increasing the reliability of the research results, it was examined whether the data on reporting disclosures were normally distributed. The Shapiro–Wilk test appropriate for small samples (n = 32) was used.

The conducted research shows that the distribution of disclosure data does not have a distribution close to the normal distribution. The use of the Spearman's rank method to test the strength of the relationship between the number of disclosures and other reporting data is therefore justified.

The significance coefficient for the examined variables was set to $p = 0.05$, and the critical area was determined in the form: $<-1, -0.3493>$ or $<0.3493, 1>$.

The basic research limitations include:

- Conducting the survey on a sample of 32 enterprises;
- The short period of reported data (3 years);
- Focusing on one country;
- The audit is based on subjective information that companies publish about themselves and that is not subject to audit by a statutory auditor.

Future research on an enlarged sample of companies from other EU countries may provide valuable information on the level of disclosure on the BM and regulatory challenges required to meet stakeholder expectations. Research extended by subsequent years of disclosures about the BM can provide information about changes in the studied patterns over time.

## 4. Results

Research on the number of disclosures about BM in surveyed companies indicate that the enterprises that prepared an integrated report (enterprises in colour in the following Table 2) are characterized by a greater number of disclosures about the BM than those that do not prepare such report.

Table 2 shows that the total number of disclosures for enterprises preparing the integrated report in 2019, 2018 and 2017 was above 70 points, with the exception of Lotos (67–68 disclosures recorded within the surveyed period), mBank (47 disclosures in each surveyed year) and INGBSK (45, 44, 44, respectively). Banks do not dominate this area of reporting. The total numbers of BM disclosures for banks are usually lower than for enterprises from the non-financial sector. Moreover, in the group of enterprises not compiling an integrated report, the number of disclosures about the BM is usually smaller, except Netia and Cyfrowy Polsat, which are the only companies from this group that exceeded 70 disclosures.

The differences in the number of disclosures about the BM in these two groups of enterprises apply to all analysed components (inputs, business activities, outputs, outcomes) to a similar degree. In addition, during the content analysis of reports in terms of disclosures about the BM, it was found that the description of the BM of enterprises preparing the integrated report is more comprehensive and clearer. The reverse relationship was also true; the information on the BM of the enterprises that did not prepare an integrated report often had to be found in other reports. The group of enterprises that did not prepare an integrated report is also characterized by the fact that some components of the BM were not disclosed in individual cases (in companies: ENEA, Kogeneracja, or Polenergia, BHW).

The entire research sample is set apart by the fact that the information highlighted in the components of the BM was approximately the same in 2017, 2018 and 2019. This is reflected in the scoring of individual components (Table 2).

The data presented in the four sections of the main components (inputs, business activities, outputs, outcomes) are presented in two reporting dimensions. The first concerns the financial and non-financial dimensions (e.g., inputs), the second concerns disclosures in the financial dimension only (e.g., inputs—only financial information).

To sum up the disclosures about the BM, it should be noted that there are many of these disclosures and that most of the analysed enterprises generate elaborated information about the BM but in many different parts of reports. It was also found that banks disclose the least detailed information about their BM from among the companies in the group studied.

The next stage of the study was an in-depth analysis of the content and substance of detailed elements of BM components for all enterprises surveyed in an integrated manner as well as separate information on financial (numerical) disclosures (Table 3).

**Table 2.** Number of disclosures about the business model in economic categories in surveyed companies. [1]

| Company | Inputs | | | Inputs—Only Financial Information | | | Business Activities | | | Business Activities—Only Financial Information | | | Outputs | | | Outputs—Only Financial Information | | | Outcomes | | | Outcomes—Only Financial Information | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 |
| ENEA | 7 | 9 | 8 | 2 | 3 | 3 | 9 | 9 | 10 | 3 | 3 | 4 | 6 | 6 | 6 | 2 | 2 | 2 | 19 | 19 | 19 | 9 | 9 | 9 | 57 | 60 | 61 |
| TAURON | 11 | 11 | 11 | 6 | 6 | 6 | 12 | 12 | 12 | 6 | 6 | 6 | 8 | 8 | 8 | 4 | 4 | 4 | 20 | 19 | 19 | 10 | 9 | 9 | 77 | 75 | 75 |
| KOGENERACJA | 8 | 4 | 4 | 3 | 2 | 2 | 12 | 6 | 6 | 6 | 1 | 1 | 7 | 3 | 3 | 3 | 1 | 1 | 18 | 7 | 7 | 8 | 2 | 2 | 65 | 26 | 26 |
| ZEPAK | 11 | 9 | 9 | 6 | 5 | 5 | 11 | 12 | 10 | 5 | 6 | 5 | 6 | 6 | 6 | 2 | 2 | 2 | 18 | 14 | 14 | 8 | 6 | 6 | 67 | 60 | 57 |
| POLENERGIA | 10 | 11 | 11 | 5 | 6 | 6 | 10 | 11 | 11 | 5 | 5 | 5 | 1 | 1 | 1 | 0 | 0 | 0 | 5 | 2 | 2 | 2 | 0 | 0 | 38 | 36 | 36 |
| PGE | 11 | 11 | 11 | 6 | 6 | 6 | 12 | 12 | 12 | 6 | 6 | 6 | 8 | 8 | 8 | 4 | 4 | 4 | 20 | 20 | 20 | 10 | 10 | 10 | 77 | 77 | 77 |
| ENERGA | 9 | 9 | 9 | 4 | 4 | 4 | 12 | 12 | 12 | 6 | 6 | 6 | 8 | 8 | 8 | 4 | 4 | 4 | 19 | 18 | 18 | 9 | 8 | 8 | 71 | 69 | 69 |
| ML SYSTEM | 10 | 9 | 9 | 4 | 4 | 4 | 12 | 12 | 12 | 6 | 6 | 6 | 4 | 4 | 4 | 2 | 2 | 2 | 18 | 18 | 18 | 9 | 9 | 9 | 65 | 64 | 64 |
| BĘDZIN | 8 | 8 | 8 | 3 | 3 | 3 | 8 | 6 | 6 | 3 | 1 | 1 | 6 | 5 | 5 | 2 | 2 | 2 | 14 | 11 | 11 | 6 | 3 | 3 | 50 | 39 | 39 |
| BOGDANKA | 11 | 11 | 11 | 6 | 6 | 6 | 12 | 12 | 12 | 6 | 6 | 6 | 8 | 8 | 8 | 4 | 4 | 4 | 20 | 20 | 20 | 10 | 10 | 10 | 77 | 77 | 77 |
| JSW | 11 | 11 | 11 | 6 | 6 | 6 | 12 | 12 | 12 | 6 | 6 | 6 | 8 | 8 | 8 | 4 | 4 | 4 | 20 | 20 | 20 | 10 | 10 | 10 | 77 | 77 | 77 |
| KGHM | 11 | 11 | 11 | 6 | 6 | 6 | 12 | 12 | 12 | 6 | 6 | 6 | 8 | 8 | 8 | 4 | 4 | 4 | 18 | 19 | 19 | 8 | 9 | 9 | 73 | 75 | 75 |
| LOTOS | 9 | 8 | 8 | 3 | 2 | 2 | 12 | 12 | 12 | 6 | 6 | 6 | 6 | 8 | 8 | 2 | 4 | 4 | 19 | 19 | 19 | 10 | 9 | 9 | 67 | 68 | 68 |
| ORLEN | 11 | 11 | 11 | 6 | 6 | 6 | 12 | 12 | 12 | 6 | 6 | 6 | 8 | 8 | 8 | 4 | 4 | 4 | 20 | 20 | 20 | 10 | 10 | 10 | 77 | 77 | 77 |
| PGNIG | 11 | 11 | 11 | 6 | 6 | 6 | 12 | 12 | 12 | 6 | 6 | 6 | 8 | 8 | 8 | 4 | 4 | 4 | 20 | 20 | 20 | 10 | 10 | 10 | 77 | 77 | 77 |
| SKOTAN | 6 | 6 | 6 | 3 | 3 | 3 | 6 | 6 | 6 | 2 | 2 | 2 | 4 | 4 | 4 | 2 | 2 | 2 | 12 | 12 | 12 | 4 | 4 | 4 | 39 | 39 | 39 |
| UNIMOT | 5 | 5 | 5 | 2 | 2 | 2 | 8 | 8 | 8 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 2 | 14 | 14 | 14 | 7 | 7 | 7 | 46 | 46 | 46 |
| ORANGE | 11 | 11 | 11 | 6 | 6 | 6 | 12 | 12 | 12 | 6 | 6 | 6 | 8 | 8 | 8 | 4 | 4 | 4 | 20 | 20 | 20 | 10 | 10 | 10 | 77 | 77 | 77 |
| NETIA | 11 | 11 | 11 | 6 | 6 | 6 | 6 | 8 | 9 | 2 | 2 | 3 | 6 | 6 | 6 | 2 | 2 | 2 | 14 | 14 | 14 | 4 | 4 | 4 | 51 | 53 | 55 |
| CYFR.POLSAT | 10 | 11 | 11 | 5 | 6 | 6 | 12 | 12 | 12 | 6 | 6 | 6 | 8 | 8 | 8 | 4 | 4 | 4 | 20 | 20 | 20 | 10 | 10 | 10 | 75 | 77 | 77 |
| INGBSK | 8 | 8 | 8 | 3 | 2 | 2 | 8 | 8 | 8 | 2 | 2 | 2 | 5 | 5 | 5 | 2 | 2 | 2 | 13 | 13 | 13 | 4 | 4 | 4 | 45 | 44 | 44 |
| GETIN HOLDING | 7 | 7 | 5 | 1 | 1 | 1 | 7 | 7 | 7 | 1 | 1 | 1 | 5 | 5 | 5 | 2 | 2 | 2 | 10 | 10 | 10 | 1 | 1 | 1 | 34 | 34 | 32 |
| GETIN NOBLE | 5 | 5 | 5 | 1 | 1 | 1 | 7 | 7 | 7 | 1 | 1 | 1 | 5 | 5 | 5 | 2 | 2 | 2 | 9 | 9 | 9 | 2 | 2 | 2 | 32 | 32 | 32 |
| BOS | 8 | 7 | 7 | 2 | 2 | 2 | 9 | 9 | 8 | 3 | 3 | 2 | 5 | 5 | 5 | 2 | 2 | 2 | 11 | 11 | 11 | 3 | 3 | 3 | 43 | 42 | 40 |
| Alior | 6 | 6 | 6 | 1 | 1 | 1 | 8 | 8 | 10 | 2 | 2 | 4 | 5 | 5 | 5 | 2 | 2 | 2 | 13 | 13 | 13 | 4 | 4 | 4 | 41 | 41 | 45 |
| Millenium | 9 | 9 | 9 | 3 | 3 | 3 | 8 | 8 | 8 | 2 | 2 | 2 | 5 | 5 | 5 | 2 | 2 | 2 | 14 | 14 | 14 | 5 | 5 | 5 | 48 | 48 | 48 |
| BNP Paribas | 7 | 7 | 7 | 1 | 1 | 1 | 8 | 8 | 8 | 2 | 2 | 2 | 4 | 4 | 4 | 2 | 2 | 2 | 16 | 16 | 16 | 6 | 6 | 6 | 46 | 46 | 46 |
| BHW | 6 | 6 | 6 | 0 | 0 | 0 | 6 | 6 | 6 | 0 | 0 | 0 | 5 | 5 | 5 | 2 | 2 | 2 | 11 | 11 | 11 | 2 | 2 | 2 | 32 | 32 | 32 |
| mBank | 7 | 7 | 7 | 1 | 1 | 1 | 9 | 9 | 9 | 3 | 3 | 3 | 5 | 5 | 5 | 2 | 2 | 2 | 15 | 15 | 15 | 5 | 5 | 5 | 47 | 47 | 47 |
| PEKAO | 7 | 7 | 7 | 2 | 2 | 2 | 8 | 8 | 8 | 2 | 2 | 2 | 4 | 4 | 4 | 2 | 2 | 2 | 16 | 16 | 16 | 7 | 7 | 7 | 48 | 48 | 48 |
| PKO | 8 | 8 | 8 | 2 | 2 | 2 | 9 | 9 | 9 | 3 | 3 | 3 | 7 | 7 | 7 | 3 | 3 | 3 | 16 | 16 | 16 | 6 | 6 | 6 | 54 | 54 | 54 |
| SANTANDER | 9 | 9 | 9 | 3 | 3 | 3 | 8 | 8 | 8 | 2 | 2 | 2 | 4 | 4 | 4 | 2 | 2 | 2 | 13 | 13 | 13 | 3 | 3 | 3 | 44 | 44 | 44 |
| Total | 279 | 274 | 271 | 114 | 113 | 113 | 309 | 305 | 306 | 125 | 119 | 121 | 189 | 186 | 186 | 84 | 84 | 84 | 505 | 483 | 483 | 212 | 197 | 197 | 1817 | 1761 | 1761 |

[1] The companies that prepare the integrated report are marked in color.

**Table 3.** Number of disclosures about the business model in the surveyed companies.

| Disclosure | 2019 | | | 2018 | | | 2017 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Only Financial Information | | Total | Only Financial Information | | Total | Only Financial Information | |
| | | In Number | % Total | | In Number | % Total | | In Number | % Total |
| **INPUTS** | | | | | | | | | |
| Financial capital | 62 | 30 | 48.4 | 58 | 28 | 48.3 | 58 | 28 | 48.3 |
| Manufactured capital | 52 | 20 | 38.5 | 53 | 21 | 39.6 | 52 | 21 | 40.4 |
| Human capital | 50 | 19 | 38.0 | 49 | 18 | 36.7 | 49 | 18 | 36.7 |
| Intellectual capital | 43 | 15 | 34.9 | 42 | 16 | 38.1 | 41 | 16 | 39.0 |
| Natural capital | 44 | 16 | 36.4 | 43 | 15 | 34.9 | 42 | 15 | 35.7 |
| Social and relationship capital | 44 | 14 | 31.8 | 44 | 15 | 34.1 | 44 | 15 | 34.1 |
| Total inputs | 295 | 114 | 38.6 | 289 | 113 | 39.1 | 286 | 113 | 39.5 |
| **BUSINESS ACTIVITIES** | | | | | | | | | |
| Planning | 52 | 21 | 40.4 | 51 | 19 | 37.3 | 53 | 21 | 39.6 |
| Design | 49 | 18 | 36.7 | 48 | 17 | 35.4 | 47 | 17 | 36.2 |
| Production/conversion | 61 | 29 | 47.5 | 61 | 29 | 47.5 | 61 | 29 | 47.5 |
| Employee training | 43 | 15 | 34.9 | 44 | 15 | 34.1 | 44 | 15 | 34.1 |
| Research and development | 56 | 24 | 42.9 | 54 | 22 | 40.7 | 54 | 22 | 40.7 |
| Relationship management | 48 | 18 | 37.5 | 47 | 17 | 36.2 | 47 | 17 | 36.2 |
| Total business activities | 309 | 125 | 40.5 | 305 | 119 | 39.0 | 47 | 17 | 36.2 |
| **OUTPUTS** | | | | | | | | | |
| Products | 63 | 31 | 49.2 | 62 | 30 | 48.4 | 62 | 30 | 48.4 |
| Services | 62 | 31 | 50.0 | 60 | 29 | 48.3 | 60 | 29 | 48.3 |
| By-products | 28 | 11 | 39.3 | 28 | 13 | 46.4 | 28 | 13 | 46.4 |
| Waste | 36 | 11 | 30.6 | 36 | 12 | 33.3 | 36 | 12 | 33.3 |
| Total outputs | 189 | 84 | 44.4 | 186 | 84 | 45.2 | 186 | 84 | 45.2 |
| **OUTCOMES** | | | | | | | | | |
| Customer satisfaction | 49 | 19 | 38.8 | 49 | 18 | 36.7 | 49 | 18 | 36.7 |
| Profit/loss | 64 | 32 | 50.0 | 61 | 30 | 49.2 | 61 | 30 | 49.2 |
| Shareholder return | 57 | 28 | 49.1 | 51 | 24 | 47.1 | 51 | 24 | 47.1 |
| Asset consumption | 43 | 19 | 44.2 | 41 | 18 | 43.9 | 41 | 18 | 43.9 |

**Table 3.** *Cont.*

| Disclosure | 2019 | | | 2018 | | | 2017 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Only Financial Information | | Total | Only Financial Information | | Total | Only Financial Information | |
| | | In Number | % Total | | In Number | % Total | | In Number | % Total |
| Job creation | 47 | 17 | 36.2 | 46 | 17 | 37.0 | 46 | 17 | 37.0 |
| Employee development and engagement | 43 | 15 | 34.9 | 41 | 14 | 34.1 | 41 | 14 | 34.1 |
| Improved standard of living | 52 | 22 | 42.3 | 51 | 21 | 41.2 | 51 | 21 | 41.2 |
| Environment impact | 45 | 18 | 40.0 | 42 | 15 | 35.7 | 42 | 15 | 35.7 |
| Licence to operate | 48 | 16 | 33.3 | 46 | 15 | 32.6 | 46 | 15 | 32.6 |
| Contribution to local economy through taxes | 57 | 26 | 45.6 | 54 | 24 | 44.4 | 54 | 24 | 44.4 |
| Total outcomes | 505 | 212 | 42.0 | 482 | 196 | 40.7 | 482 | 196 | 40.7 |
| Total | 1298 | 535 | 41.2 | 1262 | 512 | 40.6 | 1001 | 410 | 41.0 |

Empirical data confirm the dominant descriptive disclosures about the BM. There is also a lot of financial (numerical) information disclosed in the enterprises surveyed but not more than non-financial disclosures. The percentage of financial information in total information constitutes over 40% in all specified components (total). The largest proportion of financial disclosures in total information was recorded for the outputs category (44.4%; 45.2%; 45.2% in periods examined), while the lowest proportion of financial disclosures was recorded for the business activities category (36.2% in 2017).

The next stage of the research was devoted to the examination of the correlation between the sum of disclosures about the BM in selected components and economic parameters achieved by these enterprises in 2019, 2018 and 2017. The results of the correlation dependence are presented in Table 4. All statistically significant correlations are marked with colour (greater than 0.3493 with a significance level of 0.05). Table 4 presents the Spearman rank correlations for the total disclosures of the surveyed enterprises in the specified components with selected economic parameters. It should be noted that there are quite numerous statistically significant correlations, but that these correlations are not strong. No statistically significant correlations were noted for the total of all disclosures about liabilities and total assets. There were also no statistically significant correlations for only financial disclosures for the parameter: total assets. The highest statistically significant correlation for the total of components that were disclosed was found for the parameter EBITda in 2017 (0.5543), while the least significant correlation was identified for the same parameter in 2019 (0.3516). Within the detailed data, the highest statistically significant correlations were found only in 2017 between EBITda and outcomes at the level of total disclosures (0.6613), and between EBITda and outputs at the level of only financial disclosures (0.6152). What is clearly visible in the presented data is the fact that the strength of the correlation decreases over the years. This result is very interesting but also puzzling, and in-depth research is required into its causes in further research.

**Table 4.** Spearman's rank correlation coefficient for total disclosures and only financial disclosures. [1]

| Disclosures | Total Assets [Million] | | | Performance | | | Board—No of Members | | | EBITda | | | Equity | | | Liabilities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 | 2019 | 2018 | 2017 |
| Total disclosures | | | | | | | | | | | | | | | | | | |
| Inputs | −0.2065 | −0.1515 | −0.1428 | −0.0699 | 0.2279 | 0.3794 | −0.1512 | −0.0724 | −0.0507 | 0.2402 | 0.3376 | 0.4385 | 0.3038 | 0.3679 | 0.3616 | −0.2836 | −0.2367 | −0.2263 |
| Business activities | −0.2024 | −0.1397 | −0.1507 | −0.0613 | 0.2470 | 0.3937 | −0.2528 | −0.0891 | 0.0067 | 0,2756 | 0.3797 | 0.4610 | 0.3215 | 0.3710 | 0.3715 | −0.2822 | −0.2243 | −0.2371 |
| Outputs | −0.1590 | −0.1119 | −0.0828 | −0.0763 | 0.2681 | 0.4315 | −0.1172 | 0.0190 | 0.1292 | 0.3420 | 0.4377 | 0.5293 | 0.3874 | 0.4292 | 0.4353 | −0.2462 | −0.2045 | −0.1743 |
| Outcomes | 0.1885 | 0.2744 | 0.2438 | 0.1093 | 0.4317 | 0.5299 | 0.2288 | 0.3882 | 0.3501 | 0.4844 | 0.6091 | 0.6613 | 0.4993 | 0.5949 | 0.5695 | 0.1180 | 0.1912 | 0.1607 |
| Total | −0.1557 | −0.0528 | −0.0676 | −0.0478 | 0.3698 | 0.5030 | −0.1602 | 0.0281 | 0.1050 | 0.3516 | 0.5058 | 0.5543 | 0.4204 | 0.4965 | 0.4713 | −0.2485 | −0.1519 | −0.1639 |
| Only financial disclosures | | | | | | | | | | | | | | | | | | |
| Inputs | −0.3352 | −0.3357 | −0.3407 | −0.1454 | 0.1344 | 0.2780 | −0.3128 | −0.3124 | −0.3011 | 0.1433 | 0.1977 | 0.2961 | 0.2165 | 0.2394 | 0.2367 | −0.4101 | −0.4161 | −0.4212 |
| Business activities | −0.3271 | −0.2148 | −0.2262 | −0.1175 | 0.2171 | 0.3612 | −0.4001 | −0.2043 | −0.1030 | 0.1836 | 0.3273 | 0.4062 | 0.2383 | 0.3204 | 0.3207 | −0.4052 | −0.2977 | −0.3109 |
| Outputs | −0.0449 | −0.0222 | −0.0079 | −0.0225 | 0.3543 | 0.5100 | −0.0700 | 0.0731 | 0.1355 | 0.4269 | 0.5263 | 0.6152 | 0.4782 | 0.5105 | 0.5080 | −0.1364 | −0.1207 | −0.1051 |
| Outcomes | −0.1923 | −0.0752 | −0.0690 | −0.0568 | 0.3666 | 0.4994 | −0.1720 | 0.0267 | 0.1152 | 0.3066 | 0.4853 | 0.5303 | 0.3732 | 0.4706 | 0.4555 | −0.2804 | −0.1718 | −0.1623 |
| Total | −0.2665 | −0.1617 | −0.1575 | −0.1016 | 0.3126 | 0.4542 | −0.2900 | −0.0969 | 0.0041 | 0.2701 | 0.4269 | 0.4883 | 0.3453 | 0.4255 | 0.4124 | −0.3575 | −0.2589 | −0.2520 |

[1] Statistically significant correlations are marked in color.

The correlation of the specified components of the BM with the same parameters was examined also; however, the authors focused only on the financial disclosures. Here as well, the correlations are quite numerous but not very strong (see Table 4). The highest significant correlation for the sum of disclosures was identified for the EBITda category in 2017 (0.4883), while the lowest significant correlation concerns the relationship between the sum of financial disclosures and the liabilities category in 2019 (−0.3575). It should be noted that the strongest and most numerous correlations identified, both in terms of financial and total disclosures, were with the parameters—financial result (performance), EBITda and equity.

This confirms that entities with a stronger market position and better financial results use reporting tools based on the BM to a greater extent, which confirms the assumption that more effective enterprises use more advanced techniques and tools, including those for communication with stakeholders. The research did not fully confirm a dominant relationship in the literature indicating that the size of an enterprise is a factor that determines the number of disclosures. Such a statistically significant relationship was demonstrated in studies by Manes-Rossi et al. [84] into the relationship between university size and information on intellectual capital.

There was no significant correlation between the number of disclosures about the BM and total assets. However, significant correlations occurred with equity, as well as with the results achieved by enterprises (performance, EBITda). It can therefore be said that the results of the research are similar to those obtained by Czaja-Cieszyńska, Lulek and Sadowska [92], pp. 134–135, which confirmed that the scope of non-financial disclosures among Polish companies is at different levels, and that a company's affiliation to the WIG-ESG index does not guarantee a comprehensive approach to non-financial reporting.

## 5. Practical Implications of Informing about the Business Model

In order to meet stakeholders' expectations on publication of information about the BM, entities are undertaking more and more activities, e.g., for sustainable development, or related to environmental protection, employee training and protection of employees' health. These activities are then broadly reflected in non-financial reports, for which there is an increasing demand. As a result, by popularizing the problem of reporting the BM, also via this study, enterprises can compete better with one another on the market through the use of information provided in reports, especially regarding sustainable development.

Such reporting is positively perceived by stakeholders. Thus, research on reporting about the BM indirectly contributes to positive behaviour among entrepreneurs and supports the concept of sustainable development.

The authors also believe that in-depth analyses of informing about the BM may have further practical implications—they contribute to an increase in the transparency of this notion. For example, the presented research compares enterprises that publish an integrated report and those that do not publish such a report, amongst others those providing information about the BM in an orderly manner and those that publish information in a disorderly manner. The desired effect is therefore that more and more enterprises publish non-financial reports, including information about the BM, in an orderly manner according to established guidelines, for example GRI.

On the other hand, providing information about the BM is of managerial importance for enterprises. Positive behaviours are then introduced into the management of the company for supporting and conducting sustainable development. In particular, opportunities are identified, and the non-financial dimension that contributes to the value creation process is understood more deeply, which significantly supports the company's management processes. Integrated thinking requires an in-depth awareness and comprehension of the company's BM, which is necessary in the introduction of sustainable processes and business management in the spirit of sustainable development. However, managers need to find a trade-off between confidentiality and transparency of information about the firm's activities, without neglecting investors and the information needs of other stakeholders.

Competition between enterprises in the area of data reporting may cause the amount of reported information to increase. From a practical point of view, our results can support a better understanding of the disclosure of the business model by standards setters. They can better understand to what extent current standards support the disclosure of the BM, including information on sustainable development [5] and in what direction their development should be carried out. The research results allow us to indicate that the BM is not only a tool that describes the way an enterprise creates value, but also carries managerial potential in that it can shape specific attitudes and behaviours, which are then reported in order to legitimize the actions taken by the enterprise. This area has not yet been heavily exploited, but it is likely to be further developed and explored by researchers, especially against the background of legitimacy theory and stakeholder theory.

## 6. Discussion

The study confirms that entities that prepare an integrated report are characterized by a greater number of disclosures of the BM components in selected economic categories compared with entities that do not prepare an integrated report. Therefore, it can be stated that the results for hypothesis 1 confirm the relationship between the number of BM component disclosures and whether or not enterprises prepare an integrated report.

This allows us to recognize that the integrated report is an important tool from the perspective of recognizing the information needs of various stakeholder groups, which concurs with the mainstream of stakeholder theory. This is consistent with the results obtained by Manes-Rossi et al. [93]. The researchers examined the importance of the IR as a transparency and accountability tool in the context of state-owned enterprises, using a sample of European SOEs in the period 2013–2017, in accordance with IR framework requirements. This study assumes, as it also focuses on stakeholder theory and legitimacy theory, that the IR is an accountability tool which combines a wide range of information that meets the information needs of both shareholders and stakeholders [93].

In the view of the authors, from a stakeholder theory perspective, it can also be assumed that increasing scrutiny by society in general [63], promoted by the IIRC guidelines, results in enhanced stakeholder expectations. In line with these guidelines, the BM is one of the main topics in the future development of organization reporting and a key element of integrated reporting. In turn, organisations facing a higher number of stakeholders and their expectations will improve their disclosure about the BM.

The system of legal regulations and accounting standards is a determinant which has a significant impact on the reporting system of enterprises. We are convinced that an important factor that limits sufficient development of the studied area is that International Accounting Standards and the Polish Accounting Act address the issue of the BM insufficiently [40]. The Polish Accounting Act requires large entities only to present a statement of non-financial information, which includes a brief description of an entity's BM [94]. We also base our conclusions on the results of research by Ahmed Haji and Anifowose [95], which focuses on analysis of disclosure practices before and after the introduction of integrated reporting in large South African companies. Based on the theoretical framework of institutional legitimation, they showed an increase in the level of disclosure of information in the field of human and intellectual capital after the IR practice was adopted.

Moreover, the reluctance of enterprises to present a wide range of reporting which is required by legal regulations was disclosed. The scope of disclosures in the analysed research sample was strongly determined by the applicable standards and regulations. Fonseca [49] and Jenkins and Yakovleva [96] reached similar conclusions in their research.

The examined companies are large entities, which is why it can be concluded that they disclose more information and adopt international guidelines. The results are similar to those of Jensen and Berg [67] and Reverte [3], who analysed the relationship between firm size and CSR disclosure. It can also be assumed that organizations follow what other similar organizations do, which indicates the mimetic isomorphism indicated by DiMaggio and Powell [97] in their research. The occurrence of similar practices is also evident in

our study. When we compare the results regarding disclosures by enterprises in the non-financial and financial sector (Table 2), we see a lower number of disclosures about the MB in enterprises representing the financial sector (banks). Our results are similar to those presented by Cooray et al. [98], which show that there is an increase in disclosures and that the non-financial sector has better reporting performance then the financial sector. In their article, Cooray et al. [99] also show that non-financial sector companies in Sri Lanka have a better quality of IR.

Another topic discussed is the predominance of the descriptive narrative form. The results of the research confirmed the hypothesis 2 and revealed the predominance of the narrative descriptive form about the BM in relation to the amount of disclosed financial (numerical) information. This is consistent with the results of Lai et al. [31] and Walińska et al. [53], which demonstrated the predominance of the narrative nature of reporting and that the financial information was significantly limited. The value that stakeholders derive from an integrated report is influenced by its readability [100]. This effect is particularly strong in the case of integrated reporting implemented in narrative form, which facilitates dialogue with various stakeholders [3]. From the point of view of stakeholder theory, greater readability of an integrated report in which information about the BM is presented in narrative form can be considered as a tool used by management to signal activities which are in their best interest. In this context, the BM turns out to be essential also for the implementation of managerial activities.

However, it should be clearly emphasized that the predominance of a narrative disclosures is not significant in our study. There were quite a few financial disclosures about the BM, although slightly less than descriptive disclosures. Therefore, the authors conclude that the BM is a reporting area that has great information potential also for presenting financial information. This, in turn, is a step towards increasing the transparency and comparability of these reporting issues which, according to stakeholder theory, will balance and mitigate conflicts of interest between shareholders and other stakeholders [101].

Research results indicate that the BM is disclosed in a rather detailed manner by enterprises, and confirms the results obtained by Lai et al. [31]. However, BM information is reported in a highly fragmented manner and, as a result, it "loses" its information potential. This finding coincides with that of Page [38]. Even entities that prepare an integrated report do not necessarily include all elements reported of the BM in such a report. This information is dispersed and disclosed in multiple reports. These results are consistent with those of other researchers [55]. This proves that the BM in reporting is not clearly distinguishable for a large proportion of Polish enterprises, which is of great importance in pursuing the goal of sustainable development of corporate reporting.

Thus, there is no clear combination of BM components. The features of transparency, usability and comparability can therefore not be retained.

The presented research forms a backdrop to the ongoing broad discussion about the relationship between and impact of selected economic parameters of an enterprise on reporting practice, as well as the relationship between disclosures and the usefulness of information for stakeholders. It may also contribute to an increase in the amount of some economic parameters, such as share prices or financial results, as well as non-financial parameters which are the basis of sustainable development in the long term. This is partially consistent with research conducted by A. and M. Jabłoński [15], according to which the BM of companies at an early stage of their development (for those listed on the Warsaw Stock Exchange) is oriented primarily toward how the company shapes, delivers and captures value from the market in order to generate profits for shareholders and increase the value of the company. Meanwhile, the business models of mature companies include the intentions of management, used to balance objectives with respect to different groups of stakeholders and to carefully formulate and implement business objectives with particular attention paid to preserving the sustainability of the business.

The present research confirms the existence of a relationship between the level of detail in reporting on the BM and selected economic parameters of an enterprise (mainly performance, EBITda, equity and board), which led us to confirm the Hypothesis 3.

Correlation dependencies indicate that the dominant part of the studied variables affect disclosure strategies for enterprises' business models. There is a growing awareness of disclosures, about outcomes, and their information potential in shaping the decisions of various groups of users of business reports.

All examined cases (outside the sum of assets) demonstrated a significant correlation. Such a relationship exists because more accurate disclosures increase the usefulness of reporting information, which works as an incentive for potential investors or customers. The relationship between disclosures and economic parameters has also been confirmed by other studies [65–67].

Additionally, the indicated relationships provide the basis for the discussion on the concept of information efficiency of capital markets, which is part of the theory of capital market efficiency and is adopted in many financial models. The research by Czekaj et.al [102] shows that only the hypothesis of poor information efficiency can be accepted in the case of Poland. The research conducted by the authors also confirms a weak relationship between the amount of information about the BM and selected economic parameters.

However, somewhat surprisingly, the research results did not confirm the results of other researchers showing that the amount of reporting on the BM is increasing [54,56]. This may be the result of a certain stagnation of reporting during the initial period after the new disclosure requirements were introduced and may also be due to the short period covered by the study. It should be emphasized that the results were preceded by a preliminary study by the authors on a smaller group of entities for only two years (2017–2018). Nevertheless, the results showed a similar pattern.

## 7. Conclusions

This study examined the BM disclosures of selected listed companies and banks. The high level of detail in reporting elements about the BM was confirmed. In addition, it was significantly higher in the companies preparing an integrated report. Moreover, the mentioned reporting group presented information about the BM in a more comprehensive manner. Therefore, based on the assumptions of the institutional theory, it can be concluded that the accounting principles and standards have a significant impact on increasing the quality of disclosures and the scope of BM reporting. A similar relationship concerns the size and financial efficiency of the enterprise. In the remaining enterprises, the reporting result in the examined area was more chaotic and dispersed.

The authors recommend supplementing and structuring previously reported non-financial and financial information with information on sustainable development, and also recommend including this aspect in the company's BM. The authors believe that this is a natural consequence of the development of BM description.

As well as suggested by Gerwanski et al. [101], we also recommend the issuance of a "best practice guide" for materiality disclosure, specifically for first-year reporters. Accompanied by practical examples, this could supplement the existing background paper on materiality [10]. Clear guidance might increase reporting homogeneity, persuade hesitant managers to adopt IR, increase the diffusion of IR and the BM concept, and leverage the acceptance of the new reporting medium among investors and other stakeholders.

The authors also consider that the research results have a strong implication for standard setters in determining the direction of the future form of standards. The existence of additional regulations is an important factor that ensures the sustainable development of reporting on the BM to satisfy the additional information needs of various stakeholders.

The research contributes as well to accounting literature because it provides evidence that the field of accounting is developing and is adopting practical solutions, especially in the field of reporting. Bearing in mind that the main aim of reporting is to provide information for decision-making, our study sheds light on important elements of financial

and non-financial reporting and on new elements that shape the new scope of reports. This research is in line with other studies on the development of accounting.

Notwithstanding, the present study has some limitations. Firstly, the small research sample should be mentioned. This is justified by the short period the surveyed companies had to prepare integrated reports, as well as the time and space-limited requirements for reporting on the BM. As indicated above, there are still few companies listed on the Warsaw Stock Exchange that prepare an integrated report. This limitation is also the basis for determining the directions of future research, which will, inter alia, refer to a longer time horizon. Another limitation is focusing on one country, which can, however, be seen as the basis for conducting further in-depth research over a wider territorial scope and, at the same time, is a useful comparative basis for other researchers.

The synthesis of the obtained research results allows the BM to be considered as an important, future-oriented tool in the area of enterprise reporting, but also as a tool that has significant management potential. However, it is rather descriptive in form, which is justified due to the subject matter that often relates to specific activities and broad external dimensions (including social and environmental ones) that are difficult to present in financial terms. At the same time, for reporting purposes, it is recommended that regulations be developed to limit the spread and lack of comparability of data, as well as the existing chaos and oversaturation of information. Undoubtedly, however, BM is a tool for strengthening ties between the enterprise and stakeholders.

The authors consider it necessary to develop research on the BM, including the epistemological layer, which could increase the comparability of integrated reports between enterprises. This is consistent with the current discussion trend in the literature [40,41,103,104], although there are also well-known voices that question research into the BM in accounting [6]. We believe that developing research on BM reporting is a crucial step toward in development of a sustainable BM using the digital environment, as well as development of a social BM [105]. A particularly interesting direction for future research concerns the use of the BM as a tool for legitimizing enterprises' actions in relation to the theory of legitimation. An area that is also significant is further development of the relationship between accounting and the BM using the assumptions of institutional theory. It will be necessary to observe the changes in reporting on the BM under the influence of the introduction of legal and similar regulations, as well as the diffusion of knowledge about this concept and its impact on the usefulness of the reported data.

Finally, this paper contributes also to broader research on the topic of BM disclosure in reporting and to improve its usefulness for its users. The discussion on the BM contributes to the growing interest of enterprises in this reporting spectrum, which is a positive phenomenon for the increase in market information efficiency.

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*sustainability*

MDPI

*Article*

# The Degree of Dissemination of the Idea of Sustainable Development in Polish Housing Cooperatives in the Light of Empirical Research

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**Abstract:** The cooperative movement was, in a way, the forerunner of the concept of corporate social responsibility (CSR), which is due to the fact that they operate on the basis of cooperative values such as democracy, equality, solidarity, membership and social responsibility, concern for the local community. An integral part of the implementation of corporate social responsibility is the publication of sustainability reports which are currently not published by Polish housing cooperatives. The aim of this article has been defined as the identification and assessment of the idea of sustainable development implemented on the basis of General Standard Disclosures and Specific Standard Disclosures indicators presented in the reporting of housing cooperatives compliant with the Global Reporting Initiative (GRI) G4 Guidelines on Sustainability Reporting. The research used the method of literature analysis and the method of observation, as well as a comparative analysis of the information disclosures presented by the housing cooperatives studied. The obtained research results confirmed the cognitive value of non-financial reports and disclosures of information on websites in the assessment of the implementation of the sustainable development strategy. The findings have signaled the need to disseminate the idea of CSR reports among housing cooperatives and to make their preparation mandatory.

**Keywords:** sustainable finance management; housing cooperative; sustainability reporting; theory of sustainable value

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## 1. Introduction

The literature analysis carried out by the authors indicates a gap in the area of reporting on the sustainable development of housing cooperatives. By combining the stakeholder theory, the social contract theory, the agency theory, the legitimacy theory, the contingency theory and the institutional theory, the aim of the article has been defined as the identification and assessment of implemented strategies of sustainable development on the basis of General Standard Disclosures and Specific Standard Disclosures indicators presented in the reporting of housing cooperatives compliant with the Global Reporting Initiative (GRI) G4 Guidelines on Sustainability Reporting.

In pursuit of this formulated aim of the article, current regulations and the results of previously conducted research concerning the international and domestic market were reviewed. This review shows, among others, that the introduced mandatory non-financial reporting, along with a set of instruments encompassing various standards, has created the conditions for conducting research in the field of information content of reports. Among the regulations in the area covering the subject of this publication, one should cite Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 on the disclosure of non-financial and diversity information by certain large undertakings and groups. Moreover, the growing interest in issues related to corporate social responsibility and its effects is confirmed by the extensive theoretical and empirical literature in this

field [1]. W. Skoczylas has carried out a detailed review of standards and their classification, conducting theoretical and empirical research [2], which indicates a gap to which particular attention should be paid: the need for research on the structure of disclosed non-financial information which forms the basis for the assessment of corporate social responsibility of organizations by interested parties.

Corporate social responsibility and sustainability reporting have already been extensively described in the literature devoted to the theoretical aspects of this issue and empirical findings. However, the considerations of researchers in this area do not apply to housing cooperatives but to other entities characterized by the nature of operations that are different from those of housing cooperatives. It should be noted that research on housing cooperatives in Poland and in the world is very rarely conducted, and researchers focus mostly on entities with other organizational and legal forms whose operation is profit-oriented. Despite the scarcity of such studies, a few examples were found. These studies are important because of their reference to cooperatives, though they are not related to housing cooperatives, which are the subject of the research presented in this article. Those are therefore studies conducted on entities that are only similar in their characteristics to housing cooperatives.

The research conducted by A. Lemańska-Majdzik shows that one for-profit housing cooperative expressed "the need to adopt a culture of sustainable development in its activities" [3] in the context of the social dimension of stakeholders' expectations. Environment-friendly activities were undertaken when they were translated into the economic aspect [3].

B. Mazur and K. Zimoch have identified the values communicated by Polish cooperatives on their websites and have made a critical analysis of whether the values are consistent with the values of sustainable development [4]. However, as in the previous case, the study concerned cooperatives whose activities are conducted on the assumption of making a profit.

A study has also been conducted on the corporate social responsibility of cooperatives in the Republic of Moldova. It indicates that Moldovan cooperative enterprises promote social awareness of CSR practices. The authors point out that the public should be informed about the social impact of cooperatives and be provided with an opportunity to comment on their activities, thus helping cooperatives to improve their CSR practices. The Internet and websites are mentioned as the research tool. Eleven benefits of corporate social responsibility of cooperatives, which may contribute to their competitive advantage, were also listed [5].

The study presented in this article contributes to the existing literature. It is one of the first studies to provide evidence in the context of disclosure of information on sustainable development in Polish housing cooperatives. The authors' intention is for this publication to introduce to the literature a discussion on sustainable development in the context of its social aspect and role played in the development of housing cooperatives, with particular emphasis on regulatory aspects and social needs. The article fills the gap in the discussion on CSR and the research gap in the field of theoretical knowledge supported by empirical research in relation to non-financial reporting of Polish housing cooperatives taking into account the concept of CSR. Due to the aim of the article, the following types of verification were conducted:

1. Logical verification using the method of conducting in-depth studies of domestic and foreign literature related to the subject of the article;
2. Empirical verification using the method of observation.

The results will be useful for the management of housing cooperatives implementing, or planning to implement, CSR reporting. This is due to the fact that, as noted by W. Skoczylas, the implementation of corporate social responsibility management is stimulated by potential benefits such as building a reputation, improving relations with important stakeholders, expanding the ability to acquire and retain clients (i.e., members in the case of housing cooperatives) and employees, value creation of the entity, as well as the development of organizational culture and information culture [2].

## 2. Polish Housing Cooperatives and Their Environment in the Context of CSR

The national housing cooperative movement has its own history and long tradition, as well as economic and social achievements. However, both in Poland and across the world, legal, economic and social conditions are constantly changing, which requires constant adaptation to these changes from housing cooperatives (as from other entities). The degree of this adaptation depends to a large extent on the needs of people creating, interested in, and regulating the activities of housing cooperatives and the conditions in which they operate.

Housing cooperatives, as independent economic units, are co-creators of a market economy system [6]. They are distinguished by their nature from other economic units as they constitute a combination of an association and an enterprise [7] (p. 7). This association, in the interest of its members, carries out joint economic activities [8]. Overall, in Poland, there are 14,615,100 dwellings with a total area of 1,084,166.50 $m^2$. The share of Polish housing cooperatives in the Polish housing stock is 14%, representing 2,029,900 dwellings with a total area of 100,085.30 $m^2$ [9].

Housing cooperatives manage dwellings which are sometimes the fruit of lifetime of work of housing cooperative members. The Auditing Union of Housing Cooperatives of the Republic of Poland has stated that "currently the housing cooperative movement is the best organized, has the strongest economic potential, as well as the largest number of members. There are 3600 cooperatives in Poland with 4,200,000 members. It is a huge community associated on the basis of voluntary decisions, equality and self-governance" [10]. It can be concluded that the overt goal of the housing cooperative is to improve the living conditions of its members by increasing their safety and satisfaction, and the covert goal is to increase the profitability of assets through lower operating and management costs [11].

Due to the indicated number of members of housing cooperatives, their information needs ought to be identified. Other entities interested in the operation of housing cooperatives and their effectiveness should also be determined (Table 1).

Source: own elaboration based on References [12,13].

In view of the progressive development of management practice and theory, the forms of satisfying users' information needs are also evolving. After identifying and grouping the needs, it can be seen that, in practice, a particular type of information corresponds to a specific group of recipients with specific information needs (Table 1). The recognition of their needs based on dialogue as well as respect and care for the common comfort of life is a test of corporate social responsibility of the housing cooperative and, at the same time, a pillar of its sustainable development. At this point, one can quote the definition proposed by J. Michalak stating that: "sustainable development means meeting the needs of the present generation without depriving future generations of their ability to satisfy their own needs. Sustainability reporting is about measuring as well as disclosing information and being accountable to internal and external stakeholders for sustainable performance. Sustainability reports are designed to compare an organization's social and environmental performance over time and to other organizations" [14].

Taking into account the above-mentioned definition in the context of housing, its sustainable development should meet the housing needs of the current generation without depriving future generations of the possibility of living in the housing cooperative stock. The goals of GRI sustainability reports take into account the stakeholders: "the reporting organization shall identify its stakeholders and explain how it has responded to their reasonable expectations and interests. This presents challenges in balancing the specific interests/expectations of stakeholders who can reasonably be expected to use the report with broader expectations of accountability to all stakeholders" [15].

The voluntary preparation and presentation of sustainability reports by housing cooperatives can be explained on the basis of a number of theories, for example, the stakeholder theory, the social contract theory, the agency theory, the legitimacy theory, the contingency theory, or the institutional theory.

**Table 1.** Housing cooperative stakeholders and their information needs.

| Stakeholders | Information Needs |
| --- | --- |
| Members | They are interested, among others, in proper fulfilment by the housing cooperative of its goal (satisfying their housing needs) and in information on the adequacy, effectiveness and efficiency of management of the housing cooperative and its resources. |
| The management (Management Board/ Supervisory Board) | The management need additional management and financial information, though they have access to it, to help them fulfil their planning, decision-making, oversight, and control responsibilities. In the event of a change of the Management Board, they need information whether the previous management carried out its activities in accordance with applicable regulations and proper management principles (legitimacy of incurred expenses, compliance with tender procedures, compliance of adopted resolutions with applicable law). |
| Investors | Members who own housing units in the housing stock managed by the housing cooperative as well as other venture capital investors and their advisers are interested in the magnitude of the inherent risk of investments made by the housing cooperative and their rate of return. They need information to help determine whether to acquire, hold or sell a given investment.<br>They are interested in information enabling them to evaluate the activities of the housing cooperative. |
| Employees | They are interested in information on the stability and profitability of the housing cooperative, information that enables them to assess the ability of the housing cooperative to pay wages and retirement benefits, as well as to create jobs. |
| Lenders | They are interested in information that allows them to determine whether their loans along with interest on these loans will be repaid on the agreed date. |
| Suppliers and creditors | They are interested in information enabling them to determine whether they will receive the amounts due on time. |
| Future members-potential customers | They are interested in information on the continued operation of the housing cooperative as they want to maintain their relationship with the housing cooperative long-term and will be dependent on it. |
| Government and government agencies, including the Auditing Union of Housing Cooperatives of the Republic of Poland and the National Cooperative Council | They are interested in allocating resources, hence their interest in the activities of housing cooperatives. They also need information to regulate these activities, define the tax policy, calculate national income and other statistical data. Cooperative associations-the Auditing Union of Housing Cooperatives of the Republic of Poland. Tax authorities-tax enforcement/collection. |
| Society:<br>• entire society<br>• local community | Housing cooperatives influence society in various ways: they contribute to the cultural activities of the families of cooperative members and contribute to the local economy by employing workers. Society members need information on trends and recent changes in the level of wealth and profitability of the housing cooperative and its scope of activities. |

Referring to the stakeholder theory, it should be noted that the stakeholders depend on the housing cooperative and are influenced by its actions directly or indirectly, for example, as a result of agreements or contracts concluded. Each of the stakeholders is therefore interested in the housing cooperative's overall activities and their effects. In sustainability reports, housing cooperatives (similarly to businesses) should present environmental, social and economic sustainability impacts, thus taking into account various interest groups. It would allow housing cooperatives to avoid possible social opposition towards any actions taken (e.g., avoiding protests of environmental organizations when constructing new residential buildings, playgrounds, or sports facilities).

According to the social contract theory, society is perceived through the network of contacts among its various members. CSR activities are then analyzed in two dimensions: macro-contracts and micro-contracts. Macro-contracts define the relationships and expectations between society or local community and economic activity. Micro-contracts concern relationships between individuals [16].

The analysis of the behavior of members and management of a given entity shows that decisions made may be determined by the need to verify the activities of the housing cooperative, which is related to the issues of the agency theory [17] (According to the definition of M. C. Jensen and W. H. Meckling, it is "a contract under which one or more persons (the principal (s)) engage another person (the agent) to perform some service on their behalf which involves delegating some decision making authority to the agent"—see more [17]). It is therefore important to clarify the relationship between the principal (a member of the housing cooperative) and the agent (managing the housing cooperative) hired to manage the property of the principal. The agency theory indicates a situation in which the principal is not able to verify the correctness of the agent's actions, as this monitoring is costly and difficult to perform [18]. S. B. Graves and S. A. Waddock have found that agents (managers) are more inclined to take actions for sustainable development, as they participate to a lesser extent in the distribution of the company's profits in the long term. The authors emphasize that these actions may positively influence the evaluation of agents' work as this way managers will not be accused of acting to the detriment of society [19]. Similarly, a president who takes into account the sustainable development of the housing cooperative in management decisions is also more likely to maintain his/her position. The housing cooperative president can use sustainability reporting to improve his/her reputation and increase public recognition. Housing cooperative members can also benefit greatly from these reports. However, due to the costs of preparing a sustainability report, which increase the entity's operating costs, this group of stakeholders may be less inclined to develop this form of reporting, even if it translates into a better perception of the entity by its environment.

The considerations contained in this publication are also embedded in the contingency theory (already present in organizational studies in the 1960s [20]) due to the fact that information cycles are analyzed as an effect of specific external and internal determinants of the housing cooperative's operation. For this reason, in the further part of the article, an attribute of this theory will be used allowing for the application of a universal description and the explanation of phenomena specific to housing cooperatives [21] (p. 324). Due to the fact that the subordination of housing cooperative activities to legitimacy, social norms and legal regulations and the adaptation of results of its activities, in the form of sustainability reports, to the information needs of internal and external stakeholders are associated with the legitimacy theory, this theory is used to explain why housing cooperatives (or companies) decide to voluntarily submit sustainability information.

The research conducted for the purposes of this publication is also based on the institutional theory (used interchangeably with the stakeholder theory and the legitimacy theory) serving to explain motivations for sustainable development, combining the practice of housing cooperatives with the norms of society in which they operate. Voluntary disclosure by housing cooperatives of information on sustainability is perceived as part of an institutional practice aimed at maintaining, acquiring, or regaining their legitimacy. Housing cooperatives adopt institutional practices through isomorphic processes such as coercion, imitation, and normative pressures. The need to address concerns about threats to organizational legitimacy plays to a large extent the role of a potential driving force for disclosure of information on sustainable development [22]. This means that housing cooperatives are appropriate entities to implement the principles of sustainable development with the involvement of residents [23]. It should be emphasized that housing cooperatives, due to the specificity of their activities, take into account the requirements of sustainable development and act to promote it. The concept of cooperatives is therefore inherently related to the goals and tasks of sustainable development. These goals (Sustainable Development Goals–SDG) emphasize the corporate social responsibility of housing cooperatives. The 11th goal of the resolution adopted by the United Nations General Assembly on 25 September 2015 "Transforming Our World: the Agenda 2030 for Sustainable Development" sets out to "make cities and human settlements inclusive, safe, resilient and sustainable" comprising tasks related to the operation of housing cooperative:

- "11.1 By 2030, ensure access to adequate, safe and affordable housing and basic services and upgrade slums;
- 11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries;
- 11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage" [24].

It is a worldwide outlook of the problem which shows how important the issue of housing is in the 2030 time horizon from the national, EU and global perspective.

The use of CSR as a method of managing a housing cooperative means that the housing cooperative becomes an active organization, responding to changes in its socio-economic and cultural environment. The housing cooperative builds a stable position on the basis of long-term activities focused on broadly understood development through establishing a network of social relations with its environment. These are premises for perceiving this form of organization as active and acquiring knowledge through experience.

There is an increase in social awareness of housing cooperative members, who are becoming more demanding, and are driven by trust in the housing cooperative and its image. Therefore, the sustainable development of housing cooperatives can increase the loyalty of their members and suppliers/stakeholders. Pro-environmental and pro-social activities of these cooperative organizations may contribute to gaining the favor and a greater level of trust of local government authorities and the local community. The indicated activity is part of the non-financial motivation of housing cooperative employees, who may start to improve the perception of their employer based on the code of ethics implemented or involvement in matters important to people. This way, housing cooperatives can improve their labor market image.

One can agree with the position of R. Konieczna that sustainable development is an obligation [25] (p. 29) which the housing cooperative voluntarily accepts and then includes in its management system, as CSR is increasingly desired and required by stakeholders (primarily its members).

## 3. Materials and Methods

The empirical study of the prevalence of sustainability reports was conducted in the period from December 2019 to December 2020 using the observation method. Observation as a research method should be carried out intentionally and in a planned manner so that it does not affect the process, phenomenon, or object under observation. This method assumes the selection of observations according to predetermined conditions, which are subject to appropriate selection. The selection criterion is determined based on the purpose of the study. The observation method as a research method takes into account all stages of research activities, which means that it allows us, among others, to set objectives, collect specific data, verify and select research material. It also provides the conditions for conducting the preliminary study and the main study. This method also specifies how research techniques or tools may be prepared and used. The observations that are the basis for the analysis of the results of the research are recorded in protocols (or questionnaires), which makes it possible to make scientific generalizations [26] (pp. 62–63). The study presented was carried out in accordance with the research methodology shown in Figure 1.

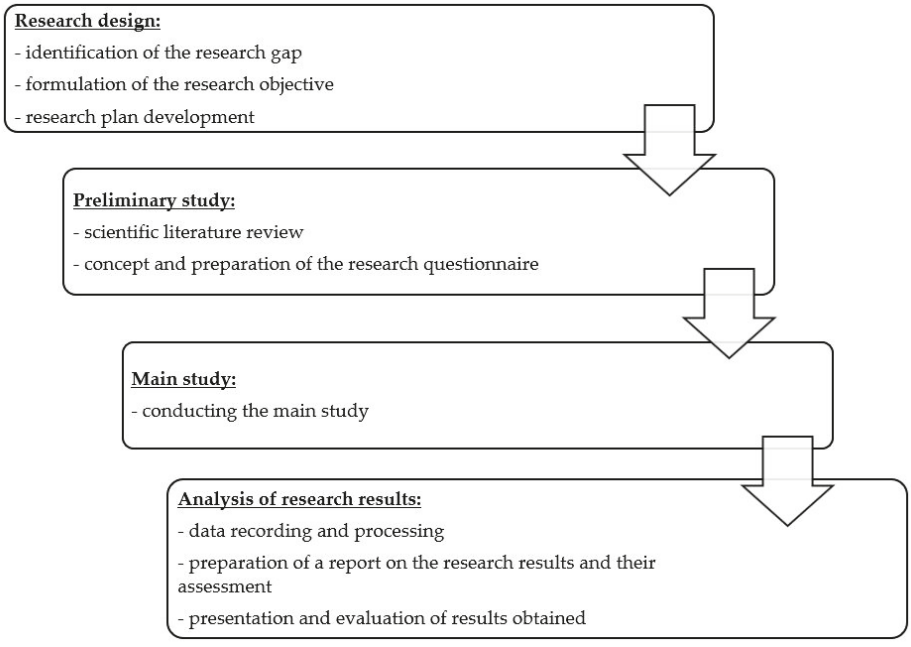


**Figure 1.** Research methodology.

The first stage in the implementation of the undertaken research task was the identification of the research gap as well as the formulation of the objective of the study and the preparation of the research plan. The analysis of the theoretical assumptions of the CSR concept and the instruments for its implementation postulated in the literature, set the research directions for the conducted study. In pursuit of thus formulated purpose of the study, the research questionnaire was prepared, in terms of content, in line with the standards of sustainability reporting, specifically with the Global Reporting Initiative G4 Guidelines on Sustainability Reporting (Table A1). The research questionnaire is presented in more detail in Appendix A. This means that the issues of sustainable reporting discussed in the article and the conducted study refer to standards developed by the Global Reporting Initiative, which are the most advanced and most widely used standards in business practice. The GRI G4 standards contain internationally agreed indicators and measures presenting the most important issues related to the sustainable development of a given organization. Therefore, the indicators and information disclosures provided by the reporting entities divided into the following groups formed the basis for the assessment:

1. General Standard Disclosures in the basic version, that is, indicators reflecting the scope of the strategy and analysis implemented, the profile of the housing cooperative, the material aspects identified and their boundaries, stakeholder engagement, report profile, organizational governance, and ethics;
2. Specific Standard Disclosures, including information on the approach to management, as well as indicators in economic, environmental and social categories (further broken down into subcategories: employment and decent work practices, human and community rights, and product responsibility which, in the case of a housing cooperative will be responsibility, for example, for a dwelling) [27] (pp. 18–235).

The assessment was made on the basis of a comparative analysis of the structure indicators reported by the Polish housing cooperatives surveyed and the structure indicators of the GRI 4 standards, including the intensity indicator (which is the ratio of the indicators

reported by housing cooperatives to the possible scope of reporting defined by the GRI standards [2]).

The empirical study of the prevalence of sustainability reports included 100 housing cooperatives operating in Poland. The collection of non-financial data was done manually and several sources were used to compile the dataset. In the first stage, the search mechanism on the website of the National Court Register was employed to find 100 housing cooperatives. For this purpose, the "cooperative" keyword was entered in the search field of the website. The website search mechanism found many cooperatives, and on the basis of the list received, the first 100 housing cooperatives were selected for the research sample. Then, non-financial reports for the selected housing cooperatives for 2018 were collected. In addition, the existence of disclosures in sustainability development reports, coded in line with the GRI G4 indicators, was checked and identified to measure the amount and variety of certain types of information. Relevant indicators recognized by the reporting entities, resulting from their strategy, were divided into two groups: the General Standard Disclosures and the Specific Standard Disclosures, formed the basis for the assessment of each housing cooperative conducted in the study.

Subsequently, the content of websites and other communication tools of the housing cooperatives studied was analyzed in order to search for declarations whether the ideas of sustainable development were important for the management.

For the above-presented research stages, a binary measure was used to record voluntary disclosure of information on sustainable development in the research questionnaire. If a given housing cooperative provided information on the issues analyzed in the form of non-financial reports or website disclosures, that fact was coded as "1".

In the final stage, the structure of information disclosures and sustainability declarations was observed and analyzed. The results were compiled using the percentage share and the intensity index was calculated.

Data sources were limited to non-financial reports, websites and annual reports of the housing cooperatives studied.

## 4. Results

As a result of the above-presented research, it was possible to analyze the information available on the relevant websites and in annual reports posted on the website of the National Court Register ICT system. According to the GRI G4 standards, first, one learns about a given organization, including: the importance of sustainable development for the organization and the actions taken to implement it, the characteristics and scale of the organization, organizational governance, and ethics. The General Standard Disclosures indicators, comprising the first group of indicators, make it possible to refer to the report as a source of information in which a given organization describes the process leading to the achievement of the goal of defining the content of the report, identifying material aspects and their boundaries, compiling data, indicating stakeholder engagement (not only for the purpose of reporting) and report profile [2].

The structure of the GRI G4 standards allows one to first familiarize oneself with the first group of indicators describing a given housing cooperative—the General Standard Disclosures indicators. The Specific Standard Disclosures indicators, on the other hand, are an important source of information when assessing the implementation of the sustainable development strategy, as they reflect the impact of housing cooperatives on the environment and society, significantly influencing the assessment and decision of both internal and external stakeholders.

Analyzing the two groups of indicators makes it possible to familiarize oneself with their structure. As indicated by the research results presented in Table 2, the assessed content of reports of the housing cooperatives studied differs significantly from that resulting from the GRI G4 standards (i.e., the reported content constitutes only 37% of the scope covered by the GRI G4 standards).

**Table 2.** General Standard Disclosures and Specific Standard Disclosures.

| Indicators | Sum of Reported Indicators | Share % | Sum of GRI G4 Indicators | Share % | Intensity Index [1] |
|---|---|---|---|---|---|
| General Standard Disclosures | 1792 | 60.8 | 34 | 42.5 | 52.7 |
| Specific Standard Disclosures | 1156 | 39.2 | 46 | 57.5 | 25.1 |
| Total | 2948 | 100 | 80 | 100 | 36.9 |

[1] The ratio of reported content in relation to the standard scope after [2].

Based on the General Standard Disclosures listed in Table 3, it can be seen that housing cooperatives do not declare the implementation of sustainable development strategy, but they present their report profile or organizational profile and organizational governance.

**Table 3.** List of General Standard Disclosures.

| Indicators | Sum of Reported Indicators | Share % | Sum of GRI G4 Indicators | Share % | Intensity Index |
|---|---|---|---|---|---|
| Strategy and Analysis | 0 | 0 | 1 | 2.9 | 0 |
| Organisational Profile | 862 | 48.1 | 14 | 41.2 | 61.6 |
| Identified Material Aspects and the Corresponding Boundaries | 200 | 11.2 | 7 | 20.6 | 28.6 |
| Stakeholder Engagement | 121 | 6.8 | 4 | 11.8 | 30.3 |
| Report Profile | 480 | 26.8 | 6 | 17.6 | 80.0 |
| Organisational Governance | 81 | 4.5 | 1 | 2.9 | 81.0 |
| Ethics | 48 | 2.7 | 1 | 2.9 | 48.0 |
| Total | 1792 | 100 | 34 | 100 | 52.7 |

In the dialogue with the internal and external environment, the name of the organization, its basic services, headquarters, location, and legal form, as well as the scale of the organization, the number of employees broken down by type of employment and gender, its reporting periods, the structure of its management bodies, along with changes in those areas were widely reported. The key issues and matters raised by stakeholders in the reporting period were presented to a slightly lesser extent (67%). In 53% of the housing cooperatives considered, the undertaken economic, environmental or social initiatives and norms of behavior were listed in the form of rules of conduct.

The list of selected Specific Standard Disclosures presented in Table 4, specific to the sector of housing cooperatives (but not obligatory), made it possible to present the structure of information published by the housing cooperatives analyzed against the GRI G4 benchmark in the context of material aspects, reflecting the significant impact of cooperatives on the economy, natural environment and society, or significantly influencing stakeholder assessments and decisions.

**Table 4.** List of selected Specific Standard Disclosures.

| Indicators by Aspects | Sum of Reported Indicators | Share % | Sum of GRI G4 Indicators | Share % | Intensity Index |
|---|---|---|---|---|---|
| Economic category | 205 | 17.7 | 4 | 8.7 | 51.3 |
| Environmental category | 416 | 36.0 | 12 | 26.1 | 34.7 |
| Social category | 535 | 46.3 | 30 | 65.2 | 17.8 |
| Total | 1156 | 100 | 46 | 100 | 25.1 |

The results indicate that the scope of information enabling the assessment of actions taken to implement the declared strategy compared to the scope agreed in the standards covers approximately 25.1% of possible aspects, that is, 51.3% of the aspects of the indicators from the economic category, 34.7% of the aspects of the indicators from the environmental category, and 17.8% of the aspects of the indicators from the social category.

The share of the amount of information classified according to the GRI G4 Specific Standard Disclosures in the economic category is presented in Table 5. The list shows that almost half of the housing cooperatives studied presented economic performance (47.8%) in the economic category, while a minority indicated indirect economic impacts (12.7%) or market presence (18.5%).

**Table 5.** List of selected indicators according to the aspects of the economic category.

| Indicators | Sum of Reported Indicators | Share % |
|---|---|---|
| Economic Performance | 98 | 47.8 |
| Market Presence | 38 | 18.5 |
| Indirect Economic Impacts | 26 | 12.7 |
| Procurement Practices | 43 | 21.0 |
| Total | 205 | 100 |

The activities of housing cooperatives should also be aimed at environmental protection. Most often they relate to energy and water consumption as well as the costs of sewage disposal and waste management (see Table 6), that is, a list of selected indicators from the environmental category relevant to the activities of housing cooperatives. Housing cooperatives most often show the costs incurred in the indicated aspects broken down by real estate properties, by comparing their amount to the previous year, additionally pointing to possible reasons for their changes.

Only in a few cases do housing cooperatives share information on the effectiveness of actions taken, for example, in terms of reducing greenhouse gas emissions. However, no environmental assessment of the impact of deliveries or employee transport on the environment was reported. Therefore, it can be assumed that such activities are not included in their sustainable development strategy.

By listing the indicators according to the aspects of the social category, the structure of indicators the most widely presented by the housing cooperatives studied was obtained, as shown in Table 7.

**Table 6.** List of selected indicators according to the aspects of the environmental category.

| Indicators | Sum of Reported Indicators | Share % |
|---|---|---|
| Materials | 68 | 16.3 |
| Energy | 73 | 17.5 |
| Water | 72 | 17.3 |
| Biodiversity | 1 | 0.2 |
| Emissions | 12 | 2.9 |
| Effluents and waste | 72 | 17.3 |
| Products & Services | 65 | 15.6 |
| Compliance | 40 | 9.6 |
| Transport | 0 | 0.0 |
| Overall | 12 | 2.9 |
| Supplier Environmental Assessment | 0 | 0.0 |
| Environmental Grievance Mechanisms | 1 | 0.2 |
| Total | 416 | 100 |

**Table 7.** List of selected indicators according to the aspects of the social category.

| Indicators | Sum of Reported Indicators | Share % |
|---|---|---|
| 1. Labor Practices and Decent Work | 127 | 23.7 |
| Employment | 89 | 16.6 |
| Employee/Management Relations | 13 | 2.4 |
| Occupational Health and Safety | 11 | 2.1 |
| Training and Education | 10 | 1.9 |
| Diversity and Equal Opportunity | 1 | 0.2 |
| Equal Remuneration for Women and Men | 1 | 0.2 |
| Supplier Assessment for Labor Practices | 0 | 0.0 |
| Labor Practices Grievance Mechanisms | 2 | 0.4 |
| 2. Human Rights | 12 | 2.2 |
| Investment | 0 | 0.0 |
| Non-discrimination | 1 | 0.2 |
| Freedom of Association and Collective Bargaining | 0 | 0.0 |
| Child Labor | 4 | 0.7 |
| Forced and CompulsoryLabor: | 1 | 0.2 |
| Security Practices | 5 | 0.9 |
| Indigenous Rights | 0 | 0.0 |
| Periodic Assessment System | 1 | 0.2 |
| Supplier Human Rights Assessment | 0 | 0.0 |
| Human Rights Grievance Mechanisms | 0 | 0.0 |

**Table 7.** *Cont.*

| Indicators | Sum of Reported Indicators | Share % |
|---|---|---|
| 3. Society | 156 | 29.2 |
| Local Communities | 59 | 11.0 |
| Anti-corruption | 1 | 0.2 |
| Public Policy | 38 | 7.1 |
| Anti-competitive Behavior | 4 | 0.7 |
| Compliance | 41 | 7.7 |
| Supplier Assessment for Impacts on Society | 0 | 0.0 |
| Grievance Mechanisms for Impacts on Society | 13 | 2.4 |
| 4. Product Responsibility Performance Indicators (e.g., responsibility for buildings) | 240 | 44.9 |
| Customer Health and Safety (here: customers are housing cooperative members) | 74 | 13.8 |
| Product and Service Labelling | 11 | 2.1 |
| Marketing Communications | 25 | 4.7 |
| Customer Privacy (here: privacy of housing cooperative members) | 56 | 10.5 |
| Compliance | 74 | 13.8 |
| Total | 535 | 100.0 |

The presented structure (Table 7) indicates that the greatest importance (44.9%) in the implementation of the sustainable development strategy is attributed to activities included in the sub-category of product responsibility (which in the case of housing cooperatives is real estate). Particular attention is paid to the health and safety of housing cooperative members, compliance with regulations, and ensuring the privacy of housing cooperative members. The second most important are activities related to society (29.2%), especially in the field of local communities, rules concerning participation in public life, or compliance with regulations. Less importance is attached to labor practices and decent work, where employment is primarily reported. The subcategory related to respecting human rights, where mainly practices related to employee occupational health and safety were reported, is the most ignored area.

The conducted research indicates that, among the additional activities within the framework of the sustainable development concept and corporate social responsibility mentioned by the housing cooperatives considered, both in their non-financial reports and on their websites, the following should be particularly noted:

1. An extensive program of "sustainable development and domestic hot water" implemented by one of the housing cooperatives;
2. Installation of water meters in residential premises allowing for remote reading;
3. A frequent phenomenon of awards given to housing cooperatives in categories such as: "significant environmental impact" for thermal modernization of buildings and reduction of $CO_2$ emissions, or "clones" for entities that function in harmony with the natural environment;
4. Purchasing and selling by some housing cooperatives so-called "white certificates", important for environmental protection;
5. Implementing measures called "Housing Cooperative Greenery";
6. Declarations that funds are provided in the cost calculations of every project for land development after the completion of construction in such a way that any interference in the environment is compensated by the creation of a properly integrated building enriching the landscape;

7. Concluding agreements with the Voivodeship Fund for Environmental Protection and Water Management concerning, for example, co-financing of comprehensive thermal modernization of multi-family buildings in the stock of housing cooperatives with the use of renewable energy installations and the Smart Energy Management System. The implementation of this kind of projects will result in the reduction of emissions of the economy by significantly improving energy efficiency of buildings, which will lead to the reduction of their energy consumption, lower operating costs, enhanced visual aesthetics, as well as an increase in the environmental awareness of housing estate residents;
8. Organizing Community Groups of local residents aimed at integrating the community of inhabitants of a given building and helping other bodies of the cooperative to identify and solve problems and needs of this community;
9. Organizing educational, artistic and entertainment activities for children, adolescents and adults;
10. Housing cooperative buildings often "drowning" in greenery. Creating a tab labelled "greenery and recreation" on housing cooperative websites;
11. Setting the sub-goal of adaptation to climate change, risk prevention and risk management by one of the housing cooperatives studied;
12. Publishing by another housing cooperative studied the information described under the "environmental protection" sub-category indicating that it is environment-friendly; carrying out renovation works, it operates in accordance with the requirements of environmental protection, that is, provides "green zones" and good conditions for birds using the area;
13. Indicating that the housing cooperatives considered strive to reduce energy consumption by improving the thermal insulation parameters of external covers of their buildings (e.g.,: in one of the housing cooperatives analyzed, as a consequence of the implementation of such a project, there will be a reduction of $CO_2$ emissions of seven tons per each building, and after investments in three buildings, a reduction of 21 tons, which shows the scale of possibilities in this regard);
14. Winning the first two awards for an ingenious and attractive design of the housing estate greenery which enriches the surroundings with different colors from spring to autumn by one of the housing cooperatives analyzed;
15. Including a point on "environmental protection" in the report on its activities by one of the housing cooperatives analyzed, pointing to modernization projects implemented over the years and bringing tangible results in the form of low fees for using the environment and no penalties for exceeding the emissions of harmful substances;
16. Improving the environmental living conditions by removing asbestos from multi-family residential buildings and using insulation made of other asbestos-free materials harmless to the human environment in the process of thermal modernization of buildings.

In one of the housing cooperatives considered, among the reports posted on the website, there was a presentation on the idea of sustainable development encompassing the following three spheres:

1. Environment-the reduction of emissions harmful to the environment; improving the quality of the natural environment; primary energy savings through energy production in high-efficiency cogeneration;
2. Society-improving the safety of residents; enhancing the quality of life of residents, increasing the awareness of residents related to the sustainable development of the city;
3. Business-improving energy efficiency; lowering operating costs; better use of production assets and transmission networks; increasing the availability of district heat for residents of the entire city.

Concluding the results of the conducted study, it can be stated that the scope of the presented indicators allows stakeholders to familiarize themselves with the profile

of housing cooperatives. However, the Specific Standard Disclosures, indicating a direct and indirect impact of the activity on society and the natural environment, were reported rather narrowly in relation to the scope defined by the GRI G4 Guidelines. Nevertheless, it should be taken into account that these are "largely lagged, not leading indicators. The cognitive value of the latter is expressed in the fact that they reflect the achievement of the goal, the actions taken to achieve them, or the level of meeting the expectations of stakeholders" [28]. In the reports and on the websites, information is presented without following any uniform standard or guidelines adjusting the specific nature of housing cooperatives to CSR reporting. None of the housing cooperatives from the selected sample prepared sustainability reports in accordance with the GRI G4 Guidelines. The lack of actions taken in the field of CSR reporting among housing cooperatives (which in fact undertake this type of activities-as indicated in this article) is puzzling. After all, housing cooperatives have to fulfil the principles of sustainable development, for example, by meeting the needs of future generations.

## 5. Discussion

It should be noted that the presented research results indicate the realized sustainable development of housing cooperatives both in the social and environmental dimension. Housing cooperatives publish on their websites various non-financial reports and information related to environmental and social issues.

As a result of the study, it can be said that the concept of sustainable development in Polish housing cooperatives is still at its initial stage, treated as a synonym for sponsorship or charity, or implemented only in the form of occasional pro-social or environmental activities aimed at creating a certain image. Most housing cooperatives do not use this concept as an overall management strategy, which makes it very difficult to assess their activities in this area.

The theoretical issues and empirical research discussed in the article allowed for the identification of areas of sustainable development of housing cooperatives and basic information about it, which is of key importance for the assessment of its level. Based on the analysis of selected Polish housing cooperatives, it has been possible to determine what information about this specific type of entity and its activities is necessary to verify the level of its sustainable development.

Housing cooperatives should initiate a dialogue with stakeholders by preparing non-financial reports in accordance with the GRI G4 requirements in order to assume responsibility for employees and contractors in the supply chain and to monitor the impact of cooperatives on the natural environment.

The research results obtained have confirmed the cognitive value of non-financial reports and disclosures of information on websites when assessing the implementation of the sustainable development strategy. At the same time, the findings have pointed to the existing gap, as the content of these reports needs improvement, including the wider publication of Specific Standard Disclosures.

One can agree with the statement of E.I Szczepankiewicz and P. Mućko that the differences in the scope and form of presentation of financial and non-financial information make it difficult for stakeholders to compare the situation and quality of management of the entities analyzed or assess their prospective performance [29].

The research results provide decision-makers with theoretical and practical implications to encourage housing cooperatives in Poland and around the world to take actions aimed at sustainable development and disclosure of corporate social responsibility information.

General conclusions regarding the analysis of Polish housing cooperatives can be formulated as follows:

1. Housing cooperatives analyze their impact on the environment;
2. They have not developed and are not yet implementing reporting according to the concept of sustainable development;

3. Initiatives to promote awareness of CSR among these entities should be introduced so that the successful popularization of sustainable development in this sector could be achieved quickly and CSR reporting could be implemented.

One can see a number of benefits from the implementation of the CSR reporting strategy in this area by housing cooperatives (not only in Poland but also worldwide). The introduction of CSR principles into housing cooperatives may lead to increased interest on the part of future members/potential investors, as they might be more willing to grant a loan or invest as a new member in purchasing a dwelling in a socially responsible and credible housing cooperative.

There are other benefits that housing cooperatives can achieve after implementing CSR principles:

1. Formation of trust-based and long-term relationships with external stakeholders (the local community, cooperating entities, investors, non-governmental organizations);
2. Building a competitive advantage and focusing on sustainable development;
3. Increasing resistance to the occurrence and consequences of random events or crisis situations;
4. Building an organizational culture that is appropriately transparent, based on cooperation and high ethical standards;
5. Creating a positive image (by strengthening the recognition among internal and external stakeholders, including the local community, public opinion, and market analysts);
6. Increasing workplace safety;
7. Creating a positive image in the eyes of potential job applicants, increasing employee satisfaction (loyalty and motivation);
8. Increasing the awareness of the impact of housing cooperatives on the natural environment among housing cooperative employees;
9. Creating a positive image of the housing cooperative management in the eyes of current and potential investors by initiating and carrying out activities in the area of CSR;
10. Reducing the negative impact on the natural environment by implementing a management system contributing to compliance with legal regulations in the field of environmental protection; faster detection and removal of any irregularities contributing to negative impacts on the environment;
11. Reducing the operating costs of housing cooperatives through rational consumption of raw materials, optimization of material selection (e.g., the materials used to build residential buildings), increasing the efficiency of infrastructure resources, reducing the costs of effluent and waste removal as well as the costs of related infrastructure, reducing fees for using the environment and lowering insurance rates;
12. Improving the image of the housing cooperative in the community, which will increase the trust of current and future housing cooperative members.

Housing cooperatives have at their disposal a growing set of various tools that facilitate the process of implementing CSR principles. The completion of the process of implementing these principles successfully depends on many situational factors, that is, economic, institutional, cultural, and social. The management board and the entire housing cooperative must be involved. The contemporary socially responsible model of housing cooperative management is not only about meeting formal requirements and legal obligations but about incorporating the idea of CSR into the management process in conjunction with the financial and investment policy of the housing cooperative.

It should be stressed that there are limitations to this study, firstly because of the size of the sample which consists of 100 housing cooperatives. The research was also limited territorially to housing cooperatives located in Poland. It should be also borne in mind that, in comparison to financial statements, the non-financial reports audited, for example, activity reports, have a lower level of credibility resulting from subjectivity and difficulties in verifying certain information. The published subjective opinions or interpretations of the

management constitute an important and valuable part of the report. It should be noted, however, that a certain degree of subjectivity of the housing cooperative management influences the content of the report which after all aims to objectively present the image of a given entity. This makes comparisons difficult, as the choice of aspects and indicators remains in the sphere of individual motivations and decisions of housing cooperatives.

The conclusions drawn from the conducted empirical research suggest the need for further studies in this area and their diffusion into economic practice. The equally low percentage of Polish housing cooperatives promoting the idea of sustainable development in their non-financial reports indicates the need to promote these principles in the housing cooperative community. After all, as a sustainable and participatory organizational form, housing cooperatives should present an alternative business model for social organizations [30].

The presented study will contribute to expanding knowledge on the relationship between sustainable development and its impact on the housing cooperative sector. There is, however, a need for further more extended research on the issue conducted on a larger research sample, involving a comparative analysis of subsequent financial years. Future in-depth studies carried out in other countries may provide results that can be compared with this study.

As emphasized by R. Konieczna, "a properly prepared social report should enable the interested party to form an opinion on the overall picture of the activities" [25] (p. 41) of housing cooperatives and their effects. The authors have put forward the idea that housing cooperatives should prepare mandatory non-financial information (CSR) statements and reports that could be called corporate social responsibility reports of housing cooperatives.

Should CSR reporting therefore be mandatory for housing cooperatives in the future? Do housing cooperatives only undertake some activities in order to make their image more environment friendly? Will sustainability reports serve as public relations materials used to create the image of a given housing cooperative in the eyes of social groups instead of being an actual presentation of its environmental impact and achievements in this area? B. Mazur and K. Zimnoch indicate that the activities of housing cooperatives "fit perfectly into the concept of sustainable development, proving that the implementation of this concept does not always require revolutionary changes in the business world" [4]. Therefore, the authors ask why this type of entity, built on the values of sustainable development, has not been obligated yet to prepare CSR reports, as such reports cannot be found on websites or in non-financial reports prepared by the indicated entities (as it has been confirmed in this study). A discussion of this subject ought to be initiated and the idea should be put forward to incorporate in the common practice of housing cooperatives non-financial reports that should be prepared in accordance with the aforementioned Directive 2014/95/EU of the European Parliament and of the Council on disclosure of non-financial information and diversity policy of 22 October 2014 for such activities to become a new trend in the housing cooperative sector. The authors postulate the promotion of sustainable development, yet the future will show whether the principles of sustainable development will become an integral part of the activities of housing cooperatives, or whether the sustainable development "fad" will fade.

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## Appendix A

**Table A1.** Research questionnaire.

| **Entity Studied** / **Items** | **Subsequently Recorded 100 Housing Cooperative Studied** |
|---|---|
| Website of the entity studied | |
| Fiscal YEAR | |
| I. GENERAL STANDARD DISCLOSURES | |
| Strategy and Analysis: | |
| G4-1 | |
| Organisational Profile: | |
| G4-3 | |
| G4-4 | |
| G4-5 | |
| G4-6 | |
| G4-7 | |
| G4-8 | |
| G4-9 | |
| G4-10 | |
| G4-11 | |
| G4-12 | |
| G4-13 | |
| G4-14 | |
| G4-15 | |
| G4-16 | |
| Identified Material Aspects and the corresponding Boundaries: | |
| G4-17 | |
| G4-18 | |
| G4-19 | |
| G4-20 | |
| G4-21 | |
| G4-22 | |
| G4-23 | |
| Stakeholder Engagement: | |
| G4-24 | |
| G4-25 | |
| G4-26 | |
| G4-27 | |

**Table A1.** *Cont.*

| Entity Studied / Items | Subsequently Recorded 100 Housing Cooperative Studied |
|---|---|
| Report Profile: | |
| G4-28 | |
| G4-29 | |
| G4-30 | |
| G4-31 | |
| G4-32 | |
| G4-33 | |
| Organisational Governance: | |
| G4-34 | |
| Ethics: | |
| G4-56 | |
| II. SPECIFIC STANDARD DISCLOSURES | |
| Information on the approach to governance | |
| Indicators and information on the approach to governance in relation to the specific Aspects | |
| Optional: | |
| Information on the approach to governance | |
| G4-DMA | |
| Indicators by Aspects: | |
| 1. Economic category: | |
| a. Economic Performance | |
| b. Market Presence | |
| c. Indirect Economic Impacts | |
| d. Procurement Practices | |
| 2. Environmental category: | |
| a. Materials | |
| b. Energy | |
| c. Water | |
| d. Biodiversity | |
| e. Emissions | |
| f. Effluents and waste | |
| g. Products & Services | |
| h. Compliance | |
| i. Transport | |
| j. Overall | |
| k. Supplier Environmental Assessment | |
| l. Environmental Grievance Mechanisms | |

**Table A1.** *Cont.*

| Entity Studied / Items | Subsequently Recorded 100 Housing Cooperative Studied |
|---|---|
| 3. Social category: | |
| 3.1. Labour Practices and Decent Work: | |
| a. Employment | |
| b. Employee/Management Relations | |
| c. Occupational Health and Safety | |
| d. Training and Education | |
| e. Diversity and Equal Opportunity | |
| f. Equal Remuneration for Women and Men | |
| g. Supplier Assessment for Labour Practices | |
| h. Labour Practices Grievance Mechanisms | |
| 3.2. Human Rights | |
| a. Investment | |
| b. Non-discrimination | |
| c. Freedom of Association and Collective Bargaining | |
| d. Child Labour | |
| e. Forced and Compulsory Labour | |
| f. Security Practices | |
| g. Indigenous Rights | |
| h. Periodic Assessment System | |
| i. Supplier Human Rights Assessment | |
| j. Human Rights Grievance Mechanisms | |
| 3.3. Society | |
| a. Local Communities | |
| b. Anti-corruption | |
| c. Public Policy | |
| d. Anti-competitive Behaviour | |
| e. Compliance | |
| f. Supplier Assessment for Impacts on Society | |
| g. Grievance Mechanisms for Impacts on Society | |
| 3.4. Product Responsibility Performance Indicators (e.g., responsibility for buildings): | |
| a. Customer Health and Safety (here: customers are housing cooperative members) | |
| b. Product and Service Labelling | |
| c. Marketing Communications | |
| d. Customer Privacy (here: privacy of housing cooperative members) | |
| e. Compliance | |
| COMMENTS | |

Source: own elaboration based on Reference [27] (pp. 18–235).

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*sustainability*

MDPI

*Article*

# Toward Cognitive Management Accounting

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**Abstract:** This paper examines the impact of cognitive technologies in management accounting. The purpose of the research was to create the current management accountant skills model. The main contributions of this paper are the literature study of the future of management accounting, the study of the impact of cognitive technologies on management accounting, the labor market research, and the current management accountant skills model. The purpose of the literature study was to highlight the opportunities and challenges of the application of cognitive technologies to management accounting and the role of cognitive abilities in the management accountant profession. The labor market study was conducted in order to analyze the impact of cognitive technologies on the management accountant profession and identify the core skills required. The paper fulfills the research gap regarding the impact of cognitive information technologies on management accounting and the management accountant profession in terms of smart and sustainable organization conception. The number of job positions with cognitive analytic skills, big data skills, cognitive abilities, and additional skills and competencies was identified. Although the research reveals differences in the demand for skills and abilities among the studied countries, the common skills model for managerial accountants was successfully created.

**Keywords:** cognitive computing; managerial accounting; management; big data; skills model; labor market

## 1. Introduction

Currently, accounting business processes are undergoing a transformation through digitalization and sustainability.

The sustainability of an enterprise is largely determined by the level of innovation potential, especially in the process of development of smart sustainable cities. Nowadays, the convergence of two conceptions, the smart city and the sustainable city, generate the data-driven smart sustainable city. The smart sustainable city consists of smart sustainable organizations, which are based on smart sustainable processes supported by cognitive and big data technologies. These organizations need to find sustainable solutions to deal with the complexity of financial and accounting data. Advances in Internet technologies have made it possible to gather, store, and process large amounts of interactive enterprise data [1]. When creating smart sustainable cities, big data and cognitive technologies generate useful information and insights for citizens, enterprises, and policymakers. The new digital technologies link big data and cognitive analytics with operational sustainability practices for sustainable business management. Transforming large amounts of data into knowledge allows them to empower cognition as well as support decision-making routines [1]. According to the IBM company, "the opportunities that cognitive Internet of Things solutions can deliver in the sustainability space are enormous, and early adopters are gaining a competitive advantage. As sustainability moves into the mainstream on Wall Street, organizations that are able to harness the power of cognitive technologies to advance their goals while helping the planet will lead the way" [2].

The background analysis indicates that accounting for sustainability entails the reporting of ecological and social information and the integrated reporting of sustainability information along with financial reporting. Moreover, the emerging technologies should provide users with sustainability reports, auditing, and the assurance of sustainability information, sustainability implications of financial failure, accounting, and auditing failures.

For years, scientists have emphasized the role of cognitive abilities in behavioral accounting, judgments, and decision making [3–10]. Individuals with good cognitive abilities are better equipped to acquire the knowledge needed to perform their jobs at the highest levels [11].

In recent years, the impact of cognitive abilities on different professions in the finance and accounting sphere has increased. On the other hand, some people are unwilling to recognize the importance of increasing the level of cognitive abilities for a better use of information technologies. The number of works in which scientists attempt to analyze the impact of cognitive skills and cognitive technologies is also constantly increasing.

For years, various definitions of cognitive abilities have been proposed, from the more common to the more concrete. For example, Carroll's definition states that "cognitive ability can be defined as variation across individuals in the successful performance of tasks primarily involving processing of mental information" [12]. According to one of the most recent definitions, "cognitive abilities are aspects of mental functioning, such as memorizing and remembering; inhibiting and focusing attention; the speed of information processing; and spatial and causal reasoning" [13].

In this paper, cognitive abilities are treated in more practical terms. They are the cognitive skills required by an employee to use cognitive technologies more efficiently and in order to increase the effectiveness of accounting processes, including the acceleration of decision-making processes.

Originally associated with artificial intelligence, the researchers began to use the term "cognitive computing" from the 1990s. Cognitive computing has attracted real attention since 2011.

Cognitive computing refers to the computer systems inspired by the human brain, which have natural language processing capability, learn from experience, interact with humans in a natural way, and help make decisions based on learning processes [3–16].

Cognitive computing can also help accountants with deep analytics. According to Deloitte, "cognitive analytics" is a term used to describe "how organizations apply analytics and cognitive computing technologies to help humans make smarter decisions" [17].

In 2017, John Baron, Managing Director of the professional segment of the Tax and Accounting Business in Thomson Reuters, argued that "very soon, cognitive computing will begin to impact the accountant profession. It can be used in risk mining, grouping and connecting entities, detecting abnormalities in structured and unstructured data, and improving the user experience" [18].

Moreover, in 2019 Forbes wrote that "the use of cognitive technologies already has changed the accounting profession. Automated solutions make the accountant's job easier, eliminating much of the manual processing of data. Such tools also provide transparency into digitized financial data to validate the quality and accuracy of ledgers, compressing the margin of error" [19].

In recent years, the convergence of Big Data and Artificial Intelligence (AI) in finance and the accounting area is gaining popularity. Cognitive Analytics relates to Big Data technologies. "With the advent of big data, which grows larger, faster and more diverse by the day, cognitive computing systems are now used to gain knowledge from data as experience and then generalize what they have learned in new situations" [20].

However, many accountants are wondering if Artificial Intelligence will be a job-killer in the accounting profession. Most firms believe cognitive computing will be a "job-creator, relieving accountants of time-consuming and mundane process work and freeing up space to work on more complex work" [21]. Scientists suggest that accounting is a business field that is "likely to be augmented by IT technology rather than fully automated" [22].

According to Jim Boomer, "it will serve as a complement to the evolution of accountants from technical advisors to strategic, value-added advisors", which does not mean that cognitive computing

does not present any risks to the accountant profession [21]. The experts suggest that managers will need to transform and expand their practice toward more advisory services. The commonality between research on human cognitive processes and auditing is usually described with regard to two issues: judgment and risk [23]. The importance of using these capabilities, especially for managers and auditors, are confirmed by many scientists. Accountants should also consider the directions in which they can enhance their knowledge and skills to prepare for the big data challenge [23,24]. Financial and accounting managers, as the leaders and advisors, should maximize their big data analytics skills [25–27].

In the literature on sustainable development, there is still a gap in the impact of modern information technologies on management accounting, and on the achievement of sustainable development by enterprises. These technologies are predominantly cognitive and big data technologies. Moreover, there is no research into the desired skills and abilities of management accountants in practice. In order to analyze the impact of cognitive technologies on managerial accounting, a literature study has been conducted.

The main contributions of this paper are the literature study on the future of management accounting and on the impact of cognitive technologies on management accounting, the labor market research, and the current management accountant skills model.

Since two methodological approaches were chosen, namely a theoretical and a practical approach to the management accountant skills model creation, the literature study was focused on scientific papers and non-scientific literature sources, such as market reports and experts' opinions.

Most of the papers in this area are based on a qualitative approach, by analyzing the experts' opinions. In this paper, the quantitative approach of labor market analysis was selected to fulfill the research gap in the area of management accounting skills analysis; therefore, the results of the present study have meaningful practical implications.

The paper is structured as follows. First, a review of the literature is provided, outlining the issues raised by the research on the impact of cognitive technologies on management accounting and the management accountant profession in terms of sustainability. This is followed by a survey conducted on selected labor markets and the description of the results of that survey. The research aimed to create the current management accountant skills model, with an emphasis on modern Information Technologies (IT). Finally, conclusions and future perspectives are presented.

## 2. Literature Review

### *2.1. The Future of Management Accounting*

There has been a substantial degree of research interest on the description of the current and future models of management accountant skills. However, the authors concentrate only on the general domain or traditional technologies, without taking into consideration the smart sustainable enterprises conception, supported by cognitive and big data technologies. Moreover, the conducted studies were based on the experts' opinion analysis. There is a lack of research based on labor market analysis.

The literature review was divided into three groups: papers describing the role of management accounting for sustainable business management, papers describing the changing role of information technologies for management accountants in commercial enterprises, and, finally, papers describing the role of cognitive and big data technologies in sustainable development.

Nowadays, many authors treat management accounting as part of a sustainable development strategy. Most of them initiate the discussion on the further development of management accounting establishing how current management accountants view their present and future role [28–36].

Already in 2004 [28] authors emphasized the extension of the role of management accountants to team leadership, leadership in using statistical/analytical techniques, the design and management of information systems, and the design and control of performance measurement systems.

In paper [32], a bibliometric analysis based on the scientific papers in the Web of Science database concerning management accounting research in Central and Eastern European countries in 1945–2017 was done. It reveals key trends in changes in the field of management accounting research. The results undergo many political, structural, social, and economic changes, with growing public awareness of the need for corporate sustainability among them.

The paper by Maas and others addresses the question of how companies can and do integrate sustainability assessment, management accounting, management control, and reporting [33].

In 2018, in the book "The Role of the Management Accountant: Local Variations and Global Influences" [35], the future of management accountants in different countries was presented: the United States, United Kingdom, South Africa, Japan, India, France, Canada. The role of IT in management accounting was also described. Most of authors emphasize the increasing role of information technologies in the studied countries. They highlight the importance of interpersonal and technical skills development. They also discuss sustainability as a fundamental challenge for management accountants. The authors state that management accountants are challenged to redefine and develop their role as the coordinators of processes for the management of sustainability information. The skills need to be developed to address sustainability issues. Therefore, educational and training programs should be changed.

In his paper, Gary Cokins describe seven trends of management accounting and, among them, management accounting's expanding role regarding managing information technology and shared services as a business [36]. He also noticed the shift toward predictive accounting.

In [30], the authors describe how social and environmental accounting and environmental management reporting contribute to more sustainable value.

Others highlight the increasing role of reporting in managerial accounting [37–41]. They also emphasize the importance and value of sustainability reporting. The Bulletin of the United States Bureau of Labor Statistics in 2002 highlights the role of IT for the managerial accounting profession [38].

In his paper "The state and development trends of management accounting in the global environment", Bartłomiej Nita presents the development trends of management accounting practice in a global environment. He highlights the role of IT in management accounting, especially the role of business intelligence and big data reporting in Enterprise Resource Planning (ERP) systems [39].

Paper [40] provides theoretical as well as practical contributions to the change of the management accounting role in the era of digital technologies. The report created by Louise Ross and Ivan Kovachev presents management accounting tools useful for today and tomorrow [41]. Unfortunately, this report does not take IT tools into consideration. However, it emphasizes the increasing role of reporting.

In recent years, several researches have been conducted in order to analyze the use of Information Technology in management accounting and the potentials and drawbacks of adopting IT in management accounting [42,43].

The relevant report associated with the use of information technologies in the management accounting profession is created by the Institute of Management Accountants and presented as the Management Accounting Competency framework [43]. Unfortunately, there is a lack of focus on cognitive technologies and cognitive abilities in it. The framework contains information about the core competencies divided according to expertise level, from the basic to the expert level. The main management accountant IT competencies are: recommending and implementing the appropriate system in a complex environment, ensuring the integration of information and performance management systems, designing Enterprise Resource Planning workflows for sound financial control, creating customized reports, analyzing data using business intelligence software, leading the organization's adoption of new technology platforms as they emerge, creating flowcharts using specialized software tools, and using spreadsheet functions (e.g., graphs, filtering and sorting data, importing data, pivot tables) [43].

In the paper by Handley, the convergence of cognitive computing and sustainability is described [44]. The new way of looking at sustainability was presented by B. Barzon in the article

"Cognitive sustainability in Digital Experiences" [45]. She describes the conception of cognitive sustainability supported by information technologies.

A significant amount of papers was written about smart sustainable cities [46–56]. These papers also underline the irreplaceable role of cognitive technologies and big data technologies for sustainable smart cities. Smart Sustainable Cities use these technologies to be more intelligent and efficient in enterprise resource management. The authors assure that Artificial Intelligence (AI) and cognitive technologies can help companies use real-time insights and enhance their sustainability efforts [1,44].

### *2.2. Cognitive Technologies in Managerial Accounting*

As previously mentioned, Artificial Intelligence can help companies use real-time insights to enhance their sustainability efforts [44]. Artificial Intelligence has already enabled advanced financial analytics [57]. Tax systems completed with AI are smarter, not only in guiding accountants through the calculations and highlighting areas they might need to review, but also in providing advice and guidance to the client [58]. "Accountants are not required to do detailed research work, as that is done through artificial intelligence" [59]. Analytics introduce the benefits of efficiency in mass data collection and the potential to locate tax evaders [60]. The Internal Revenue Service (IRS) has indicated that it will continue to invest in data technologies to identify tax return errors and address issues with taxpayers as early as possible [60,61].

In turn, Baron argued that "the future of cognitive computing will revolutionize the accounting processes" [18]. Because audit judgment skills are typically developed and refined through years of experience, training, and interaction, the cognitive and big data technologies can harness these judgments from across thousands of audits to aid continuous, real-time auditing [18].

Digital cognitive assistants are helpful when users need to process data from a large number of knowledge sources. Cognitive assistants are often speech-enabled technologies that understand voice commands, recognize a conversation's context, and answer questions in a personal manner [62,63]. "Digital assistants support the complicated accounting tasks, including responding to common queries around billing and cash flow management, and even searching accounting policies and procedures and calling subject matter experts in the organization to get the appropriate information" [64]. Cognitive assistants can provide interactive decision support for information retrieval and risk assessment in the audit brainstorming sessions. On the other hand, users should be able to manage and monitor modern technologies, so they will have more time to focus on more complex, higher-risk, and strategic tasks [65].

Currently, many companies have already applied cognitive analytics in managerial accounting. "Forward-looking Certified Public Accountant (CPA) firms are investing heavily in emerging technologies" [18]. "Audit firms have nowadays been investing many resources into AI-related projects" [63,64,66]. KPMG company signed an agreement with IBM company to apply IBM Watson to a series of audit processes [63,67]. KPMG has also announced plans to apply IBM's Watson cognitive computing in other departments, for example the Human Resources department. "This technology gives the ability to analyze a large amount of data, giving them enhanced insights into their client's financial and business operations, drawing conclusions regarding client's tax statements and returns" [68]. KPMG's cooperation with Watson tries to develop selected cognitive services designed to help KPMG "meet its extensive audit-specific security, confidentiality, and compliance requirements" [64,69]. Deloitte is trying to assemble different cognitive capabilities from various vendors and integrate them to support audit processes, such as document review and predictive risk analytics [64,70]. PricewaterhouseCoopers and EY are increasing their usage of audit platforms and predictive analytics [64]. Additionally, the American Institute of CPAs and Rutgers Business School have partnered on a research initiative to advance the use of analytics in auditing [71].

However, most firms do not have access to the capital required to make large-scale investments in technologies like cognitive computing [18].

To manage and monitor advanced technologies, management accountants need to have high cognitive abilities in order to solve strategic tasks. To use cognitive analytic tools, managers need to constantly develop their cognitive abilities. Over the years, scientists and market experts have emphasized the importance of using cognitive skills in managerial positions [72].

### *2.3. The Role of Cognitive Abilities in the Managerial Accounting Profession*

Using cognitive technologies frequently requires management accountants to possess cognitive analytics skills.

According to the Institute of Management Accountants (IMA), "Management accounting is a profession that involves partnering in management decision making, devising planning and performance management systems, and providing expertise in financial reporting and control to assist management in the formulation and implementation of an organization's strategy" [73]. Management accountants are responsible for managing the team. Therefore, they are expected to exhibit excellent leadership skills, conduct performance evaluations, provide mentoring and training on technical skills, conduct regular meetings, and provide guidance based on the directives and strategies given by management [74].

The knowledge of different accounting systems is also included in a management accountant's duties, with main modules like general ledger, accounts payable, accounts receivable, cash flows, and revenue reconciliation, among others [74]. Forecasting and preparing the yearly budget are also included in a management accountant's responsibilities. A management accountant prepares periodic closing and management reports that help the executive team with their strategic planning. Finally, a management accountant is responsible for preparing the company's financial statements and auditing the accounting data of the different departments of the organization.

The management accountant is also expected to exhibit high cognitive abilities. Researchers also underline the importance of these abilities in practice. According to one of the most popular job searching web portals, Indeed.com, cognitive skills are "the ways that your brain remembers, reasons, holds attention, thinks, reads, and learns" [73].

According to Lachman, "cognitive abilities are key competencies that are needed to meet the challenges of job demands, education, and advanced training and a key selection criterion for entry into many elite professions [75]. The cognitive ability could also be defined as a "general mental capability involving reasoning, problem-solving, planning, abstract thinking, complex idea comprehension, and learning from experience" [76].

According to experts, cognitive abilities are especially meaningful in auditing. Studies on cognitive abilities in auditing use the lens model [77], Bayesian statistics and the literature on heuristics and biases [78], analysis of variance techniques [79], descriptive variants of expected utility theory, learning and memory processes [80,81], and various aspects of process tracing methodology [82]. Later, Frederick analyzes how auditors encode knowledge in memory and the implications this might have for the construction and use of memory aids in auditing [83].

The paper of J. Dillard presents the discussion on the relevance of cognitive science to decision-making research in accounting [84].

The paper of Choo presents a major concept from social cognition called "script" and applies this notion to auditing and accounting behavior [85].

In 1992, Libby and Lipe investigated how the performance-related incentive effects of monetary payments depend on the cognitive processes involved in accounting judgment tasks [86]. They argue that this dependency exists.

J. Amernic describes another cognitive ability needed for accounting managers – cognitive complexity: "leaders in the accounting profession have cited the need for accountants to be able to function professionally in a complex and changing environment. The literature of cognitive development suggests that such individuals must possess a high level of cognitive complexity" [87].

Some authors examine the effects of adaptive/innovative cognitive style and professional development on the initiation of radical and non-radical innovations by individual management accountants [88].

Further research involved the use of cognitive tests, cognitive reflection tests, and magnetic resonance imaging to analyze brain work during the accountants' decision making process [89,90].

In 2016, researchers underlined the role of cognitive reflection abilities in accounting and proved that managers' decisions, analysts' recommendations, auditors' reports, and professors' lessons tend to be highly influenced by cognitive reflection abilities [3].

Summarizing the results of the literature study, management accountants need to collect, extract, and analyze the information from extensive databases. So, among cognitive abilities, they need to acquire advanced IT skills. This will result in a link to the skills of data extraction, information management, processing of a large amount of data, pattern recognition and privacy, and security management, and will bring new challenges to the labor market. The 2016 survey revealed that 59 percent of employers say data science and analytics skills will be necessary for accounting managers by 2020 [58].

The experts noticed that nowadays there is also a growing need for accounting students to learn financial and accounting data analysis and reporting in order to enhance their abilities [19]. This reveals the labor market's need to recruit the new generation of managers in the accounting sphere. The universities should be prepared, offering education courses that meet market needs for new specialists. In 2016, it has been noted that many accounting programs do not currently prepare students for such roles [71,91].

Wang and Wang predicted in 2016 that the accounting managers' skills needed for the next decade will be: knowledge of data extraction tools in the mining of business intelligence; use of tools that support data modeling and analysis; knowledge management skills; project management skills; change management skills; knowledge of new approaches to funding and product development; ability to use technology to attract, develop, and manage talent; knowledge of emerging payment platforms; better working knowledge of connectivity and IT security; knowledge on how applications integrate [92].

Summarizing all of the above, the main directions of the management accountant profession's transformation are related to digitalization, sustainable development, big data, cognitive computing, cloud computing, and cognitive abilities development.

Furthermore, the situation should also be analyzed in practical terms. What does the situation look like in local labor markets? Are enterprises already looking for qualified management accountants with cognitive analytics skills and big data knowledge and experience?

To check the current situation in labor markets, a study of the current demand for management accountants' positions was conducted.

## 3. Materials and Methods

The research was conducted in November-January 2019. First, data were collected at the beginning of November, and after that results have been checked two times until the beginning of December, during a 1-month period. A similar procedure was conducted in December and January. The empirical research was conducted according to the framework presented in Figure 1. The quantitative approach was selected to fulfill the research gap in the area of management accounting skills analysis.

The labor markets of the selected countries were examined. The goal was to compare the demand for management accountant positions in different continents and countries according to the following criteria: differentiation in GDP level, labor force, IT development level, geographical position (different continents and different European regions), population differentiation. The 5 following countries were taken into consideration: the United States of America, Canada, Poland, the United Kingdom, and Ukraine.

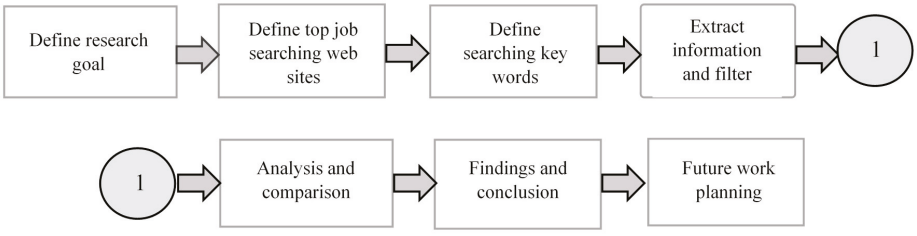


**Figure 1.** The research framework.

At the beginning, the most popular job search websites were selected, and their comparison was carried out. The following selection criteria were used: (1) the largest number of current management accountants posts, (2) ability to provide "advanced search" with the finding options, which allowed us to search for specific key words within the job posts' textual content, (3) applicability in studied countries. Consequently, the "Indeed" job search website was chosen.

About 33 of thousands of job posts were analyzed. For all selected countries, the same research procedure was used. To filter the job posts, the website searching mechanism was used. For this purpose, the following keywords were entered in the webpage search field: "cognitive", "analytics", "cognitive analysis", "Cognos", and also "big data", "large data", "large data sets", "large amounts of data", etc. For skills analysis, "cognitive skills" and "cognitive abilities" key words were used. For position analysis, the following key words were primarily used: "management accountant", "accounting manager", "managerial accountant", and similar.

The website searching mechanism found many relevant positions, such as: Accounting Manager, Senior Accounting Manager, Manager Accounting and Reporting, Department Budget Manager, Cost Accounting Manager, etc.

Based on the list of obtained, the number of job offers for management accountants (MA) and relevant positions containing cognitive skills requirements, cognitive analytics skills, and big data skills requirements was calculated. The results are presented in Table 1. After that, the additional core competencies were identified by using the following key words: "Project management", "Business process management", "Change management", "ERP" [93], etc.

**Table 1.** The number of job offers for selected labor markets in November 2019.

| Skill | USA | Canada | UK | Poland | Ukraine |
|---|---|---|---|---|---|
| Cognitive A skills | 719 | 36 | 57 | 3 | 0 |
| Big data skills | 652 | 38 | 60 | 4 | 3 |
| Cognitive skills | 10 (173) | 10 | 3 | 0 | 0 |
| Total | 18,398 | 5272 | 9019 | 563 | 596 |

The significant difference in the number of offers among the studied countries was noticed (Figure 2). The demand for management accountant positions in the Polish and Ukrainian labor markets was more than 30 times lower than in the United States labor market.

The filtered searches in the indeed.com website yielded 18,398 offers in the United States in November, 17,600 offers in December, and 17,496 offers in January (Tables 1 and A1–A4). It was found that cognitive analytics skills are currently very important for management accountants. Comprehensive cognitive skills were required only in 9–18 positions, and 173 companies were looking for professionals with different concrete cognitive abilities—with cognitive flexibility, cognitive thinking, cognitive skills to synthesize multiple inputs and reach a single optimal solution, and similar. In 3.1% of the total number of offers, companies require from management accountants knowledge of the Cognos system. In December and January, the situation on the labor market was subject to slight fluctuations (Tables 2 and 3, Tables A5–A12). The descriptive statistics are presented in the Appendix A.

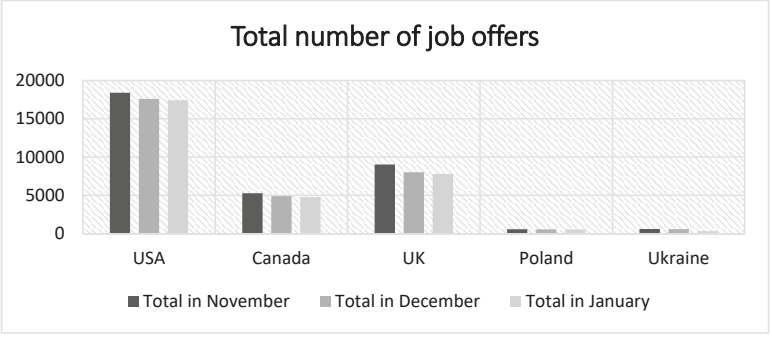


**Figure 2.** Total number of job offers for accounting managers in November–January 2019 (without filtering).

**Table 2.** The number of job offers for selected labor markets in December 2019.

| Skill | USA | Canada | UK | Poland | Ukraine |
|---|---|---|---|---|---|
| Cognitive A skills | 594 | 33 | 51 | 2 | 1 |
| Big data skills | 631 | 13 | 21 | 3 | 1 |
| Cognitive skills | 18 (194) | 3 | 0 | 0 | 0 |
| Total | 17,600 | 4889 | 8015 | 548 | 573 |

**Table 3.** The number of job offers for selected labor markets in January 2020.

| Skill | USA | Canada | UK | Poland | Ukraine |
|---|---|---|---|---|---|
| Cognitive A skills | 614 | 16 | 40 | 6 | 0 |
| Big data skills | 602 | 7 | 13 | 1 | 1 |
| Cognitive skills | 14 (113) | 0 | 0 | 0 | 0 |
| Total | 17,426 | 4763 | 7782 | 518 | 310 |

However, the comparison of this data should be further considered in terms of labor market statistics (Table 4).

**Table 4.** The comparative statistics of job offers for the total research period.

| Rate | USA | Canada | UK | Poland | Ukraine |
|---|---|---|---|---|---|
| Average of MA offers | 17,808 | 4974 | 8272 | 543 | 493 |
| Labor force | 154.9 | 18.59 | 31.45 | 17.00 | 22.06 |
| Labor force per 1000 | 500,775 | 54,474 | 50,505 | 44,522 | 48,092 |

Source: own elaboration based on Reference [93].

The following data were acquired. According to NationMaster database the United States labor force was 154.9 million. It was ranked at 4th place, that is, 8 times more than Canada and many times more than the other studied countries. The Canadian labor force was made up of 18.59 million people, and the United Kingdom's 31.45 million. Poland's labor force comprises 17 million of people, while Ukraine's labor force comprises 22.06 million. On the other hand, the UK's labor force per 1000 was 505.05 m, 1% more than that of the United States, which was 500.77. In Canada, the labor force per 1000 was 544.74, 9% more than in the United States. Poland's labor force per 1000 was 445.22, and in Ukraine, the labor force per 1000 was 480.92 [93]. In terms of labor force per 1000 analysis, the United States was in the leading position. However, the labor force statistics analysis significantly eliminates the difference in size demand between Canada and the United Kingdom. The results of labor force statistics analysis allow for the elimination of the difference in size demand between Canada, the United

Kingdom, and the United States, and gives these countries an advantage. Poland and Ukraine are in lower positions, but with better results due to a lower rate of labor force and labor force per 1000.

In the next step, the obtained data were filtered, and information about the demand in selected labor markets was analyzed in detail. Additionally, the descriptive statistics were calculated in order to prove the data's usefulness and to enable further analysis and data comparison for future and deeper research. These statistics are presented in the Appendix A.

In the United States, predominantly, the software experience required included, among other systems: Cognos, SAP, Essbase, Oracle Hyperion, Alteryx and Micro-Strategy Peoplesoft, SQL, Excel, DOMO, Lawson, JD Edwards, QAD, CostPoint, etc.

In Canada, the number of job offers for management accountants was about 3.5 times lower than in the United States in November (Table 1). The total of 5272 offers was filtered. It was found that 38% required big data skills; 36% required cognitive analytics skills; 0% required cognitive skills; 10% required different cognitive abilities. The popularity of Cognos and Tableau software skills requirement was noticed. In December and January, the demand for big data skills and cognitive skills dropped dramatically (Tables 2 and 3).

The software currently required for management accountants in Canada included, among others: AS 400, Cognos, Epicor, MS SSAS, SSRS, MS Power BI, QlikView, Tableau, PMP, PeopleSoft, SAP, Oracle Hyperion, NetSuite, Workday, Microsoft Dynamics, Adaptive Insights, etc.

In the United Kingdom, the total number of offers was about 9000 in November, with a subsequent decrease in the following months (Table 1). It was found that 57% of offers required Cognos experience in November; 3% required with cognitive abilities; 0% required cognitive skills; 60% required with big data skills.

The software experience required in the United Kingdom most often concerned the following systems: Essbase, Cognos, Oracle Hyperion, Anaplan, Spotfire, Microsoft Power BI, Sage, eFinancials, Excel, SAP Hana, Vector, Wims, Capex, Caseware, Lawson, JD Edwards, SAS software. Additionally, some companies were looking for experienced managers with knowledge of VBA, Python, SQL, and R.

A total of 563 offers were filtered in Poland in November, 548 in December, and 518 in January (Tables 1–3). It was found that 3% of offers required Cognos experience; none required cognitive skills; 4% required big data skills.

The software experience required was related to the following systems: SAP, Excel, Oracle, Sage. Additionally: Power Query, Power BI, SQL. In Poland, specialists with Tableau software experience were looked for more often than with Cognos. No job posts with cognitive abilities requirements were found.

In order to analyze the demand in Ukraine, the rabota.ua job searching portal was also checked, because of its greater popularity when compared to indeed.com. Very few companies were looking for management accountants with big data skills and cognitive analytic skills (from 1 to 3% of offers depending on the month), and no offers mentioned cognitive abilities.

In Ukraine, 1C was the preferred software (354 offers in November). The significant popularity of MS Excel was also noticed. It was also found several job posts with SAP, Oracle, and Cognos experience requirements, but no offers mentioned Tableau experience. Sometimes, companies (for example, Deloitte) were looking for management accountants only with BI, MySQL, or R skills.

## 4. Results

It was found that the situation in different European labor markets varied significantly. Generally, the research revealed differences in cognitive analytics skills, big data skills, and cognitive skills demand between the United States and the other studied countries. Presently, the number of job offers with BD skills and cognitive analytics skills requirements are higher in the United States. The smallest number of offers with skills requirements was noticed in Poland and similarly in Ukraine. In the United Kingdom, the number of these offers was often as high as that of the abovementioned countries (Figures 3–5).

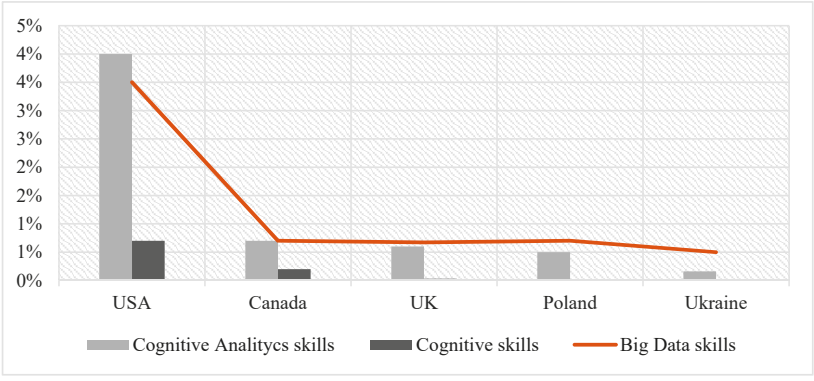


**Figure 3.** The total number of offers by country in November 2019.

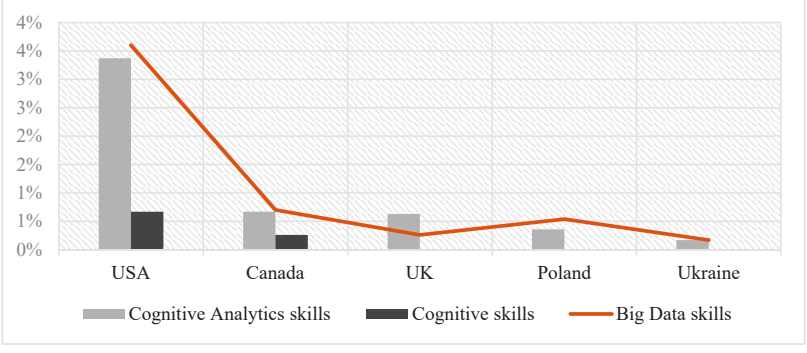


**Figure 4.** The total number of jobs offers by country in December 2019.

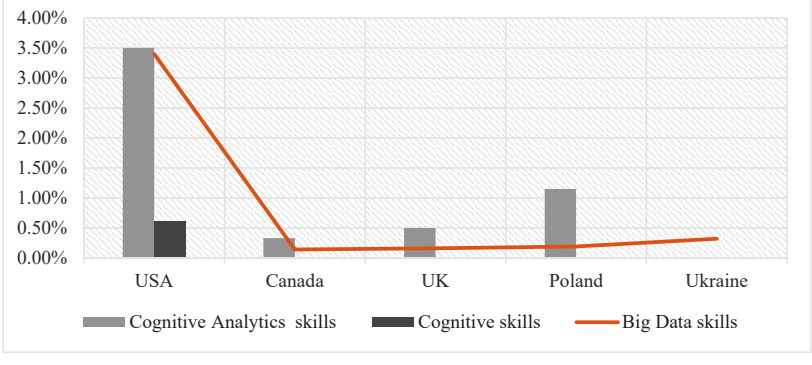


**Figure 5.** The total number of offers by country in January 2020.

The highest popularity of cognitive abilities was noticed in the United States' labor market, and it was about 3.5%. In the United Kingdom, the United States, and Canada, accounting managers are generally expected to have more advanced IT skills. In Ukraine and Poland, these skills are currently not so required.

20–30% of UK companies require management accountants to be familiar with ERP systems. In Poland, about 30% of companies require SAP knowledge or experience; 40% require advanced Excel

knowledge; 24% require a combination of ERP and Excel; 2% require Oracle experience; and 0.5% require Sage experience.

In Ukraine, the low demand for cognitive analytics and big data skills for management accountants was noticed. On the other hand, the traditional analytic skills requirements were high. The most popular software required in Ukraine was 1C (with a deviation from 60 to 70% of total job posts) and Excel (with a deviation from 20 to 25%, in SAP of about 5%, and in Oracle of about 1%). The most popular IT tool for managing a large amount of data in Ukraine was Microsoft Excel. Several companies were looking for management accountants specialized in soft programming skills: SQL, Python, and R.

Additionally, the decision to check the demand for Cognos software skills among countries was due to the fact that, according to the ranking on Cognitive Analytics Solutions Quadrant presented at the 360 quadrants website, this system is in the first place (retrieved 05.01.2020) [94]. It was found that IBM Cognos is currently the most popular software in the U.S.A. 3.3% of U.S.A companies were looking for management accountants with experience in using this software (Figure 6).

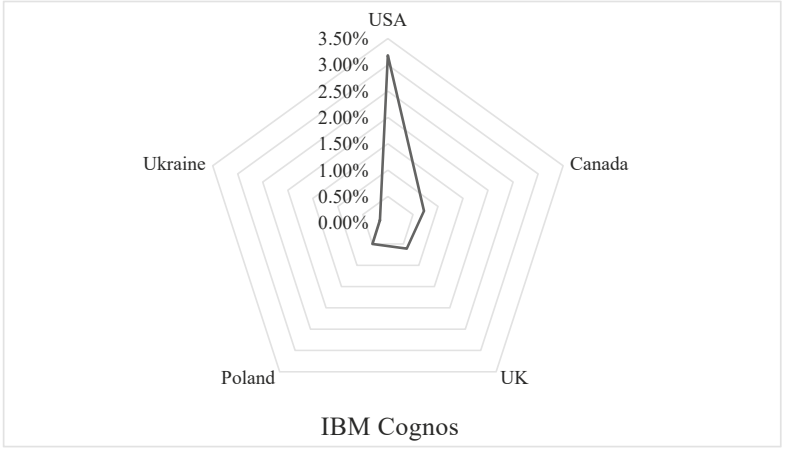


**Figure 6.** The percentage of job offers for management accountants requiring Cognos software skills in November 2019–January 2020 in relation to the total number of offers.

## 5. Discussion

Summarizing the results obtained from the literature study and labor market research, it was concluded that the main technologies that have an impact on managerial accounting development are: big data technologies, cloud computing, cognitive computing, ERP systems, payment platforms, e-commerce platforms, Business Intelligence technologies. These technologies create new IT trends toward cognitive managerial accounting.

The research also revealed that the additional competencies needed for management accountants are, among others: ata anagement and Information Management skills, Change Management skills, Quality Management skills, strong IT and systems knowledge, Supply Chain Management skills, Program Management skills, Project Management skills, IT system implementation skills, and Business Process Management skills. So, the experts' opinion [43,89,92,95] on the core competencies of future management accountants were confirmed. Additionally, we observed the increasing popularity of the cognitive ability "to understand the big picture" in the United Kingdom, Canada, and the United States.

On the basis of the literature study from Section 2 (especially regarding [76,87,92,96,97]) and the labor market analysis from Section 3 (on the basis of the appearance frequency in job posts), the current model of management accountants' core skills and abilities was created (Figure 7).

The model considers two methodological approaches: the theoretical and the practical approach. In this model, one set of competencies is defined for a broad range of similar job positions corresponding to management accounting. The skills model of management accountant positions is built around 3 main groups: technical (specific skills), cognitive skills, and social and behavior skills. Due to the generic character of the skills considered, the model was qualified as a generic skills model.

The procedure of model creation was constructed in line with the methodological requirements presented in the literature on the subject [98–104].

The following methodological approach was used in order to build the current management accountant skills model (Figure 7).

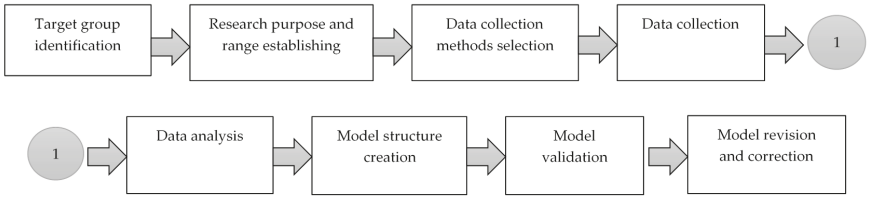


**Figure 7.** The framework for skills model creation.

The first stage was the target group identification. In this case, the target group consisted of management accountants and similar job positions. The second stage was the purpose and range establishing. The main purpose was to create a current model taking into consideration cognitive technologies and cognitive abilities and clearly highlighting them. The third stage was the selection of data collection methods. Among different methods, such as literature reviews, surveys, focus groups, interviews, etc., the literature review and labor market survey were selected. First, the literature study was conducted. The next stage was the model structure creation. Based on the literature study, the main structure of the model was created, including building the skills hierarchy by synthesizing them into the three main groups and providing a description with the relevant competencies for each group.

To evaluate and extend the results of the literature review, the labor market research was conducted. The next stage was the model validation through a labor market research and the model complementation with additional abilities corresponding with the main groups. At this stage, the frequency of the occurrence of abilities in job posts was analyzed. The last stage was the model revision and correction. The abilities that frequently appear in job posts and were not identified as a result of a literature study were added to the model. The abilities that do not appear in labor market analysis were excluded from the model. The model revision should be continuous. The enterprises should develop the framework checking current demand and market tendencies.

Based on the literature, a total of 30 competencies were derived. Various authors underline the key competencies required. The model contains three skill groups (Figure 8):

1. Technical skills (specific skills):

   - ✓ Accounting skills: depend on job position.
   - ✓ Management skills: Business Process Management [43,92], Change management [43,92,97], Supply Chain Management [43,97], Quality Management [43,97], Project Management [43,92], Data and Information management [92,97], Knowledge Management [92,97], etc.
   - ✓ IT skills: ognitive Analytics [18,20–22,44,58,59,62–64], Artificial Intelligence [18–22,44,58,59,62–64,97], Integrated Information systems [39,43,92,97], Cloud Computing [95,97], Big Data [20,25–27,39,97], Business Intelligence [39,43,97], programming [97], data mining [43,92], data reporting and visualization [19,37–41,43,97], e-commerce [92], e-marketing [92], system implementation skills [43,97], etc.

2. Cognitive skills: flexibility [76], analytical skills [43,58,76,92,97], synthesis skills [76,97], ability "to see the big picture" (labor market research), judgment abilities (evaluation) [76,84,86,97], prediction abilities [76,97], reflection abilities [3,89,90].
3. Social and behavioral skills: Leading skills [92,97], Team working [92,97], Communication skills [92], Organizational skills [97].

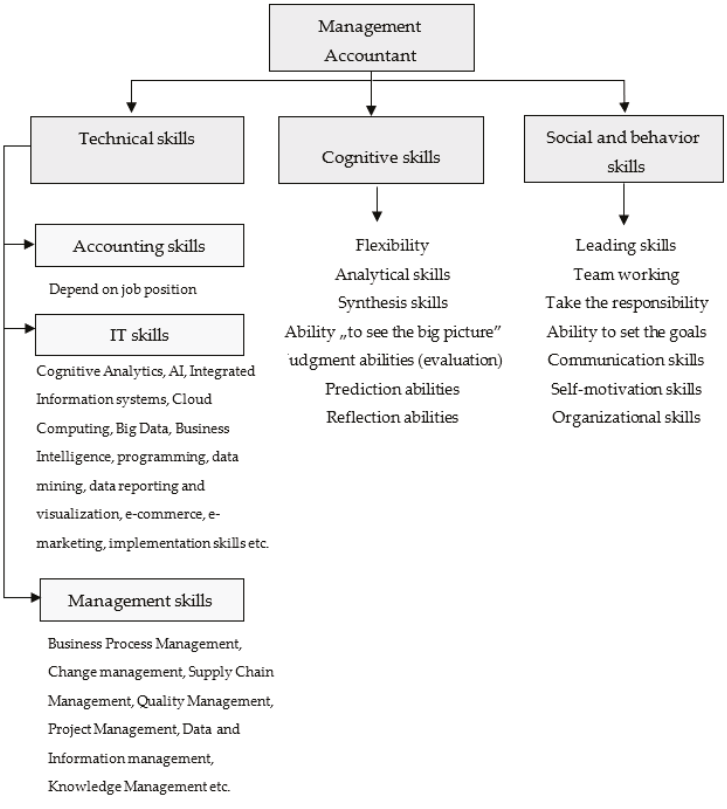


**Figure 8.** The model of current management accountants core skills.

The research has several limitations. First, it was hard to identify and exclude repeated job posts. The second limitation was that the study investigates only the "conscious demand". That means that the research was based only on the job posts which contain the concrete definition of technologies like "big data", "cognitive analytics", and more soft definitions like "large data sets" analysis or "large amounts of data". It could be presumed that some enterprises are also looking for management accountants with advanced cognitive analytics skills. However, they do not specify it sufficiently in job posts.

## 6. Conclusions

The era of cognitive technologies is approaching. However, many doubts related to the future of the accountant profession have appeared. Management accountants need to stay up to date with technological advances and accounting software.

Currently, cognitive technologies are already changing the labor markets of the surveyed countries, serving as an essential addition to the accounting profession. They are a tool for deep data analysis and decision making. Routine work is still carried out using ERP and financial systems.

Cognitive Analytics skills are currently required for managerial accountant positions, especially in the United States' labor market, where cognitive technologies are used by many companies. The Cognitive Analytics skills are currently predominantly required in U.S.A. companies or international large companies. The number of positions where knowledge of cognitive technologies is required in Polish and Ukrainian markets is negligible. Small and medium enterprises still implement the concept of traditional or cloud accounting with Microsoft Excel analytics. In international companies, additionally, geographical analysis skills and knowledge of multidimensional visualization tools are required. The demand for additional advanced competencies in the field of data, information, and knowledge management for managerial positions in accounting was also proved and noticed.

To wrap up, most posted jobs were targeting highly qualified specialists. Therefore, high education institutions need to modernize and modify their programs in order to meet the labor market expectations. Moreover, future management accountants should not only be technically strong, but also have high cognitive abilities in order to support strategic decision-making and drive the business forward through increasingly large data sets.

The created skills model considers the management accountant profession in terms of smart sustainable business management. It takes into consideration the cognitive abilities and technical skills which are necessary for using cognitive information technologies. The proposed model had the advantage of being based on job offers, which clearly define competencies required of management accountants, associated with new technology skills and cognitive abilities. This enables the calculation of the "aware" demand.

There is a wide range of practical applications for the developed skills model. First, it can serve as the basis for developing a competency model in enterprises. In addition, the model can be used as a starting point for the development of new and more sustainable curricula at universities, as well as the creation of new training courses, including IT courses for various educational organizations. This model also indicates the directions of software development for management accounting users.

In the future, the number of analyzed countries should be enlarged. Such a comparison could reveal the geographical spread directions of cognitive technology development in the sphere of managerial accounting. It may also help high education institutions to prepare educational programs for the next decade.

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## Appendix A

**Table A1.** Descriptive statistics to Table 1.

| Value | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Mean | 466 | 28 | 40 | 2.33 | 1 |
| Standard Deviation | 256.8 | 15.62 | 32.08 | 2.08 | 1.73 |
| Minimum | 173 | 10 | 3 | 0 | 0 |
| Maximum | 652 | 38 | 60 | 4 | 3 |
| Range | 479 | 28 | 57 | 4 | 3 |
| Median | 573 | 36 | 57 | 3 | 0 |
| Geometric Mean | 401.31 | 23.92 | 21.73 | 0 | 0 |
| Harmonic Mean | 331.15 | 19.47 | 8.16 | 0 | 0 |
| Variance | 65,947 | 244 | 1029 | 4.33 | 3 |
| Kurtosis | 0 | 0 | 0 | 0 | 0 |
| Skewness | –1.55 | –1.7 | –1.72 | –1.29 | 1.73 |
| First Quartile | 373 | 23 | 30 | 1.5 | 0 |
| Third Quartile | 612.5 | 37 | 58.5 | 3.5 | 1.5 |
| Interquartile Range | 239.5 | 14 | 28.5 | 2 | 1.5 |
| Sum | 1398 | 84 | 120 | 7 | 3 |

**Table A2.** Pearson correlation (see Table 1).

| Column Number | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Column 1 | 1 | 0.6639 | 0.6628 | 0.6641 | 0.4182 |
| Column 2 | 0.6639 | 1 | 0.6666 | 0.6561 | 0.3696 |
| Column 3 | 0.6628 | 0.6666 | 1 | 0.6539 | 0.36 |
| Column 4 | 0.6641 | 0.6561 | 0.6539 | 1 | 0.4623 |
| Column 5 | 0.4182 | 0.3696 | 0.36 | 0.4623 | 1 |

**Table A3.** Spearman correlation (see Table 1).

| Column Number | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Column 1 | 1 | 0.6667 | 0.6667 | 0.6667 | 0.5774 |
| Column 2 | 0.6667 | 1 | 0.6667 | 0.6667 | 0.5774 |
| Column 3 | 0.6667 | 0.6667 | 1 | 0.6667 | 0.5774 |
| Column 4 | 0.6667 | 0.6667 | 0.6667 | 1 | 0.5774 |
| Column 5 | 0.5774 | 0.5774 | 0.5774 | 0.5774 | 1 |

**Table A4.** Covariance (see Table 1).

| Column Number | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Column 1 | 439,646,719 | 2,663,333 | 5460 | 355 | 186 |
| Column 2 | 2,663,333 | 1,626,667 | 334 | 213,333 | 10 |
| Column 3 | 5460 | 334 | 686 | 436,667 | 20 |
| Column 4 | 355 | 213,333 | 436,667 | 28,889 | 16,667 |
| Column 5 | 186 | 10 | 20 | 16,667 | 2 |

**Table A5.** Descriptive statistics (see Table 2).

| Value | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Mean | 473 | 16.33 | 24 | 1.67 | 0.67 |
| Standard Deviation | 24,233 | 15.28 | 25.63 | 1.53 | 0.58 |
| Minimum | 194 | 3 | 0 | 0 | 0 |
| Maximum | 631 | 33 | 51 | 3 | 1 |
| Range | 437 | 30 | 51 | 3 | 1 |
| Median | 594 | 13 | 21 | 2 | 1 |
| Geometric Mean | 41,739 | 10.88 | 0 | 0 | 0 |
| Harmonic Mean | 35,617 | 6.81 | 0 | 0 | 0 |
| Variance | 58,723 | 23,333 | 657 | 2.33 | 0.33 |
| Kurtosis | 0 | 0 | 0 | 0 | 0 |
| Skewness | –1.69 | 0.94 | 0.52 | –0.94 | –1.73 |
| First Quartile | 394 | 8 | 10.5 | 1 | 0.5 |
| Third Quartile | 612.5 | 23 | 36 | 2.5 | 1 |
| Interquartile Range | 218.5 | 15 | 25.5 | 1.5 | 0.5 |
| Sum | 1419 | 49 | 72 | 5 | 2 |

**Table A6.** Pearson correlation (see Table 2).

| Column Number | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Column 1 | 1 | 0.4692 | 0.5092 | 0.6448 | 0.6647 |
| Column 2 | 0.4692 | 1 | 0.6641 | 0.3333 | 0.504 |
| Column 3 | 0.5092 | 0.6641 | 1 | 0.3831 | 0.5406 |
| Column 4 | 0.6448 | 0.3333 | 0.3831 | 1 | 0.6299 |
| Column 5 | 0.6647 | 0.504 | 0.5406 | 0.6299 | 1 |

**Table A7.** Spearman correlation (see Table 2).

| Column Number | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Column 1 | 1 | 0.3333 | 0.3333 | 0.6667 | 0.5774 |
| Column 2 | 0.3333 | 1 | 0.6667 | 0.3333 | 0.5774 |
| Column 3 | 0.3333 | 0.6667 | 1 | 0.3333 | 0.5774 |
| Column 4 | 0.6667 | 0.3333 | 0.3333 | 1 | 0.5774 |
| Column 5 | 0.5774 | 0.5774 | 0.5774 | 0.5774 | 1 |

**Table A8.** Covariance (see Table 2).

| Column Number | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Column 1 | 391,486,719 | 1,736,667 | 3163 | 2,386,667 | 93 |
| Column 2 | 1,736,667 | 1,555,556 | 260 | 77,778 | 44,444 |
| Column 3 | 3163 | 260 | 438 | 15 | 8 |
| Column 4 | 2,386,667 | 77,778 | 15 | 15,556 | 0.5556 |
| Column 5 | 93 | 44,444 | 8 | 0.5556 | 0.2222 |

**Table A9.** Descriptive statistics (see Table 3).

| Value | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Mean | 443 | 7.67 | 17.67 | 2.33 | 0.33 |
| Standard Deviation | 28,585 | 8.02 | 20.4 | 3.21 | 0.58 |
| Minimum | 113 | 0 | 0 | 0 | 0 |
| Maximum | 614 | 16 | 40 | 6 | 1 |
| Range | 501 | 16 | 40 | 6 | 1 |
| Median | 602 | 7 | 13 | 1 | 0 |
| Geometric Mean | 34,696 | 0 | 0 | 0 | 0 |
| Harmonic Mean | 24,713 | 0 | 0 | 0 | 0 |
| Variance | 81,711 | 64.33 | 41,633 | 10.33 | 0.33 |
| Kurtosis | 0 | 0 | 0 | 0 | 0 |
| Skewness | –1.73 | 0.37 | 0.98 | 1.55 | 1.73 |
| First Quartile | 357.5 | 3.5 | 6.5 | 0.5 | 0 |
| Third Quartile | 608 | 11.5 | 26.5 | 3.5 | 0.5 |
| Interquartile Range | 250.5 | 8 | 20 | 3 | 0.5 |
| Sum | 1329 | 23 | 53 | 7 | 1 |

**Table A10.** Pearson correlation (see Table 3).

| Column Number | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Column 1 | 1 | 0.5596 | 0.509 | 0.4299 | 0.3211 |
| Column 2 | 0.5596 | 1 | 0.6613 | 0.6378 | –0.048 |
| Column 3 | 0.509 | 0.6613 | 1 | 0.6573 | –0.132 |
| Column 4 | 0.4299 | 0.6378 | 0.6573 | 1 | –0.2395 |
| Column 5 | 0.3211 | –0.048 | –0.132 | –0.2395 | 1 |

**Table A11.** Spearman correlation (see Table 3).

| Column Number | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Column 1 | 1 | 0.6667 | 0.6667 | 0.6667 | 0 |
| Column 2 | 0.6667 | 1 | 0.6667 | 0.6667 | 0 |
| Column 3 | 0.6667 | 0.6667 | 1 | 0.6667 | 0 |
| Column 4 | 0.6667 | 0.6667 | 0.6667 | 1 | 0 |
| Column 5 | 0 | 0 | 0 | 0 | 1 |

**Table A12.** Covariance (see Table 3).

| Column Number | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Column 1 | 54,474 | 1283 | 2969 | 395 | 53 |
| Column 2 | 1283 | 428,889 | 1,082,222 | 164,444 | –0.2222 |
| Column 3 | 2969 | 1,082,222 | 2,775,555 | 431,111 | –1.5556 |
| Column 4 | 395 | 164,444 | 431,111 | 68,889 | –0.4444 |
| Column 5 | 53 | –0.2222 | –1.5556 | –0.4444 | 0.2222 |

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# Business Intelligence: Business Evolution after Industry 4.0

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**Abstract:** Industry 4.0 is a set of technologies that companies require to promote innovation strategies and obtain a rapid response in dynamic markets. It focuses mainly on interconnectivity, digital technology, predictive analytics and machine learning to revolutionize the way companies operate and develop. Therefore, this article proposes and motivates the implementation of Industry 4.0 in organizations. Studying the state of the art and reviewing the current situation of business intelligence (BI) technology, the way it has positively impacted organizations at the economic and business level in terms of decision-making and some success stories implemented in different business, academic, social and governmental environments. Moreover, it addresses the future expected for Industry 4.0 primarily in BI and how companies should face this revolution. This article provides knowledge contribution about the current state and positive consequences of Industry 4.0, and high development in technology when implemented in the organization and the harmonization between production and intelligent digital technology.

**Keywords:** big data; business intelligence; industry 4.0; data analysis; digital transformation; internet of things

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## 1. Introduction

Business intelligence (BI) is defined as a decision-making process supported by the integration and analysis of an organization's data resources. In fact, BI plays an increasingly more critical role in several types of companies because, as information has been identified as the most valuable asset of a company, it is a fundamental resource for its development.

At present, because data constitute a new class of economic asset, similar to currency or gold [1], BI has become a challenge for information technology—Industry 4.0—as well as a very important management issue. Its importance has been especially recognized for developing analytics-based decision-making capabilities reflected in software and computer systems [2].

Business environments are becoming complex in the contour of Industry 4.0. Therefore, to provide quick responses in these dynamic markets, companies require innovations and advanced technologies [3]. In this context, technological tools, such as business intelligence (BI), are required both for processing information and for making correct decisions at corporate level. If this technological tool is implemented in an organization, it may provide several benefits such as architecture, efficient information and customer data management [4]. With this approach, companies may acquire a clearer picture of how important BI becomes in all different environments.

The highly unstable business environment, as well as the opportunities arising within the economy, require a fast and efficient decision-making process. Tracking these dynamic changes within and outside organizations while maintaining sustainable goals is indeed a challenging feat. However, this is possible because of the different modern concepts and tools available such as Industry 4.0 and BI [5].

A survey in Thailand in which 500 questionnaires were collected from those responsible for PYME, it was found that elements of Industry 4.0, such as Big Data, IoT and Smart Factory, have a positive role in promoting the implementation of information technology (IT), which contributes to sustainable business performance [6].

A study by Ślusarczyk showed that most people recognize the concept of Industry 4.0 as a great opportunity for development and improvement of competitiveness, although the state of readiness of each company to implement it varies greatly depending on the country, sector or each company [7].

Other environments are positively impacted by BI, as per 39 studies cited in Table 1. At 56%, the industrial or business environment is the most positively affected by BI from all the others, as attested by 22 studies out of the 39 reviewed. Here, the academic environment ranks second at 21% and a total of eight studies published out of the 39 reviewed. Throughout this document, the different environments in which BI exerts a total positive impact will be discussed in detail. This paper is a review of existing technologies.

**Table 1.** Impact from BI in certain environments.

| Environment | Reference | Percentage |
|---|---|---|
| Academic | [2,22,25,37,39,46,47,50] | 21% |
| Governmental | [13,23,41] | 8% |
| Industrial | [1,3,10–12,14,24,26-28,30–35,42,44,45,48,49,54] | 56% |
| Social | [4,5,15,29,43,53] | 15% |

This article motivates companies to install or implement the technologies that cover Industry 4.0, showing the state of the art and benefits that have been identified by the use of these tools that cover the concept of BI and Industry 4.0. This contribution will help small and medium-sized companies since these technologies constitute a support for their development and constant growth, making processes and operational aspects easier with intelligent digital technology.

The motivation for writing this article is to determine the impact of Industry 4.0 on the administrative and operational processes of all companies, regardless of their size or sector, relying on studies carried out in different countries to show the real contribution of this concept that has transformed many companies.

This article aims to motivate the implementation of Industry 4.0 and highlight the positive consequences for companies that undertake the change and technological revolution.

## 2. Methodology

Document selection for this paper was carried out through the following electronic sources: MDPI, IEEE, Scopus and Science Direct. These information sources were selected as a basis for being indexed and cataloged as Q1 to Q3, being pioneers in technology knowledge base and for having a lot of research. Firstly, 3689 articles were identified as the initial basis, 1354 articles and conference proceedings were selected from the journal MDPI, 1160 articles corresponding to the IEEE source, 745 were chosen by Scopus and finally 470 articles were filtered by Science Direct. After this identification, and looking for updated information, articles between 1 and 3 years of publication were selected, with this filter producing 1774 articles. Next, files that did not have Business Intelligence or similar terms were excluded, and in this process, 650 documents resulted. Finally, 44 papers were selected, that included research, case or further studies, and paper reviews on Business Intelligence, Big Data, Industry 4.0 and the Internet of Things. The process is presented in the Figure 1.

Review articles can be classified into several categories according to target, evaluation, reasoning and examination. In [8], we observed a list with the main categories and methodological aspects of search, analysis and synthesis, which is shown in Table 2.

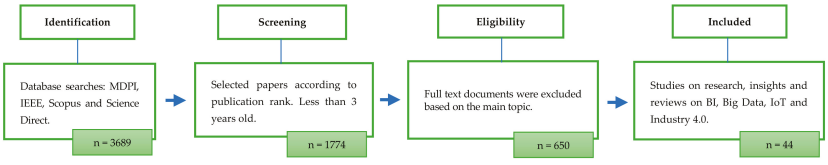


**Figure 1.** Paper selection process.

**Table 2.** Review categories and their methods.

| Review Category | Target | Evaluation | Reasoning | Examination |
|---|---|---|---|---|
| Critical | To charaterize relevant aspects | Quality estimation is not strict and it is according to contribution | Commonly narrative, maybe conceptual or chronological | Etablish contribution to embody or derive |
| Literature | Retrieving is optional | Quality assessment is elective | Commonly narrative | Study may be chronological, conceptual, thematic, etc. |
| Mixed studies | Exploitation of selected studies | Evaluation with checklists | Textual or graphical means of engaging studies | Correlates or identifies absent but missing aspects |
| Scoping | The search depends on time or scope, possible active research | Quality estimation is not strict | Commonly tabular with some commentaries | Characterizes literature by key features; attempts to specify a review |
| State-of-the-art | To search current literature | Quality estimation is not strict | Commonly narrative, it can have graphics | Shows current state-of-the-art and new ideas for research |
| Systematic search | Exhaustive search | Quality assessment is elective | Minimal narrative, tabular summary | What is known, advice for practice and constraints |

The structure and approach of this paper correspond to a state-of-the-art review as shown in Table 2. It also addresses the issue, contrasting the approaches of the different sources and proposing how these can guide future research on the subject. Regarding the synthesis methods, the document is structured by thematic points or sources, as needed [9].

## 3. The Impact of Business Intelligence

BI has become indispensable for strategic decision-making in companies and governments around the world. It plays an important role in business survival, in maintaining relationships with other companies, counterintelligence, goals and both short-term and long-term objectives. Moreover, the studies [10] confirm benefits from BI implementation, including improved performance, efficiency, productivity, business growth, resource planning, supplier–buyer relationship and cost reductions, which can ultimately lead to a competitive advantage [11].

Based on these studies, we classified the studies considering the different reasons that the authors of these studies were motivated to examine BI. The motivators have been classified into five different categories in which successful implementation factors is the most cited reason in the different studies with a total of 19 studies. These categories are listed in Table 3.

As per the information denoted in Table 3, organizations are faced with large datasets that cannot be used without BI as a motivator for competitive advantage [12]. For better decision-making, organizations use BI to build insights from their data. A BI solution follows a BI architecture. The uses of these technologies in all fields, including healthcare,

automotive, finance, gaming, environmental surveillance, agriculture, sports, energy management and safety, are changing the perspective at the work as well as fun levels [13]. Note that additional advancement of these technologies can contribute to developing hyper automation and hyper connectivity, leading us to the dawn of Industry 4.0. The advancement of BI is at the core of improved performance of all other technologies and the evolution of this industry.

**Table 3.** Authors' BI research motivators.

| Investigation Motivators | Reference | Percentage |
|---|---|---|
| Skills and qualifications | [48–52] | 13% |
| Successful implementation factors | [3,5,23,25,27,30,31–46] | 49% |
| Literature | [1,2,4,14,47] | 13% |
| User satisfaction | [10,11,13,22,24] | 13% |
| Competitive advantage | [12,15,25,28,29] | 13% |

The sources defined Industry 4.0 as "a concept used to describe related technological advances that provide the basis for increasing the level of digitization of industrial and business environments" [14]. Usually, when discussing the development of Industry 4.0, four key components are distinguished. The key components are shown in Figure 2 in an ascending manner as per their impact. Figure 2 was designed according to the information analyzed from [15].

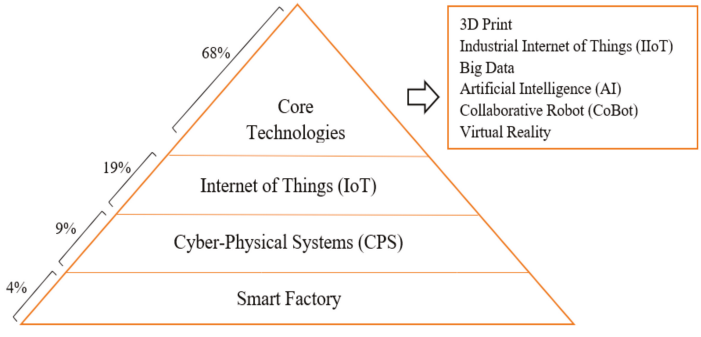


**Figure 2.** Industry 4.0 key components.

From the information consulted in [15] and shown in Figure 2, it is considered that Core Technologies have had a 68% impact on Industry 4.0. This 68% has been reflected in organizations with a high implementation of Big Data and Artificial Intelligence, providing organizational development and multiple advantages for the management of the main assets of the company. On the other hand, it offers predictive analytics for high-value decision making. Virtual reality and 3D printing have also worked to support training and operational processes. In other words, Industry 4.0 grows stronger every day and becomes more critical for organizations. Secondly, we have the Internet of Things, which continues to grow exponentially to position itself at the top of the key components. Cyber–physical systems and smart factories have continued to gain strength.

In Industrial Revolution 4.0, which is defined by the extensive use of different technologies in all fields, particularly on the Internet, users are required to be able to quickly access data and information to make proper decisions wherever they are [15].

Industry 4.0 is a process that generates technological transformations in the design, production and distribution of manufacturing systems and products, oriented towards automated and interconnected industrial production [16]. This has a significant impact not only on production processes, but on project management in companies [17], on the operation and future of the regions, and it is essential to understand the phenomena that take

place in the social and economic space and even in human resources [18]. Industry 4.0 has been shown to contribute to overall efficiency gains in sustainability (clean and renewable energy) [19], adaptive work environments, financial performance and innovation [20].

The era of smart factories is called "Industry 4.0." This term was first coined at the Hannover Fair [21] in 2011. Industry 4.0 awareness and the vision of "smart factories" initially emerged because of government projects to support using Information Technologies in manufacturing [22]; therefore, it is closely linked to industrial, technological and automation operations. Moreover, as expressed by a government procurement specialist in Florida, this indicates that part of the intelligence collected by organizations should be focused on directly doing business with the government [23].

In this era of smart factories, market intelligence and BI are key to their development. Market intelligence is the cornerstone of the marketing concept; it is essential for strategic marketing planning and implementation [24]. Although the importance of market intelligence is widely accepted, the manner in which managers can ensure the generation, dissemination and responsiveness of market intelligence throughout the organization remains an ongoing challenge.

It is a challenge for company managers to identify tools that can be highly effective and have considerable impact when applying BI in their organizations. Using a survey [25], certain suitable data visualization tools were selected: Jasper Reports, Pentaho, SpagoBI, Palo/Jedox, Tableau and Qlik. Table 4 provides a comparison of these BI tools among one another [26].

**Table 4.** BI Tools and application analysis.

| S. No. | BI Tool | Applications |
|---|---|---|
| 1 | Tableau | Data visualization products |
| 2 | Cognos | Performance management products |
| 3 | Sisense | Analyzes and visualizes big data sets and ideal tool for building interactive dashboards |
| 4 | SAP Business Objects | Real-time Business Intelligence |
| 5 | Microsoft Power BI | Interactive visualizations with self-service business intelligence capabilities |
| 6 | Domo | SaaS |
| 7 | Pentaho | Data integration, business analytics and big data |
| 8 | Klipfolio | Building real time business dashboards |
| 9 | Dundas BI | Data visualization |
| 10 | Necto | Business Intelligence |

The information generated via different reports is fed by source databases (such as social networks and news websites that can be heterogeneous in practice) [27]. These collections bring about the difficulties of managing and organizing complete information and they have been optimized using different algorithms to achieve the best decisions for companies. One of the multiple algorithms is submitted through a study [28] that discussed the implementation path and configuration of the reinforcement learning model in a big data scenario. Then, it uses the relevant background of the zero-inventory case and the current zero-inventory situation. Subsequently, the specific application of the reinforced learning method in BI is validated through an assessment with zero-inventory application cases in companies using the Qlearning algorithm. In this manner, the authors proved that an enhanced learning method can be used to solve certain practical problems.

A study suggests that organizations are increasingly expecting their employees to make data-driven decisions to gain competitive advantages [29]. This expectation requires greater flexibility and faster decision-making support. Classic BI standard reporting

often cannot sufficiently meet these demands. The use of Self-Service BI (SSBI) software has provided increased flexibility, and thus has been instrumental in meeting these new demands. Consequently, this software can help reduce the workload of the IT department and free up resources for other activities.

However, the implementation of SSBI software alone does not necessarily lead to a better BI environment. It has already been determined that, to realize the full potential of a BI environment, a change in culture and behavior is necessary.

## 4. BI Implementation Today

In today's economy, intangible assets have gained considerable appreciation. Therefore, an important part of business value, such as the IP strategy, plays an essential role in defining, creating and maintaining a winning business strategy. This allows the creation of value and the strengthening of the multiple aspects of a strategy [30].

As a strategy, BI goes hand in hand with competitive intelligence (CI). Because of their multiple advantages, both make up an interesting pair for organizations. CI is based on scanning and monitoring information that significantly influences the market [31]. In this perspective, the development of CI tools provides organizational individuals with the most appropriate conditions for facing challenges. CI generates analyzed data and information that can be integrated into organizational business.

However, the BI and Analytics (BI&A) operational combination has emerged as a new approach to value production data in real time, thus favoring companies in their managerial decisions [32]. Big Data create value and exhibit transformation potential in the organization and for process improvement.

In accordance with these concepts, the applications and implementations of BI in the different organizational environments will be detailed, thus demonstrating its valuable contribution. A case to be highlighted is a BI application for an industrial and food company in which information from various database sources is arranged to provide objective and vital information for the company to visualize its weaknesses and strengths [33]. This study seeks to gather enough evidence for integrating information through BI technology, which would allow management to make more assertive and effective decisions that will benefit the aims of different organizations. Moreover, there is the case study of the largest fertilizer manufacturing company in Indonesia [34], which implemented BI in its business activities. This study discusses the vital role that BI plays in the process of providing relevant information based on accurate data available in a BI application.

Another implementation was conducted at two Mexican companies [35] where the adoption of a BI platform is reviewed. The results from this study revealed that the response of these organizations is based on information management because this information is generated and shared through historical data. For these reasons, the company is deemed as having reached a high level of maturity, which fosters a culture in the standard management of information. This data governance provided the company with capabilities to successfully meet market requirements and therefore guarantee its survival [36].

Another case study, but this time in an academic environment, describes the implementation of BI in libraries [37]. The application of BI technology is presented as a case study where libraries overcome the limitations of their existing reporting module using the BISIS library system. During the development of a data warehouse model, both user requirements for reports in BISIS and existing transactional databases are assessed. Based on that analysis [38], three data storage models were proposed:

- A Model Describing Data in the Library Collection:

A dimensional model of the BISIS data warehouse used for analytically processing the data included in the library collection.

- A Model Describing Library Circulation Data:

A dimensional model of the BISIS data warehouse used for analytically processing library circulation data.

- A Model Describing Member Data:

A dimensional model of the BISIS data warehouse used for analytically processing member data.

In addition to these models, examples of reports generated using an OLAP tool are provided. BISIS users can perform business analysis in a more user-friendly and interactive manner because these reports are not limited to predefined report templates. Librarians can easily generate customized reports tailored to specific library requirements.

Another academic study [39] introduced a BI framework design for data visualization and its associated text narration. The key idea is to display an image as a response to the reading position in the text area and vice versa because an image can express an idea better than text. Still, the interpretation of the displayed information sometimes leads to a lack of communication between the author and readers because an image can have multiple interesting characteristics and readers can perceive the author's point of view at different angles. To convey points of interest to readers without reducing the effectiveness of the text, synergy is required between the imaged displayed and the corresponding text narration. This aim was achieved via a BI framework [40].

Examples of BI implementations were reported at the government level. The study conducted an analysis based on a BI system at a bank to identify areas where value may be added [41]. The results of this study demonstrated the positive effect from technology resources in the process of adopting this technology and the importance of effective results. As per all these cases described above, it is possible to conclude that the dissemination of data in real time between companies, given the availability of adequate analytical tools and methods, can have a significant impact on any company. These findings are reinforced in a case study conducted in Hungary on the Industry 4.0 phenomenon [42].

## 5. Future Research Issues

Sustainable development and the circular economy are two important issues for business development and market competition. The programs seeking to integrate sustainability with industrial activities include the reconfiguration of production processes to reduce their impact on the natural system, the development of new eco-sustainable products and the redesign of the business model [43]. The use of information and management support tools is at the core of company digitization assessments. One study examined integrated enterprise resource planning (ERP) systems and business intelligence (BI) tools, which had been used independently of each other when migrating to industry 4.0 technology [44]. Centralized functions such as research and development, asset optimization, corporate planning (strategy, investment planning, finance) and supply chain, along with any other functions, provide significant business value. The integration of these functions across Industry 4.0 offers significant business value, providing strategic and operational benefits. The resulting main digital transformation objectives are listed in Figure 3.

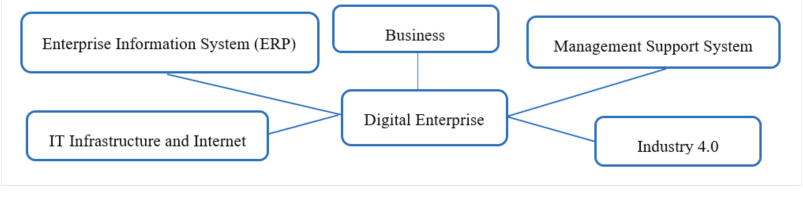


**Figure 3.** Digital transformation goals.

Another relevant Digital Transformation objective is specified in the study conducted by Zafary [45], which denotes the value of integrating information systems and ERP in successful BI implementations. The results of this study provide an opportunity for other researchers to implement a cost optimization approach.

If we continue reviewing the digital transformation process for BI, in the age of Industry 4.0, highly automated industries have been created by advanced digital technologies such as Internet of Things, Big Data analytics and data visualization [46]. These recent technologies have been extensively used in industries as dashboards, a BI tool that provides analytical data insights to corporate executives and business managers for decision making regarding system and process performance optimization [47].

Figure 4 shows certain Industry 4.0 technologies as an industry framework with core technologies.

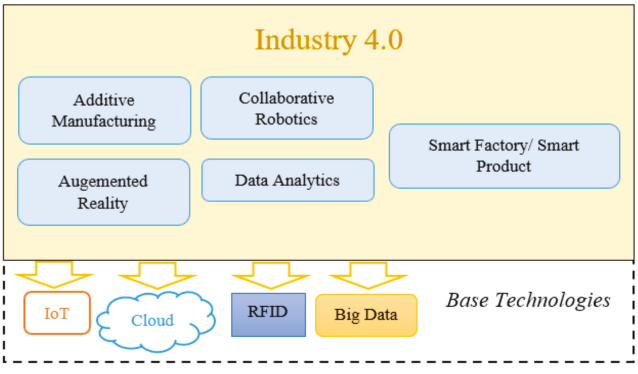


**Figure 4.** Industry 4.0 framework with core technologies.

A study conducted in Dubai on adopting the new advances of Industry 4.0 [48] reveals the critical role marketing teams play when influencing the decisions to adopt said technology and achieve results. This study concludes that adopting the revolutionary Industry 4.0 technologies may generate a high level of unemployment, but both Millennials and Gen Z have a greater competitive advantage in this technology. The results make it unequivocally clear in all respects that certain issues of this technology remain a notable area of concern. For example, large global companies usually understand innovations and procedures faster, and SMEs are lagging behind because of the weight of speculation [49].

This could be considered as a prediction for the near future of organizations. BI and ERP have become key for business activities and a requirement for the later phases of industrialization. For instance, an Industry 4.0-compliant ERP system is able to fully integrate with manufacturing execution systems [49], put the puzzle pieces together and provide a unified view of business operations that allows companies to better manage and improve industrial processes. A joint BI and ERP implementation is reflected in a study performed in China [50]. This study assesses the background, related technologies and the existence of demand controls in BI projects. The BI project is an analysis of business data generated by ERP, and it will serve as an important tool for leaders to assess the current situation of the company, make forecasts and plan future decisions [51]. Therefore, business intelligence (BI) and enterprise resource planning (ERP) have become key issues for business activities and a requirement for later phases of industrialization. They have also been recognized as important in decision-making by building an analytical capacity and providing a holistic framework for technical systems in production, quality management, predictive modeling and maintenance, simulation techniques, etc. [52].

At present, the acquisition, development and retention of human resources is of strategic importance [53]. Companies send the best and brightest expats to foster their development and guide the development of local talent who may eventually replace expats. From this perspective, domain-specific job offers can be considered as an indicator for analyzing and understanding competencies. Considering the requirement for a qualified BI workforce in the near future, an empirical study was conducted [54] on job offers to assess basic skills. The results from this study can provide valuable information:

- For businesses: In identifying a qualified BI workforce and integrating new analytical processes into ongoing industry policies.
- For BI professionals: In the evaluation and improvement of their own skills.
- For academic institutions: In planning BI programs and curricula as per industry requirements.

## 6. Data Privacy and Security Approaches through AI Approaches for Business Evolution

Companies handle a lot of decentralized information, and with the arrival of Industry 4.0 and business evolution, it is required to have a complete, available, private and confidential repository. Six articles were reviewed showing the effect of the implementation of information technology from the technological point of view through Artificial Intelligence, Business Intelligence, IoT and Cloud Computing. A summary is shown in Table 5.

**Table 5.** Concepts of information technology implementation.

| Reference | Concept |
|---|---|
| [55] | The Internet of Things (IoT) has produced a large flow of data and services, which has changed the access control paradigm from a fixed desktop environment to dynamic environments in the cloud. This contributes to the reduction of administrative and computational expenses. |
| [56] | Security and privacy are two important requirements. Big Data security refers to the use of Big Data to implement solutions that increase the reliability and security of a distributed system. Big Data privacy, instead, focuses on protection of Big Data against unauthorized use. |
| [57] | Cloud computing has become a major research topic by generating multiple benefits for businesses. Therefore, it has become necessary to offer Business Intelligence (BI) to companies through the Internet as a solution. |
| [58] | Global economic crisis focuses the information technology industry on productivity. Cloud Computing is one of the instruments that can bring efficiency to an organization. |
| [59] | Business intelligence systems use information technology to manage structured and unstructured data that comes from various sources. Cloud computing services enhance legacy BI systems and applications with cost-effective scalability and flexibility. |
| [60] | More advanced organizational interactions have led to changes in the way that business is done. Newer forms of collaboration, such as Business Process as a Service (BPaaS), allow different partners to leverage business intelligence within organizations. |

The implementation of the technologies that cover Industry 4.0 allows to improve the information of the companies, with a focus on privacy and security.

## 7. Conclusions

In brief, this study concludes that technologies such as big data, BI and the Internet of Things are actual development pillars for companies because they support companies in terms of decision-making, forecasting and corporate economy. If these technologies are in turn supported by effective leadership and training, development would be even greater.

Moreover, this study evidenced that implementing these technologies fosters company success when coupled with the proper use of their primary asset, which is information. Furthermore, BI technology helps a company to achieve their primary business objectives.

This study highlights the importance that the integration of ERP, IoT and BI technologies acquires, contributing to growth in all organizational aspects, beginning with changes at the operational level and concluding with a decisive basis for managerial decision making.

In the near future, the implementation of these technologies will be promoted in smaller companies, thus strengthening their economy and constituting an indispensable support for their development.

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