Supply Chain Management and Big Data Concept Effects on Economic Sustainability of Building Design and Project Planning

Tomáš Mandičák *, Peter Mészároš, Andrea Kanáliková and Matej Špak

Institute of Technology, Economics and Management in Construction, Faculty of Civil Engineering, Technical University of Košice, 042 00 Košice, Slovakia; peter.mesaros@tuke.sk (P.M.); andrea.kanalikova@tuke.sk (A.K.); matej.spak@tuke.sk (M.Š.)
* Correspondence: tomas.mandicak@tuke.sk; Tel.: +421-55-602-4378

Abstract: Building design and project planning face significant challenges in the 21st century. On the one hand, it is the requirement of building users. On the other hand, new possibilities and technologies contribute to the overall efficiency of construction projects. The progress of information and communication technologies is one of the most extensive opportunities that can significantly streamline designing sustainable buildings. The big data concept is increasingly being implemented in all areas of industry. The design of buildings and the entire civil engineering industry is where these processes are becoming automated with the help of information technology. Supply chain management based on information systems represents a great potential in the design of buildings and planning of construction projects in materials procurement. These facts lead to the assumption that the concept of big data and supply chain management systems can effectively influence the sustainable design of buildings. These technologies are expected to improve economic sustainability by reducing costs and shortening materials’ delivery time and construction time. The research is carried out on a sample of construction projects. The level of use of the concept of big data and SCM systems and their impact on economic sustainability in the form of parameters such as construction project costs, delivery time of materials and building construction were examined. Data collection took place through a questionnaire survey. Within the used methods, this research worked data-free but also scaled to the Likert scale. Data processing was performed using Pearson dependence and the use of a correlation coefficient. The main goal of the research was to analyze the impact of using the concept of big data and supply chain management on the cost of the building, the time of delivery of materials and the construction of the building. It was found that the use of SCM and BD has an impact on the monitored parameters, and the correlation rate is high.

Keywords: supply chain management; big data; sustainable building design; novel concept; information systems and technology; cost

1. Introduction

Confidence in the rapid development of the digital economy and the impact of available technologies are gradually increasing to many demands for the use of devices that can process large amounts of data, which should improve these businesses’ performance [1]. The global business is currently driven by data [2]. In recent years, it has pointed to the trend of using big data widely in all spheres of life due to the digital economy’s times [3]. In addition, another study confirms and states the importance of data in construction and building design [4]. The availability of information and communication technologies presupposes that extensive data will enable the creation of new paradigms for the management of construction projects and increase the efficiency of building design and construction activities [5]. The marketing approach has transformed from a product-centric
concept to a customer-centric concept [6]. The big data (BD) concept brings new possibilities for determining customer relationship management (CRM) strategies and supply chain management (SCM) in support and adaptation of sales, services and logistics to clients [7]. According to [8], big data has great potential to create value for architecture, engineering and construction. Big data is one of the revolutionary technologies. This process’s result has a high rate of generating a large amount of disparate data that is analyzed to improve the process [9]. The big data issue is often researched to validate strategies that will give businesses a competitive advantage [10].

The use of information and communication technologies based on large amounts of data is a prerequisite for making the right decisions. Construction project management and building design and data are closely related. Timely delivery of material increases construction time [11]. Insufficient material management can lead to a 50% decrease in costs. Conversely, proper material delivery management can significantly reduce costs [12]. Sustainability in building design also means saving material, shortening construction time or reducing costs. From this point of view, a distinction is made between ecological and economic sustainability. Studies have also found that realistic cost and time estimates are among the 10 most important success factors in residential building projects [13]. The need to develop infrastructure projects where one of the proofs is economic sustainability was the subject of another study [14]. The delay in the construction project is a worldwide reality and all the countries faced this global fact. Construction project management and supply chain collaboration play a vital role in managing any project [15].

A few theoretical perspectives address the issue of big data in construction, such as a study focused on a comprehensive mapping of resources on the adoption of information technology, including the concept of big data [16]. The study of using the big data concept in investment estimation is an important process in the feasibility study phase of residential projects. In this study, the influence of BD on the costs of managing construction projects was pointed out [17]. Based on the study, there is an assumption that the construction project’s success are decisive factors of cost and time. These factors are closely linked and, therefore, need to be constantly monitored [4].

According to several studies, supply chain management impacts the performance of construction projects and building design [1,11,18]. The claim from these studies is based on the perception of SCM and the big data concept as a technology that affects the performance of construction projects and companies. Studies addressing the benefits of exploiting show that time and cost are probably important benefits of using big data and SCM [4,6,19–21]. However, these studies did not quantify the effect on the selected parameters and did not quantify the strength of the dependence of the investigated quantities. The benefit of this study is that it also quantifies the investigated dependence between the selected parameters and describes the relationships between them.

Based on the above information and studies, it is assumed that the time of delivery of materials and services for construction depends on several factors. The research question, which stems from the previous knowledge of this issue, is whether it is possible to shorten the delivery time of materials and services for construction by the result of the big data concept and SCM. In connection with this, there is another question of whether the construction time is also shortened. If the considerations are confirmed, it is logical to focus this research on the assumption of the cost side of CRM and big data (BG) concept use. Based on these assumptions, primary research questions will be opened:

1. Does the use of the big data concept in SCM impact on the delivery time of materials and services?
2. Does the use of the big data concept in SCM impact on the delivery time of construction?
3. Does the use of the big data concept in SCM impact on project cost?

All these scientific questions are based on the perception of ecological and economic sustainability in the design of buildings. The use of digital technologies and innovations as a supply chain management by big data concept can potentially reduce the time of material delivery and thus save material (ecological and economic aspects of sustainability), shorten
construction time (the economic aspect of sustainability) and reduce costs (the economic aspect of sustainability).

2. Literature Review

The construction industry must accept that their industry is data driven [2]. Advances and the ubiquity of technology and the big data concept have enabled the dissemination of intelligence and innovative solutions in various industries, including architecture, engineering, and construction [5]. BIM and Industry 4.0 technologies, as well as big data applications, can bring new value to building logistics management [22]. The digitization of the construction industry through progressive innovations and the processing of large volumes of data and the management of contracts with customers are increasingly the subject of research [9]. Construction logistics is an important part of the construction process. It has become a new source of profit for the construction industry [22]. The supply chain management (SCM) study argues that the biggest challenges in implementing supply chain management technologies are the two most important challenges: slow IT adoption in material flow management and lower training and parents’ motivation [23].

The concept of big data uses a large amount of data, which is difficult to process with one available software solution. However, it should be remembered that processing a huge amount of data is divided into many tables [24]. The first step in processing this data is to use individual software solutions, such as SCM. In sustainable planning and design, this concept is associated with data on the building and material items such as volume and other characteristics, time, costs, etc. This means that big data analysis is a set of sophisticated and specialized software applications and database systems that run machines with very high computing power [25]. The result is a possible time of shortening the delivery of material, lower stocks, more efficient and more accurate material consumption, and reduced costs. Therefore, it is economic sustainability of building planning and design.

SCM is complex, using applications and platforms across the entire information system. It also includes supplier relationship management or customer relationship management. Supplier relationship management involves establishing discipline in strategic planning and managing all interactions with organizations’ suppliers [26].

The essence of the customer relationship management (CRM) system is the effort to streamline relationships and adapt products and services to customers. Nowadays, this not only has an impact on costs, but it affects more things. Profitability increasing is the aim of most companies, which is performed by analyzing customer relationship management (CRM) and providing appropriate business strategy [3,25]. CRMs are advantageous for companies that want to better understand their customers by reviewing customer information by generating useful information from the data [10]. CRM needs big data to improve customer experience, especially customization and customization of services [7].

Big data and SCM’s whole concept require a large amount of information technology, whether it is various sensors and sensors based on RFID, information and communication technologies in the form of service devices, applications and decision-making tools themselves.

Big data is also an important tool in construction. In recent years, only a few studies addressed the issue and synergistic link of CRM and big data concept [27]. The study pointed to the implementation of BD in investment estimation, an important process in the feasibility study phase of residential projects [28]. In this study, the influence of BD on the costs of managing construction projects was pointed out [17]. Another study addressed designing a data processing algorithm for integrated cost management with cost scheduling using big data technology [4]. There are also a few survey studies in the field of big data in construction [19]. An extensive study from China identified factors that significantly affected large data and examined how these factors interact [29]. Further research focuses on the main issues in construction project management and the possibility of creating a platform for the managing enterprise technical data [30]. Another research study brings issue, and there is no benchmarking system to assess organizations’ ability to receive big
data and predictive analytics. Therefore, this study aims to develop a tool to evaluate the ability to predict large volumes of data and predictive analysis [8]. Several studies speak of the benefits of BD [2].

Another study re-evaluated the benefits of using SCM systems in the construction industry [25]. Some studies support the claim that supply chain management impacts the performance of construction projects and companies [20]. A study focusing on the Chinese construction industry highlights the importance of SCM, data analytics and quality links [20].

3. Materials and Methods

3.1. Research Hypotheses and Aim

Based on a literature review and previous research, questions were asked (described in more detail in the introduction section). These questions were the basis for establishing research hypotheses [1,18–20]. These are based on previous studies’ claims that big data in SCM impacts the performance of construction projects [20]. Some also specified key performance indicators such as time and cost [4,6,20,21]. When analyzing the impacts in supply chain management, it is necessary to distinguish between construction time and materials delivery time. These are two views that are also discussed in this research.

**Hypothesis 1.** Exploitation of big data concept and supply chain management shortens the delivery time of materials and services in sustainable building project.

New information and communication technologies represent new possibilities in the management of the supply chain, as well. Ordering materials and services for construction can work in other than the traditional way. Inventory management can be time-consuming. Timing is an important aspect of managing construction projects. Timely delivery of construction materials can be an important step to the success of a construction project. Here is the assumption that the use of modern ICTs can affect the time of delivery of material. The use of hardware tools such as RFID sensors and components, cameras and other data collecting tools, and advanced supply chain information systems, especially analytical processing of large data, can positively affect material delivery time.

**H10.** Exploitation of big data concept and supply chain management doesn’t shorten the delivery time of materials and services in sustainable building project.

**H11.** Exploitation of big data concept and supply chain management shortens the delivery time of materials and services in sustainable building project.

**Hypothesis 2.** Exploitation of big data concept and supply chain management shortens construction time.

This consideration assumes that the use of advanced technologies and the use of data analytics and the concept of big data can shorten the delivery of material, which can affect the shortening of construction time [6,16,31,32]. If the first hypothesis is assumed, a high degree of correlation with the second hypothesis can be expected in this relationship. Construction time is an important parameter for all participants in a construction project. Many studies report this benefit of the big data concept in construction. So far, none of the available studies has examined exactly the real impact.

**H20.** Exploitation of big data concept and supply chain management doesn’t shorten construction time.

**H21.** Exploitation of big data concept and supply chain management shortens construction time.

**Hypothesis 3.** Exploitation of big data concept and supply chain reduces construction project cost.
The idea that the use of big data concept in construction project management can also impact cost reduction is based on the considerations and statements of several authors who have conducted studies on big data. This is also a logical assumption when monitoring key performance indicators. In implementing this concept (several studies have confirmed that cost reduction may be a sufficient motivator for implementing BD and ICT [4,32]), it could be one of the most important motivators. If the dependence between the use of BD in SCM and cost reduction is also demonstrated empirically, this can lead to faster implementation of these technologies.

**H30.** Exploitation of big data concept and supply chain management doesn’t reduce construction project cost.

**H31.** Exploitation of big data concept and supply chain management reduces construction project cost.

Since the established hypotheses focus on BD’s impact in SCM on selected key performance indicators, namely on costs and time (also the basic parameters of CP). The research aims to analyze the impact of big data concept in supply chain management on selected performance indicators (time and costs). Fulfilment of this research goal depends on an exact examination of the established hypotheses and subsequent reassessment of their validity.

The selection of monitored parameters was discussed with experts from practice. Initially, several factors were defined, which were defined by the practice. Subsequently, selected experts in large construction companies evaluated the importance of examining individual factors. However, data for other factors (sales, client satisfaction, employee productivity and so on) were also obtained for research purposes.

### 3.2. Research Step Line

Research activities consist of several steps. The first step was to examine the issue, identify the research problem and find the research gap. Several research pieces have only marginally addressed this issue, or rather it has been addressed from a different research perspective. The next step was to determine the research areas (asking basic research questions) and the research goal, which resulted in setting research hypotheses.

The data collection was carried out based on an anonymous questionnaire, which included questions focused on the level of use of technologies and the big data concept in SCM, as well as impacts on key performance indicators (time and cost).

Validation of questions based on Cronbach’s alpha, followed by the main research hypotheses were tested using the Kruskal–Wallis test and Pearson correlation coefficient and analysis. The whole chronological process of the research is shown in Figure 1.

### 3.3. Data Collection and Research Sample

A questionnaire provided data collection. Respondents operating in the construction sector were randomly selected. A total of 1376 random respondents were contacted. The ratio of respondents was based on the ratio of the distribution of construction in the market. This means the number of copied fair values so that the ratio of respondents reflects the real situation in the construction market. They involved various participants in construction projects such as investors, contractors and sub-contractors, and designers. The research involved 55 respondents, i.e., real projects. Given the size of the market (the construction market in Slovakia, where there are about 5.5 million inhabitants and only about 10 to 15 large construction companies and a few hundred medium-sized construction companies), this sample is sufficiently representative. Individual respondents were also classified according to the size of the construction company. These are large, medium and small enterprises and microenterprises. Among the basic characteristics, the level of use of information and communication tools such as SCM systems and solutions for big data embedding was also monitored. Among the basic characteristics of the research sample can also be mentioned SK NACE classification according to construction activity, use of foreign capital, or know-how (Table 1).
3.3. Data Collection and Research Sample

A questionnaire provided data collection. Respondents operating in the construction sector were randomly selected. A total of 1376 random respondents were contacted. The ratio of respondents was based on the ratio of the distribution of construction in the market. This means the number of copied values so that the ratio of respondents reflects the real situation in the construction market. They involved various participants in construction projects such as investors, contractors and sub-contractors, and designers. The research involved 55 respondents, i.e., real projects. Given the size of the market (the construction market in Slovakia, where there are about 5.5 million inhabitants and only about 10 to 15 large construction companies and a few hundred medium-sized construction companies), this sample is sufficiently representative. Individual respondents were also classified according to the size of the construction company. These are large, medium and small enterprises and microenterprises. Among the basic characteristics, the level of use of information and communication tools such as SCM systems and solutions for big data embedding was also monitored. Among the basic characteristics of the research sample can also be mentioned SK NACE classification according to construction activity, use of foreign capital, or know-how (Table 1).

Table 1. Literature review of previous surveys in SCM and BD concept issue.

| Type of Information                  | Categories          | Percentage |
|--------------------------------------|---------------------|------------|
| Construction Enterprise Size         | Large enterprises   | 12.73%     |
|                                      | Medium enterprises  | 21.82%     |
|                                      | Small enterprises   | 30.91%     |
|                                      | Microenterprises    | 34.55%     |
| Private equity                       | Home                | 80%        |
|                                      | Foreign             | 20%        |
| Participant of construction project  | Contractor          | 50.91%     |
|                                      | Sub-contractor      | 23.64%     |
|                                      | Designer            | 18.18%     |
|                                      | Investor            | 7.27%      |
| Age of enterprises                   | 0–5                 | 20.00%     |
|                                      | 6–10                | 16.36%     |
|                                      | 11–20               | 27.27%     |
|                                      | 21–50               | 25.45%     |
|                                      | 51 and more         | 7.27%      |
|                                      | N/A                 | 3.64%      |
| SK NACE classification               | Building Projects   | 47.27%     |
|                                      | Civil Engineering Projects | 16.37% |
|                                      | Specialized construction works | 36.36% |

3.4. Data Processing

Data processing is based on methods that are primarily intended to verify the accuracy of the data and the research questions asked through a questionnaire. For these purposes, Cronbach’s alpha was used in the research to verify the suitability and relevance of all research questions [33]. The studied reliability takes values from 0 to 1 (where values close to 0 mean a low degree of reliability and values close to 1 mean a high degree of reliability). Due to the fact that the respondents had to state their perception and quantify the situation
not only on the financial statements, this verification is very important for assessing the relevance of the research results. The statistic test for measures reliability is [34]:

$$\alpha = \frac{N \times \bar{c}}{\bar{\sigma} + (N - 1) \times \bar{c}}$$  \hspace{1cm} (1)

where $N$ is number of items, $c$ is the average covariance between item-pairs and $\bar{v}$ is the average variance [35].

Correlation analysis is another tool to clarify the results. This is a measure of the relationship between the results or their relationship. This research is based on Pearson’s Correlation, also known as the Pearson Product Moment Correlation (PPMC). This indicates a linear relationship between the two data sets. Simply put, it answers the question. The following form’s correlation is:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{n \sum x^2 - (\sum x)^2} \sqrt{n \sum y^2 - (\sum y)^2}}$$  \hspace{1cm} (2)

4. Results and Discussion

**Hypothesis 1.** Exploitation of big data concept and supply chain management shortens the delivery time of materials and services in sustainable building project.

**H_{10}**. Exploitation of big data concept and supply chain management doesn’t shorten the delivery time of materials and services in sustainable building project.

**H_{11}**. Exploitation of big data concept and supply chain management shortens the delivery time of materials and services in sustainable building project.

The big data concept and supply chain management systems represent work with data at the highest level. Therefore, these technologies represent investments that are expected to return. When monitoring 55 projects, the level of use of SCM systems and the big data concept were observed, and their impact on economic sustainability. In this case, it was assumed that the level of use of these technologies correlates with the time of delivery of material. The basis of this assumption is that these intelligent technologies are efficient in processing large amounts of data, and their use reveals the need for material. Subsequently, management can respond more quickly, resulting in a faster flow of material delivery, from ordering to delivery.

Figure 2 shows the relationship between the level of use of the big data concept and SCM and material delivery time in days. As can be seen from the data trend, the higher the BD and SCM utilization rates, the shorter the material delivery time. Most respondents confirmed this.

This trend needed to be statistically examined. The correlation coefficient analysis shows that in the given case from the obtained data, it is not only a trend, but these results are not random. The relationship between the variables, i.e., the level of use of big data and SCM and material delivery time in days (Figure 3) is strongly dependent. There is a strong negative correlation between these animations, which is also confirmed by the correlation coefficient $-0.92171$ (Table 2).

The following Table 3 describes the individual values and the correlation coefficient calculation, including the degrees of freedom. All the results point to a strong negative relationship between these variables. The results and statistical processing clearly show a strong correlation, and the results can be considered significant.
it was assumed that the level of use of these technologies correlates with the time of delivery of material. The basis of this assumption is that these intelligent technologies are efficient in processing large amounts of data, and their use reveals the need for material. Subsequently, management can respond more quickly, resulting in a faster flow of material delivery, from ordering to delivery.

Figure 2 shows the relationship between the level of use of the big data concept and SCM and material delivery time in days. As can be seen from the data trend, the higher the BD and SCM utilization rates, the shorter the material delivery time. Most respondents confirmed this.

Figure 3. (left) Correlation between the examined variables (level of SCM and BD usage for material delivery time in days) and (right) linear correlation between variables

| Table 2. Pearson correlation (SCM and BD use level and material delivery time in days). |
|---|---|---|
| SCM and BD Use Level = x | Material Delivery Time in Days = y |
| SCM and BD use level = x | 1 |
| Material Delivery Time in days = y | -0.92171092 | 1 |
Table 3. Results of correlation analyses: Exploitation of big data concept and supply chain management shortens delivery time of materials and services in sustainable building project.

| Respondents $= n$ | SCM and BD Use Level $= x$ | Material Delivery Time in Days $= y$ | $xy$ | $x^2$ | $y^2$ | Alfa | Degrees of Freedom |
|-------------------|-----------------------------|--------------------------------------|------|------|------|------|-------------------|
| $\Sigma$          | 55                          | 135                                  | 1039.4 | 2339.4 | 22229.38 | 0.05 | 0.273             |

Hypothesis 2. Exploitation of big data concept and supply chain management shortens construction time.

$H_{20}$. Exploitation of big data concept and supply chain management doesn’t shorten construction time.

$H_{21}$. Exploitation of big data concept and supply chain management shortens construction time.

It has been mentioned several times that information technologies help process large amounts of data and increase working with data. When designing buildings and all construction projects, a large amount of data is used. Therefore, these technologies should contribute to efficiency. Economic sustainability in the design and planning of buildings and projects is also based on faster construction times. With their efficiency, these technologies should contribute to shortening the construction time of sustainable buildings. The relationship between the level of use of these systems and the construction time is also shown in the following Figures 4 and 5.

![Figure 4](image_url)  
**Figure 4.** Relationship between SCM and BD use level and level of construction time.

The relationship between the investigated variables is shown in the following graphs. A strong negative correlation is shown in almost all respondents. From these figures, it can see not only the trend but also a strong negative correlation. In cases where the level of use of BD and SCM was high, shorter times for the construction of sustainable buildings were also recorded. This negative correlation can also be seen in the table, reaching a value of $-0.778753$ (Tables 4 and 5).
The relationship between the level of use of these systems and the construction time is also shown in the following figure 4 and 5.

**Figure 4.** Relationship between SCM and BD use level and level of construction time.

**Figure 5.** (left) Correlation between the examined variables (level of SCM and BD usage and construction time level) and (right) linear correlation between variables.

The relationship between the investigated variables is shown in the following graphs. A strong negative correlation is shown in almost all respondents. From these figures, it can see not only the trend but also a strong negative correlation. In cases where the level of use of BD and SCM was high, shorter times for the construction of sustainable buildings were also recorded. This negative correlation can also be seen in the table, reaching a value of $-0.778753$ (Table 4 and 5).

**Table 4.** Pearson correlation (SCM and BD use level and construction time level).

| SCM and BD use level = x | Construction Time = y |
|-------------------------|-----------------------|
| Level of construction time = y | 1                     | $-0.778753$ |

**Table 5.** Results of hypothesis: Big data concept in supply chain management shortens construction time.

| Respondents = n | SCM and BD Use Level = x | Construction Time Level = y | xy  | $X^2$ | $Y^2$ | Alfa | Degrees of Freedom |
|-----------------|--------------------------|-----------------------------|-----|-------|-------|------|-------------------|
| $\Sigma$       | 55                       | 135                         | 203 | 430   | 421   | 835  | 0.05              | 0.273             |

**Hypothesis 3.** Exploitation of big data concept and supply chain reduces construction project cost.

$H_{30}$. Exploitation of big data concept and supply chain management doesn’t reduce construction project cost.

$H_{31}$. Exploitation of big data concept and supply chain management reduces construction project cost.

Economic sustainability is often perceived through economic parameters such as sales and profit, but also the critical parameter, namely, costs. Therefore, investigating the impact on the costs is one of the most critical possible impacts of the use of information technologies SCM and BD concept. This is a strong premise and a motivator for using the BD concept and SCM systems both in the design and planning of buildings and in construction projects in general. The following figure (Figure 6) shows the relationship between the level of use of these technologies and cost reduction, respectively, the level of costs. Costs were lower in situations where the level of utilization was higher. The correlation coefficient, in this case, was also strongly negatively dependent (Figure 7). This points to another situation where these technologies have a significant impact on reducing costs. The economic sustainability of building design and planning is based on cost reduction, to which the use of these technologies also makes a significant contribution. The correlation coefficient reached the value $-0.936777457$ (Table 6).
Correlation between the examined variables (level of SCM and BD usage and cost level) and (b) linear correlation between variables.

Figure 6. Relationship between SCM and BD use level and cost level.

Figure 7. (left) Correlation between the examined variables (level of SCM and BD usage and cost level) and (right) linear correlation between variables.

Table 6. Pearson correlation (SCM and BD use level and cost level).

| Correlation          | SCM and BD Use Level = x | Cost Level = y |
|----------------------|--------------------------|----------------|
|                      | 1                        | -0.936777457   |

In addition to correlation coefficients, a degree of freedom is required to evaluate hypotheses, based on which negative hypotheses can be refuted. Figure 8 shows the degree of freedom. The following table shows the correlation coefficients and subsequently rejected the negative hypothesis in all cases.
supply chain management doesn’t shorten delivery time of materials and services in sustainable building project.

Hypothesis 2

H20: Exploitation of big data concept and supply chain management doesn’t shorten construction time.

H21: Exploitation of big data concept and supply chain management shortens construction time.

Hypothesis 3

H30: Exploitation of big data concept and supply chain management doesn’t reduce construction project cost.

H31: Exploitation of big data concept and supply chain management reduces construction project cost.

As already mentioned, the economic sustainability of building design and planning is based on the effort to reduce costs and construction time. Therefore, this dimension of sustainability needs to be planned and designed at an early stage.

Studies confronted by us have hypothesized that these technologies may be helpful in the field. However, none of them confirmed their positive impact strictly. Sustainable building design is based on a large amount of data. Therefore, big data and SCM technology concepts are also very important in the sustainable construction industry.

In contrast to previous studies, the results of this study quantified the level of correlation between the studied variables. There is a strong correlation, especially concerning the use of these technologies in shortening the supply chain for materials and reducing costs.

Likewise, despite being carried out in a small market, this study has a significant contribution to this market, as conditions and factors in this market have been largely considered.
5. Conclusions

Sustainable building design and planning in the 21st century is full of challenges. The requirements of investors and thus building users are becoming more and more demanding concerning sustainability. Sustainability in building design can be seen from several angles. On the one hand, materials can be incorporated into the design of a building that looks sustainable, as well as construction technology. On the other hand, intelligent solutions and digital technologies bring innovations in information technology in the design process.

Information technologies based on the processing of large amounts of data are, on the one hand, challenges and, on the other hand, possibilities to plan and design more efficiently. Therefore, this area has been the subject of this research.

The concept of big data and information systems for supply chain management in building design represent an excellent potential for achieving economic sustainability. Economic sustainability is based on achieving the effectiveness of selected parameters such as the cost of the construction project and construction time or the supply of materials. The concept of designing sustainable buildings should also take this aspect into account. Building design in the next decade probably expects a breathtaking space for automation, data handling and dynamic innovation.

The impact of the use of these technologies on the delivery time of materials has a positive effect. The research confirmed the positive impact and dependence between BD and SCM technologies and the time of delivery of materials.

Research has also confirmed the relationship between the level of use of these technologies and the construction time. Therefore, intelligent building design with the help of BD and SCM can shorten construction time.

Economic sustainability in the effort to reduce costs is the basis for economic sustainability. This dependence has also been confirmed by research. The correlation coefficient was significant for all hypotheses.

Future research should focus on other areas of sustainability. In addition to economic sustainability, it is also necessary to look at material sustainability and look for ways to minimize material consumption with the contribution of data processing technologies. Since data is the fundamental decision-making basis for management, it is essential to explore these options for sustainability in construction.

Further research should also focus on examining the impact of these technologies in building design and the whole life cycle of buildings. The complex sustainability perceived throughout the life cycle is the basis for further research in this area.

This section is not mandatory but can be added to the manuscript if the discussion is unusually long or complex.

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

Funding: This work was supported by the Slovak Research and Development Agency under the contract no. APVV-17-0549. This paper presents partial research results of project VEGA 1/0557/18 Research and development of process and product innovations of modern methods of construction in the context of the Industry 4.0 principles. The paper presents a partial research results of project KEQA 059TUKE-4/2019 “M-learning tool for intelligent modeling of building site parameters in a mixed reality environment”.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All research activities have been carried out in accordance with the MDPI Ethics, and there is no obstacle on our part.
Acknowledgments: This work was supported by the Slovak Research and Development Agency under the contract no. APVV-18-0360 Active hybrid infrastructure towards to sponge city.

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

References
1. Chen, D.Q.; Preston, D.S.; Swink, M. How the use of big data analytics affects value creation in supply chain management. J. Manag. Inf. Syst. 2015, 32, 4–39. [CrossRef]
2. Srinavin, K.; Kusonkhum, W.; Chonpikatkong, B.; Chaitongrat, T.; Leungboontrak, N.; Charnwawanunth, P. Readiness of applying big data technology for construction management in Thai public sector. J. Adv. Inf. Technol. 2021, 12, 1–5. [CrossRef]
3. Janabi, S.; Razaq, F. Intelligent big data analysis to design smart predictor for customer churn in telecommunication industry. Big Data Smart Digit. Environ. 2019, 8, 246–272.
4. Cho, D.; Lee, M.; Shin, J. Development of Cost and Schedule Data Integration Algorithm Based on Big Data Technology. Appl. Sci. 2020, 10, 8917. [CrossRef]
5. Al-Sehrway, R.; Kumar, B. Digital twins in architecture, engineering, construction and operations a brief review and analysis. Lect. Notes Comput. Sci. 2021, 98, 924–939.
6. Atuahene, B.T.; Kanjanabootra, S.; Gajendran, T. Benefits of Big Data Application Experienced in the Construction Industry: A Case of an Australian Construction Company. In Proceedings of the ARCOM 2020-Association of Researchers in Construction Management, 36th Annual Conference, Leeds, UK, 7–8 September 2020; pp. 346–355.
7. Anshari, M.; Almunawar, M.N.; Lim, S.A.; Al-Mudimigh, A. Customer relationship management and big data enabled: Personalization and customization of services. Appl. Comput. Inform. 2019, 15, 95–101. [CrossRef]
8. Ngo, J.; Hwang, B.G.; Zhang, C. Factor-based big data and predictive analytics capability assessment tool for the construction industry. Autom. Constr. 2020, 110, 103042. [CrossRef]
9. McNamara, A.J.; Sepasgozar, S.M.E. Intelligent contract adoption in the construction industry: Concept development. Autom. Constr. 2021, 122, 1–20. [CrossRef]
10. Sharma, S. Big Data Analytics for Customer Relationship Management: A Systematic Review and Research Agenda. Commun. Comput. Inf. Sci. 2020, 1244, 430–438.
11. Nolz, P.C. Optimizing construction schedules and material deliveries in city logistics: A case study from the building industry. Flex. Serv. Manuf. J. 2020, 33, 846–878. [CrossRef]
12. Hasim, S.; Fauzi, M.A.; Yusof, Z.; Endut, I.R.; Ridzuan, A.R.M. The material supply chain management in a construction project: A current scenario in procurement process. ALP Conf. Proc. 2018, 2020, 1–8.
13. Youneszadeh, H.; Ardestish, A.; Hassan Sebt, M. Predicting Project Success in Residential Building Projects (RBPs) using Artificial Neural Networks (ANNs). Civ. Eng. J. 2020, 6, 2203–2219. [CrossRef]
14. Ezirim, N.O.; Okpoechi, C.U. Community-driven Development Strategy for Sustainable Infrastructure. J. Hum. Earth Future 2020, 1, 48–59. [CrossRef]
15. Ali Shaikh, F.; Saeed Shahbaz, M.; Ud Din, S.; Odhano, N. The Role of Collaboration and Integration in the Supply Chain of Construction Industry. Civ. Eng. J. 2020, 6, 1300–1313. [CrossRef]
16. Wang, M.; Wang, C.C.; Sepasgozar, S.; Zlatanova, S. A Systematic Review of Digital Technology Adoption in Off-Site Construction: Current Status and Future Direction Towards Industry 4.0. Buildings 2020, 10, 204. [CrossRef]
17. Chcen, Y.; Cui, B.; Sun, X. Real estate investment estimation based on BD neural network. Adv. Intell. Syst. Comput. 2021, 1303, 1610–1615.
18. Battula, V.R.; Namburu, S.K.; Kone, V. A study on factors involved in implementation of supply chain management in construction industry. Mater. Today Proc. 2020, 33, 446–449. [CrossRef]
19. Jing, K.T.; Ismail, R.B.; Yee, H.C.; Shafiei, M.W.M.; Wai, T.K. The practices of green supply chain management towards corporate performances in construction industry. Int. J. Supply Chain Manag. 2019, 8, 1084–1120.
20. Zeng, W.; Tse, M.Y.K.; Tang, M. Supply chain quality management: An investigation in the Chinese construction industry. Int. J. Bus. Manag. 2018, 10, 1–16. [CrossRef]
21. Patracco, A.; Ciccillo, F.; Pero, M. Industry 4.0 and supply chain process re-engineering: A coproduction study of materials management in construction. Bus. Process. Manag. J. 2020, 26, 1093–1119. [CrossRef]
22. Wan, L.; Bai, Y. Application Research on the BIM and Internet of Things Technology in Construction Logistics Management in the Period of Big Data. Adv. Intell. Syst. Comput. 2021, 1191, 704–716.
23. Okafor, C.C.; Ani, U.S.; Ugwu, O. Evaluation of supply chain management lapses in Nigeria’s construction industry. Int. J. Constr. Res. 2021. [CrossRef]
24. Katal, A.; Wazid, M.; Goudar, R. Big Data: Issues, Challenges, Tools and Good Practices. In Proceedings of the 6th International Conference on Contemporary Computing (IC3), Noida, India, 8–10 August 2013; pp. 404–409.
25. Elias Bibri, S.; Krogsjte, J. ICT of the new wave of computing for sustainable urban forms: Their big data and context-aware augmented typologies and design concepts. Sustain. Cities Soc. 2017, 32, 449–474. [CrossRef]
26. Sadeghi Darvazeh, S.; Raeesi Vanani, I.; Mansouri Musolo, F. Big Data Analytics and Its Applications in Supply Chain Management. New Trends in the Use of Artificial Intelligence for the Industry 4.0; IntechOpen: London, UK, 2019; p. 931.
27. González-Serrano, L.; Talón-Ballestero, P.; Muñoz-Romero, S.; Soguero-Ruiz, C.; Rojo-Álvarez, J.L. A Big Data Approach to Customer Relationship Management Strategy in Hospitality Using Multiple Correspondence Domain Description. Appl. Sci. 2020, 11, 256. [CrossRef]

28. Nazeer Wassouf, W.; Alkhatib, R.; Salloum, K.; Balloul, S. Predictive analytics using big data for increased customer loyalty: Syriatel telecom company case study. J. Big Data 2020, 7, 1–24.

29. Yu, T.; Liang, X.; Wang, Y. Factors affecting the utilization of big data in construction projects. J. Constr. Eng. Manag. 2020, 146, 1–19. [CrossRef]

30. Xiao, X.; Liu, J.; Ren, L. Study on Construction Engineering Management Based on BIM from the Perspective of Big Data. In Proceedings of the 2020 International Conference on Computer Information and Big Data Applications, CIBDA, Guiyang, China, 17–19 April 2020; pp. 111–115.

31. Yuan, X.; Chen, Y.W.; Fan, H.B.; He, W.H.; Ming, X.G. Collaborative Construction Industry Integrated Management Service System Framework Based on Big Data. In Proceedings of the 2020 EEE International Conference on Industrial Engineering and Engineering Management, Macao, China, 15–18 December 2019; pp. 1521–1525.

32. Delgado, J.M.D.; Oyedele, L.; Bilal, M.; Ajayi, A.; Akanbi, L.; Akinade, O. Big data analytics system for costing power transmission projects. J. Constr. Eng. Manag. 2020, 146, 1–12. [CrossRef]

33. Tavakol, M.; Dennick, R. Making sense of Cronbach’s alpha. Int. J. Med. Educ. 2011, 2, 53–55. [CrossRef]

34. Statistics How To. Cronbach’s Alpha: Simple Definition Use and Interpretation. 2014. Available online: https://www.statisticshowto.com/cronbachs-alpha-spss/ (accessed on 12 November 2018).

35. Moeletsi, M.E. Socio-Economic barriers to adoption of electric vehicles in South Africa: Case study of the Guateng province. World Electr. Veh. J. 2021, 12, 167. [CrossRef]