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The Importance of Digitalization for the Sustainability of the Food Supply Chain

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Abstract: This paper aims to define the negative impact of various indicators on the sustainability and functioning of the traditional food supply chain (FSC) in the segment of wholesale and retail activities and to propose a set of measures and incentives for the digitalization of its business processes. After a systematic review of the literature, the most common indicators significant for the functioning of the FSC were defined, primarily in the segment of wholesale and retail activities. Empirical research examined the influence of given indicators on the FSC. The obtained results showed that indicators such as poor coordination and transfer of information among FSC participants, food loss, economic performance, transaction costs, external elements, chemical and microbial contamination, and control of raw material, food, and waste flows significantly complicate the sustainability and functioning of the FSC. Based on the obtained results, a set of measures and incentives is proposed that the management of the supply chain should undertake to digitalize business processes, primarily in the segment of wholesale and retail activities. This paper also lists shortcomings of the research and gives guidelines for future research.

Keywords: food supply chain; digitalization; sustainability; global market

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1. Introduction

In recent years, a significant number of academic studies have appeared with a focus on the functioning and sustainability of the Food Supply Chain (FSC), particularly those related to its segment of wholesale and retail activities [1–5]. The traditional FSC shows a lot of shortcomings, primarily in the segment of food safety and security [6], losses in the fruit and vegetable placement system [2], dysfunctionalities caused by the COVID-19 pandemic [3,4], inadequate food labeling [7], downtime in production, distribution and retail [8], etc. Two major global events have significantly changed the way the traditional FSC operates. The gap that appeared on the demand side for durable food products (rice, flour, canned food, etc.) as a result of the lockdown due to the coronavirus epidemic, pointed to the dysfunctionality of the FSC as well as its weak response to market needs and the lack of cooperation and timely transfer of information between participants [3,4,9]. Geopolitical turmoil and the Ukrainian conflict have shown the vulnerability of the FSC [10]. The influence of external elements led to a complete halt of the grain supply to the global market, and the safety of food and the safety of shipments were called into question.

The traditional FSC is not ready to mitigate all shocks and uncertainties that appear in the market [1,10]. Authors point out that the flow of information between participants is not at a level that will enable supply chain management to react in time in terms of adequately finding alternative supply channels for raw materials and final products [1,2,4,7,8,11]. The speed at which an uncertainty appears in the market is inversely proportional to the speed of FSC's reaction to eliminate the consequences of that uncertainty. The FSC is characterized by robustness, non-transparency, weak coordination of cross-channel activities, and lack of

digitalization [11,12]. All of this points to the need to transform the traditional FSC into a modern digitized chain based on modern IT technologies (blockchain, IoT, etc.).

The objective of this study is to define how critical indicators influence the sustainability and functioning of the traditional FSC and propose a set of measures and incentives for the digitalization of its business processes, primarily in the segment of wholesale and retail activities. The basic research objective is supported by three specific goals: (1) defining the impact of critical indicators on the sustainability and functioning of FSC; (2) defining how the implementation of the digitalization process affects the analyzed indicators; (3) defining the impact of the digitalization process on the sustainability and functioning of the FSC. Through a systematic review of the literature, the indicators that most strongly influence the sustainability and flexibility of the FSC in the segment of the wholesale and retail activities were indicated. The results of empirical research show the positive and negative sides of the influence of each indicator. Based on the results obtained in this way, a set of measures and guidelines are proposed for the gradual digitization of the FSC to eliminate and minimize negative impacts and make the supply chain more transparent and flexible.

2. Literature Review

The FSC is a complex system responsible for the circulation of food from the initial stage of production to the final stage of consumption [13]. The FSC should function as a single entity with full coordination and exchange of information between participants (producers, distributors, wholesalers, and retailers) [14]. The authors indicate that any deficiency in the unity of the FSC leads to the creation of a market gap and an inadequate response to consumer needs [11–14]. At the same time, the optimization of chain activities leads to greater profitability and business efficiency. Many studies advocate better control of business processes. A 2020 study by Patidar and Agrawal shows that 92% of total food marketing costs appear in the transportation of products from producers (agricultural processors) to retail outlets [15]. The authors complain that traditional FSCs are often disorganized [16] and show a lack of communication between agricultural farms and consumers [17]. They are subject to significant influence from middlemen who dictate the output prices of products [15]. In addition, there is an inadequate distribution of benefits, rewards, and risks among participants in the FSC [14], and there are increasing influences from external factors [10], food waste [18], etc. The importance of the good functioning of the FSC on the global market in the years to come is best illustrated by the data. Rezaei and Liu, in their 2017 study, state that by 2050, the world's population will reach 9.1 billion people, which will require a 70% increase in food availability [19]. As much as 30% of food produced for human consumption globally is lost or wasted within the FSC. The biggest problem of food delivery will occur in urban centers whose populations are continuously growing. This will lead to the creation of complex supply chains involving numerous participants, which will present challenges in the delivery of safe and quality food [19]. In addition, the conventional systems implemented in FSC are centralized, monopolistic, asymmetric, and nontransparent, and they may lead to a serious lack consumer confidence in food safety. That trust has been particularly damaged after a series of incidents over the last decades, such as mad cow disease, aflatoxin problems with milk, the horsemeat scandal, toxic milk powder, genetically modified food, etc. [13]. As the biggest problem of FSC, Lemma, Kitaw, and Gatew cite food losses of 20 to 60 percent of total production [20]. The same authors state that in the global market, approximately one-third of food produced for human consumption is lost or wasted, which amounts to approximately 1.3 billion tons per year. The reasons for food waste lie primarily in inconsistencies and inefficiencies in production, storage, handling, and transportation along the entire FSC [20].

Based on the presented subject of the paper, we conducted our research in two phases. In the first phase, it was necessary to define the indicators that affect the sustainability and functionality of FSC, primarily in the role of the supply chain in the segment of wholesale and retail activities. In the second phase, the impact of the digitalization process on the indicators underwent empirical examination. In the first phase, through a systematic

literature review based on the methodology set by Xiao and Watson [21], indicators that directly affect the sustainability, functioning, and traceability of the FSC were identified. According to this methodology, the literature review began with a search exclusively by the keywords and titles of publications, followed by a review of abstracts, and continues with the analysis of the entire texts; the final stage includes reporting on the obtained findings. All analyzed articles were retrieved from the Web of Science, Scopus, and SpringerLink databases. The search was performed using keywords relevant to the research subject: Food Supply Chain (FSC) AND Digitalization AND Sustainability; Food AND Supply Chain Management (SCM) AND Sustainability; Safety AND Food Supply Chain AND Security; Food Supply Chain AND Economic performance AND External elements; Traceability AND Food Supply Chain AND Functionality; Waste AND Food Supply Chain AND Costs. Only high-quality peer-reviewed papers were taken into consideration. The number of hits per database was 48 papers for WoS, 39 papers for Scopus, and 45 papers for SpringerLink. Based on their titles, abstracts, and keywords, a total of 58 papers that fit the research topic were selected for further analysis. Among them, 17 duplicates were observed and were excluded from further analysis. The remaining 41 papers were read in detail, out of which 10 papers were discarded because they could not contribute to the resolution of the set research subject. Out of all remaining papers, nine were general, meaning that they dealt with the issues of food placement, supply chain management, et cetera. The remaining 21 papers were entirely on the line of research; that is, they analyzed the importance of the digitalization process on the sustainability of FSC, especially in the segment of wholesale and retail activities [1–9,11,15–17,19,20,22–28]. As such, the last group served to identify the following indicators that directly affect the sustainability, functioning, and traceability of FSC.

Poor coordination and transfer of information among FSC participants–One of the biggest problems is the untimely exchange of information, both from upstream to downstream and vice versa, to FSC participants [1,2,4,5,7,8,11]. As a result of this, the chain reacts untimely and poorly to market demands, which results in the appearance of gaps, primarily on the demand side. We witnessed huge gaps on the demand side for durable food products and other essentials during the first months of the COVID-19 pandemic. Within this indicator, we should also point out the ubiquitous whiplash effect (amplification of demand from lower to higher channel members), which leads to significant inefficiencies along the FSC in the food distribution and retail segment, such as missed deliveries, poor customer service, excessive stocks, and wrong capacity plans. To adequately minimize the adverse effects of this problem, it is necessary to continuously monitor the performance of food distributors so that the flow of demand information, order delivery, transportation planning, and inventory management can be significantly improved [29].

The loss and/or waste of food is a problem that is frequently caused by the malfunctioning of food production processes and the inefficiency of the supply system [19,20]. The most common reasons are some managerial and technical limitations, such as the lack of suitable storage facilities, poor food storage and preservation conditions, cold chain, improper food handling practices, insufficiently developed infrastructure, inadequate packing and packaging, ineffective marketing systems, etc. The fact that the annual estimate of food loss on the global market is around 1 trillion US$ is worrying [19].

Economic performance (inflation and price of energy)—The global factor of inflation and the sharp increase in the price of energy significantly complicate the functioning of the FSC [15,22]. The decline in energy imports from Russia and economic sanctions against the Russian market caused an increase in the inflation rate in the EU and a sharp increase in the price of energy (about a 16% increase in the price of electricity in Germany, 8% increase in the price of gas in the EU, etc.). There is a direct correlation between the growth rate of these economic indicators and the growth of food prices.

Transaction costs–A problem for FSC is also the growth of transaction costs. These costs arise in the process of moving products from farmers to final consumers [15]. These are transport costs, trade costs (commission), profit margin, information costs, etc. It

is estimated that their growth rate rose 30% compared to 2019. It is precisely such an inefficient movement of food that leads to low profitability in the FSC [15].

External elements–The global instability and crisis caused by the COVID-19 pandemic and the Ukrainian conflict caused unfathomable consequences and uncertainty in the global food market [3,4,9,23]. The pandemic occurred suddenly and caused an enormous demand for essential products during the quarantine (lockdown) period. On the other hand, the Russian–Ukrainian conflict caused a halt in the supply of agricultural products and raw materials (cereals), fertilizers, energy, food, etc. While the economy is recovering from the consequences of the COVID-19 pandemic, new market instability and instability in the supply of resources seriously threaten the functioning of the FSC, threatening to cause hunger in rural regions with poorly developed supply chains (e.g., African countries).

Chemical and microbial contamination—Accidentally or intentionally, during the transfer of food and raw materials from the farm to the place of final consumption, various sources of contamination appear [6,24–26]. Such contaminations lead to food quality and safety incidents and attract increasing public attention [25]. First, easily perishable food and products, such as milk and dairy products, meat and meat products, fresh fruits and vegetables, fish, etc., are exposed to contamination. The biggest problems are microbial contamination (pathogenic microorganisms), problems related to chemical and physical contamination, as well as issues caused by inadequate control (e.g., allergens, industrial pollutants, microtoxins, small objects, chemical residues, false documentation, etc.). Although many companies have recently integrated food safety early warning systems in the FSC, and the number of incidents has decreased significantly, contaminants can still pose a significant risk to human health depending on their toxicity and exposure time.

Control of raw material, food, and waste flows in FSC—A frequent criticism of the traditional FSC is the lack of control at critical points in the FSC. This primarily refers to problems related to supply chain management (SCM), the coordination of activities of participants related to raw materials and final product flow, cooperation among members, chain flexibility, logistics operations, packaging, and waste management [15–17,26–28]. Without continuous control of critical points, it is not possible to achieve full functionality, efficiency, and sustainability in the FSC, especially in the segment of timely placement of food products in the market [28]. Potential solutions appear in the form of Vendor-Managed Inventory (VMI) implementation in FSC. VMI is a concept in which the producers manage the vendors' inventory. In this way, they take full responsibility for making decisions regarding the timing and extent of restocking. The essential prerequisites for VMI implementation in FSC are trust, long-term cooperation, integration, transparency, and information-sharing [30].

From the given presentation of critical indicators, we understand that insufficient control and records [28], external factors [23], economic challenges [22], lack of digitalization and standardization of processes [28], as well as the non-transparent exchange of data and information [11,31] are some of the most critical challenges facing the FSC, its segment in wholesale and retail activities first and foremost. The key research question that arises is whether these challenges can be eliminated and FSC made more flexible through the implementation of digitalization processes and the application of modern technologies based on IoT, BT, DLT (distributed ledger technology), TTI, RFID, etc. The originality of the paper is reflected in the precise definition of the impact of the above indicators on the sustainability and functioning of the FSC as well as the impact of modern technologies on minimizing their importance and improving the efficiency of the entire FSC. The given paper and the obtained results fill the gap of previous research conducted in the western Balkans region, as almost no academic study has dealt with the concrete consequences of FSC digitalization. Defining the influence of critical indicators is significant for taking adequate measures in order to minimize their negative effects through the implementation of modern technologies in the FSC as well as for improving working conditions and achieving the sustainability of food placed on the market.

3. Methodology

3.1. Hypotheses

Previous research indicated the problem of transparency and functioning of the FSC and emphasized the need for digitalization of its business in the segment of wholesale and retail activities [1–9,11,15–17,19,20,22–28]. However, no research has provided a comprehensive overview of the negative effects of individual indicators and the path to minimize those effects through the implementation of modern technologies (BT, IoT, DLT, etc.). Obtaining a complete picture of the importance of critical indicators and the usefulness of the implementation of the digitalization process in FSC first requires defining the impact of all indicators in a mutual comparison.

The first research hypothesis, H_1, was set as follows: H_1—critical indicators have a statistically significant impact on the sustainability and functioning of the FSC in the segment of wholesale and retail activities. By testing this hypothesis, the first specific goal of this research is achieved, and the individual influences of each of the analyzed indicators are clearly defined. The first research hypothesis must be supported by seven supporting hypotheses $H_{1(a)}$–$H_{1(g)}$, which test the individual influence of each of the critical indicators. The supporting hypotheses are: $H_{1(a)}$—poor coordination and transfer of information among FCS participants has a statistically significant impact on the sustainability and functioning of FSC in the segment of wholesale and retail activities; $H_{1(b)}$—food loss and/or waste has a statistically significant effect on the sustainability and functioning of the FSC in the segment of wholesale and retail activities; $H_{1(c)}$—economic performance has a statistically significant effect on the sustainability and functioning of FSC in the segment of wholesale and retail activities; $H_{1(d)}$—transaction costs have a statistically significant effect on the sustainability and functioning of FSC in the segment of wholesale and retail activities; $H_{1(e)}$—external elements have a statistically significant influence on the sustainability and functioning of FSC in the segment of wholesale and retail activities; $H_{1(f)}$—chemical and microbial contamination have a statistically significant effect on the sustainability and functioning of the FSC in the segment of wholesale and retail activities; $H_{1(g)}$—control of raw material, food, and waste flows has a statistically significant effect on the sustainability and functioning of FSC in the segment of wholesale and retail activities.

Studies confirm that digitalization improves business processes that take place among FSC participants [1,11–13]. Implemented technologies such as BT, IoT, DLT, TTI, RFID, etc., minimize negative effects and make the FSC more functional and transparent, especially in the segment of wholesale and retail activities. In this context, and in accordance with the other specific objectives of this research through the following group of research hypotheses, we define the influence of the digitalization process on minimizing the negative impact of critical indicators. The second research hypothesis, H_2, states the following:

H_2—digitalization of business processes has a statistically significant effect on critical indicators in FSC in the segment of wholesale and retail activities. Testing this hypothesis determines if and in what way the implementation of BT, IoT, DLT, etc., minimizes the negative effect that critical indicators have on the sustainability and functioning of the FSC. As in the previous step, the second research hypothesis must be supported by seven supporting hypotheses $H_{2(a)}$–$H_{2(g)}$, which test the connection of the digitalization process with each of the analyzed critical indicators. The supporting hypotheses are: $H_{2(a)}$—the digitalization process has a statistically significant effect on the coordination and transfer of information among FSC participants in the segment of wholesale and retail activities; $H_{2(b)}$—food loss and/or waste has a statistically significant effect on the sustainability and functioning of the FSC in the segment of wholesale and retail activities. $H_{2(c)}$—the digitalization process has a statistically significant effect on economic performance in the segment of wholesale and retail activities; $H_{2(d)}$—the digitalization process has a statistically significant effect on transaction costs appearing in the FSC in the segment of wholesale and retail activities; $H_{2(e)}$—the digitalization process has a statistically significant effect on external elements in the segment of wholesale and retail activities; $H_{2(f)}$—the digitalization process has a statistically significant effect on chemical and microbial contamination in the

FSC in the segment of wholesale and retail activities; $H_{2(g)}$—the digitalization process has a statistically significant effect on the control of raw material, food, and waste flows in the FSC in the segment of wholesale and retail activities.

Considering that the direct correlation between the implementation of modern technologies and the sustainability of FSC was confirmed in previous research, it is necessary to precisely define that influence with the third research hypothesis. The third research hypothesis, H_3, states:

H_3—the implementation of the digitalization process has a statistically significant effect on the sustainability and functioning of the FSC in the segment of wholesale and retail activities. By testing the third hypothesis, the last specific goal of the research is achieved, and it is defined whether the implementation of modern technologies by minimizing the negative effects of critical indicators significantly affects the sustainability, transparency, and flexibility of the FSC.

The presented research objectives and hypotheses are illustrated in the following research model (Figure 1).

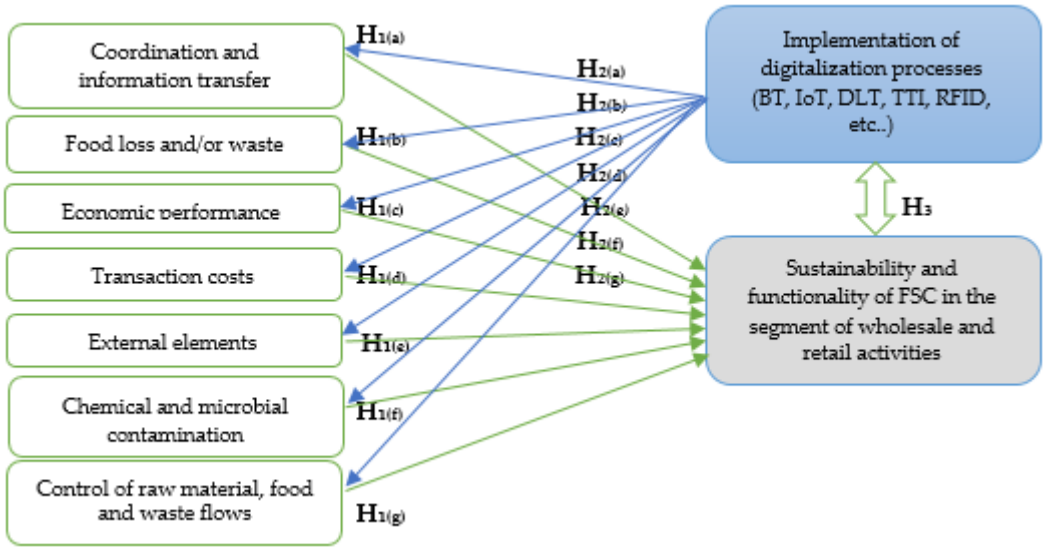

Figure 1. Presentation of the research model.

3.2. Variables

The mentioned research involved the realization of the research based on several dependent and independent variables. Due to the nature of the research subject, the procedure was implemented in three parts. The first part examined the influence of critical indicators on the sustainability and functionality of the FSC in the segment of wholesale and retail activities. The functioning of the FSC appears as a dependent variable, whereas seven critical indicators that appear in the functioning of the FSC were chosen as the independent variables of the interval type of measurement. These variables are the coordination and transfer of information; loss and/ or waste of food; economic performance; transaction costs; external elements; safety and security of food; control of raw materials, food, and waste flows [1,2,4,5,7,8,11,15,22,23]. The impacts of the given indicators on the sustainability and functioning of the FSC in the segment of wholesale and retail activities were evaluated based on a Likert scale (0—no impact; 5—very high impact). In the second segment, the impact of the implementation of modern technologies on critical indicators in FSC was examined. The implementation of BT, IoT, DLT, TTI, RFID, etc., appears as an independent variable of the interval type of measurement, whereas the dependent variables are all of the analyzed indicators. The impact of digitalization on the critical indicators was also assessed using a Likert scale. In the last part of the research, the sustainability and functioning of the FSC appear as a dependent variable, which is evaluated based on the impact of the digitalization process, the independent variable. The ratings were determined

based on a Likert scale. In all segments of the conducted research, FSC participants in the segment of wholesale and retail activities (physical distributors, wholesale, and retail), and the managerial positions of respondents (top management, mid-level management, and operational management) were chosen as independent grouping variables.

3.3. Research Sample

As many as 242 managers in the physical distribution, wholesale, and retail sectors participated in the survey. The representativeness of the selected sample stems from the fact that the respondents are FSC managers who are directly responsible for food marketing, who know best the dependence of marketing on the mentioned indicators, and who have experience with the implementation of digitalization processes in the FSC. This type of sample belongs to the group of large statistical samples and is suitable for testing set hypotheses and achieving the research goal. In addition, the sample was uniform in terms of the number of FSC participants, the managerial position of the respondents, and their demographic characteristics, which contributed to obtaining representative data. The research sample is presented in Table 1.

Table 1. Research sample.

Gender	***n***	**Structure (%)**
Female	104	41.6%
Male	138	58.4%
FSC Sector	*n*	Structure (%)
Physical distribution	77	31.8%
Wholesale	78	32.2%
Retail	87	36.0%
Managerial level	*n*	Structure (%)
Top management	55	20.8%
Mid-level management	86	35.5%
Operational management	101	41.7%

Source: Author's calculations.

The reliability of the conducted testing and the correctness of the selected scales were confirmed using standard statistical coefficients: Cronbach's alpha, skewness, and kurtosis (Table 2). From the tabular presentation, there are no statistically significant deviations for the skewness and kurtosis coefficients, whereas Cronbach's alpha coefficient for all variables has values that are above 0.750. The obtained coefficient values confirm that the selected questions describe an identical problem and can be used to examine the opinions and attitudes of FSC managers on the impact of critical indicators on its sustainability and functionality as well as on the possibilities of implementing modern technology in business processes related to food marketing.

Table 2. Cronbach's alpha, skewness, and kurtosis coefficients.

Indicators	**Cronbach's Alpha**	**Skewness**	**Kurtosis**
Coordination and information transfer	0.852	0.069	−1.020
Food loss and/or waste	0.939	−0.228	−0.118
Economic performance	0.774	−0.442	−0.883
Transaction costs	0.903	−0.527	−1.151
External elements	0.752	−0.212	−1.236
Chemical and microbial contamination	0.843	0.079	−1.307
Control of raw material, food, and waste flows	0.812	−0.338	−0.525
Digitalization	0.804	0.473	−0.663

Source: Author's calculation.

3.4. Procedure and Data Analysis

The online questionnaire was sent to all FSC participants in the period from August–September 2022. Wholesalers, independent carriers, and retailers, as well as the largest agricultural holdings, transport and logistics centers, and retail chains in the territory of the western Balkans (Serbia, Croatia, B&H, Montenegro, North Macedonia), are equally represented in the sample. The sample consists of business entities that primarily deal with fast-moving consumer goods, except for fresh fruits and vegetables, fresh meat, fish, and other products that are marketed unpackaged or in bulk.

The questionnaire consisted of 22 questions that were structured based on similar questionnaires and research conducted in some earlier studies [14,16,18,28]. The questionnaire had three parts. After collecting general demographic information about the respondents (gender, age, and position), in the first part of the questionnaire, respondents were asked to evaluate the impact of each of the offered indicators on the functioning of the FSC. The indicators were evaluated based on three Likert-type items (0–5 scale). After that, in the second part, respondents ranked how implemented modern technologies (digitalization) minimized the negative impact of critical indicators. Digitalization was also operationalized through three items: (1) application of information technology: BT, IoT, DLT, etc.; (2) application of sensor and identification technology: WSN, TTI, Barcode, RFID, etc.; (3) application of location-based technology: RS, GPS, RTLS, etc. In the last part of the questionnaire, the direct impact of digitalization on the sustainability and functioning of the FSC was also assessed through three Likert-type items.

The total number of sent questionnaires was 600, which shows a return rate of filled questionnaires of 33.7% (242/640). The collected data were analyzed and used to test research hypotheses. The method of descriptive statistics was used to present the most significant characteristics of the sample, whereas the basic and supporting research hypotheses were tested using the statistical method of structural modeling (SEM) or path analysis.

IBM SPSS Amos 23 structural equation modeling software was used for data design and analysis. Path coefficients (R*ij*) were calculated programmatically based on the following pattern:

$$Rij = Pij + \sum(R\ ik \times P\ kj) \quad (1)$$

wherein:

R*ij*—the mutual connection between independent indicators (i) and dependent variables (j) measured by the correlation coefficient (r),

P*ij*—the component that shows the direct influence (effect) of independent indicators (i) on the dependent variable (j) measured by the path coefficient,

$\sum$(R *ik* × P *kj*)—the sum of the components of the indirect influence of a given independent indicator (i) on a given dependent variable (j) through independent characters (k).

The residual effect is determined based on the formula $\sqrt{1 - R_2}$, where—$R_2 = \sum(Rij \times P\ ij)$.

To evaluate the model, that is, whether there is enough information to calculate unknown parameters in SEM, the following coefficients were used: NFI—Bentler-Bonett Normed Fit Index, RFI—Relative Fit Index, IFI—Incremental Fit Index, CFI—Comparative fit index, TLI—Tucker-Lewis index, RMSEA—Root Mean Square Error of Approximation, and CMIN/DF—Chi-square value/degree of freedom.

Other used statistical indicators were: Standard Error (SE = SD/$\sqrt{n}$, where SD is the standard deviation and n is the number of elements in the sample), Standard Deviation (SD = $\sqrt{1/N\sum(xi - \mu)^2}$, where N is the number of elements in the sample, xi is the ith member of the sample, and μ is the arithmetic mean), Coefficient Beta ($\beta = (S_x/S_y)b$, where S_x is the standard deviation of variable x, S_y is the standard deviation variables y, and b is the standard regression coefficient), T value ($t = (\bar{x} - \mu)/(SD - \sqrt{n})$, where $\bar{x}$ is the arithmetic mean of the sample, μ is the arithmetic mean of the population, SD is the standard deviation of the sample, and n is the sample size).

4. Research Results

The average scores (M) of the respondents' agreements with statements that critical indicators and the digitalization process significantly influence the sustainability and functionality of the FSC in the segment of wholesale and retail activities are presented in Table 3. In addition to the average rank, for each of the tested indicators, the most important indicators of descriptive statistics are listed (Min., Max., SE, and SD).

Table 3. Descriptive statistics.

Order No.	Indicators	Min.	Max.	Mean (M)	Standard Error (SE)	Standard Deviation (SD)
1	2	3	4	5	6	7
1	Coordination and information transfer	2.00	5.00	4.71	0.0804	0.8604
2	Food loss and/or waste	2.00	5.00	3.74	0.0628	0.9380
3	Economic performance	1.00	5.00	4.24	0.0783	0.8014
4	Transaction costs	1.00	4.00	3.17	0.0472	0.9116
5	External elements	2.00	5.00	4.25	0.0700	0.9314
6	Chemical and microbial contamination	1.00	4.00	3.87	0.0731	1.2408
7	Control of raw material, food, and waste flows	2.00	5.00	4.17	0.0665	1.0537
8	Digitalization	2.00	5.00	4.20	0.2167	0.8390

Source: Author's calculation.

The above table shows that the respondents agree that coordination and information transfer (M = 4.71) is the most important indicator that influences FSC in the segment of wholesale and retail activities. In other words, respondents believe that the lack of coordination and untimely transfer of information among FSC participants has the greatest negative impact on its sustainability and flexibility. The degree of agreement among respondents with this statement is significant and amounts to SD = 0.8604. Such a result is expected because inadequate exchange of information within the FSC results in an untimely and weak reaction to the demands and needs of the market [1,2,4,5,7,8,11]. Second place is shared by external elements (M = 4.25) and economic performance (M = 4.24). It is particularly interesting to observe that the respondents in their answers are most in agreement about the negative impact that economic performance can have on FSC (SD = 0.8014). Having in mind the volatility and unpredictability of the global market and its impact on supply chains, these are expected responses. Out of the critical indicators, the control of raw material, food, and waste flows (M = 4.17), chemical and microbial contamination (M = 3.87), and food loss and/ or waste (M = 3.74) follow. Transaction costs (M = 3.17) are in last place in importance for the functionality of FSC, which is possibly attributed to the fact that FSC managers consider that they take more care and more efficiently monitor the expenses that appear on the journey of the product from the farmer to the final consumer. It is interesting to note that the process of digitalization and its impact on the entire FSC was assessed with a high average score of 4.20, with high agreement among respondents on this statement (SD = 0.8390). This confirms the awareness among FSC managers of the necessity of introducing modern technologies in FSC business operations.

The SEM method will be used to precisely test the impact of critical indicators on the sustainability and functionality of FSC in the segment of wholesale and retail activities (hypothesis group $H_{1(a)}$–$H_{1(g)}$). Before actual testing, it was necessary to determine the degree of correlation between the analyzed indicators and the functionality of the FSC. For this purpose, multiple regression analysis was applied, i.e., the Enter method, which combines all independent variables (critical indicators) to predict the dependent variable (sustainability and functionality of FSC). The obtained regression model is statistically significant ($F(200;6) = 6.97$, $p < 0.01$), which means that the set of critical indicators is statistically significant in predicting the sustainability and functionality of FSC. The resulting

model describes 66.3% of the criterion variance. The contribution of each indicator is presented in Table 4.

Table 4. Contribution of critical indicators.

Indicators	Stand. Coefficient		*t*	*Sig.*
	Beta	St. Error		
(const.)	0.786	1.181	3.457	0.000
Coordination and information transfer	0.774 **	0.673	0.813	0.009
Food loss and/or waste	0.633	0.604	1.031	0.087
Economic performance	0.627 **	0.721	1.136	0.004
Transaction costs	−0.557	0.780	0.495	0.117
External elements	0.756 **	0.678	1.350	0.000
Chemical and microbial contamination	0.448 *	0.793	0.603	0.040
Control of raw material, food, and waste flows	0.561 *	0.844	0.790	0.034

Note: ** Correlation is significant at the 1%level; * correlation is significant at the 5% level. Source: Author's calculation.

Testing the impact of critical indicators on the sustainability and functionality of the FSC was implemented using the SEM method, or the path analysis method. The essence of the SEM method is that the influence of each critical indicator on the sustainability and functioning of the FSC can be defined based on the established paths or directions of influence. The obtained model is statistically significant (NFI = 0.984; RFI = 0.926; IFI = 0.957; TLI = 0.950; CFI = 0.950; RMSEA = 0.048, CMIN/DF = 1.495). The results of testing the first group of research hypotheses $H_{1(a)}$–$H_{1(g)}$ and the display of statistically significant mutual influences between the analyzed indicators are presented in Table 5.

Table 5. Path analysis.

Ord. No.	Path	Path Coefficient	*t* Value	Result
1	Coordination and information transfer » Sustainability and functionality of FSC	0.861	14.331	Support
2	Food loss and/or waste » Sustainability and functionality of FSC	0.066	4.088	Reject
3	Economic performance » Sustainability and functionality of FSC	0.628	11.030	Support
4	Transaction costs » Sustainability and functionality of FSC	0.117	1.924	Reject
5	External elements » Sustainability and functionality of FSC	0.801	11.240	Support
6	Chemical and microbial contamination » Sustainability and functionality of FSC	0.420	1.627	Support
7	Control of raw material, food, and waste flows » Sustainability and functionality of FSC	0.266	3.227	Support
8	Coordination and information transfer » Food loss and/or waste	0.648	9.033	Support
9	Coordination and information transfer » Transaction costs	0.474	3.549	Support
10	Coordination and information transfer» Control of raw material, food, and waste flows	0.548	8.212	Support
11	Economic performance » Loss and/ or waste of food	0.554	0.887	Support
12	Economic performance » Transaction costs	0.732	3.549	Support
13	Transaction costs » Loss and/ or waste of food	0.772	8.212	Support
14	External elements » Economic performance	0.831	10.611	Support
15	External elements » Chemical and microbial contamination	0.730	4.088	Support
16	Control of raw material, food, and waste flows » Chemical and microbial contamination	0.661	9.033	Support
17	Digitalization of FSC » Coordination and information transfer	0.758	14.221	Support
18	Digitalization of FSC » Food loss and/or waste	0.426	4.088	Support
19	Digitalization of FSC » Economic performance	0.310	11.030	Reject
20	Digitalization of FSC » Transaction costs	0.228	1.924	Support
21	Digitalization of FSC » External elements	0.055	11.030	Reject
22	Digitalization of FSC » Chemical and microbial contamination	0.517	1.627	Support
23	Digitalization of FSC » Control of raw material, food, and waste flows	0.376	3.227	Support

Source: Author's calculation.

The obtained results show that critical indicators such as coordination and transfer of information, economic performance, external elements, chemical and microbial contamination, and control of raw material, food, and waste flows affect in a statistically significant way the sustainability and functionality of the FSC in the segment of wholesale and retail activities. That confirms research hypotheses $H_{1(a)}$, $H_{1(c)}$, H_{1I}, $H_{1(I)}$ i $H_{1(g)}$, i.e., considering that these are critical indicators, any increase in the intensity of the given indicators and failures in control, information flows, and security and the like, has a direct negative impact on the flexibility of the FSC. In the case of the remaining two indicators, no statistically significant influence can be read, and we conclude that hypotheses $H_{1(b)}$ and $H_{1(d)}$ are not accepted. Based on the conducted testing, the conclusion is that the first research hypothesis H_1 is partially accepted and that critical indicators in most cases have a statistically significant effect on the sustainability and functionality of FSC in the segment of wholesale and retail activities. Figure 2 (structural model) presents the influence paths of critical indicators on the sustainability and functionality of FSC.

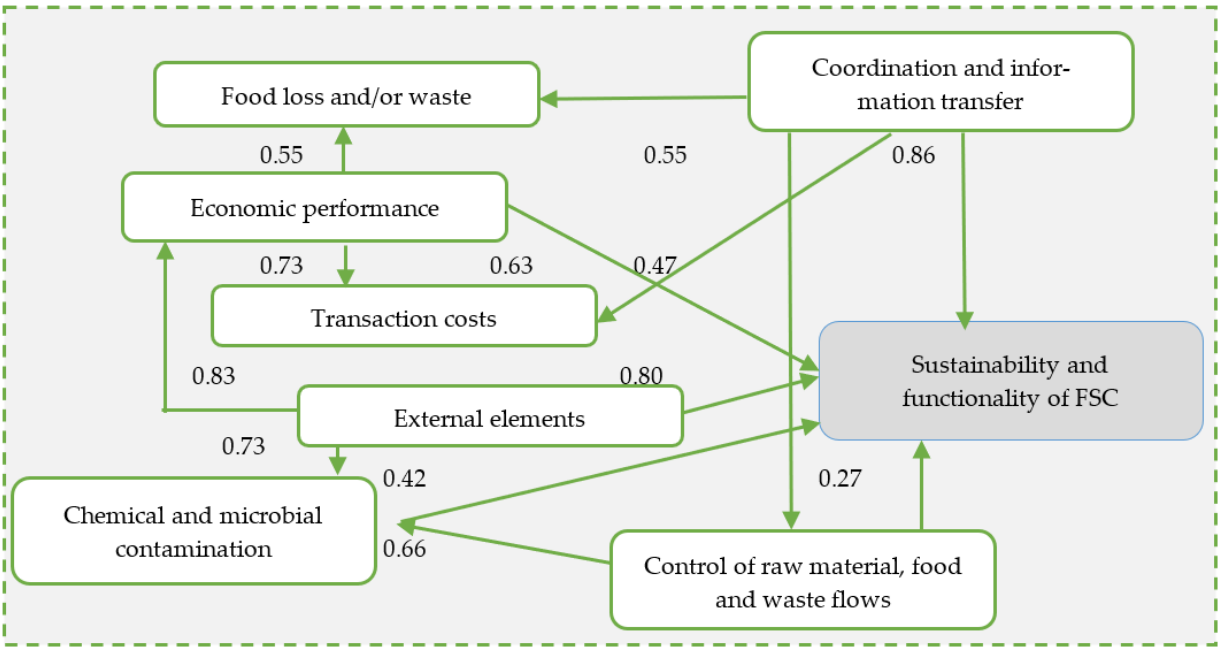

Figure 2. Structural model.

In the second part of the questionnaire, respondents assessed the impact of digitalization; that is, a ranking was made to establish if the application of modern information technologies, location-based technologies, and sensor and identification technologies (BT, IoT, DLT, WSN, TTI, Barcode, RFID, RS, GPS, RTL, etc.) minimizes the negative impacts of the critical indicators defined in the first segment of the research. The average scores (M) of respondents' agreements with the statement that the digitalization process significantly affects critical indicators are presented in Table 6. In addition to the average rank, the most important indicators of descriptive statistics (Min., Max., SE, and SD) are listed.

Table 6. Descriptive statistics for the impact of the digitization process on critical indicators.

		Indicators of Descriptive Statistics	Coordination and Information Transfer	Food Loss and/or Waste	Economic Performance	Transaction Costs	External Elements	Chemical and Microbial Contamination	Flows of Raw Materials, Food and Waste
1	Digitalization nof FSC	Min.	2.00	1.00	1.00	2.00	1.00	2.00	1.00
2		Max.	5.00	5.00	5.00	5.00	4.00	5.00	5.00
3		M	4.84	4.22	3.21	4.14	3.21	4.02	4.36
4		SE	0.0715	0.1241	0.0684	0.0474	0.0700	0.0574	0.2410
5		SD	0.8057	0.9914	1.0541	1.2112	0.9758	0.8824	0.8110

Source: Author's calculation.

From the given tabular representation, it is noticeable that the respondents believe that the digitalization process most influences and shapes the coordination and transfer of information in the FSC (M = 4.84) and the control of raw material, food, and waste flows (M = 4.36). Together, these answers show the highest degrees of mutual agreement between the respondents' views (SD = 0.8057; SD = 0.8110). These answers are expected, bearing in mind that improving the flow of information, products, and services through the FSC is impossible without modern technologies [1,11–13,28]. Slightly less importance was attributed to the impact of digitalization on food loss and/or waste (M = 4.22), transaction costs (M = 4.14), and chemical and microbial contamination (M = 4.02). With all of these indicators, it is noticeable that with an increase in the degree of control and better monitoring of information, their negative effects are eliminated. The least importance was given to the impact of digitalization on economic performance (M = 3.45) and external elements (M = 3.21). The respondents' opinion is that these last two indicators are the most dependent on external factors that come from outside the FSC, and that, therefore, digitalization cannot have a direct impact on them.

For testing the second group of research hypotheses $H_{2(a)}$–$H_{2(g)}$, the SEM method was also be used; that is, the impact path analysis. Previously, using the Enter method, it was determined that the obtained regression model is statistically significant ($F(200;1) = 6339$, $p < 0.01$), which means that the digitalization process significantly predicts the influence of each of the critical indicators. The resulting model describes 71.3% of the criterion variance. Using the SEM method, we defined the direction of the influence of the digitalization process on each of the critical indicators. The obtained model is statistically significant (NFI = 0.977, RFI = 0.962, IFI = 0.945, TLI = 0.971, CFI = 0.977, RMSEA = 0.028, and CMIN/DF = 1.266). The results from testing the second group of research hypotheses $H_{2(a)}$–$H_{2(g)}$ are presented in Table 5.

The results show that implementing modern technological solutions in the FSC significantly affects the coordination and transfer of information, loss and/or waste of food, transaction costs, food security and safety, and raw materials, food, and waste flows in the FSC in the segment of wholesale and retail activities. These results confirm the research hypotheses $H_{2(a)}$, $H_{2(b)}$, $H_{2(d)}$, $H_{2(f)}$ i $H_{2(g)}$; that is, the growth of the intensity of the digitalization process is directly reflected in the minimization of the negative impacts of the mentioned critical indicators on the sustainability and functioning of the FSC. In the case of the remaining two indicators, no statistically significant influence can be read, and we conclude that hypotheses $\mathbf{H_{1(c)}}$ i $\mathbf{H_{1(e)}}$ are not accepted. In other words, FSC digitalization has no impact on economic performance (inflation rate and energy prices) or external effects (global instability, crises, etc.).

Based on the conducted testing, the conclusion is that the second research hypothesis H_2 was partially accepted, and that the implementation of modern technologies in most cases statistically significantly affects and minimizes the critical indicators that appear in the business operations of FSC in the segment of wholesale and retail activities. Figure 3 (structural model) presents the paths of influence of the digitalization process on critical indicators as well as the mutually statistically significant influence between the critical indicators.

In the last segment of the research, the respondents made a final judgment on whether the digitalization process affects the sustainability and functionality of the FSC in the segment of wholesale and retail activities. The average ranking of respondents' answers and the most important indicators of descriptive statistics on this issue are presented in Table 7.

The average rank of M = 4.20 shows that the respondents believe that the implementation of modern technologies through the impact on critical indicators directly contributes to greater flexibility and transparency in the FSC, that is, its sustainability and functionality. It is noticeable that the respondents are quite unanimous on this statement (SD = 0.839). This result gains additional importance because most respondents from the sample have already implemented various modern information and technological solutions in their business processes; thus, their answers are based on real data. As in the case of the previous research hypotheses, when testing $\mathbf{H_3}$ by employing the SEM method, the direction of the influence of

the digitalization process on the sustainability and functionality of the FSC was defined. The obtained model is statistically significant (NFI = 0.965, RFI = 0.974, IFI = 0.961, TLI = 0.975, CFI = 0.966, RMSEA = 0.044, and CMIN/DF = 1.342). The results of testing the third research hypothesis $\mathbf{H_3}$ are presented in Table 8.

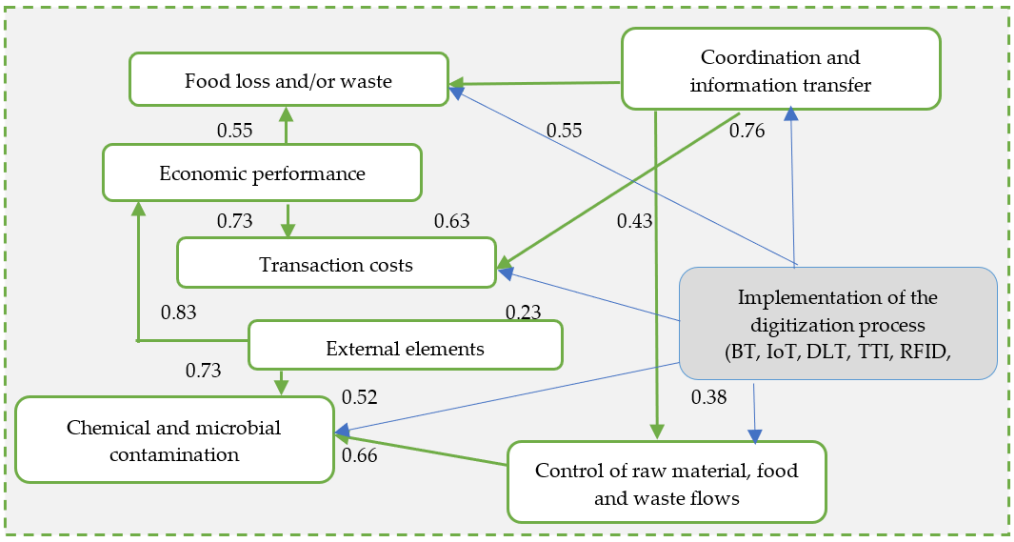

Figure 3. Structural model.

Table 7. Descriptive statistics.

Order No.	Indicators	Min.	Max.	Mean (M)	Standard Error (SE)	Standard Deviation (SD)
1	**2**	**3**	**4**	**5**	**6**	**7**
1	Digitalization of FSC in the segment of wholesale and retail activities	2.00	5.00	4.20	0.2167	0.8390

Source: Author's calculation.

Table 8. Path analysis.

Ord. No.	Path	Path Coefficient	*t* Value	Result
1	Digitalization » Sustainability and functionality of FSC	0.863	8.212	Support

Source: Author's calculation.

The result shows that the digitization of FSC, that is, the implementation of information technologies, location-based technologies, and sensor and identification technologies (BT, IoT, DLT, WSN, TTI, Barcode, RFID, RS, GPS, RTL, etc.), affects the sustainability and functionality of FSC in the segment of wholesale and retail activities. That confirms the third research hypothesis $\mathbf{H_3}$, that is, the growth of the intensity of the digitalization process and the greater inclusion of modern technologies in the business processes of the FSC directly reflects on the sustainability, transparency, and functioning of the FSC. The direction of influence is quite clear and simple (Figure 4).

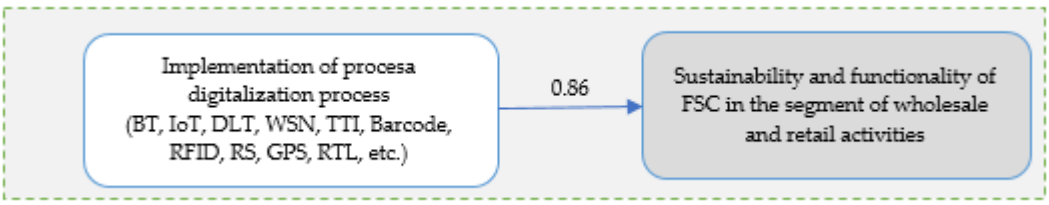

Figure 4. Structural model.

5. Discussion

The results of the conducted research show that various indicators, called critical indicators in the literature, significantly influence the sustainability and functionality of FSC in the segment of wholesale and retail activities. The research confirmed the results of previous studies that inadequate exchange of data and information [1,2,4,5,7,8,11], failures in the control of flows of raw materials, food, and waste [15–17,27,28], external factors [3,4,9,23], economic challenges [15,22], food loss and waste [19,20], and the lack of digitalization and standardization of business processes are the most critical challenges for FSC sustainability, primarily in the segment of wholesale and retail activities [11–13]. The introduction of modern technological solutions such as information technologies (BT, IoT, DLT, etc.), sensor and identification technologies (WSN, TTI, Barcode, RFID, etc.), location-based technologies (RS, GPS, RTLS, etc.), Internet technology (web applications), etc., significantly minimizes the negative impacts of critical indicators. It eliminates their negative effects and, with complete digitalization, turns them into positive inputs that contribute to the efficient functioning of the FSC. The findings of the study confirm the results of recent research. Kittipanya-Ngam and Tan conclude that digitalization enables food supply chains to be flexible, highly connected, and efficient, responding on time to customer needs and regulatory requirements [32]. Annosi, Brunetta, Bimbo, and Kostoula point out that FSCs are increasingly relying on advanced technological solutions for big data management to encourage collaboration along the entire supply chain and improve its business performance, especially in the segment of waste, food recovery, losses, et cetera [33]. Similarly, the conclusions of the Amentae and Gebresenbet study show that the implementation of digital technologies such as blockchain, IoT, big data analytics, artificial intelligence (AI), and related IT and communication technologies enable greater traceability, sustainability, and resistance of FSC to crises and unexpected market fluctuations on one hand and the reduction of waste, losses, and wastage of food on the other [34]. In addition, the study of Michel-Villarreal, Vilalta-Perdomo, Canavari, and Hingley testifies to the great importance of the digitalization process, which points out that even cheap digital technologies such as free software and social media significantly support the flexibility, visibility, collaboration, and agility of the FSC [35]. Bearing in mind these aspects, it is necessary to propose measures and incentives so that the FSC management effectively digitalizes its business processes and activities, minimizes the negative effects of critical indicators, and increases the functionality and transparency of the food market. The proposed measures can be divided into two groups: economic and financial measures and incentives; organizational and technical measures.

Economic and financial measures and incentives—The introduction of modern technological solutions requires significant investments, including investments in equipment and infrastructure [28]. Chambers of commerce, relevant ministries, secretariats and institutions, business associations, commercial banks, etc., should help all FSC participants to feel economically secure, reduce the financial risks of investing in digitalization processes, and, at the same time, provide the necessary funds (incentives, loans, co-financing, joint ventures, etc.) to transform their business activities. This implies a whole range of measures and incentives such as (a) direct investments for FSCs that digitize their business processes; (b) credit relief for the purchase of modern IT equipment; (c) special credit lines for the implementation of advanced technology (longer repayment period, low interest rates); (d) the possibility of paying for equipment on a deferred basis; (e) tax benefits such as reductions in income tax, property tax, etc., for the most vulnerable FSC participants (small agricultural producers and processors, independent transporters and retailers); (f) incentive measures for participation in programs for co-financing the development of information infrastructure (e.g., IPA EU funds and national funds); (g) exemption from VAT on devices and equipment for the implementation of modern information technologies, etc.

Organizational and technical measures—These aim at training FSC employees for the effective application of advanced technology on one hand and building and developing an adequate infrastructure capable of accepting a new business model on the other [30]. In the

segment of human resources, these measures include the implementation of special courses and training programs for employees who work with new technologies, encouraging the retraining of employees in the IT sector, subsidies for FSC participants who employ workers to work with modern technologies, strengthening the concept of lifelong learning, organizing seminars, conferences, and counseling centers as forms of additional education for employees, etc. These measures should be encouraged by FSC managers based on the transfer of knowledge and experience from systems that have already integrated advanced technologies into their business processes. When it comes to infrastructure, in the segment of wholesale and retail activities, the following technical measures must be taken: (1) introduction of blockchain technology and implementation of big data analytics (BDA); (2) introduction of modern IT solutions for more efficient monitoring of processes, products, and services (TT indicators, RFID, biosensors, and IoT); (3) implementation of clear standards, measures, supervision, and procedures for digitalization of business processes; (4) strengthening the system for electronic food placement (e.g., electronic ordering and food delivery) and increasing its participation to a minimum of 15–20% in total placement; (5) transition from traditional to new processes, electronic stores, etc.

Only with the full implementation of the recommended measures and incentives is it possible to influence the FSC's management to start implementing the digitalization process. Bearing in mind that the geopolitical situation is changing drastically on the global market, that food prices have started to rise rapidly, and that in some places, food shortage is already felt, only through the application of advanced technologies will the FSC be able to effectively perform its primary function, which entails the continuous supply of food products to the market. All of the above measures, if applied, will enable the FSC to meet the basic needs of the market in a timely and efficient manner; that is, it will make the supply chain more flexible, and the final consumers will be more satisfied and more confident in the quality and safety of food. The assumption is that only those FSC participants who digitize their business processes in time and adapt to the new business reality will succeed.

Shortcomings of research. During the work on this study, several shortcomings were identified that do not diminish the quality of the results obtained and the confirmed findings but that should be mentioned to marginalize them in subsequent research. First of all, the research dealt exclusively with the segment of wholesale and retail activities. The reasons for the selection of this part of the FSC are the author's familiarity with the problems of distribution, wholesale, and retail, as well as the excessive scope of research, which, if producers and processors were involved, would require significant investments in financial and personnel terms. Next, the research focused on the region of the western Balkans. The objective reason for this geographical limitation is the author's familiarity with the ways and problems in the functioning of regional FSCs as well as easier access to data. Second, a large number of unfilled questionnaires (return rate 33.7%) is noticeable, which speaks of insufficient promotion and explanation of the need to conduct such a survey among FSC employees. Thirdly, the structure of the questionnaire consisted mostly of questions with pre-given answers (Likert-type items) that might have misled respondents to give certain attitudes and answers. It is recommended that a larger number of open questions be included in subsequent examinations.

Guidelines for future research. As the most important suggestions for future research, we recommend the following: (1) include FSCs from the region of southeast and/or central Europe in the research sample and make a comparison of the impact of critical indicators and digitization processes on the sustainability of the FSC between EU and non-EU countries; (2) include all FSC participants in the research, primarily processors, producers, agricultural holdings, etc.; (3) expand the number of respondents in the survey sample to include administrative workers, workers in warehouses, transportation, workers in retail, etc.; (4) expand the questionnaire with a larger number of open-ended questions where respondents are expected to enter the answers themselves; (5) expand analysis and

testing to a larger number of critical indicators, or examine their subcategories in more detail within the existing indicators.

6. Conclusions

The results of the research and the testing of the set hypotheses showed that there are indicators that can have significant negative effects on the sustainability and functionality of the FSC in the segment of wholesale and retail activities. These are, in descending order of impact, the coordination and transfer of information (r = 0.861), economic performance (r = 0.628), external elements (r = 0.801), chemical and microbial contamination (r = 0.420), and control of flows of raw materials, food, and waste (r = 0.266). In addition, this research proved that the digitization process significantly affects critical indicators, except for external factors. The results showed that digitization of the FSC in the segment of wholesale and retail activities minimizes negative effects and improves the coordination and transfer of information (r = 0.758), food loss and/or waste (r = 0.426), chemical and microbial contamination (r = 0.517), transaction costs (r = 0.228), and control of flows of raw materials, food, and waste (r = 0.376). Thereby, the digitalization process directly contributes (r = 0.863) to greater sustainability and flexibility within the FSC. This answered the research question in that. through the implementation of the digitization process and the application of modern technologies based on IoT, BT, DLT, TTI, RFID, etc., the challenges of food placement can be eliminated, and the FSC can be made more flexible. Based on the findings of this study, this paper proposes a whole set of economic, financial, organizational, and technical measures and incentives that should be applied by FSC management in the segment of wholesale and retail activities to effectively digitize its business processes, minimize the negative effects of critical indicators, and increase the functionality and transparency of the food market.

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