



Article Benefit Optimization of Short Food Supply Chains for Organic Products: A Simulation-Based Approach

Blanka Tundys * D and Tomasz Wiśniewski

Faculty of Economic, Finance and Management, University of Szczecin, 71-004 Szczecin, Poland; tomasz.wisniewski1@usz.edu.pl

* Correspondence: blanka.tundys@usz.edu.pl; Tel.: +48-504-026-556

Received: 11 March 2020; Accepted: 13 April 2020; Published: 17 April 2020



Featured Application: The method herein can be useful for supply chain managers, leaders, and individual units. The paper concisely demonstrates simulation modeling as an evaluative tool for stochastic systems, which facilitates the ability to obtain performance measurement estimates under any given system configuration of short food supply chains (SFSCs).

Abstract: Creating alternative supply chains can help increase economic and social benefits for all beneficiaries of the supply chain. Alternative short supply chains for organic products are considered when seeking optimal scenarios to obtain the highest profit for producers, with maximizing profit being one of the main reasons for taking up business within this type of supply chain strategy. The aim of this study was to clarify the ideas of short food supply chains (SFSCs) and the organic production of food products and to indicate how economic benefits can be achieved in individual markets. The identified research gaps include the lack of a strong theoretical basis, as well as the lack of empirical studies concerning the multi-objective optimization of the economic effects of producers using computer simulation methods. However, the aim of this research was to identify the activities within such structures that can produce economic effects and influence the competences and soft relationships between the organizations participating in the chains. The adopted research methods included a critical analysis of the literature and the use of information technology tools and computer simulation. We found that computer simulation methods can lead to better decisions (to increase manufacturer benefits) regarding how to service selected markets within the SFSC. The most important limitations are the small territorial scope of the research and the consideration of only three of the most frequently purchased and manufactured products in Poland. This study was a pilot study, which will be developed further by the authors, from both a territorial and product point of view.

Keywords: short food supply chain; organic product; multi-objective optimization; simulation; supply chain management

1. Introduction

Conventional food supply chains include producers, processors, distributors, consumers, and food processors, and they are often networked. Conventional food is often offered using wide and long chains, where small producers struggle to be included in this structure or to strengthen their bargaining power. This situation has led to the emergence of alternative food systems in the food production market, in which production and trade play more of a role in social relationship implementation, links between individuals in the supply chain, as well as the location of production. They often create local food systems linked to the functioning of short food supply chains (SFSCs). The structure and components of trade are constantly changing and evolving. Grewal et al. [1] pointed to five elements

that will play roles in creating world trade in the future: (1) technology and tools to facilitate decision making, (2) visual display and merchandise offer decisions, (3) consumption and engagement, (4) big data collection and usage, and (5) analytics and profitability. Generally, alternative food systems link local producers to consumers, wherein people try to counteract environmental degradation, economic concentration, and dependence on global, homogeneous products in the agri-food industry [2].

The creation and functioning of short food supply chains can contribute to finding new key success factors and motivators for such activities and produce measurable results, including influencing changes in profit and loss. Therefore, motives for undertaking business activity may be different from financial motives; personal goals, non-economic values, and links and development trends may be sought in the cooperation and relationships with customers, adapting to their requirements and meeting consumer expectations. Agriculture is changing and the SFSC is a consequence of the crisis in intensive farming models and consumers' expectations of fresh, safe, and high-quality products. SFSCs also help producers to establish direct relationships with consumers based on trust and building loyalty to increase the added value of their activities and their profits [3].

SFSCs play a special role in organic production. This type of activity requires producers to make an increased effort in terms of production, to maintain appropriate standards, and to pay more attention to relationships within the supply chain, its structure, and the strategy adopted. The foci include the characteristics of the product as well as composition and ingredient requirements.

The related SFSC literature [4–14] allowed us to identify a research gap. The basic rationale for addressing the research subject includes an insufficient theoretical foundation for SFSCs, the lack of theoretical frameworks and backgrounds with a particular emphasis on ecological products, and the lack of simulation studies related to the optimization of activities and opportunities to achieve benefits in the implementation of the SFSC strategy, in which the starting point and leader is a producer of food products. Similar themes were found in the literature, but they do not discuss the scope and methods used as widely as we do here [9,14].

Our research was based on the literature on SFSC and optimization studies, using a computer simulation conducted on the basis of real empirical research conducted among Polish producers of three food products in the West Pomeranian Voivodeship in Poland. Empirical research was based on the SFSC market service and classification methodology available in the related literature.

The remainder of this paper is structured as follows: Section 2 identifies research gaps and questions and presents the study objectives. This section also provides a systematic literature review. Section 3 describes the problems, including a descriptive analysis and characterization of organic production around the world and in Poland. Section 4 describes the simulation modeling with the multi-objective method based on empirical research. Section 5 provides a discussion and outlines the limitations of the research; the conclusions and future research directions are described in Section 6.

2. Materials and Methods

2.1. Research Gaps and Questions

We identified research gaps related to both theoretical and empirical aspects, with the use of computer simulation to support the introduced theses. The SFSC strategy is rarely described in the literature as a new trend or an area of scientific interest. The deficiencies in terms of theoretical foundations and support for future directions of research are visible. The existing studies refer to practical examples, without focusing on or defining a strong theoretical basis for the study, including the identification of SFSC solutions as a new supply chain strategy that can be part of global trends, related to sustainable development and the functioning of sustainable supply chains.

The novelties of this research include the application of simulation-based optimization in the search for the proportion of organic products supplied by a local farmer. The use of computer simulation with an optimization module allows the local farmer to find the best balance of supply for each type of market. From a theoretical viewpoint, we systematize the scientific knowledge and identify motivators,

barriers, and drivers, and relate SFSCs to organic products in sustainable supply chains (SSCs) in order to search for profit and benefit opportunities for individual links serving different types of local markets and short food supply chains.

We raised the following research questions: How does a change in a market within the SFSC affect the achievement and change in producers' profits? Which of the presented solutions are optimal for the selected organic products? How can local producers be encouraged to take interest in the new supply chain strategy, i.e., the SFSC, for organic products?

The research methods included the following: (1) a critical analysis of the literature showed that extensive theoretical foundations related to the discussed issues are lacking. (2) Computer simulation was used to identify possible scenarios of optimization of changes in the profits of producers servicing different markets within the SFSC, with the example of three selected products. (3) The data for empirical research were collected on the basis of interviews with farmers producing organic goods in the West Pomeranian Voivodeship in Poland. The selected products included goods produced in the studied area, which met the organic products requirements, with producers that served various markets, including those that were identified as a part or element of an SFSC.

2.2. Literature Review

We began by defining both local supply chains and markets, moving on to the SFSC concept and strategy. The vast majority of agricultural products are available worldwide through complex and often highly industrialized supply networks. These mostly include conventional products. Organic production represents a negligible percentage of the world's agricultural production. Recent reports on organic production [15] show that 69.8 million ha in 2017 were under organic agricultural management worldwide, representing 1.4% of the world's farmland. The highest organic shares of the total agricultural land are found in Oceania (8.5%), Europe (2.9%), and Latin America (1.1%). In the European Union (EU), the organic share of the total agricultural land is 7.2%. Organic production resources have been implemented in 181 countries. The market value of this type of product is estimated to be 92 billion Euros, indicating that consumer demand is growing. When analyzing the supply and demand sides in relation to the sale of organic products, many barriers and drivers contribute to the change in demand [16]. The production and trade of such products must reflect many requirements, both for the production and labelling of packaging [17]. Alternative forms of food supply, including local food markets, are typical for small farmers, heterogeneous products, and short supply chains in which farmers also perform marketing functions, including storage, packaging, transportation, distribution, and advertising [18].

Organic food can be produced using different systems and supply chain strategies. Alternative methods of delivering food are becoming increasingly popular [19,20]. The food supply system is transforming [21] by combining production and consumption within a short geographical distance [22]; organic farming is increasingly supported by the community, including direct farm sales. The most frequent and easiest method to market such products is through local food systems and short food supply chains. In the literature, a local food system is defined as a system in which food is produced, processed, and sold in a defined and close geographical area [23]. These solutions are also referred to as alternative food chains [24], as opposed to conventional solutions characterized by the mass production of food. Their structure is based on various criteria, including the number of intermediaries, geographical distance, organizational structure, and social relationships [25]. These are essentially shortened relationships between producers, sellers, and consumers [24]. The shortening of a supply chain plays a significant role in creating a new chain structure. Goland and Bauer [26] stated that, traditionally, the average morsel of food travels 2092 km from the time it leaves the field (or pasture) and arrives on the table. When analyzing SFSC-related issues, many areas have already been explored, especially those related to the social and economic relationships of entities in the implementation of the SFSC principles [27,28]. Local food systems cover a short geographical distance from producers to consumers, usually containing little or no processed food, and the whole food chain of origin

can be accurately and quickly identified. Today's food systems are extremely complex and it is therefore difficult to practically determine a local system or supply chain, especially for processed products consisting of multiple products or requiring the production of inputs from remote locations. The intermediate stages (e.g., packaging or processing) may occur in places far from production sites, but returning to a place close to production and selling there may also indicate a local food system. A characteristic of SFSCs is that they allow the consumer to assess the value of the food used within the framework of their own knowledge and experience. This food is identified by the local community or even associated with a specific local farm. Short food supply chains [29] are intended to redefine the relationship between the producer and the consumer, clearly and precisely indicating the origin of the product. Alternative supply chains are referred to as more natural or more local. They reflect the attempts of both producers and consumers to adapt to new types of supply and demand. The characteristic feature is an emphasis on the types of relationships that build value and improve the quality of offered products and services. The shortening of the distance between consumers and producers and the building of other types of consumer-producer relationships, and their redefinition, contribute to creating transparent chains, emphasizing information about the origin of the food, and focusing on the quality of the food, which, in turn, create added value. Shortening the distances and redesigning the relationship between the links in the chain (producers-local community) contribute to the reorientation of agriculture toward more sustainable and greener production methods [24]. These activities result in increased chain activity between different actors in the agri-food chains: farmers, processors, wholesalers, retailers, and consumers. Changing shopping preferences and the development of different distribution channels, including e-commerce, can contribute to the success and development of alternative supply chains in terms of food supply [30]. In the literature, there are three types of markets served by the SFSC. The characteristics are presented in Table 1.

Market Type	Characteristics	Examples
face to face	Consumer purchases a product directly from the producer/processor on a face-to-face basis. Authenticity and trust are mediated through personal interaction. The Internet now provides opportunities for a variety of face-to face contact through online trading and web pages.	 Farm shops Farmers markets Roadside sales Pick your own Box schemes Home deliveries Mail order E-commerce
Spatial proximity	Products are produced and retailed in the specific region (or place) of production, and consumers are made aware of the local nature of the product at the point of retail. Networks are mainly based on spatial proximity, so that products are sold in the region (or place of production) and consumers (e.g., tourists) are aware of the local nature of the product at the retail outlet. The expression of action in space and time, through the organization of specific events, fairs, or thematic routes, can contribute to the regional identity of the products. Consumer co-ops and community-supported agriculture can also include specialized retailers (dietary or organic products) or restaurants.	 Farm shop groups Regional hallmarks Consumer cooperatives Community supported agriculture Thematic routes (articulation in space) Special events, fairs (articulation in time) Local shops, restaurants, tourist enterprises Dedicated retailers (for example, whole food, specialty, or dietetic shops) Catering for institutions (canteens, schools) Sales to emigrants
Spatially extended	Value and meaning-laden information about the place of production and those producing the food is translated to consumers who are outside the region of production and who may have no personal experience with that region. In most cases, products are exported from the region to national markets, but some extended SFSCs may span large distances covering the globe. In most cases, they are exported or domestic products but covering a larger territorial area, e.g., champagne or Parmigiano Reggiano cheese or fair trade products. This is not a matter of geographical proximity, but of traceability. In this case, the products and their place of origin are not anonymous.	 Certification labels Production codes Reputation effects

Table 1. Characteristic and	l examples of short food	l supply chains (SFSCs).
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Source: own elaboration based on [24,29,31,32].

SFSC activities are beneficial to all participants. The benefits can be considered in terms of economic, social, and environmental aspects [23]. The characteristics of the different types of benefits are presented in Table 2.

Impact	Benefits			
Economic	 Increased revenue for producers Fairer prices Price stability Avoidance of intermediaries Support of local farmers Reduction of labor costs Reduction of transaction costs Reduction of marketing margin Increased profitability 			
Social	 Relationships based on respect and trust Interaction/connection between manufacturer and costumer Greater importance of human relationships A broader concept of social capital A sense of community Increased knowledge Behavioral change 			
Environmental	 Reducing the number of food miles Reduction of carbon footprint Positive impact on (agricultural) biodiversity, Limiting use of agrochemical measures on organic farms Increased energy efficiency (trade and transport concentration in terms of energy consumption per unit of product placed on the market may be less) Reduction of greenhouse gases Protection of water, soil, and habitats Reduction of soil and water pollution Reduced soil degradation 			

Table 2. Benefits of SFSCs.

Source: own elaboration based on [23].

This does not mean, however, that SFSCs only provide benefits. In many cases, actions do not produce better economic, social or environmental results. Profits and disadvantages may vary depending on the type of product, type of agricultural activity, transport used, season, scale of production, or research methodology. Problems in creating SFSCs include the expectations of consumers who demand a uniform range of products throughout the year [33].

The general benefits of the SFSC activity may include: improved negotiating positions for farmers, increased communication between producer and consumer, reduced transportation costs, and increased transparency. The advantages of the SFSC in the context of the farmers were enumerated by Bimbo et al. [34] using a different approach to the SFSC and its different contexts, including the farmer as a producer and an SFSC beneficiary. Introducing CSR principles into this strategy is easier [35].

Although both positive effects and barriers have been identified, in-depth research into the motivation of farmers to participate and engage in SFSCs is lacking [27,36]. The characteristic features of such markets and chains include their dynamism, trust, social involvement, and identifiability. They have a better image, encourage initiatives, and often use other competencies (including soft skills) to conduct business rather than customer relationships; they offer products of better quality, and they more quickly adopt the principles of sustainable development. Their conduct and functioning require greater social skills and involvement of human resources. Creating added value within such a chain is easier, although networking is not excluded in making local products available to a wide range of

audiences. SFSCs include community-supported agriculture systems, local farmers' markets, basket delivery systems, or pick-it-yourself orchards [37]. The literature shows that the SFSC is becoming a competitive tool for modern diversified farms, by allowing farms to obtain added value and consumers to save time and costs (close location). This consequently allows both parties to share and create added value simultaneously [38]. Proponents of a sustainable food system combine the quality, distance, and biodiversity that can be supplied to the local community by local producers [26]. Therefore, considering this issue seems important with particular reference to organic products. This is also because, by definition, the supply chains of organic products should be established in accordance with the principles of sustainable development. SFSCs can provide opportunities to market agricultural products by reducing food production costs and creating positive relationships between producers and consumers.

2.3. Framework

The transition to empirical research requires further consideration of the theoretical basis of the construction and organization of SFSCs. Considering previous studies [39–41] that focused on sustainable supply chains, we focused on the sustainable food chain as a methodology to develop our theoretical basis and framework. Supply chains, especially food supply chains, have a variety of stakeholders that include more than just individual enterprises [42]. Considering organic products and a specific short supply chain, the role of individual stakeholders and the types of market being served significantly impact the fulfilment of triple bottom line (3BL) requirements and the individual needs of each of the parties, including, e.g., profit for producers, who must be motivated to undertake this type of activity. SFSCs play a large role in local markets and the majority of served customers, especially local consumers (Figure 1).



Figure 1. Theoretical framework for the short food supply chain (SFSC) for organic products.

The proposed model and framework indicate the structure and possible links between actors in the organic supply chain, considering their characteristics (short food supply chains). Only types of possible sales are identified, without links to the characteristics of the supply chain. There is no graphical representation of these links in the literature.

3. Problem Description

The issues addressed in this study are related to the definition of a theoretical basis and research methodology for a new short food supply chain strategy based on serving local markets, with a particular focus on selected organic products.

The choice of organic products in this study faced certain restrictions. The organic production of food products incurs additional costs and expenses related to obtaining certificates, as well as meeting the related requirements, including the adaptation of supply chains. Global economic trends in the operation and management of supply chains are linked to sustainability. Meeting the requirements for such chains is difficult in mass or conventional production. This means that with organic production and local market operations, the requirements of sustainable supply chains can be met more effectively. The globalization of markets and the trend to mass production are not conducive to the implementation of sustainable development principles in supply chains or to fair relationships between its participants (including ensuring a good profit for producers).

Organic Production of Food: Descriptive Analysis

Foods to be labelled organic shall contain at least 95% organic ingredients in their composition in both the U.S. and the EU. These products must be produced and supervised in accordance with accepted guidelines. Products are usually accompanied by a certificate of their organic nature. Organic agricultural production, to a large extent, uses renewable resources, and the objectives of agricultural activity are to protect the environment, including water, soil, and air resources. Organic food is produced without the use of most conventional pesticides, fertilizers, sewage sludge, or bioengineering or ionizing radiation [43]. Organic farming is designed to have a lower environmental impact than large-scale and high-efficiency conventional systems due to the substitution of the pesticides used [44]. Sustainable food production and its effects from the point of view of organizations focus, among others, on energy efficiency to help increase resource efficiency and reduce emissions of harmful substances into the environment [45].

Fertilizers may be used in this type of production, but they must be natural (e.g., green manure, compost, and minerals available in nature). In the production of animals, organic fodder with conventional admixture is used, or feed from the farm. This type of food, due to restrictive requirements set out in legal acts and controls by authorized certification bodies, must not contain artificial additives, dyes, or preservatives. The control includes that of the products and their components, and of the entire infrastructure and objects of the agricultural holding, from pastures, open-air runs, stables, and equipment, to machinery, warehouses, and production documentation, such as accounting records, proof of purchase of means of production and raw materials, accounting labels (or records, and advertising materials), balance sheets (including the origin of purchased raw materials), and sale of organic products. Organic producers implement a wide range of instruments and strategies to develop and maintain biodiversity and restore soil fertility. This type of production in relation to sales can appropriately and sustainably support SFSCs. Its main objective is to create a sustainable management system in agriculture, minimizing the use of non-renewable resources.

This type of agriculture is developing systematically. A report entitled "Organic Agriculture Worldwide" [15] stated that, in 2017, organic products were sold all over the world with a total value of USD \$97 billion. The area of organic production is growing, covering almost 70 million hectares and 2.9 million producers. Most organic agriculture is located in Australia and Oceania (35.9 million hectares), Europe (14.6 million hectares), South America (8 million hectares), Asia (6.1 million hectares), North America (3.2 million hectares), and Africa (2.1 million hectares). Organic production occurs in

181 countries around the world, 93 of which are regulated by law. However, this represents only a 1.4% share of total agricultural land. Europe is the second largest organic area with 14.6 million hectares, of which 12.8 million hectares are located in the European Union (7.2% of agricultural land). Spain (2.1 million ha), Italy (1.9 million ha), and France (1.7 million ha) have the largest shares of organic land. In terms of the percentage of organic farming, in total, Liechtenstein (37.9%), Austria (24%), and Estonia (20.9%) rank at the top. Organic product sales in 2017 amounted to 37.3 billion Euros (EU = 34.3 billion Euros); the largest market is Germany, with sales of over 10 billion Euros, followed by France (7.9 billion Euros) and Italy (3.1 billion Euros). In May 2018, the EU issued new legislation on both organic production and labelling. Ten countries (Table 3) with the largest organic agricultural areas represent 79% of the world's organic agricultural land and 14 countries have 10% or more of their agricultural land under organic management.

10 Countries with the Largest Organic Agricultural		10 Countries with the Largest Number of Organic		
Areas (Millions of Ha)		Producers 2017 (Thousands)		
Australia	35.65	India	835	
Argentina	3.39	Uganda	210	
China	3.02	Mexico	210	
Spain	2.08	Ethiopia	203	
USA	2.03	Philippines	166	
Italy	1.91	Tanzania	148	
Uruguay	1.88	Peru	87	
India	1.78	Turkey	75	
France	1,.74	Italy	66	
Germany	1.37	Paraguay	58	
Countries with an organic share of at least 10% of the agricultural land 2017		Distribution of retail sales value by country 2017 (%)		
Liechtenstein	37.9	USA	43	
Samoa	37.6	Germany	11	
Austria	24	France	9	
Estonia	20.5	China	8	
Sweden	18.8	Italy	3	
Sao Tome and Principle	18	Canada	3	
Italy	15.4	Switzerland	3	
Latvia	14.8	Sweden	3	
Switzerland	14.4	Other	17	
Uruguay	13	Distribution of retail sales value by region 2017		
Czech Republic	12.2	North America	47	
Finland	11.4	Europe	41	
French Guiana	10	Asia	10	
Slovakia	10	Oceania	1	
		Latin America	0.9	
Ten countries with the largest markets for organic food 2017 (million Euros)		Ten countries with the highest per capita consumption 2017 (Euros)		
USA	40,011	Switzerland	288	
Germany	10,040	Denmark	278	
France	7921	Sweden	237	
China	7644	Luxembourg	203	
Italy	3137	Austria	196	
Canada	3002	Liechtenstein	171	
Switzerland	2435	USA	122	
Sweden	2366	Germany	122	
United Kingdom	2307	France	118	
Spain	1903	Canada	83	

Table 3. General data for world organic farming in 2017.

Source: own elaboration based on [15].

In Poland, 3.4% of the agricultural area is organic (49,797,979 ha). The agriculture is produced by 20,257 farms, 795 processors, 161 importers, and 216 exporters. Annual sales amount to 235 million Euro, which is 6 Euros per person (data for 2017; Table 4).

Poland	Organic Area (ha)	Organic Share (%)	Area Fully Converted (ha)	Area under Conversion (ha)
General	494,979	3.4%	-	-
Cereals	116,083	1.6%	86,981	29,102
Dry pulses	43,272	14.5%	10,604	5754
Temperate fruit	289		205	84
Oilseeds	4084	0.5%	2496	1588
Vegetables	10,236	5.2%		
		Land use in organic agric	culture by Poland 2017	
	Arable land crops (ha)	Permanent crops (ha)	Permanent grassland (ha)	Total (ha)
	351,192	27,473	11,6314	494,979
		C	ion bacad on [15]	

Table 4. Organic production in Poland in 2017.

Source: own elaboration based on [15].

In Poland, 108,655 hectares are undergoing transformation, changing from conventional to organic farming. Of the total 494,979 hectares, 383,246 ha are fully organic and 111,733 ha are being converted.

4. Simulation-Based Multi-Objective Optimization of SFSC

Many studies have recently investigated the supply chain management problem using simulation. Using analytical methods is generally impractical because mathematical models for realistic cases are usually too complex to be solved. A modeling and simulation approach is the only practical option for exploring the performance of large-scale situations in reality, particularly when facing multi-criteria problems [46]. Analyzing large and complex stochastic systems is a difficult task due to the complexities that arise when randomness is embedded within a system. Unexplained randomness is a common and unavoidable characteristic of real-world systems, e.g., the uncertainty of demand. Using simulation modeling as an evaluative tool for stochastic systems has facilitated the determination of performance measure estimates under any given system configuration [47,48].

We used the discrete event computer simulation because the analyzed process can be naturally described as a sequence of operations. The purpose of the simulation modeling was to analyze how changing the proportion of delivery to different types of markets influences the profit of regional farmers in SFSCs. An optimization algorithm was used to find the best solution and best proportion of delivery for different kinds of markets. The problem is complex and the space for potential solutions is large. The solution may be found via the discrete event computer simulation. It enables the simulation and even optimization of delivery strategies under conditions of uncertainty. Additionally, this paper demonstrates the application of this tool using a case study and analyzing the optimization decisions that lead to a more sustainable supply chain, providing valuable managerial insights for supply chain managers.

The Arena simulation package from Rockwell Software (version 14.0, Austin, TX, USA) was used for modeling the manufacturing system. The experiment design is described in the following section. A fragment of a tested model of supply chain in the Arena environment is shown in Figure 2. This environment can simulate any complex system, considering possible uncertainties. The problem of optimizing the delivery proportion in different markets in the supply chain is solved using software included with Arena's software dedicated to optimization, OptQuest. It is a generic heuristic optimizer that effectively separates the method from the model. In this case, the multi-optimization problem is defined outside the system (represented by the simulation model). This design allows the creation of a supply chain model that contains as many parameters as are necessary for accurate modeling.



Figure 2. A fragment of the analyzed model of short food supply chain in Arena software (Rockwell Software, version 14.0, Austin, TX, USA).

4.1. Research Methodology

The general outline of our methodology is shown in Figure 3, and is described in detail below:

- Statement of the problem: the proportion of delivery to different types of consumers can effectively increase the profits of local farmers;
- Objectives: supporting the decisions of local farmers in the delivery strategy using simulation modeling and an optimization module;
- Tools: computer simulation software, including the Arena environment with the optimization module;
- Variables:
 - Input variables:
 - Number of sold products: *n*
 - Product type: $p_i, i \in \{1, 2, 3, ..., n\}$
 - Prices for products: $c_i \ i \in \{1, 2, 3, \dots, n\}$
 - Delivery amount: d_i (kilograms per delivery for each p_i), $i \in \{1, 2, 3, ..., n\}$
 - Number of destined markets: *m*
 - Market type: $t_i, j \in \{1, 2, 3, ..., m\}$
 - Delivery quantities: q_i (for each market type t_i), $j \in \{1, 2, 3, ..., m\}$
 - Distance from the market: $h_j, j \in \{1, 2, 3, \dots, m\}$
 - Transport cost for 1 km: *k*
 - Cost of unsold products: $cu_i, i \in \{1, 2, 3, ..., n\}$
 - Demand considering uncertainty (for each product type in each market in kilograms): u_{ij} (triangular distribution), $i \in \{1, 2, 3, ..., n\} j \in \{1, 2, 3, ..., m\}$
 - Control parameters:
 - Delivery proportion: Pr_j (percent of delivery for each market type t_j) $\sum_{j=1}^{m} Pr_j = 100\%$, $j \in \{1, 2, 3, \dots, m\}$
 - Output variables:
 - Number of sold products in each category: $s_i, i \in \{1, 2, 3, ..., n\}$
 - Number of unsold products in each category: us_i , $i \in \{1, 2, 3, ..., n\}$
 - Profit: $f = \sum_{i=1}^{n} s_i \times c_i \sum_{j=1}^{m} k \times h_j \sum_{i=1}^{n} us_i \times cu_i, i \in \{1, 2, 3, \dots, n\}, j \in \{1, 2, 3, \dots, m\}$

- Experiments: performed using discrete event simulation software to analyze the current values of variables with the established delivery proportion. Additionally, it calculates the values of output variables transferred to the optimization module;
- Optimization: the optimization module changes the control parameters, which include the delivery proportion to the different markets. For these new parameters, the simulation model calculates a new value for the criterion functions. In this way, the scope for potential optimal solutions is analyzed (Figure 3).



Figure 3. Practical methodology used to support decisions in the short food supply chain using simulation modeling and an optimization module.

To find an optimal delivery strategy, the simulation model calculates criterion functions, which can be the profit of the local farmer, the number of unsold products (economic factors), the shortest road route or usage of green transport (environmental factors), or number of persons employed in the transport of goods (social factor). In our case, we only considered economic factors.

One local farmer from the West Pomeranian Voivodeship in Poland (SFSC presented in Figure 4) served as a test bench for the analysis.



Figure 4. Analyzed short food supply chain: a local farmer from West Pomeranian Voivodeship.

In the analyzed short food supply chain, a local farmer sells their products in three abovementioned markets: face-to-face, spatially proximal, and spatially extended markets. The farmer cultivates three main types of organic products and sells them in season (3 months) on the markets: tomatoes (sold for 3 months), apples (sold for 3 months), and potatoes (sold for 2 months).

4.2. Simulation Parameters and Assumptions

The fixed model parameters are shown in Table 5, including the number of products that the farmer is going to sell in different markets, the frequency of delivery, and the matrix of prices. All the data in the model were compiled from an interview with the local farmer.

Product	Delivery Amount (Kilograms Per Delivery)	
Tomatoes	300	
Apples	1000	
Potatoes	700	
Market type	Delivery frequency	
Face-to-face markets	Once a week	
Spatially proximal markets	Twice a week	
Spatially extended markets	Once a week	

Table 5. Simulation parameters: delivery amounts and frequency of delivery.

The prices for products for spatially proximal markets are (per kg): tomatoes, 13 PLN; apples, 5 PLN; and potatoes 4 PLN. Prices in face-to-face markets and spatially extended markets are 20% higher and 25% lower than the spatially proximal markets, respectively. The presented prices influence the farmer's profit, but the profit also depends on losses. For each unsold kilogram of a given type of product, 30% of its value is deducted from the profit. In addition, the farmer bears the costs associated with transport to a particular type of market. The costs are calculated proportionally according to the distances shown in Figure 1, the frequency of delivery (Table 4), and the cost of transport of PLN 7.68/10 km.

Real supply chains have many stochastic components. In this case, triangular probability distributions were used to represent uncertainty in demand. Table 6 presents the parameters for the demand of different types of products on different markets. Each market is characterized by a different level of demand randomness. The largest randomness, according to what was previously highlighted in Table 1, occurs in the face-to-face markets, while it is lower in the spatially proximal markets, and the spatially extended markets have a negligible randomness of demand due to constant large orders.

	Market Type			
Product	Face-to-Face Markets	Spatially Proximal Markets	Spatially Extended Markets	
Tomatoes	(50,150,300)	(130,180,300)	(250,280,300)	
Apples	(100,350,700)	(300,500,700)	(600,650,700)	
Potatoes	(200,500,1000)	(500,700,1000)	(900,950,1000)	

Table 6. Simulation parameters and uncertainty in demand (triangular distribution: lower limit, mode, upper limit) in kg.

The purpose of modeling was to conduct experiments regarding scenario alternatives. We examined how changes in the proportion of delivery to different types of markets influence profit, considering the demand uncertainty (Table 5) and finding an optimal delivery proportion for each type of market.

The simulation run parameters were selected to assure reliable results; the warm-up time was set to 10 days, the replication length to 3 months, and number of replicates to 10.

Verifying and validating the data collected from the interviews was difficult. It is impossible to directly compare all results from a simulation model of analyzed system with a real system. However, one of the validation methods involves testing the collected data using techniques such as internal consistency checks [49]. For this reason, several replications of the analyzed model were conducted to determine the amount of internal variability in the model. Even in extreme cases (high variability

of demand), the simulation model behaved correctly. The accuracy of the results was additionally checked by consulting the farmer. Other methods also were used to validate the model, including checking the correctness of the model (check errors) and animations of the processes.

4.3. Analysis of the Results

The optimizer, together with the simulation software, searches for the optimal solution in the simulation model, i.e., for a set of decision variables (proportion of delivery for each type of market) that maximize the profit and minimize the number of unsold products in each category. The algorithm was set to 500 iterations.

Figure 5 depicts the progress of the algorithm search. The graph shows the value of the criterion function: the profit (in PLNs) for the current solution (dashed line) and the best ones so far (solid line).



Figure 5. Progress of the optimization algorithm.

The algorithm started with the scenario with an even distribution of products among all markets. The results showed that it is worth looking for the best way to sell products in an SFSC because different proportions of deliveries produce different results in terms of profit. The best solution was found in iteration 104: 78% of production should be sold in face-to-face markets, 17% in spatially proximal markets, and only 5% in spatially extended markets. The detailed results of the 10 best solutions are shown in Table 7. The results of the computer simulation showed that despite lower risk related to the uncertainty of demand, directing the largest amount of agricultural products to spatially extended markets produces the weakest profits. This occurs because the prices in these markets are lower than in face-to-face markets, where directing the largest amount of products produced the best results (despite the greater risk due to the greater uncertainty of demand). The near-optimal results outline cases where a little less is delivered to the face-to-face markets and more to the spatially proximal markets (iterations 110 and 93). The best obtained solution (97,456.53 PLN) yields a 18% higher profit than the initial iteration of an even distribution of products among all markets (82,850.61 PLN) and 26% higher than the worst found solution (profit 77,397.88 PLN), where deliveries to each market were: face-to-face markets 17%, spatially proximal markets 78%, and spatially extended markets 5%.

Iteration No.	Profit (PLN)	Face-to-Face Markets	Spatially Proximal Markets	Spatially Extended Markets
104	97,456.53	78%	17%	5%
11	95,403.26	82%	12%	4%
18	94,381.18	75%	20%	5%
56	93,808.17	76%	19%	5%
19	93,184.65	80%	18%	2%
39	92,541.05	79%	16%	5%
110	92,484.89	71%	24%	5%
93	92,352.09	73%	22%	5%
79	92,193.10	77%	17%	6%
57	92,102.90	78%	16%	6%

Table 7. Ten best results (profit and delivery proportion) found by the simulation with optimization.

5. Discussion and Limitations

In this study, we limited ourselves to organic products only in the West Pomeranian Voivodeship in Poland. As a result, the presented data and results should be considered as part of a pilot study, which should be extended—firstly, territorially, and, secondly, through comparisons with conventional products and the traditional supply chain. Another constraint and aspect for future research is a focus on the subsequent elements of the supply chain that make a chain sustainable. Another restriction is the choice of products. The range of products should be extended to increase methodological and scientific reliability so that selected products on the European market can be compared.

A significant limitation was that the surveyed manufacturers do not always identify the SFSC strategy, perhaps due to a lack of knowledge about a given structure or about this specific structure. They often do not identify the markets they serve, as stated in the literature. In the next stages of the project and research, both the market and the range of products will be significantly expanded to comprehensively examine all identified types of SFSC strategies, and perhaps contribute to finding new forms of handling and modifying the segments identified so far. Another limitation is the scope of elements considered in the simulation. However, our aim was to indicate activities within the structures that can increase the economic benefits as much as possible, and influence the competences and soft relationships of organizations participating in the chains. On the basis of an in-depth analysis of the literature review, we found deficiencies in the creation of theoretical foundations. Most of these studies refer to specific cases of specific activities in a given region or product. Drawing meaningful and useful conclusions for all chains on this basis is difficult. However, the studies (including those with specific examples) are theoretical attempts to build a general basis for SFSCs and determine the impact of this structuring on the economic behavior of chain participants.

The discussion should also include the results of simulations, limited here to only a few months and variants in the supported market. The context of repetitive periods and the selection of other variables affecting the profits of producers should also be considered. The simulation did not include any reference to the principles, determinants, or theoretical attitudes of creating sustainable supply chains and dedicated indicators.

However, the results of the simulation with multiple objectives indicated that an appropriate proportion of organic products supplied to different markets can result in a significant increase in profits (up to 18%). Therefore, the presented methodology, or at least suggestions from the article, can be used to increase the profits of local organic producers. Despite the higher risk, the results are better.

Here, the simulations were only applied to economic aspects, although the theoretical considerations apply to all areas of sustainable development. This approach was dictated by the assumption that economic aspects play the most important role in starting up a business, even in organic production, whereas other, sustainable development-related aspects are considered in subsequent stages of activity, including changing development strategies and implementing innovations. Drawing general conclusions and management implications from a single case study is impossible, but the findings showed that companies and their supply chains operate in many different environments and that different factors influence decision making, including the implementation of specific supply chain

strategies. Addressing this topic requires a broad field of research on the company and its strategies, including economic, social, and environmental aims.

6. Conclusions

The concept and main assumptions of short food supply chains, which are part of alternative food systems, were the focus of this study. We examined the organic products produced in one of the voivodships in Poland. Next, we used multi-objective computer simulation modeling to indicate scenarios of possible increases in profit for producers who produce organic goods operating within the SFSC. Selection and appropriate modeling, including the adoption of a strategy corresponding to the selected scenarios, indicate how profit can be increased. This is only one of the positive elements of the SFSC business, but it is crucial for the producers. In these types of strategies, other elements are also important for the various activities undertaken, including fair trade or closer relationships, including those between producers and consumers. For consumers, the origin of a product is important—such chains enable them to better identify producers and other links. Empirical studies show only one aspect (economic profit); future directions of research should also cover other links in the chain and consider issues from the point of view of sustainable supply chains. Discussions and deeper research on the theoretical basis should, on the basis of scientific research, determine practical implications and encourage this type of activity. The SFSC and alternative local supply chains can help not only to improve relationships between actors in the chain, but also to change business strategies by offering and operating within sustainable supply chains. This idea is much easier to implement in short chains. In the future, these principles can be transferred to long and conventional supply chains. Local markets and chains are becoming increasingly popular, and properly constructed chains and activities undertaken within their processes can bring economic, social, and environmental benefits to all stakeholders.

Author Contributions: Conceptualization, B.T. and T.W.; methodology, B.T.; software, T.W.; validation, T.W. and B.T.; formal analysis, B.T.; investigation, T.W. and B.T.; resources, T.W. and B.T.; data curation, T.W.; writing—original draft preparation, B.T.; writing—review and editing, T.W. and B.T.; visualization, T.W.; supervision, B.T. All authors have read and agreed to the published version of the manuscript.

Funding: Text editing was funded by the framework of the program of the Polish Minister of Science and Higher Education under the name "Regional Excellence Initiative" 2019–2022; project number 001/RID/2018/19; the amount of financing PLN 10,684,000.00.

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

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