Supply Chain Management in the Food Industry: A Comprehensive Hierarchical Decision-Making Structure

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***Abstract*- in the new economic management conditions, the existing models of supply chains in the food industry cannot meet current realities. This makes it relevant to develop models and algorithms for supply chain management, design and use various alternative configurations in order to achieve efficiency and competitive advantages. The proposed algorithm and methodological support for modeling supply chains in the food industry are based on the commodity flow classification according to the importance of resources and take into account modern methods and concepts of logistics. Our research deals with the current problems in supply chain management, production planning, supply and transportation, warehouse management and vehicle selection to maximize the logistics efficiency in the supply chain. The purpose of our research is to study the existing problems in the food supply chain management and to propose a decision-making algorithm for efficient and competitive business development. The study and generalization of theoretical studies in the field of food supply chain management allowed us to identify and formulate the specifics of this industry with the help of the following research methods: selection of logistics intermediaries, forecasting (indicators, flows, etc.), arrangement of nomenclature groups, optimization under risk conditions, statistical methods in data processing. Based on the research results and the methods described in it, a supply chain management algorithm is proposed. It will provide optimization and control in supply chain management. An algorithm for systematizing and efficient management of the supply chain of the "Klinsky" meat-packing plant is also suggested.**

Key words: *supply chain, food industry, sustainability, Cold Chain Management, technological trends in Chain Management.*

1. Introduction

Food supply chain management (FSCM) plays an important role in our daily life since it supplies us with the necessity for our lives. However, inefficient and inappropriate management systems may cause a large number of food losses. Food safety has become the subject of serious debates in recent years. The rapid growth of production and the product range expansion have led to the fact that the consumer needs a guarantee of safety and high quality at all stages, not only in food production, but also in its supply. This problem can be solved by improving supply chains (SC)[1]. Having studied the modern methodology of supply chain management, we can say that modern transportation of perishable food is carried out through Cold Chain Management. This concept appeared quite recently. It is voluminous and includes the definitions used earlier, such as ECR (Efficient Customer Response) and DRP (Distribution Resource Planning). SCM is based on a new company strategy: the formation of a sales network, in which the right goods will be delivered to the right place at the right time and at the lowest cost, taking into account storage and transportation conditions of perishable products. Food factories do not have a transportation management methodology. At the sales stage, this leads to disrupted delivery schedules, uneven export of finished products, incomplete transport performance, and therefore increases the cost of rolling stock operations and the price [2]. At the procurement stage, late delivery leads to an increase in the average level of raw materials, increased safety stocks, a failure in the production timeline and, consequently, an increase in the cost

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of finished products [3]. Supply chain management includes production planning, resource allocation, transportation of raw materials and finished products, management of goods flows, goods stock, warehouse resources, delivery of orders, after-sales support and other related processes [4]. The advantages of the effective supply chain management are better customer service, cost reduction, lower prices, optimal stock distribution in the supply chain, as well as effective management of production processes and inventory [5]. The following functions play an important role in achieving the goals regarding optimality and efficiency. Demand management with the help of different statistical forecasting methods, seasonal factors and the choice of the optimal algorithm. Forecasting can be used throughout the whole supply chain, including distributors and customers. Applications for collaborative planning, forecasting and replenishment (CPFR) and vendor-managed inventory (VMI) provide this opportunity. As a result, we get the agreed for all departments distribution plan, which determines where the product should be specifically produced, when it should be shipped, where and in what quantity it should be stored for the best sales plan implementation [2, 6, 7]. Production planning is the planning of the production facilities use in the light of maximization of production load, minimization of production costs and equipment readjustment. Thus, it gives detailed information on what, when and how to produce taking into account the constraints of production lines, raw materials, size of production lots, large-scale and small-scale commissioning depending on the product [6, 8]. Relationship management between suppliers and customers is a collaborative planning process with suppliers of raw materials, buyers of finished products and logistics operators [5]. Supply and transportation planning is modeling of multi-level supply chains while managing constraints on inventories and other resources. It is also possible to transfer inventory if there is a shortage. Transportation routes are chosen taking into account minimization of costs, on-time delivery and other factors [2, 9-11]. Inventory and warehouse management is stock planning and management of warehouses and distribution centers. The system automatically optimizes the work of the warehouse and monitors, controls and distributes tasks [12]. This solution also makes it possible to calculate safety stock with the help of statistical and heuristic methods. This prevents a decrease (increase) in stocks below (above) critical values [3, 13-15]. As it was mentioned earlier, the advantages of the effective supply chain management are better customer service, cost reduction, lower prices, optimal stock distribution in the supply chain, as well as effective management of production processes and inventory [5]. The results of the study revealed that for effective management and control of supply chains in the food industry, it is necessary to use methods of demand management, production planning, supply and transportation planning, relationship management between suppliers and customers, inventory and warehouse management [2, 6-8, 13, 14, 16, 17]. In order to ensure the most efficient supply chain management and obtain the best transportation outcome in supply chains, it is necessary to analyze and process a large amount of information. Supply chain management tasks and methods for their solution and control are presented in Table 1.

Table 1. Supply chain management tasks and methods for their solution and control

Task	Criteria	Solution and control methods
Transportation choice	Physical and chemical properties of the cargo The method of cargo operations Lot size Urgency of delivery	Multi-criteria optimization with the search for supply chain options and scenarios
Collaborative planning of transportation processes with warehouse and production operations	Product range Output plan Warehouse capacity Speed of cargo operations Transport performance Specialization and diversification of the rolling stock Deployment of the supply chain participants	Mixed linear integral programming Dynamic programming Queuing techniques Stochastic optimization Simulation modeling
Ensuring of		Mixed linear integral programming

technological coherence of transportation and storage processes	Plan of cargo loading and unloading zones Warehouse capacity Schemes for consolidation and deconsolidation of cargo flows Time allowance for transport and technological operations Transport performance and specialization of vehicles	Queuing techniques Simulation modeling
Search for rational delivery routes	Deployment of the supply chain participants Transportation system characteristics (transport performance, speed) Product supply terms and requirements (urgency of the delivery, frequency) Specialization and diversification of the rolling stock	Mixed linear integral programming Theory of graphs Dynamic programming Stochastic optimization Branch and bound method Heuristic methods (one-phase or biphase algorithms, heuristics, adding, etc.) Metaheuristic methods (genetic algorithms, ant colony optimization, simulated annealing, tabu search, etc.)

Source: [5]

The companies that are the global food supply chain participants must be very careful in choosing their suppliers. Any supplier must meet the established standards and requirements [18]. The companies must carry out an audit of their suppliers, both with the help of their own quality departments and by engaging third parties to obtain an independent evaluation of compliance with their own corporate standards or standards developed by business associations, which are also based on key food production elements. Studying and generalization of theoretical studies in the field of supply chain management allowed us to define the following research objectives: studying and systematizing supply chain management methods, studying the advantages and disadvantages of planning approaches, organizing and communicating in SC management, making decisions and developing an algorithm for organizing efficient supply chain management of the “Klinsky” meat-packing plant.

2. Materials and Methods

Our research has been conducted in the form of an empirical study. We have developed and evaluated the scenarios of food supply chain to the seaports of the Far Eastern basin. The scenarios that simplified the design of the logistics chain taking into account the main specifics of work with perishable products have also been developed. For obtaining more accurate results, expert assessment, planning and forecasting methods have been used. These techniques were the basis for building a new and improved supply chain management algorithm. A large number of studies do not solve the problem of making effective decisions in supply chain management, which need to be implemented in enterprises along with the definition of the necessary equipment configuration and risk assessment. The studies were based on mechanical samples using state statistical data and the data obtained from the enterprises under study. The research base was the “Klinsky” meat-packing plant. We improved the food supply chain on the example of the “Klinsky” meat-packing plant and the transportation of frozen meat to China. We concluded that at this enterprise the efficiency of supply chains lies in a limited number of business practices that would strengthen each other and would not stand out from a number of work benchmarks. To develop an ideal supply chain, it is not necessary to do everything at a very high level, because in this case nothing will be done well. In order to ensure its optimal functioning, the supply chain concentrates its resources on reducing the highest costs and applies appropriate resources to those areas that are not so important for its strategy and work. The term “system of actions”, which was formulated by Michael Porter, can be applied to the developed business practices. This system is important necessary for maintaining a competitive advantage [13]. We proposed to introduce an algorithm for systematization and efficient management of the enterprise supply chain (Fig. 1.) in order to ensure an effective logistics system as an element of supply chain management. The algorithm provides for a limit control of the shop requests used to check the specified borderline values for the resources with their total consumption by each shop.

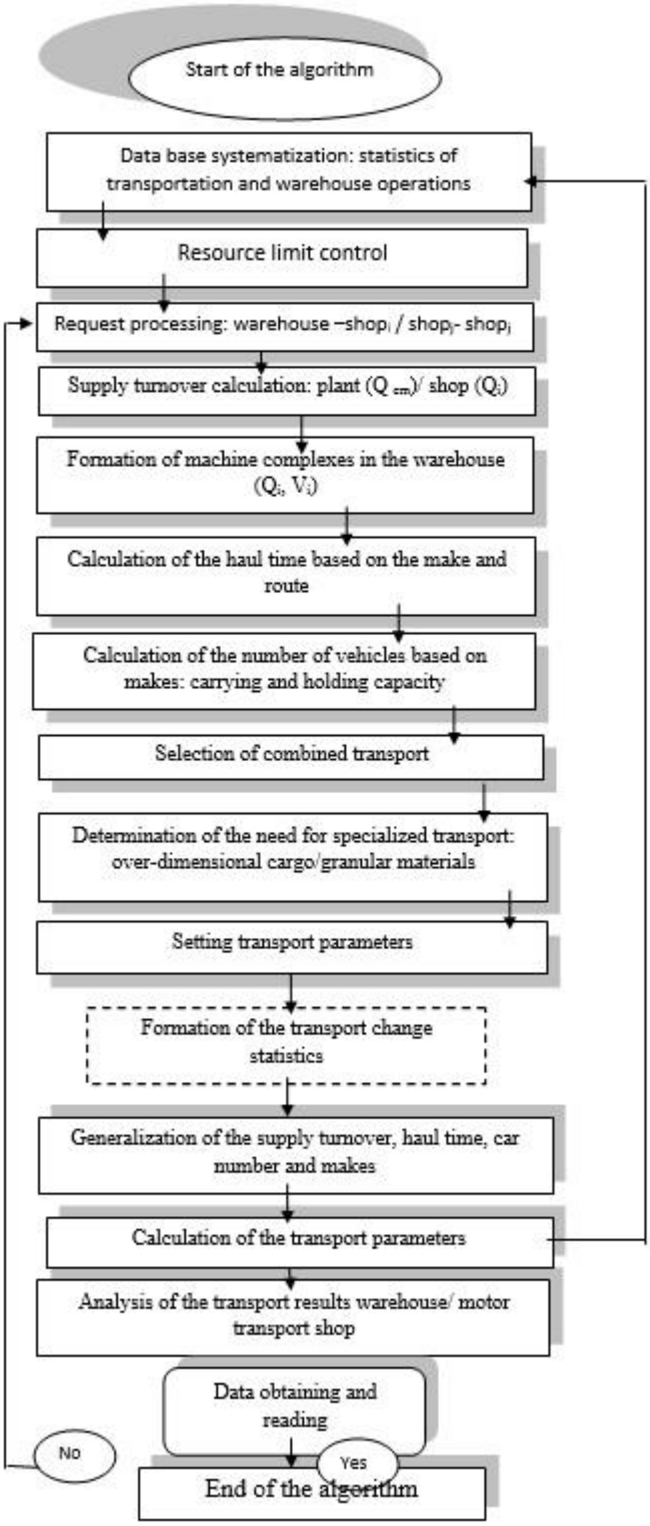

Figure 1. Algorithm for systematization and efficient supply chain management of the "Klinsky" meat-packing plant (developed on the basis of [19])

The algorithm provides for a popular method of limit control of the shop requests used to check the specified parameters and values of the resources and their total consumption by each shop. The algorithm also presents calculations according to the formulas: calculation of the number of hauls, number of vehicles, transport change coefficients, calculation of the simultaneous operation of three forms of transport. Studying the process of round transportation, we found out that it is necessary to support it with a number of services and departments of the meat-packing plant: the planning department, the motor transport shop, the main and auxiliary shops, storage facilities, information and analytical centers. As there are many stages of solving transport distribution problems and all specialists must cooperate, it is practicable to form the following structure (Fig. 2.)

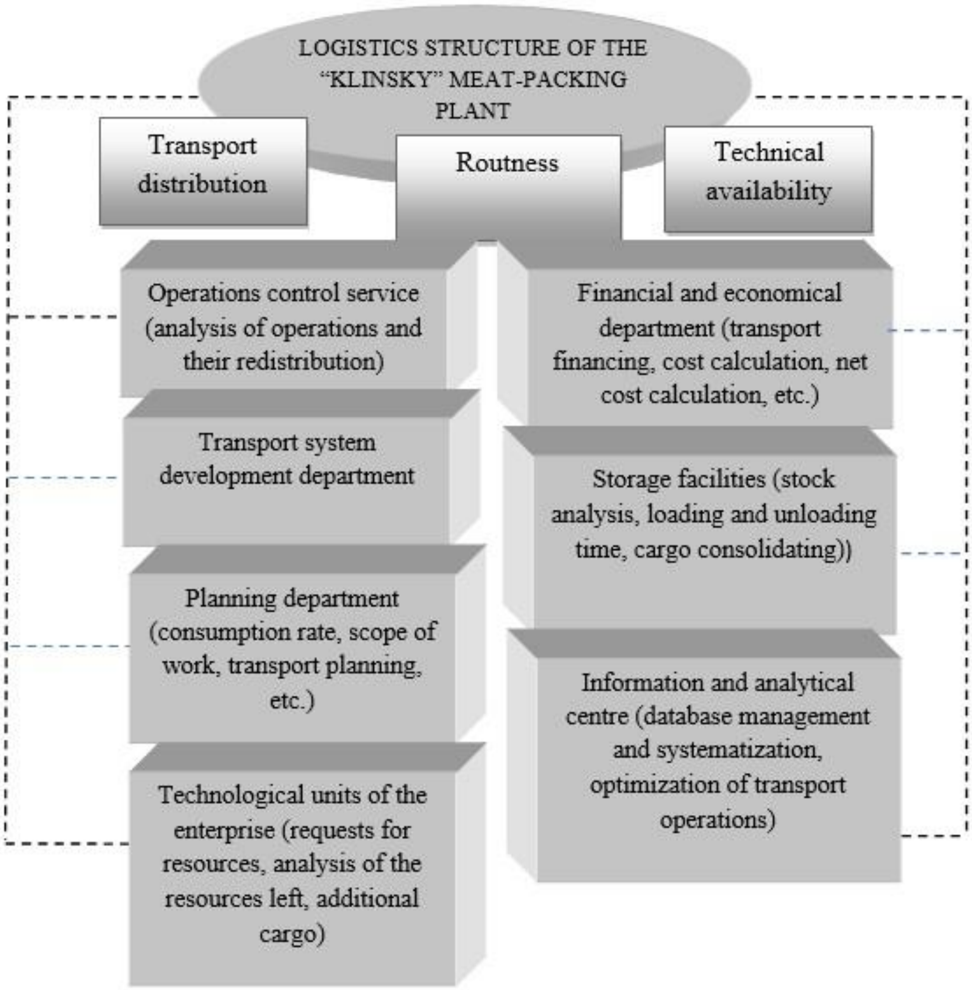

Figure 2. The structure of logistics and transport management of the "Klinsky" meat-packing plant [our development]

Each unit indicated in the diagram solves certain tasks (some of them are marked in the blocks). These tasks are eventually integrated and contribute to improving the management decisions in the field of goods transportation within the food factory.

3. Results

All over the world there is a food spoilage problem at all stages of the logistics chain. For example, according to the Food and Agriculture Organization of the United Nations, in the USA, Canada, Australia and New Zealand in 2017 the following losses (in total) were observed: grain products: 38% lost against 62% consumed, seafood: 50% lost against 50% consumed, fruits and vegetables: 52% lost against 48% consumed, meat: 22% lost against 78% consumed, milk: 20% lost against 80% consumed [20]. In the FMI / GMA 2017 report on perishable products, the total volume of unsold goods increased by 3-5 billion US dollars compared to 2016 [20]. We have singled out three reasons explaining this deterioration. The first reason is the decline in consumer tolerance in relation to the quality of perishable products. Secondly, this is the potential absence or lack of control over the cargo. This may result in the fact that unfit for consumption products will find their way to the market and pose a threat to the health of consumers. Food spoilage problem during the transportation process is a serious problem. Approximately one third of the total food produced worldwide is spoiled or lost. The total loss is 1.3 billion tons per year [19]. Food losses in the United States alone are estimated at about 10% of the total retail food supply in the country [20]. Thirdly, it is difficult to reduce the high operating costs in the supply chain and, at the same time, improve operational efficiency. Having faced with these problems, the food industry of perishable products should review current models and supply chain systems. It should also modernize their management so that the logistics system can cope with unpredictable situations more efficiently and meet the quality requirements for food products. To solve the above-mentioned problems, we studied the GFSI (Global Food Safety Initiative) methodology. Its mission is "Provide continuous improvement in the food safety management systems ... to ensure safe food to consumers worldwide." It is an organization engaged in benchmarking food safety management schemes for their integration and mutual recognition. These schemes include FSSC 22000, IFS, BRC Global Standards (we will talk about them later), as well as SQF, Global GAP, Canada GAP, Primus GFS, Synergy 22000. The companies that accept and use GFSI approved schemes are both global retailers (for example, Fozzy, Metro, Auchan) and well-known food processing brands (such as Nestle, Coca-Cola, McDonalds, Mondelez International (formerly Kraft Foods), Danone). In other words, this means that a food company certified by one of the recognized GFSI schemes receives a "license" to supply its products to these brands and is "exempt" from the counterparty audits or the frequency of such audits is significantly reduced. The main components of the supply chain management structure are shown in Figure 3.

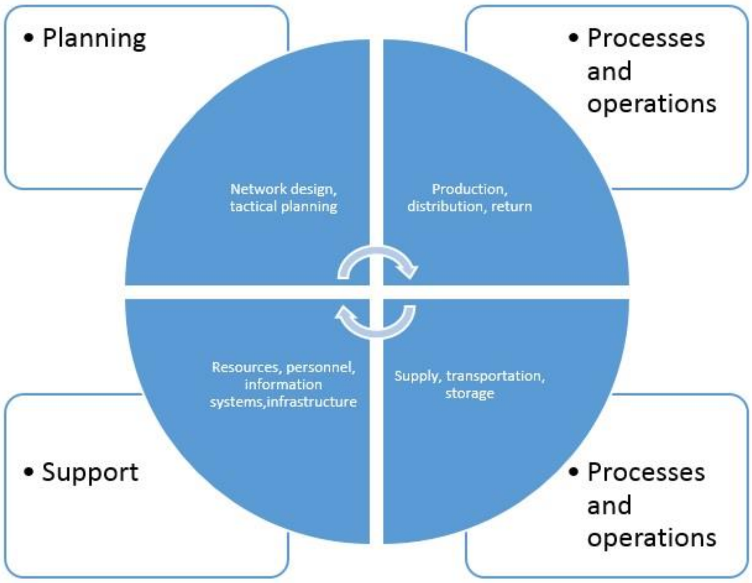

Figure 3. Key elements in logistics and supply chain management. Source: [our development based on [4, 5, 8]

As in other types of commercial activities, in logistics and supply chain management, it is very important to use the experience of advanced companies that are leaders in their business. In this perspective, the term "Best Practice" has become widespread abroad. "Best practice" does not evaluate the quality level of these methods, but is their common name. With the help of logistic concepts/technologies that have already been put into practice, we can avoid the problems that other companies have faced with. As a result of this project implementation under the patronage of the European Logistics Association, positive results have already been achieved for both individual companies and groups of shareholders: a decrease in transportation costs; higher transport rates (in particular, a 100% increase for trailers); increased efficiency of warehouse operations (storage areas are reduced by 25%); improved operational logistics performance; higher rate of equipment use for cargo handling; reduced loading time [21]; development of European transport corridors; significant reduction in fuel consumption; decrease in demand for the required transport capacity (for the same volume of cargo 4 trailers are used instead of 5); fewer problems associated with road overloading; CO2 reduction; more efficient use of logistics capacity [22]. It was determined that the "MIT 2020 Council" plays a significant role in the methodology of supply chain management. Great attention to the success of such companies as Toyota, Wal-Mart and Dell, contributed to the fact that the supply chain managers of key industries started to apply their experience in practice, as well as create new practices within their own organizations. Unfortunately, the principle of coping the practices of successful companies rarely brings good results. Toyota's first-class approach to supply chain management is significantly different from Dell and Wal-Mart's strategies. One size does not fit all: the apparent difference is not even that it is impossible to compare the automated warehouse management system (WMS) with the high-tech sector, but that the companies themselves operate in very different supply chains and their areas of competition do not match. The supply chains of some companies, such as Wal-Mart's and Dell, must be very effective in order to keep low prices and remain competitive. Other companies are focused on customer relationships rather than prices. For example, it is IBM. The company pays more attention to maintaining customer feedback in order to sell its high-margin goods and services (by keeping a high level of investment and operating costs). The company has to resort to such measures in order to maximize the profit potentially accumulated over the period of establishing relationships with customers [23]. Based the research results, we have made the following conclusions. In order to optimize the supply chain of the “Klinsky” meat-packing plant: it is necessary to systematize the statistics on the transport process with the constant analysis of indicators and transport availability; requests for shipment/delivery of products should arrive at the transport department and warehouse no later than a day before the forthcoming delivery; safety stock of the production materials should be organized. In case of export activities of the “Klinsky” meat-packing plant, the key indicator is costs. That is, the most important task is to minimize costs, provided that the remaining indicators are within the acceptable range:

• product safety must be ensured without critical damage that may be the reason for denying the product;

• the product must be delivered within two months and there must be approximately 7-15 days left for unforeseen circumstances/delays and so on. Taking into account the fact that the delivery from the ports of the Far Eastern basin (after customs clearance) to China is carried out within 7-15 days, the maximum delivery time to the port should be approximately 45 days (preferably 35-40 days).

Based on the above-mentioned information on the delivery of perishable goods, we have developed the best supply chains of frozen meat and by-products to the seaports for future export operations. Considering the priorities of the “Klinsky” meat-packing plant, it is advisable to adjust and apply only some of the proposed routes. We proposed three main product delivery routes: motor transportation and a combination of several modes of transport (motor + rail transport; motor + sea transport). Table 2 shows more specific parameters of the potential delivery of the “Klinsky” meat-packing plant products to the seaports, such as the length of the route, the delivery cost and time.

Table 2. Examples of possible delivery options of the “Klinsky” meat-packing plant products to the seaport

Route	**Route length, km**	**Delivery time, days**	**Delivery cost, thousand rubles**
Motor transportation: Klin-Vladivostok	9147	13	380
Motor + railway: Klin-Moscow; Moscow-Vladivostok	9625	23	325
Railway transportation: Klin-Moscow; Moscow-Vladivostok	9720	23	335
Sea transport: Moscow-Saint Petersburg Saint Petersburg Port- Vladivostok Port	19200	44	290

Source: [our development]

The destination is the port of Vladivostok. The information in the table is approximate and averaged. When choosing a route for transporting food products, we recommend paying attention to the influence of such key factors as transportation costs, cargo safety and delivery time. We analyzed the more efficient supply chains using the methods of guaranteed strengths and weaknesses. It helped us to summarize the strengths and weaknesses of the routes and to find out which one is better taking into account certain factors. We have compiled a table of options for supply chain routes. The best option we gave 5 points, the worst – 1 point. For example, the “motor transport” received 1 point on the “cost” criterion, as it is the highest. But at the same time we gave 5 points to the “sea transport” on this criterion. All calculations were carried out according to the highest and lowest points using proportions. Having carried out the calculations of the guaranteed advantages and disadvantages, the following results were obtained:

The first - 5.2 points.

The second - 3.8 points.

The third - 3.1 points.

The fourth - 4.6 points.

We believe that the best option will be the one that has maximum advantages or minimum disadvantages. The best option in terms of advantages may not coincide with the best option in terms of disadvantages. First of all, when analyzing this method, we excluded those options in which the generalized disadvantages exceed the generalized advantages. These options are route 1 and 2. As a result, route 3 and 4 are the remaining options. The important thing is that the difference between generalized advantages and disadvantages of route 4 is greater. Thus, the advantages almost double the disadvantages. It was concluded that in this method an effective route is option 4: transportation of meat and by-products by sea. Bearing in mind the recommendations of the financial department of the “Klinsky” meat-packing plant, the most important factor is the costs: transportation costs should be minimized, but the other parameters should be taken into account. We applied a method that allowed us to analyze the route in more detail, taking into account the importance of the selected indicators, as well as the features of the selected routes. We used the supply chain improvement method in the form of the decision tree method (Fig. 4). The implementation of the decision tree in practice will allow: managing risks in supply chains, analyzing and comparing given criteria and factors, choosing the best option to increase the efficiency of the enterprise, improving the enterprise's logistics system. In order to choose the supply chain route, each branch should be considered in detail in accordance with the criteria given. A generalized decision tree must be divided into separate decision trees for each supply chain option.

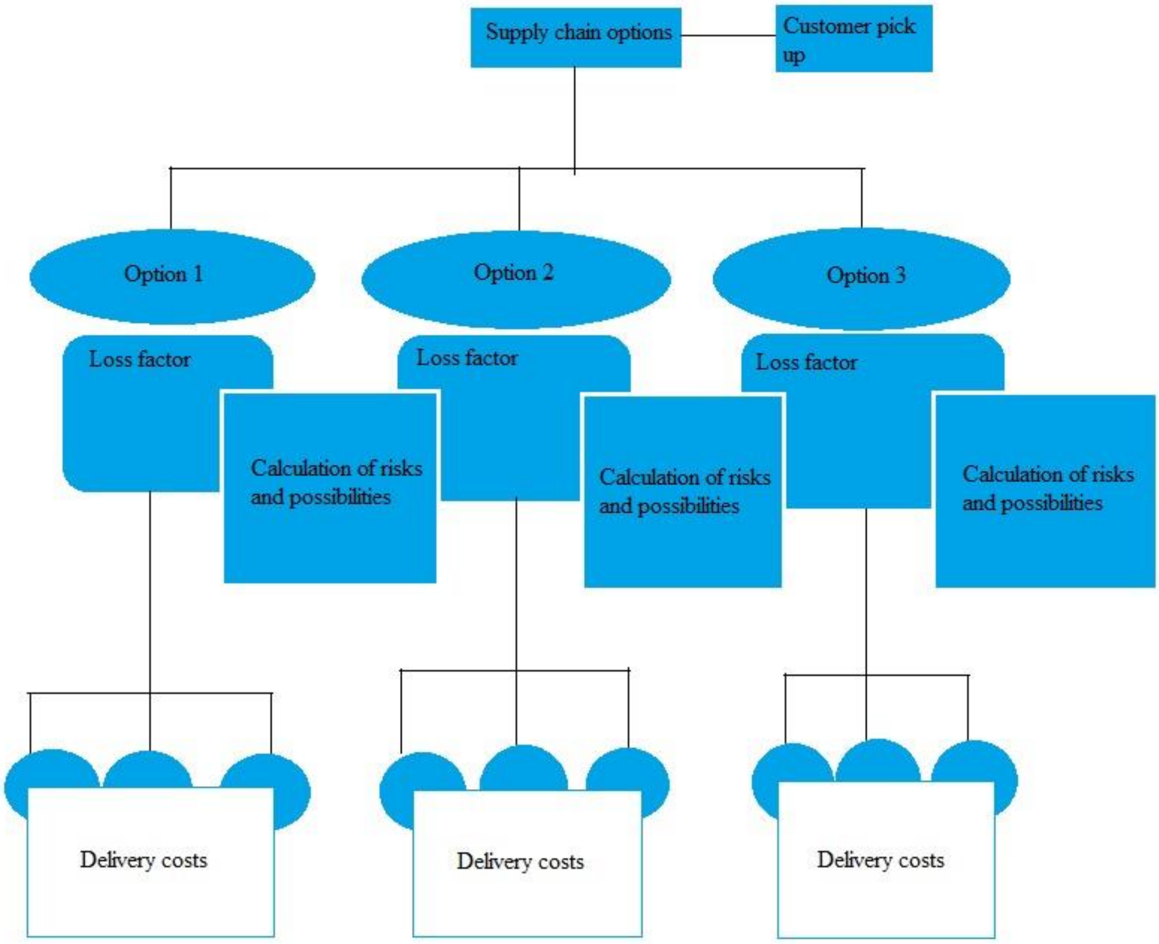

Figure 4. Generalized decision tree for choosing the supply chain for the “Klinsky” meat-packing plant products

Thus, on the basis of our research results and the analysis of the potential supply chains for delivering meat and by-products of the “Klinsky” meat-packing plant to the seaports, we can draw the following conclusions regarding the improvement of supply chains: 1) the railway transportation will ensure a basic supply chain that will guarantee consistency and reduce risk; 2) according to our calculations, sea transportation is the best option for the logistics chain, which minimizes delivery costs and time. In order to improve supply chain management in the enterprise under study in terms of information support and automation, it is necessary to organize smart warehouses and use AGVs, as well as perform pooling delivery and centralize warehouse systems and supplies. We believe that the use of such modern developments and resources at the enterprise, as cloud technologies, Big Data, Internet of Things, robot-based production, artificial intelligence and Online Retail will simplify business and supply chain management, organize the information related to logistics and transportation, as well as reveal hidden opportunities and trends.

4. Discussion

The analysis of the studies devoted to this issues showed that many theoretical and methodological aspects have not sufficiently been developed and the problem of the supply chain management in the food industry [3, 7, 8, 10, 11, 19, 20] is not fully understood. A big number of studies do not give clear recommendations for solving this problem [5, 24]. Most papers and course books have only a descriptive and recommendatory character with insufficiently formalized tools that can be put into economic practice [5, 9, 10, 16, 25]. The study of scientific materials helped us to divide food industry products into four categories according to the storage temperature: frozen foods, refrigerated foods (transported at the temperature between -5° C and -1° C); cooled products (transportation at 0° C to 15° C); ventilated products (transportation is possible without temperature and humidity control, but good ventilation is required). The first three categories are often combined into a single category of refrigerated goods. In addition to the temperature and humidity requirements, perishable products must meet the travel time standards. For example, vegetables and fruits must be transported within six hours and the temperature should not exceed 0° C. This is true for all seasons of the year, except winter. However, the maximum travel time is determined for every type of product by season. The practical interest of enterprises in supply chain management emphasizes the need to consider the following issues: development of priority measures for the selection and implementation of supply chain management methodologies [5, 14, 19]; justification of the choice and development of the methodologies for evaluating the indicators necessary for building a decision tree for effective supply chain management [6]; improvement of the theoretical approach to the formalization of the existing methods of food supply chain management [17-19]. The introduction of the proposed methodology in enterprises will create a methodological basis for the selection and effective implementation of decision-making tools in supply chain management, which can be used in Russian enterprises [19]. A review of the experience of managing food supply chains in the enterprises revealed the following shortcomings in the management system: there is no methodology for ensuring uninterrupted supplies throughout the whole supply chain. The enterprises should improve the quality of the information flow, because communication problems result in delivery delays. It is obvious that the financial side is also very important. Constant information exchange makes it easier to avoid many problems, including the disruption of supplies [26]. We believe that the reduction of storage costs can be achieved with the help of the so-called “Just in time” concept. In this regard, it is possible to change the development vector of the food supply chain management system towards the improvement of the logistics scenarios, implementation of the systematization algorithm and efficient management of the enterprise supply chain, using the example of the “Klinsky” meat-packing plant.

5. Conclusions

In our research we have analyzed the process of managing supply chains in the food industry to ensure the continuous and efficient operation of the enterprises and the timely delivery of goods. Such common methods, as Cold Chain, Global Food Safety Initiative, the MIT Council 2020 have also been analyzed. This allowed us to identify their main features and to find the advantages and disadvantages. The adaptation of the methods to the food supply chain management has also been considered [27, 28]. As a result of our study, we have proposed an adapted algorithm for systematization and efficient management of the supply chain on the example of the “Klinsky” meat-packing plant. The logistics structure and management of the “Klinsky” meat-packing plant have been developed and proposed. The developed structure takes into account the existing logistics scheme and is characterized by many stages of solving the transport distribution problems and the obligatory involvement of all the departments. On the basis of our research we have developed supply chain options for the enterprise that can be put into practice. Moreover, the options have been evaluated by the method of guaranteed advantages and disadvantages with due regard to the Cold chain critical factors. To take into account the risk factors and their impact on the supply chain, a multi-criteria improvement of the supply chain has been carried out in the form of the decision tree method. Thus, companies should review their current practices, paying attention to both the critical logistics factors of perishable products and the degree of risk impact on the logistics chain. The above-mentioned information will facilitate the choice of a suitable supply chain for the company based on risk acceptance. It will also reduce the potential risks of major financial losses.

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