STUDYING THE IMPACT OF RESTRICTIONS AND RISK FACTORS ON THE SUSTAINABILITY OF THE FUNCTIONING OF THE FOOD DISTRIBUTION CHAIN: USING THE EXAMPLE OF PERISHABLE PRODUCTS IN KAZAKHSTAN

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Abstract - In conditions of risk and uncertainty, food security is ensured taking into account the requirements of isolation, safety and health, which requires changes to the existing supply chain (SC) system in the food environment, as well as the creation of more sustainable food supply chains.
The aim of the study is to assess the conditions and factors of the functioning of the food commodity distribution chain (FCDC) of the agri-food market in conditions of risk, in particular, the COVID-19 pandemic. To formulate a conceptual framework reflecting the structure of the SC elements, the method of systematic review and generalization of literature was used; the method of expert survey of participants in the SC of food products (FP). During the analysis, seven significant factor constraints (technological, financial, economic, institutional, social, epidemiological, geographical) were revealed, the environment and operating conditions of the FCDC associated with the impact of the pandemic were identified. The risk factors of the environment and operating conditions of the FCDC and their possible effects on the SC are evaluated. The ranking of conditions and risk factors in the functioning of the agro-food production FCDC allows to use data for the design and development of measures to improve and develop elements of regional distribution network (DN), the adoption of organizational and economic measures and the financing of DN projects. Practical recommendations are given to reduce risks and improve the efficiency of the agro-food commodity distribution SC.
The study attempts to study the influence of various factors caused by the restriction of the functioning of the food environment and affecting the stability of the SC of perishable products. The results could also be used to inform SC participants about the measures needed to create more sustainable SC foods in the future.

Keywords - Food Supply Chains, Supply Chain, Agri-Food Market, Perishable Products, Risk Factors, Environment and Conditions of Supply Chain Functioning, Distribution Network

I. INTRODUCTION

The policy of strict isolation and physical distancing in the context of the spread of COVID-19 has led to a serious decrease in economic activity and disruption of the functioning of commodity supply chains, provoking new trends that have had an indirect impact on food systems, as well as food security and nutrition of the population. The impact was complex and affected various aspects: production, logistics and transport, supply and demand, employee health, stocks and storage, prices, global trade relations.
These changes have highlighted the importance of flexible and sustainable food supply chains (FSC). And affected the following sensitive sectors: food supply chains affecting the delivery of food to the end consumer; trade and agricultural activities of micro, small and medium-sized enterprises; transport; product storage; product sales [1].
The study of the food environment and SC requires consideration of many factors limiting the interdependent processes inside and outside organizations that affect the effective and sustainable functioning of the FSC.
Food security and the effective functioning of FSC in a pandemic, caused by certain factor constraints, is related to the environment and conditions in which they live. In this regard, it is important to identify the factors and limitations, and assess the risks caused by these factors. Limiting factors affect the economic and physical accessibility of FP.
The purpose of the study is to assess the factors, environment and conditions of functioning of the commodity distribution chain in the agri-food market in the context of a pandemic, which will further determine priorities in the design of the distribution network. Main tasks:

1) identification of significant factors caused by the environment and different operating conditions of the FSC;
2) assessment of the environment and operating conditions of the commodity distribution chain under risk conditions.

2. Analysis of the environment, operating conditions of food supply chains and factors limiting the effectiveness and sustainability of their functioning

Recently, many studies have been conducted to study the impact of the pandemic and other risks on the management of STDs in order to identify factors and priorities during the pandemic: control, traceability, information exchange, etc. [2], risk assessment, decision-making, food safety and food waste [3]; improving the efficiency of supply chains with using blockchain technology [4], blockchain in logistics

and SCM [5]; digital transformation (sensors, Internet of Things) in FSC logistics [6]; the tasks of planning the distribution of SC of perishable products in conditions of failures affect the speed, time, and efficiency of the FSC [7].

At the same time, there are groups of factors affecting the food environment and the FSC: demographic, political, economic, innovation, technology and infrastructural factors, socio-cultural, biophysical, environmental factors [8], where the key elements are physical and economic access to food; measures to promote food sales, advertising and information about them; product quality and safety.

The systematization of the environment of functioning of food distribution chains (FDC) allowed us to identify the most important of them: physical, economic, institutional, socio-cultural, anthropogenic and consumer. In each of these environments, certain conditions are created to ensure their functioning under the influence of factors that create risks that limit the sustainable functioning of the FSC.

The listed environments are associated with the following limitations: physical, economic, financial, institutional, socio-cultural, sanitary-epidemiological, environmental and consumer. The presence of these restrictions has different effects on the sustainability of SC, on the economic and physical accessibility of FP.

Summing up, based on a theoretical analysis of the literature, we present in a systematic way the environments and operating conditions of the FSC, the factors and risks affecting them.

1. The physical environment (availability and physical accessibility) ensures the physical availability of food, that is, the availability of food at any given time and in the required assortment anywhere in the country.

The functioning of the physical environment is associated with geographical, technical, technological and infrastructural constraints and opportunities: disruptions in commodity supply chains, lack of access to digital technology services, restrictions on infrastructure capacity, including transport, logistics and trade.

1.1. Geographical restrictions (spatial and temporal restrictions) are associated with a ban on the movement of goods and people within the country [9]; suspension of intercity transportation; prohibition/restriction of public transport and passenger air transportation[10].

Restrictive measures are very effective in reducing mobility on a global geographical scale in the short term, but also have a large socio-economic impact in the long and short term. The losses from geographical (tourism, transportation) restrictive measures have been studied - the greater the restrictions, the greater the loss of GDP [11].

1.2. Technological limitations are associated with technical and technological consequences in the food production and distribution system: disruptions in commodity distribution chains [1]; lack of access to digital technology services; restrictions on infrastructure capacity, including transport, logistics and trade; underutilized capacities; cyclical demand for transport services; delays in deliveries and spoilage of goods[12].

1.3. Infrastructure constraints (availability and density of trade, transport, logistics, information and other infrastructures by region) are associated with a low level of infrastructure provision; poor infrastructure quality; remoteness of raw material bases from product processing centers; long payback period for infrastructure projects in the food market.

2. The economic environment is characterized by the economic availability of food, that is, the possibility of purchasing food of proper quality at current prices, in volumes and assortment corresponding to the incomes of the population.

Factors related to economic constraints: reduced demand for products [13], rising prices in local food markets, unemployment, reduced sales and sales of products, social and economic losses, limited access to economic resources (raw materials, labor, fixed assets); reduced productivity of the food sector and food production [14]; restrictions on the export of basic crops [15]. Financial constraints are associated with a decrease in the purchasing power of the population, loss of income of the population and firms, reduced costs for the purchase of fresh fruits and vegetables, increased budget expenditures on food [14], limited access to financial resources for the development of the industry for the production and distribution of products.

The economic environment of the SC is provided based on the following conditions.

2.1. Macro- and microeconomic conditions (main task: regulation of the activities of participants in the commodity distribution chain, specialization of the territory; economic relations of the territory, prices and costs, income, etc.).Risk factors and possible consequences: uneven development of the region's economy and associated high costs; low labor productivity; low level of financial resources, insufficient support and lack of incentives for the production of safe and high-quality food.

2.2. Resource conditions (main task: provision of raw materials, labor, financial and information resources).Risks include: a shortage of qualified personnel; instability of raw materials supplies or non-fulfillment of deliveries to customers, deterioration of product quality, interruptions in production; the risk of an increase in the cost of raw materials and product prices. Possible consequences:

supply disruptions, reduced product quality, changes in prices for raw materials and products.

2.3. Competitive conditions (ensuring a competitive distribution network, including manufacturers, processors of products and trade, transport and logistics). The main risks are: higher prices for resources and final products; low level of competition; the likelihood of changes in demand for the company's products; instability of commodity markets, etc.

2.4. Financial conditions - access to basic financial services - which will lead to increased sustainability of production and sales, as well as increased income and purchasing power. The risks are associated with a decrease in production due to a lack of financial resources and income. Households in a financially disadvantaged position reduce the cost of buying fresh fruits and vegetables with a high content of trace elements and spend more money on purchasing basic products containing fewer nutrients [12]. According to the results of other studies, the population is switching to processed foods [19].

3. The institutional environment is related to the rights and rules of action of SC participants and consumers of products. The factors of institutional restriction characterize the growing inequality in society: restrictions in rights, in access to means of meeting basic needs such as food, water [16], closure of markets, restaurants or restrictions on the opening hours of retail facilities, lack of clear rules of the game, etc.
The factors and risks limiting the institutional environment are related to the conditions:

3.1. trade (a set of measures aimed at organizing trade operations, reducing the level of shadow business);

3.2. regulatory documents that ensure legislation and control over their compliance by all participants in the commodity distribution chain.

4. The socio-cultural environment is characterized by social and cultural conditions and creates conditions for wages and employment, a consumer basket and incomes of the population. Factors related to socio-cultural restrictions include increasing social inequality in society [17], which restricts access to high-quality and diverse food; failures in the functioning of social protection programs; panic buying of consumers, changes in consumer behavior in the catering sector [18].
During the epidemic, the level of malnutrition among socially vulnerable groups of the population, especially among pensioners, may increase sharply [19]. Under the current conditions, the authorities decide to cancel or postpone indefinitely many cultural events in order to avoid the rapid spread of the virus [20].

5. The anthropogenic environment includes product safety conditions and environmental conditions.
The main risks associated with sanitary and epidemiological restrictions include: a high level of product loss; low quality and hazardous products [21]; unwillingness to provide products in emergency conditions; a sharp increase in the volume of spoiled food products [21]; increased costs associated with maintaining a strict operating regime.
The factors and risks associated with environmental restrictions have a positive impact on the environment due to the reduction of carbon dioxide as a reason of the reduction of restrictions on transport and environmental projects [22]. At the same time, they also cause negative consequences. For example, it is known that due to the low activity of people, there have been changes in the contents of garbage cans, primarily due to plastic packaging - a significant increase in the amount of plastic waste.

6. The consumer environment is closely related to the creation of comfortable conditions in the commodity distribution chain [23]: the presence of consumers and their attitude to product quality and product requirements, consumption structure and consumer preferences of the population.
Factors-constraints caused by consumer behavior: during the pandemic, consumers demonstrated a shift in their consumer behavior in favor of hygiene, sustainable development and local products; consumption of processed foods increased and the amount of fruits and vegetables consumed decreased, which led to a decrease in the quality of nutrition.
The risks are primarily associated with non-compliance of product quality with consumer expectations; non-compliance of consumption structure with recommended physiological standards. Sales models based on e-commerce and digitalization, sustainable production and consumption play an indispensable role, exerting a sensitive influence on people's purchasing behavior.

II. MATERIALS ANDMETHODS

As shown in Fig. 1, the methodological basis of the study consists, first of all, in the systematic collection of data from literary sources; identification of factors affecting and limiting the functioning of SC in the food system; systematization of the environment and the conditions of its functioning. To assess the impact of the environment and the conditions of the functioning of the food system on the SC DN of Kazakhstan, we used a standard expert survey of specialists by collecting and studying the opinions of experienced entrepreneurs and specialists of the country with advanced experience in production,

trade in perishable products of the agro-industrial complex (AIC) and the food industry.

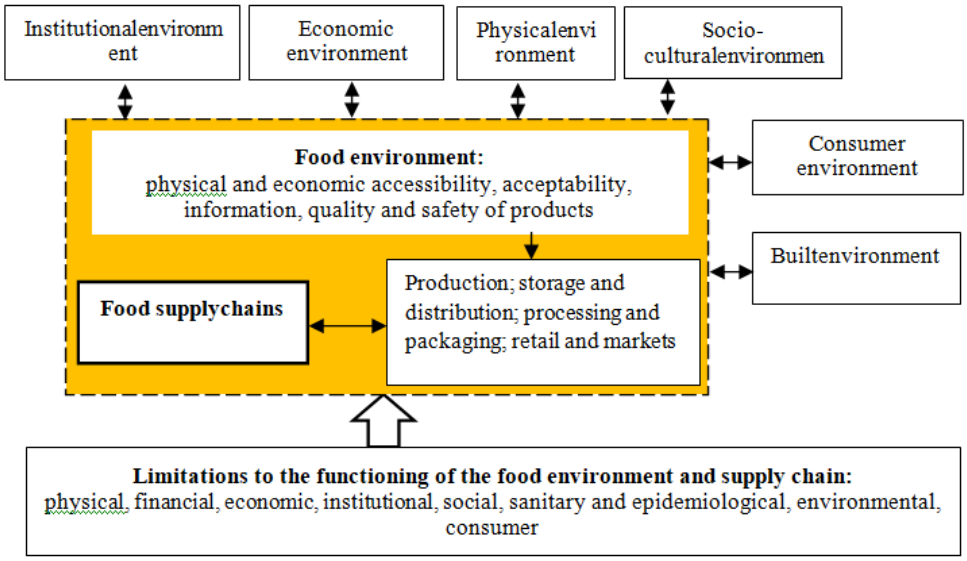


Figure 1. The environment of the food supply chain and the constraints caused by the pandemic
Source: Compiled by the authors

The 45 experts participated in the survey. The study was conducted during 2023. The factors and risks we have identified are characterized by several indicators. Their values were determined in points by an expert method. Moreover, each of the indicators in the evaluation system had its own weight corresponding to its significance. A 5-point Likert scale was used (where: 1 - very bad, 2 – worse or bad, 3 - acceptable, 4 - good, 5 – excellent). The points obtained during the examination were summed up for all indicators, taking into account the weight coefficients, forming a generalized assessment of this type of risk for this region or a specific DN:

$$R = \sum A \times r, \qquad (1.1)$$

where: r - the value of each indicator in points; A - weighting factor; R - generalized risk assessment.
The relative variability of the values of the factors is characterized by the coefficient of variation (Cv), as the ratio of the standard deviation to the average value of the factors. The stability coefficient (Cs) describes the degree of variability of supplies depending on factors, defined as Cs= 100-Cv
Table 1 presents the conditions and environments that ensure the functioning of the SC and the factors that limit or improve the FSC.

Conditions ensuring the functioning of SC	Environment/risk factors/indicators affecting the efficiency and sustainability of SC under risk conditions	Designationoffactors
1.Physical environment		
1.1.factors associated with physical limitation		
Spatiotemporal conditions (physical proximity and accessibility)	availability and sufficiency of food supply on the domestic market at any given time	q1
Technicalandtechnologicalconditions	access to digital technology services (online purchase, online order and delivery)	q2
Infrastructure conditions	Availability and access to agricultural, transport, logistics and trade infrastructure	q3
2.Economic environment		
2.1.factors associated with economic restrictions		
Macroeconomicconditions	growth/or decline: population, trade volume, investment, product price, unemployment	q4
Conditionsforprovidingresources	sustainability of production and availability of resources (materials, information, personnel)	q5
Conditionsofcompetition	rising food costs and prices due to additional costs; household food expenses	q6
2.2.factors related to financial constraints		

Financial conditions	Access to basic financial services for the development of the industry for the production and sale of products	q7
	income level and solvency of the population	q8
3. Institutionalenvironment		
3.1.factors limiting the institutional environment		
Trading conditions	restriction of activities of retail facilities, closure of restaurants and other public catering facilities	q9
Regulatoryconditions	Isolation or restriction on population mobility and movement of goods, transport	q10
4.Socio-cultural environment		
4.1. factors caused by social and cultural restrictions		
Social, living and cultural conditions	increasing inequality among social groups due to limited access to products	q11
5. Man-made environment		
5.1. sanitary-epidemiological and hygienic restrictions on operating hours		
Conditions for ensuring product safety and health	product quality and safety	q12
	Food loss rate	q13
5.2.Environmentallimitingfactors		
Environmental conditions	reduction of harmful emissions from vehicles, increase in plastic waste	q14
6.Consumer environment		
6.1.factorslimitingconsumerbehavior		
Consumer terms	reducing the quantity and volume of fresh products and switching to processed products	q15
Behavioralconditions	lack of information about product preferences and requirements	q16

Table 1: Environment, conditions and risk factors affecting the sustainability of supply chains under risk conditions

Further studies were conducted on the basis of tabular data.

III. RESULTS

Based on the analysis of the environment and operating conditions, assessment of the influence of limiting factors on the stability of FSC in risk conditions, their quantitative assessment was obtained (Table 2).

Факторы Factors	Averagevalue, qi	Standard deviation	Stabilityfactor	Specificgravity	Average Perishable SCScore (1 to 5 points)	Theoretical value (page 5 x 5 points)	Actual value (page 5x page 6)
1	2	3	4	5	6	7	8
1.Physicalenvironment (specificgravity 0.25)							
q1	4,69	0,47	90,02	0,08	4,12	0,40	0,33
q2	4,49	0,55	87,78	0,07	4,45	0,35	0,31
q3	4,04	0,80	80,31	0,06	4,15	0,30	0,25
2.Economic environment(0,24)							
q4	4,56	0,50	88,97	0,07	3,15	0,35	0,22
q5	3,47	0,55	84,20	0,06	3,14	0,30	0,19
q6	3,98	0,72	81,83	0,03	3,72	0,15	0,11
q7	3,47	0,76	78,17	0,06	3,31	0,30	0,20
q8	4,13	0,81	80,29	0,05	4,11	0,25	0,21
3.Regulatoryenvironment(0,13)							
q9	4,07	0,72	82,30	0,07	3,88	0,35	0,27
q10	3,96	0,71	82,16	0,06	4,25	0,30	0,26
4.Socio-culturalenvironment(0,06)							
q11	4,07	0,69	83,09	0,06	3,35	0,30	0,20

5.Builtenvironment(0,23)							
q12	4,31	0,56	87,08	0,09	4,12	0,45	0,37
q13	3,93	0,72	81,70	0,07	3,20	0,35	0,22
q14	3,93	0,72	81,70	0,07	3,64	0,35	0,25
6.Consumer environment(0,09)							
q15	3,02	0,78	74,09	0,05	3,65	0,25	0,18
q16	3,58	0,62	82,64	0,05	3,12	0,25	0,16
Total	63,69			1,00		5,00	3,73

Table 2: Assessment of factors affecting the sustainability of the agro-food distribution chain in the context of a limited food environment in Kazakhstan

Our expert survey of FSC participants shows that the main environments are, in terms of importance, the physical environment (0.25), the economic environment (0.24), the anthropogenic environment (0.23), the regulatory environment (0.13), the consumer environment (0.09), the socio-cultural environment (0.06) (Table 2).

The consistency of expert opinions was determined by the criterion of concordance. The value of this coefficient was 0.73. The calculated value of the Chi-square criterion was 65.34. Verification of significance by Pearson's Chi-square criterion: with the number of degrees of freedom f=45-1=44, Chi-sq. table= 60.2, for a significance level equal to 0.05. Since, Chi-sq. the calculated value is greater than the tabular one (65.34>60.2), this confirms the consistency of expert opinions at a significance level of 0.90.

The ranking of the main conditions and risk factors in the operation of FCDC is arranged in the following sequence: spatial and temporal conditions (0.08), technical, technological and communication conditions (0.07), infrastructural conditions (0.06); macroeconomic conditions (0.07), financial conditions (0.11), trading conditions (0.07), product safety conditions to health (0.16) and resource conditions (0.06). Consumer (0.05), behavioral (0.04), and competitive conditions (0.03) also occupy an important place.

For example, when designing a DN for perishable products, the maximum risk was 5.0. In a particular region and network, it is lower - 3.46.

An analysis of the development strategy, program documents of companies, regions and states showed that, although the entire environment for the functioning of the commodity distribution chain has been formed, not all conditions are fully fulfilled. It seems to us that all the listed conditions for the formation and functioning of FCDC depend on the level of development of the environment (highly developed, medium, low) and the level of state support for the conditions of functioning (full support, partial support, not supported by the state, self-regulating conditions).

IV. DISCUSSION

These conditions and the operating environment impose certain obligations on FSC regarding the maintenance of the quality and volume of products, transportation, storage, trade and delivery of food to the end consumer. All these processes occur unevenly depending on the degree of influence of the studied factors [24].

The high values of the evaluation results (closer to 5 points) of the factors of limitations: physical (q1, q2, q3), economic (q4), financial (q8) and institutional (q9), increased inequality among social groups (q11), product quality and safety (q12) - confirm the previously conducted separate studies on the strong influence (from moderate to strong) of these factors on the stability of FSC under risk conditions [25].

Factors such as q5, q6, q7, q13, q14 and q16, which have values above the average, also have a moderate impact (from weak to moderate) on the stability of SC. The q15 factor has a lesser effect on the stability of SC, which is also confirmed by an earlier study.

The main factors determining the trends in the development of SC are [26]: restriction of food exports, reduction of production and, consequently, exports and imports, due to the introduction of quarantine measures, reduction of trade, decrease in transport services, increased demand for digital products and services (digital content, distance education, etc.).

Based on the analysis of the research results, we have identified the following trends.

- During the pandemic, there are significant losses of food products, especially perishable products, which is also confirmed by the assessment of factor q13=3.93.
- In a pandemic, the population spends more money than under normal conditions to purchase the same product, and there is an increase in budget expenditures on food (q6=3,98, q8=4,13).
- There is a decrease in the number of buyers and demand for certain types of products; an increase in debts; the formation of barriers to the delivery of goods across the region and/or to other regions, an increase in the cost of purchased products (q4=4,56).

Economic activity is declining. The COVID-19 pandemic has affected the volume of trade,

production activities and income of micro, small and medium-sized enterprises (q9=4,07).

The introduction of strict restrictions on movement and closure of borders around the world has led to a sharp drop in production volumes and the market for transportation of perishable products (q1=0.33, q3=0.25), product quality and safety (q12=0,37). At the same time, less dependent factors are observed: household food costs (q6=0.11), lack of information on product preferences and requirements (q16=0.16) – which have almost the least impact on the supply of perishable products.

The study of the average values of the assessment of the impact of factors on the sustainability of the FSC shows that the priority factors are geographical, technological, and infrastructural factors. Then, according to priority, there are resource factors and then - trade, which is consistent with the work [10].

The ranking of the main conditions and risk factors in the operation of the FSC was arranged in the following sequence: product quality and safety (q12=0.37); availability and physical access to food (q1=0.33); access to digital technology services (q2=0.31); restriction of the activities of retail facilities, closure of restaurants and other catering facilities (q9=0.27); isolation or restriction on the mobility of the population and the movement of goods, transport (q10=0.26); access to agricultural, transport, logistics and trade infrastructure (q3=0.25); environmental factors (q14=0.25). Consumer (q15=0.18) and behavioral conditions (q16=0.16) also occupy an important place. Household nutrition costs have a weak impact (q6=0,11).

Thus, our study confirms that the factors limiting the operation of FSC have different effects on the stability of the functioning of SC perishable FP. Of these, some factors are very important: the availability and sufficiency of food supply in the domestic market at any given time, access to digital technology services, the number of buyers, the price of products, unemployment, etc.

To solve the problems of reducing the influence of limiting factors, the following priority measures are recommended: the formation of shorter commodity distribution chains; flexible FSC, developed taking into account the peculiarities of regions and the situation in the country; active transition to digital platforms and a change in approach to the innovative digital commodity distribution chain (production, trade, intermediaries); creation of higher-quality capacities for long-term storage grains and other products; the development of local and regional markets that will help to increase the sustainability of food systems by reducing the length of SC, using and expanding the ability of local markets to sell food.

In the conditions of the limitations identified above, in order to increase the stability of the FSC, the following actions should be carried out:

- active investment of financial resources in the development of production, trade and warehouse infrastructure to support and develop local food markets, using various mechanisms of state support, public-private partnership;
- changing trade policy at the local level, giving preference to local formal markets, rural fairs, street vendors, which are points of contact between small producers and consumers, who are least susceptible to congestion and exposure to virus infection, compared with retailers;
- adopting stricter regulations against unscrupulous competitors, providing more opportunities for small and medium-sized agri-food enterprises to participate in regional and global value chains;
- increasing the sustainability of supply chains by streamlining SC, limiting their degree of complexity and length by moving production/suppliers of basic production resources;
- creation of network associations for flexible transportation planning and integration of various modes of transport, allocation of funds to improve sanitary conditions in transport, digitalization of all processes and document flow in order to increase the effectiveness of monitoring outbreaks of the disease; close international cooperation and increased readiness for rapid response.

V. CONCLUSION

As a result of the analysis, the factors, environment and conditions affecting FCDC in the food system have been identified.

1. The main factor constraints include technological, financial, economic, social, epidemiological, geographical.

It is necessary to ensure the smooth functioning of food supply chains. The supply of basic food products should be well established. One of these measures is the close placement of production and consumers, an increase in production volume for supply to local markets to the main sources of consumption. What is the condition for creating short commodity distribution chains with or without minimal intermediaries.

Actively use innovations - digital e-commerce platforms specifically designed for small and medium-sized enterprises, and not controlled by large corporations, which can also support the functioning

of local markets and respond more quickly to disruptions in SC.

2. Quantitative relationships between the environment and the operating conditions of DN food have been established, and risk factors have been identified. The data obtained could be used in the design and development of measures to improve and develop elements of regional commodity-distributing SC agro-industrial productsи.

The results obtained are of practical importance and are aimed at taking into account the degree of importance of each environment for the further development and improvement of the FCDC operating conditions with appropriate risk factors. This data could be used in the design and development of measures for the improvement and development of FCDC elements, the adoption of organizational and economic measures and the financing of FCDC projects.

This or a similar methodology can be applied at the country level, as well as for individual regions and regions in the design of SC, based on the type of products supplied, delivery conditions, etc.

The established risk values require clarification for individual components of the agri-food market - vegetables and fruits, dairy products, meat products, etc. – which will be the objects of our further research.

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