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SELECTION OF VIABLE SUPPLIERS FOR PROJECT ORGANIZATIONS DURING THE LONG-TERM DISRUPTION OF SUPPLY CHAINS USING IMF SWARA

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***Abstract**: The Covid 19 pandemic has led to long-term disruption in the supply chain. Therefore, refocusing on the supplier selection process was a logical sequence. The new approach of viable suppliers appears as a solution to long-term disruption. This research aims to determine the importance of criteria in selecting suppliers within the Viable supplier framework. Based on the questionnaire, the opinion of companies with different profiles on the importance of the viable suppliers' criteria was collected. The ranking of the importance of the criteria in selecting viable suppliers was done with the IMF SWARA (Improved Fuzzy Stepwise Weight Assessment Ratio Analysis) method. Based on the analysis, the criteria were ranked and the most important criterion is the Finance criterion. The findings can be a valuable basis for making public policies that will support project organizations to survive the long-term disruption of supply chains. The core contribution of this paper is about determining the importance of criteria in the selection of viable suppliers as a new approach to their selection. A significant amount of research has been done in the field of choosing sustainable suppliers, but this is one of the first works related to defining the significance of the criteria of viable suppliers using the MDCM method, which represents the novelty of this paper.*

***Keywords**: Viable suppliers, long-term disruption, selection of suppliers, IMF SWARA*

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1. Introduction

The supply chain concept can be linked with an organized business that enables the supply of products and services to customers (Kumar, 2001). Suppliers and customers were connected through historical trade routes such as the Silk Route even in ancient times. During ancient times, supply chains faced many challenges, including inadequate transport infrastructure, robberies on transport routes, and wars (Sénquiz-Díaz, 2021). Seland (2015) highlighted the issue of the non-existence of trade route maps necessary for better navigation of traders who were transporting goods at that time (Seland, 2015).

In the modern era, apart from similar challenges that one can find in the past for supply chains, new challenges are on the horizon (Bairagi, 2022). The biggest issues are the legal access to the market caused by trade barriers (Dymond & Hart, 2008), bioterrorism as a new form of war (Gummow, 2010), climate change and sustainability issues (Barbosa-Póvoa et al., 2018; Garcia & You, 2015; Gummow, 2010). Stadtler (2005) tried to frame different challenges related to business micro, business macro, and technical challenges (Stadtler, 2005). Nowadays, the Covid-19 pandemic become a great challenge to supply chains (Aday & Aday, 2020; Chowdhury et al., 2021; Remko, 2020).

Supply chains have faced many challenges and pressures in the last few years. The Global Supply Chain Pressure Index introduced by the Federal Reserve Bank of New York showed intensive pressure on supply chains during the period of the Covid 19 pandemic. This pressure caused delays in the delivery of raw material subcomponents across supply chain networks.

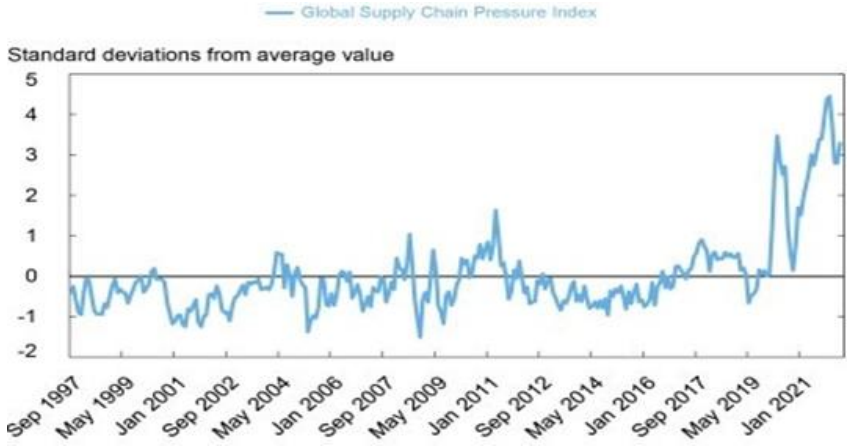

Figure 1. Global Supply Chain Pressure Index Source: (Benigno et al., 2022)

Different challenges have caused supply chain disruption (Puška et al., 2018) which differs in size, length, and severity causing negative effects on consumers. Wu et al. (2007) highlighted uncertainty as the main trigger for supply chain disruptions that can be considered unexpected events in supply chains (Jokić et al., 2021; Wu et al., 2007). No one could predict the Covid-19 pandemic and its unprecedented long-term disruption effects on supply chains that have led to delays of ongoing projects and rising project delivery costs. The Covid-19 pandemic supply chain disruption is

completely different from others in size, length, and severity. The agreed project delivery terms began to be extended for a long period, and the costs of project deliverables began to rise sharply.

The Covid-19 pandemic has influenced the re-shifting of orientation in the selection of suppliers. Instead of focusing on the criteria that can be associated with the short-term resilience of suppliers, agility of suppliers, or sustainability of suppliers, the Covid-19 pandemic highlighted the need to select viable suppliers, those who are capable to survive long-term disruptions (Ivanov, 2020).

In this study, we investigated the priority criteria in selecting viable suppliers to understand how can the effects of long-term disruption of supply chains be overcome or at least mitigated. Although Ivanov (2020) proposed a framework for the selection of viable suppliers, we assume that companies will have different weights for different criteria (Ivanov, 2020). Thus, the initiation of this study enables the analysis of priorities in the selection of suppliers to respond to problems in the period of long-term disruption of supply chains. Particular research interest is given to the analysis of priorities in selecting viable suppliers with the characteristics of supply chains in mind.

This paper is composed of six sections. After the introduction section, the second section provides the relevant literature about the evolution in a selection of suppliers' approaches. A special review is given to the literature on the selection of viable suppliers in response to the long-term disruption of the supply chain that occurred during the Covid 19 pandemic. The third section is a description of the research methodology and how the criteria for the selection of viable suppliers were prioritized. The findings are presented in the fourth section with the presentation of weights and prioritization of viable suppliers' selection criteria. In the first section, the findings are discussed in terms of their meaning for the theory and practice. Finally, in the sixth section, a conclusion is given on the results of the study and the possible implications of the results.

2. Literature review

A proper selection of suppliers is one of the most important aspects of any organization, but determining the appropriate approach for selecting suppliers can be one of the most challenging tasks (Jauhar et al., 2014). Patil (2014) indicated a change in the orientation of supplier selection (Patil, 2014). The previous approach in which price played a fundamental role in supplier selection has been replaced by a multi-criteria approach. Based on his overview, scholars used many criteria in supplier selection.

Thiruchelvam (2011) argued that companies must have multiple decision-making criteria to select suppliers using qualitative and quantitative approaches(Thiruchelvam, 2011). For every purchasing organization, a supplier determines the firm's purchasing costs (Mešić et al., 2022), ameliorates net profits, minimizes lead times, and enhances CSAT (customer satisfaction score). De Boer (1998) proposed a supplier selection model, which acclimatizes to suit different situations. Purchasing activities on one axis and actual steps of purchasing on another (De Boer, 1998). The purchasing process is divided into a matrix comprising problem description, development criteria, and choice on the vertical plane. On the horizontal

axis, new task, modified rebuy, straight, rebuy, and strategic straight rebuy.

Pal et al. (2013) identified the mathematical programming selection methods as linear programming, goal programming, and multi-objective linear programming with data envelopment analysis as a prequalification (Pal et al., 2013). Cheraghalipour *et al.* (2017) used a hybrid multi-criteria decision-making (MCDM)-method and mixed integer linear programming (MILP) in their study of collection center selection (Cheraghalipour et al., 2017). A very interesting study is conducted by Cheraghalipour (2018) in which they used the BWM-VIKOR approach to supplier selection (Cheraghalipour et al., 2018). Ghoushchi *et al.* (2021) applied SWARA- WASPAS Framework in Landfill Site Selection for Medical Waste (Ghoushchi et al., 2021).

Ivanov (2020) provided an overview of the historical evaluation of supply chain management and the focus on the supplier selection process (Ivanov, 2020). He noticed that different triggers affected changes in approaches to supplier selection. He noticed well several triggers affecting re-shifting the supplier selection approach:

- Responsiveness that shifted focus on Leagility;
- Natural and man-made disasters that shifted focus on Resilience;
- Climate changes, Society, and Economics that shifted focus on Sustainability;
- Global Pandemics that shifted focus on Viability.

Agarwal et al. (2006) highlighted the necessity of supply chains to be adaptable to changes in the business environment and proactively address needs (Agarwal et al., 2006). They highlighted the importance of combining two concepts, leanness and agility in managing supply chains. According to them, the main determinants for leagile supply chains are managing lead time, costs, quality, and service level.

Leagility is a supply chain approach that combines cost efficiency, time responsiveness, and a hybrid of the two, or a lean and agile approach (Soni & Kodali, 2012). Leagility (lean-agile) is an essential supply chain strategy for an organization's competitiveness (Galankashi & Helmi, 2016; Li & Lu, 2020). Galankashi & Helmi (2016) proposed a new assessment tool for leagility including different drivers such as facility layout, facility location, inventory, transportation, sourcing, pricing, and information (Galankashi & Helmi, 2016). Li & Lu (2020) indicated several criteria important for the selection of suppliers including raw material costs, increasing quality, delivery, customer satisfaction, and improving reactions to market changes (Li & Lu, 2020).

As per Ivanov (2020), natural and man-made disasters triggered changes in the focus of supply chains to the concept of resilience (Ivanov, 2020). Rajesh & Ravi (2015, p.343) state that "resilience that stands for the adaptive capability to respond to disruptions and recover from it needs to be considered in supplier selection."(Rajesh & Ravi, 2015) The vulnerability of supply chains to catastrophic events was discussed by Sahu et al. (2016) who indicated the effects of different man-made events (e.g., terrorist attacks) and environmental (e.g., earthquakes)(Sahu et al., 2016). Thus, effective supplier selection is the key to the survival of supply chains in these conditions. Hosseini & Barker (2016) discussed different resilience-based supplier selection criteria. They especially put focus on absorptive, adaptive, and restorative capacities(Hosseini & Barker, 2016).

With the re-shifting of the economic focus to the concept of sustainability, sustainable suppliers become a very hot topic in the literature. The focus of sustainable

supply chains is on collaborating with suppliers to balance economic, social, and environmental issues (Gimenez & Sierra, 2013). Puška et al. (2021) highlighted the importance of selecting sustainable suppliers for achieving sustainability in business (Puška et al., 2021). Puška & Stojanović (2022) used the fuzzy MABAC, MARCOS, and CARDIS techniques to select green suppliers in the example of an Agri- Food Company in Bosnia and Herzegovina. (Puška & Stojanović, 2022). With the COVID-19 pandemic, fully new challenges appear in supply chain management. At the beginning of the pandemic, Remko (2020) highlighted that the lack of preparedness for long-term disruption and the shortcomings of risk response strategies are major concerns for supply chain resilience in the long run (Remko, 2020). This opens new research opportunities in the arena of supply chain management (Puška et al., 2020). Within just two years, a great amount of the literature discussed the issue of long-term disruption and the selection of suppliers.

Polyviou et al. (2022) conducted a scenario-based role-play experiment on 286 sourcing professionals. It was revealed that sourcing professionals encounter high levels of feeling of culpability during two situations (Polyviou et al., 2022). Firstly, when responsible for selecting a disrupted supplier. Secondly, they reckon that the supply disruption was controllable, however, the supplier thought vice versa. Hence, the emotions of guilt led many sourcing professionals to select less risky though more advantageous suppliers for new sourcing decisions. Supply disruptions have carryover effects on future sourcing decisions in unrelated situations.

MDCM (Multi-Criteria Decision Making) criteria were proposed to control the product development cycle and to dispense firms with a structured way to grade risks and select suppliers. A study by Ilyas et al. (2021) proposed supplier selection criteria to include pandemic-related risks. After analyzing the COVID-19 risks, the authors calculated the criteria weights using the Best-Worst method (Ilyas et al., 2021). Furthermore, FTOPSIS (fuzzy Technique for Order of Preference by Similarity to Ideal Solution) was then applied to categorize and prioritize risks affecting suppliers. The following methods were used in real case studies of the automotive industry and can be extended to other industries as well (Arce et al., 2021).

A fuzzy rough decision-making approach for the supply chain in the healthcare sector was proposed by Pamucar et al. (2022) (Pamucar et al., 2022). Considering the high uncertainty during COVID-19, the study used the “measuring attractiveness through categorical- based evaluation technique” MACBETH (Measuring attractiveness through a categorical-based evaluation technique) approach. It’s a distance-based assessment method to address supplier selection problems during COVID-19. Fuzzy sets and rough numbers were utilized as superior uncertainty sets.

Multiple-stage multiple-objective organization model, proposed by Shao et al. (2022), can be applied to different stages of COVID development and the intensity of the pandemic spread (Shao et al., 2022). The model's objective is to solve problems related to sustainable supplier selection and order allocation during pandemics like COVID-19. The study utilizes a novel nRa-NSGA-II (The non-dominated sorting genetic algorithm II) algorithm to solve the Multiple-stage multiple-objective organization model. The case has experimented on a multinational company. The advantages of the algorithm used are as follows: could be used for high dimensional optimization, provide a non-dominated set and reflect t priorities of decision-makers in different

situations

Ivanov (2020) introduced the concept of "viability" which is a concept that balances agility, resilience, and sustainability (Ivanov, 2020). “Viability is a system ability to meet the demands of surviving in a changing environment” (Ivanov & Dolgui, 2020). Additionally, Ivanov (2020) highlighted three main features of the dynamically adaptable and structurally changeable viable supply chain: agility reaction, resilience to negative events, and survival in long-term disruptions by adjusting capacities utilizations. Based on Ivanov (2020) there are 5 main indicators of a viable supply chain (Ivanov, 2020):

- Organizational structure;
- Informational structure;
- Technological structure;
- Financial structure;
- Process-functional structure.

This study aims to assess the importance of these indicators and sub-indicators while selecting viable suppliers.

3. Methodology

For this study, the following phases were applied used:

- Phase 1. Data collection
- Phase 2. Data processing
- Phase 3. Determination of criteria weights
- Phase 4. Comparison of weights by company location and company supplier

The first phase of this research is data collection. Based on the theoretical model proposed by Ivanov, D. (2020), a questionnaire was prepared that included the proposed criteria for viable suppliers (Ivanov, 2020). Ivanov (2020) made a significant contribution to the development of the concept of viable suppliers and he proposed criteria for their selection (Ivanov, 2020). This study enables further investigation of the significance of criteria and subcriteria suggested by this author. The questionnaire made it possible to identify the importance of criteria by companies in the field of supply chain management, as well as project organizations. The criteria are divided into five main criteria, each into sub-criteria (Table 1).

Table 1. Criteria for selecting viable suppliers

ID	Criteria	Description
C1	Organization	
C11	Back-Up suppliers	Reserve suppliers in case of long-term disruption
C12	Back-Up sub-contractors	Reserve sub-contractors in case of long-term disruption
C13	Facility fortification	Preventive measures within your company that protects the process in a period of long-term

		disruption (e.g., social distancing methods)
C14	Workforce resilience	The level of workforce readiness to continue working under the situation of disruption (e.g., vaccinated workforce)
C2	Information	
C21	Digital twins	Computerized Supply Chain models of real state network or virtual supply chain replica that consists of hundreds of assets, warehouses, logistics, and inventory positions used for prediction
C22	Data Analytics	Processes organizations use to gain insight and extract value from the large amounts of data associated with the procurement, processing, and distribution of goods
C23	Visibility tools	Real-time tracking of shipments with integrated operations and analytics capabilities
C24	Supplier portals	A platform for buyers and suppliers to connect with each other and exchange data
C25	Blockchain technology	Access to the same information, potentially reducing communication or transfer data errors
C3	Technology	
C31	Additive manufacturing	Digital manufacturing technology enables companies to rethink their supply chain design
C32	Robotics	Automate the process of storing and moving goods as they make their way through the supply chain
C33	Smart manufacturing and warehousing	Help store managers keep track of all inventory- related activities
C34	Industry 4.0 tools	Global networks of machines in a smart factory setting capable of autonomously exchanging information and controlling each other
C4	Finance	
C41	Liquidity reserves	Available cash and cash equivalents during long-term disruption
C42	Business-government collaboration	Two or more autonomous organizations from the public and private sectors working jointly to plan and execute supply chain operations
C43	Revenue management	Use of pricing to increase the profit generated from a. limited supply of supply chain assets
C5	Process-functional	
C51	Inventory and capacity buffers	The level of inventory that is taken to address disruption of supply chains (e.g., safety stocks)
C52	Flexibility capacities and sourcing	The capability of the buying firm and its processes to respond or react rapidly to changing supply requirements, and the possibility to respond to short-term changes in demand or supply situations. of other external disruptions together with the adjustment to strategic and structural shifts in the environment
C53	Omni-channel	Omni-channel supply chains also serve customers across different channels and it is fully integrated to provide a seamless customer experience
C54	Product diversification and substitution	Increasing choices when to order what supplies and from whom to bring products to the market

A survey questionnaire was sent to the companies, that were supposed to evaluate the importance of a particular criterion when choosing viable suppliers (VS). The grades ranged in value from 1 to 7 in which grade one is the lowest grade and indicates that the criterion has no importance for the company, while grade seven is the highest and indicates that the criterion has great importance for the company. Other values are formed about the importance of the criterion for the company. The 7-grade scale was used to enable respondents with more freedom of expression about the importance of specific criteria and sub-criteria for the selection of viable suppliers. Having in mind the volume of different sub-criteria used, a wider scale enables better understanding of the importance of individual subcriteria.

After the data was collected from the companies, using the Survey Sparrow online survey software, it was necessary to convert the data for analysis. The conversion was done by transferring all the data to Microsoft Excel. This program was then used to determine the weights of the VS criteria.

Weight calculation was done as follows. Based on the company information, the average rating was determined. If the difference between criteria is 0.1, one criterion is considered to be slightly less significant, if the difference is 0.2, one criterion is considered to be moderately less significant, etc. according to the scale of values used in the IMF SWARA (Improved Fuzzy Stepwise Weight Assessment Ratio Analysis) method.

The IMF SWARA method represents a modification of the SWARA method developed by (Keršuliene et al., 2010). IMF SWARA modifies the fuzzy SWARA (Stepwise Weight Assessment Ratio Analysis) method (Vrtagić et al., 2021). This method uses the same steps as the SWARA method except that it uses a different scale of values (table 2)

Table 2. Scale for the evaluation of the criteria

Linguistic Variable	Abbreviation	TFN Scale		
absolutely less significant	ALS	1	1	1
dominantly less significant	DLS	1/2	2/3	1
much less significant	MLS	2/5	1/2	2/3
really less significant	RLS	1/3	2/5	½
less significant	LS	2/7	1/3	2/5
moderately less significant	MDLS	1/4	2/7	1/3
weakly less significant	WLS	2/9	1/4	2/7
equal significant	ES	0	0	0

The basis of IMF SWARA, like all SWARA methods, has the following steps (Stanujkić et al., 2021):

Step 1. Identification and selection of criteria

Step 2. Sorting the criteria according to their importance from the most to the least important

Step 3. Determining the relative importance of criteria. Here, the criterion that has the greatest importance takes the value of one (1), while the value of the other criteria is determined by their importance.

Step 4. Calculation of the coefficient value K_j, based on expression:

$$K_j = \begin{cases} 1 \; if \; \text{j} = 1 \\ s_j + 1 \; if \; \text{j} > 1 \end{cases} \quad (1)$$

Step 4. Calculation of significance values q_j, based on expression:

$$q_j = \begin{cases} 1 \; if \; \text{j} = 1 \\ \frac{q_{j-1}}{k_j} if \; \text{j} > 1 \end{cases} \quad (2)$$

Step 5. Calculating the weight of criteria w_j , based on expression:

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_k} \quad (3)$$

More details about this procedure will be given in the results section.

After the weight for the criteria and sub-criteria were determined for all observed companies in total, the weights were determined for certain companies divided by their main location and by the location of suppliers. After companies were subgrouped, criteria and sub-criteria weights were calculated for those groups, and a comparison of those weights was conducted. The obtained weights were compared by correlation Person analysis for weights correlation and Spearman for rank correlation.

4. Results

A prepared survey questionnaire was sent to the addresses of 273 companies, with which companies assessed the importance of criteria for selecting valid suppliers. A total of 67 companies filled out the questionnaire, while 64 completed questionnaires were suitable for analysis. Companies from different parts of the world participated in the research, most of them from Europe (Figure 2).

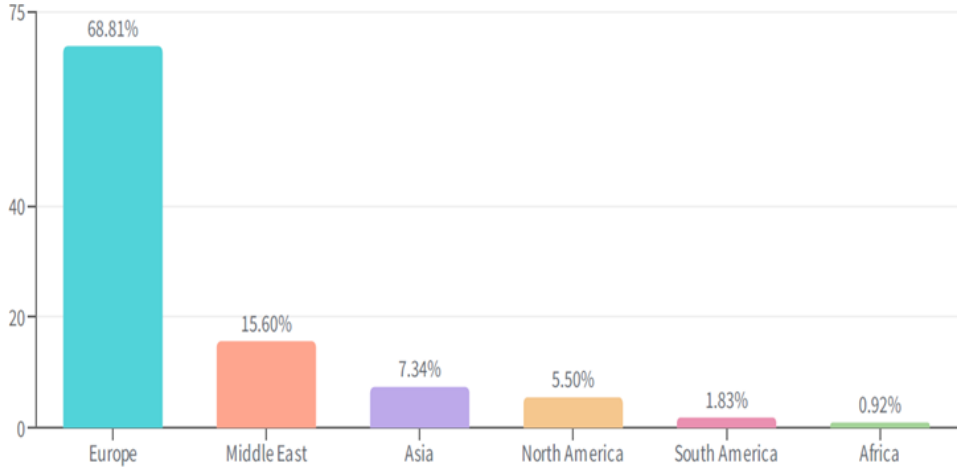

Figure 2. Respondent profile: Main location

Bearing in mind the specificity of the research problem, it was interesting to see if there are different perceptions about the importance of the VS criteria among companies that have suppliers from the local and national markets, compared to companies that mainly deal with suppliers outside national borders. Figure 3 shows the percentage of participation of companies in the research from the aspect of the location of their suppliers.

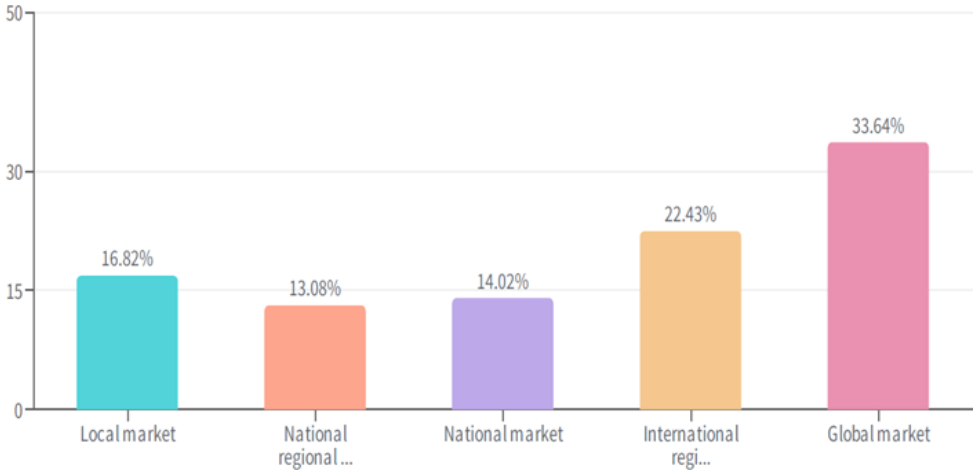

Figure 3. Respondent profile: Location of suppliers

The results presented in Table 3 were obtained based on the completed questionnaires. The results showed (Table 3) that criterion C2 has the highest overall score (sum = 265) and the highest average score (mean = 5.80), while sub-criterion C25 has the lowest overall score. grade (sum = 192) and the lowest average grade (mean = 4.39). Regarding the deviation of grades from the mean value of the largest deviation, sub-criterion C14 (SD = 1.87) has the corresponding highest dispersion of grades, while sub-criterion C12 (SD = 1.06) has the smallest dispersion of grades. This deviation calculated by the indicator of standard deviation shows that if the value of this indicator is higher, the higher the score deviates from the average score and vice versa. The maximum value of all criteria is 7, while the minimum score for criteria is 1, that is, for criteria C2 and C4, the lowest score is 3.

After the data were collected, they were processed to calculate the weights of the criteria and sub-criteria. Using the example of the main criteria, the method of determining the weight of the criteria is explained. The importance of the criteria was determined based on the aggregate evaluation. The main criterion with the highest sum was placed first, then the criterion with the next highest number of marks. In this way, the criteria are ordered by their importance (table 3). Value *sj* was formed in this way by subtracting the total scores of the Information criterion from the total scores of the Finance criterion.

Table 3. Descriptive research results

Criteria	Overall score	Mean	Standard deviation	Maximum score	Minimum score
C1	247	5,47	1,33	7	1
C11	247	5,42	1,28	7	1
C12	238	5,22	1,05	7	1
C13	211	4,78	1,67	7	1
C14	208	4,81	1,87	7	1
C2	265	5,80	1,06	7	3
C21	208	4,81	1,54	7	1
C22	221	5,02	1,45	7	1
C23	235	5,31	1,41	7	1
C24	221	4,95	1,52	7	1
C25	192	4,39	1,54	7	1
C3	255	5,56	1,31	7	1
C31	230	5,02	1,56	7	1
C32	203	4,61	1,71	7	1
C33	221	4,98	1,64	7	1
C34	213	4,80	1,61	7	1
C4	260	5,66	1,13	7	3
C41	256	5,55	1,32	7	1
C42	230	5,06	1,33	7	1
C43	230	5,13	1,28	7	1
C5	243	5,39	1,28	7	1
C51	239	5,36	1,25	7	1
C52	242	5,39	1,32	7	1
C53	223	4,95	1,27	7	1
C54	239	5,25	1,15	7	1

After the data were collected, they were processed to calculate the weights of the criteria and sub-criteria. Using the example of the main criteria, the method of determining the weight of the criteria is explained.

The importance of the criteria was determined based on the average evaluations of the criteria. The main criterion that had the highest average score was placed first, then the criterion that had the next highest average score was placed in second place, etc. In this way, the criteria were ordered by their importance (table 3). The value s_j was formed in such a way that the average evaluations of the criteria were observed. For example, the difference from the average ratings of the Information and Finance criteria is 0.1, and then the weakly less significant (WLS) value is taken from the value scale. If the difference is 0.2, it is a value moderately less significant (MDLS). In this way, the values for all differences were determined and the value for s_j was formed. The value k_j was formed by adding one (1) to the value sj (expression 1). The value q_j was formed based on expression 2. For the Information criterion, the value was overwritten, and the value one (1) was overwritten, for the finance criterion, the value q_j of the previous criterion (in this case, the Information criterion) was divided by the value k_j of that criterion. The q_j values for all criteria were formed in the same way.

Then all q_j values were added. The value of w_j was formed by dividing the individual values of q_j by the aggregate value of q_j (expression 3).

The results obtained in this way show that the Information criterion (w = 0.27) received the highest weight value, while the Process-functional criterion (w = 0.11) received the lowest value (table 4)

Table 4. Calculation of weights for the main criteria

Criteria	s_j			k_j			q_j			w_f			w_j
Information	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.28	0.27	0.25	0.272
Finance	0.22	0.25	0.29	1.22	1.25	1.29	0.82	0.80	0.78	0.23	0.22	0.20	0.217
Technology	0.22	0.25	0.29	1.22	1.25	1.29	0.67	0.64	0.60	0.19	0.18	0.15	0.174
Organization	0.22	0.25	0.29	1.22	1.25	1.29	0.55	0.51	0.47	0.15	0.14	0.12	0.139
Process-functional	0.22	0.25	0.29	1.22	1.25	1.29	0.45	0.41	0.37	0.12	0.11	0.09	0.111
						sum	3.48	3.36	3.22				

In the same way, the decision matrices for the sub-criteria were formed and the weights of the sub-criteria were calculated (table 5). In the Organization criterion, sub-criterion C11 (w = 0.347) received the highest weight, while sub-criterion C13 and C14 (w = 0.192) received the lowest weight. For the Information criterion, sub- criterion C23 (w = 0.286) received the highest weight value, while sub-criterion C25 (0.119) had the lowest value. In the Technology criterion, sub-criterion C31 and C33 (w = 0.296) received the highest weight, while sub-criterion C32 (w = 0.179) received the lowest weight value. In the Finance criterion, sub-criterion C41 (w = 0.413) received the highest weight value, while sub-criterion C42 and C43 (w = 0.294) received the lowest weight value. For the Process-functional criterion, sub- criterion C51 and C52 (0.294) received the highest weight value, while sub-criterion C53 (w = 0.176) received the lowest weight value.

Table 5. Calculation of weights of sub-criteria

Criteria	sj			kj			qj			wf			wj
C11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.32	0.33	0.35	0.347
C12	0.25	0.29	0.33	1.25	1.29	1.33	0.80	0.78	0.75	0.26	0.26	0.26	0.269
C13	0.25	0.29	0.33	1.25	1.29	1.33	0.64	0.60	0.56	0.21	0.20	0.20	0.192
C14	0.00	0.00	0.00	1.00	1.00	1.00	0.64	0.60	0.56	0.21	0.20	0.20	0.192
						sum	3.08	2.99	2.88				
Criteria	sj			kj			qj			wf			wj
C23	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.27	0.29	0.30	0.286
C21	0.29	0.33	0.40	1.29	1.33	1.40	0.78	0.75	0.71	0.21	0.21	0.22	0.214
C22	0.00	0.00	0.00	1.00	1.00	1.00	0.78	0.75	0.71	0.21	0.21	0.22	0.214
C24	0.25	0.29	0.33	1.25	1.29	1.33	0.62	0.58	0.54	0.17	0.17	0.16	0.166
C25	0.33	0.40	0.50	1.33	1.40	1.50	0.47	0.42	0.36	0.13	0.12	0.11	0.119
						sum	3.64	3.50	3.32				
Criteria	sj			kj			qj			wf			wj
C31	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.29	0.30	0.30	0.296
C33	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.29	0.30	0.30	0.296

C34	0.25	0.29	0.33	1.25	1.29	1.33	0.80	0.78	0.75	0.23	0.23	0.23	0.230
C32	0.25	0.29	0.33	1.25	1.29	1.33	0.64	0.60	0.56	0.19	0.18	0.17	0.179
						sum							
Criteria	s_j			k_j			q_j			w_f			w_j
C41	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.40	0.41	0.43	0.413
C42	0.33	0.40	0.50	1.33	1.40	1.50	0.75	0.71	0.67	0.30	0.29	0.29	0.294
C43	0.00	0.00	0.00	1.00	1.00	1.00	0.75	0.71	0.67	0.30	0.29	0.29	0.294
						sum	2.50	2.43	2.33				
Criteria	s_j			k_j			q_j			w_f			w_j
C51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.29	0.29	0.30	0.294
C52	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.29	0.29	0.30	0.294
C54	0.22	0.25	0.29	1.22	1.25	1.29	0.82	0.80	0.78	0.24	0.24	0.23	0.235
C53	0.29	0.33	0.40	1.29	1.33	1.40	0.64	0.60	0.56	0.18	0.18	0.17	0.176
						sum	3.45	3.40	3.33				

The global values of those sub-criteria were calculated based on certain weights for the main criterion and its sub-criteria. These values were calculated in such a way that the weight values of the sub-criteria were multiplied by the weight values of the corresponding criterion. In this way, the weights of the sub-criteria for SVS were formed (table 6). Sub-criterion C41 (w = 0.0896) has the highest weight, followed by sub-criterion C23 (w = 0.0778), while sub-criterion C53 (w = 0.0195) has the lowest weight. These results showed that the sub-criteria of the Finance criterion received the highest weight values.

Table 6. Weights of sub-criteria of viable suppliers

Criteria	Local value	Global value	Rank
Organization	0.139		
C11	0.347	0.0482	9
C12	0.269	0.0374	12
C13	0.192	0.0267	17
C14	0.192	0.0267	17
Information	0.272		
C21	0.214	0.0582	5
C22	0.214	0.0582	5
C23	0.286	0.0778	2
C24	0.166	0.0452	10
C25	0.119	0.0324	15
Technology	0.174		
C31	0.296	0.0515	7
C32	0.179	0.0311	16
C33	0.296	0.0515	7
C34	0.230	0.0400	11
Finance	0.217		
C41	0.413	0.0896	1
C42	0.294	0.0638	3
C43	0.294	0.0638	3
Process-functional	0.111		

C51	0.294	0.0326	13
C52	0.294	0.0326	13
C53	0.176	0.0195	20
C54	0.235	0.0261	19

In the same way, as sub-criteria weights were determined for all companies in total, criteria weights were determined for two sub-groups of companies that operate within national borders and outside national borders considered global companies. First, the companies were divided into those operating within national borders and those operating on the international market, and then weights were determined for these companies.

As with the aggregate weights, the sub-criteria of the Finance criterion received the highest weights in this scenario (table 7). By observing those weights using correlation analysis, it was determined that there is a good connection (r = .634). However, when the rankings between these companies were observed using the Spearman correlation coefficient, the correlation value was lower than when the weight of the criteria was observed (r = .333). Based on that, it can be determined that the weights did not change significantly, but the ranking orders did change. Even then there was no significant statistical difference between the observed ranking orders of the sub-criteria weights. The obtained results show us that there is still a difference, which is not statistically significant, between the importance of sub- criteria for companies according to their business location. The first criterion is in favor of companies operating in the global market, and the second sub-criterion is in favor of companies operating in the local market. The highest weight value for companies operating in the local market is for sub-criterion C41, while the lowest weight is for sub-criterion C14. When looking at companies operating on the global market, sub-criterion C41 has the highest weight, while sub- criterion C25 has the lowest weight. The biggest change in rankings was in sub- criteria C14 and C31, where the ranking changed by 15.

Table 7. Value of the criteria about the main location of the company

Criteria	Local value	Global value	Rank	Local value	Global value	Rank
	National borders			Global company		
Organization	0.1498			0.2141		
C11	0.3838	0.0575	8	0.2814	0.0603	6
C12	0.2979	0.0446	11	0.2302	0.0493	12
C13	0.1768	0.0265	17	0.2302	0.0493	12
C14	0.1414	0.0212	20	0.2968	0.0636	5
Information	0.3019			0.2478		
C21	0.1611	0.0486	10	0.2293	0.0568	8
C22	0.2152	0.0650	6	0.2293	0.0568	8
C23	0.2877	0.0868	2	0.2818	0.0698	3
C24	0.2152	0.0650	6	0.1713	0.0424	16
C25	0.0710	0.0214	19	0.1217	0.0302	20
Technology	0.1874			0.1708		
C31	0.3511	0.0658	3	0.2091	0.0357	18
C32	0.1646	0.0308	14	0.2091	0.0357	18

C33	0.2726	0.0511	9	0.3313	0.0566	10
C34	0.2118	0.0397	12	0.2617	0.0447	15
Finance	0.2412			0.2141		
C41	0.4578	0.1104	1	0.4132	0.0885	1
C42	0.2711	0.0654	4	0.2521	0.0540	11
C43	0.2711	0.0654	4	0.3244	0.0695	4
Process-functional	0.1198			0.2141		
C51	0.2523	0.0302	15	0.3446	0.0738	2
C52	0.3157	0.0378	13	0.2781	0.0595	7
C53	0.1809	0.0217	18	0.1677	0.0359	17
C54	0.2523	0.0302	15	0.2159	0.0462	14

The following analysis was taken into account the location of suppliers. Thus, companies were divided into two sub-groups: those whose suppliers are within national borders and those whose suppliers are outside of national borders. The results showed (table 8) that when we use this structure of a grouping of companies, the sub-criteria of the Finance criterion had the highest weight values. Observing the connection between the values of the weights of the sub-criteria, there is a greater connection than was the case with the sub-grouping companies by their main location (r = .636). Looking at the ranking of the alternatives using the Spearman correlation coefficient, there is a greater connection (r = .355).

The highest weight in the sub-criteria for companies that use a global supplier is C22, while the lowest weight is in sub-criteria C32. When looking at companies with suppliers from the global market, the highest weight is in sub-criterion C41, while the lowest is in sub-criteria C13 and C14. When looking at the rankings, the biggest change was in sub-criterion C34, where the change was in favor of companies that use global suppliers.

Table 8. Value of the criteria about the location of suppliers

Criteria	Local value	Global value	Rank	Local value	Global value	Rank
	National suppliers			Global suppliers		
Organization	0.2069			0.1262		
C11	0.3540	0.0732	4	0.3641	0.0459	12
C12	0.2649	0.0548	8	0.2908	0.0367	15
C13	0.1693	0.0350	16	0.1726	0.0218	19
C14	0.2118	0.0438	12	0.1726	0.0218	19
Information	0.2765			0.2542		
C21	0.2183	0.0604	5	0.1553	0.0395	14
C22	0.2732	0.0755	1	0.2075	0.0527	7
C23	0.2183	0.0604	5	0.3134	0.0796	2
C24	0.1745	0.0482	10	0.2075	0.0527	7
C25	0.1158	0.0320	18	0.1164	0.0296	17
Technology	0.1549			0.2542		
C31	0.3473	0.0538	9	0.2988	0.0759	3
C32	0.1675	0.0259	20	0.1788	0.0454	13
C33	0.2697	0.0418	13	0.2988	0.0759	3

C34	0.2156	0.0334	17	0.2236	0.0568	6
Finance	0.2069			0.2031		
C41	0.3572	0.0739	2	0.5000	0.1016	1
C42	0.2855	0.0591	7	0.2500	0.0508	9
C43	0.3572	0.0739	2	0.2500	0.0508	9
Process-functional	0.1549			0.1624		
C51	0.1973	0.0306	19	0.2830	0.0460	11
C52	0.2469	0.0382	14	0.3542	0.0575	5
C53	0.2469	0.0382	14	0.1510	0.0245	18
C54	0.3089	0.0478	11	0.2118	0.0344	16

5. Discussion

Viable suppliers become a very important tool in sustaining project business during long-term disruptions. Thus, the framework for the selection of viable suppliers proposed by Ivanov (2020) seems very suitable for long-term disruptions such as the Covid-19 pandemic, or similar events that can cause long-term disruptions (Ivanov, 2020). This study aimed to rank the main criteria and sub-criteria based on this framework.

As per the findings, the most important criterion for selecting viable suppliers is the Financial criterion. The characteristics of the effects of long-term disruptions on project business can justify this. The first visible effect of the Covid 19 pandemic was the delay in delivering projects. Keeping in mind contractual obligations in terms of delivering dates caused penalties for project organizations and delays in charges for carrying out projects.

Additionally, the costs of raw materials and sub-components that should be included in project deliverables increased. Putting it all together and considering the duration of the supply chain disruption, this affected great challenges in managing cash flow for project organizations, putting them into a serious situation that brought many project organizations to the brink of survival. Therefore, the result of the study, which places the Financial criterion in the first place in the selection of suppliers, is quite justified. Similar findings are provided by Zamani et al. (2020) who showed two major issues; operational and financial including late payment increased cost of the project and declining number of projects. Payments are made as the project phase completes (Zamani et al., 2020). During the Covid 19 pandemic, the payments were delayed when government operations were impeded. As a result, companies suffered from working capital problems. Additionally, due to increased demand and reduced supply of materials, the cost of materials rose.

In addition, among the other 20 sub-criteria, the sub-criterion Liquidity reserves from the Finance main criterion is ranked as the most prominent, which further gives the impression of the importance of available cash and cash equivalents during long-term disruption. As a secondly ranked sub-criterion was Inventory and capacity buffers from the Process-functional criterion. This sub-criterion refers to the inventory level taken to address the disruption of supply chains (e.g., safety stocks). As per this finding, just in time approach should not be the focus of the procurement strategy of project organizations.

Delays in delivering projects and issues with the rising costs of raw materials raise the issue of availability of raw materials during disruptions, thus safety stocks are necessary regardless of additional inventory costs that they raise. As the third sub-criterion is the Additive manufacturing from the Technology main criterion which is about digital manufacturing technology enables companies to rethink their supply chain design.

Due to preventive measures that were taken during Covid 19 pandemic, it is necessary to find an additional solution for supply channels that will replace the one under disruption. Thus, the technology that enables fast redesign is appreciated by project organizations. The revenue management sub-criterion is ranked in fourth place. It refers to the use of pricing to increase the profit generated from a limited supply of supply chain assets. Rising costs of raw materials that occur during long-term disruptions increase the cost for project organizations. Those project organizations that had fixed-cost contractual relations with their customers felt all the negativity of this kind of relationship in the period of long-term disruption. Thus, the tools of revenue management should be reconsidered carefully to address these types of challenges.

Katsaliaki et al. (2021), while analyzing the operational and financial impact of supply chain disruptions, found a correlation with the increased globalization of businesses (Katsaliaki et al., 2022). A big challenge for project companies is their previous full orientation to cost reduction which has been achieved through the offshoring and outsourcing of many manufacturing and R&D (Research and Development) facilities, especially in emerging markets and underdeveloped nations.

For these supply chain operations to be successful, the economy and business environment must be stable. However, due to globalization, economies have become interconnected, leading to supply chain operations being vulnerable to global disruptions. For instance, US retailers reported a massive $700 million loss from production and transportation shortages due to Coronavirus. Katsaliaki (2021) highlighted also that hindrances in cargo movement, infection prevention control, and labor shortage accumulated supply disruption (Katsaliaki et al., 2022).

However, we should not think only on Covid 19 pandemic as a cause of long-term disruptions. There are many other causes. Although wars occur in developing and underdeveloped economies, their effects penetrate global supply chains, endangering the global supply of metals, energy, and agrarian commodities supplied by war zones. According to Jola-Sanchez & Serpa (2021), a typical war generates approximately $14.4 trillion in costs including $98.3 billion in losses in the supply chain. During conflicts, the fighters attack business facilities and workers, thwarting supply networks and daily operations (Jola-Sanchez & Serpa, 2021). Hence, fair policymaking is extremely pivotal for global supply chain assurance and mitigating war's crippling effects.

According to our study, information is also a pivotal indicator for the selection of viable suppliers. This is in line with the findings by Bäckstrand and Fredriksson (2020) who identified how supplier information can affect delivery patterns in construction businesses (Bäckstrand & Fredriksson, 2022). It was deduced that a lack of supplier information and coordination resulted in a surplus/shortage of goods, data entry errors (wrong address or wrong transport inputs), extra administration costs, and delayed deliveries.

Based on this study, digital communication methods, weekly meetings, and B core SCM software allow the free flow of information. Consequently, these methods would aid businesses to avoid hindrances in projects due to a lack of information flow. Our study indicated the very strong importance of Digital twins that enables Computerized Supply Chain models of real state network or virtual supply chain replica that consists of hundreds of assets, warehouses, logistics, and inventory positions used for prediction. This sub-criterion is ranked in fifth place.

Considering the period of lockdowns in specific counties during the Covid 19 pandemic, it is crucial to see some alternative possibilities for supply while simultaneously keeping the focus on minimizing the costs. Thus, Digital twins can play a very important role, and a suggestion for software developers is to find these findings as an opportunity for business collaboration with project organizations around the world.

The organization is among lowers ranked criteria, but still important for the selection of viable suppliers. Thus, we should agree with Hou & Sun (2016) who suggested adjusting sourcing decisions to cope with long-term disruption (Hou & Sun, 2016). This scholar proposed several strategies that can work. The first strategy is to have a single-source supplier along with a contingent supplier. Under this strategy, the contingent supplier restores inventory during unexpected events when the main supplier faces disruption. However, firms may suffer due to contingent suppliers' lack of adequate capacity or technical uncertainty. This is because of variability in the production coefficient. The results showed that companies would benefit from stocking more under long disruptions rather than using contingent suppliers. A larger disruption probability increases the firm's optimal base stock level and expected cost.

The second sourcing strategy is the dual sourcing strategy. The firm uses a second supplier as a regular source when the supply chain of the first supplier is disrupted. According to the literature, bifurcating orders among different suppliers can mitigate the disruption caused by the pandemic. The strategy is beneficial, as the second supplier can increase its output with extra capacity. The study observed that buyers prefer to stock more during a large disruption to avoid large purchasing costs.

Process-functional criterion was ranked in last place for the importance of the selection of viable suppliers. We cannot say it is not an important criterion, but compared with other criteria, it has not the same value when selecting a viable supplier. Zamani et al. (2020) pointed out that construction projects had to follow "standard operating procedures", causing a slow and lengthy project timeline (Zamani et al., 2020). Authority offices were closed during Covid 19 pandemic hence, getting approval for processes became time-consuming leading to delays in project completion. Secondly, foreign workers were sent back to their respective countries during the pandemic as their work permits expired. Logistics was another factor that caused delays in the projects. For instance, most project materials were imported from foreign countries.

As the supplier operations were suspended due to the pandemic, the deliveries of materials ceased. Even when government regulations were relaxed, the delivery of supplies became slow due to new procedures that needed to be followed. Thus, although ranked last place, the Process-functional criterion should also take a place in deciding on supplier selection.

Some measures proposed by Perez-Batres & Treviño (2020) can work for this situation (Perez-Batres & Treviño, 2020). He suggested a physical hedging supply chain option that enables global suppliers to continue operations during pandemics. It's essential to create physical capacity to power supply chains when lockdown measures are put into effect. Hence, businesses and governments should build regional sourcing by creating miscellaneous webs of indispensable supply chain nodes in low-density locations that are less likely to be affected by pandemics, avoiding global supply chain systemic disruptions.

Additionally, other benefits include increased job creation, enhancement of human resources, regional development, and, global supply chain survival. However, economists would argue against this strategy, as this would threaten global connectedness. Secondly, the globalization of the supply chain is responsible for huge productivity and monetary gains during normal economic conditions. This strategy is more likely to focus on adverse and abnormal economic conditions.

To better understand which criteria are more important while selecting viable suppliers, it is not only important to look at findings in general. It is also important to the importance of main criteria and sub-criteria for different types of companies. It is not the same if a company has suppliers only within national borders, or outside of the national borders. Usually, during Covid 19 pandemic the lockdowns disabled communication outside of national borders preventing people and goods from entering the national market. Thus, the same criteria for supplier selection are not always the same for companies that have different supplier profiles. Our study provides adequate insight taking into consideration also this perspective. Determining sub-criteria weights is significant because if there is a difference between them, it means that the importance of the sub-criteria is different for companies that operate within the national border compared to those that operate on the global market. Having in mind the specificity of long-term disruptions of supply chains that are sometimes affected by closing national borders for a transition of people and goods, and Covid 19 pandemic is an example, this is very important to understand.

6. Conclusion

The evolution of the literature regarding the choice of suppliers is evident. Various challenges have led to a change in the framework for supplier selection, starting with a focus on price-based supplier selection, agile suppliers, and a reorientation of sustainable suppliers. The Covid 19 pandemic unexpectedly impacted project organizations that had contracted business ventures. The first visible effect was a delay in the implementation of projects that lasted several months. Another obvious effect was the increase in costs caused by the delay, which increased prices. This was a challenge for some project companies that had fixed contracts and it was very difficult to adjust the price to the newly created circumstances of increased costs. Precisely this situation demanded a reorientation towards the selection of viable suppliers that enable survival in the period of long- term disruption of supply chains.

This paper aimed to assess the importance of certain criteria in the selection of viable suppliers. In this research, 5 basic and 20 sub-criteria were evaluated. The results show that the financial criterion was evaluated as the most important. This

indicates that in the period of long-term disruption of supply chains, the greatest danger lies in the financing of business when there is a long-term disruption in project operations. This fact is also indicated by the most important evaluated sub- criterion: Liquidity reserves showing the importance of available cash and cash equivalents during long-term disruption.

Due to the interruption of business operations, but also due to unavoidable running operating costs, many companies found themselves in a liquidity problem, so their survival was threatened. Thus, the financial criterion take the most important place in the selection of viable suppliers. After the Financial criterion, the results show the order of importance of the other main criteria, namely Information, followed by the Technology criterion, then followed the Organization criterion, while the Process-functional criterion is ranked in the last place. This distribution of importance of the criteria indicates that having timely information about possible disruption, but also information about alternative solutions, becomes very crucial in the period of supply chain disruption.

The research results made it possible to understand the importance of certain criteria for selecting viable suppliers that were proposed within the Viable supplier framework. They provide a good basis for enacting public policies that would help project companies survive the conditions of long-term supply chain disruption.

The results of the research provide a good basis for companies when choosing suppliers in the period of long-term disruption of supply chains. The recommendation to companies is to consider the importance of certain criteria and to apply this model when choosing suppliers. The results of the research can help in the development of stimulation policies by government bodies to avoid the negative consequences of long-term disruption of supply chains.

The limitation of the research is the inclusion in the survey of companies of different profiles from different sectors. Companies from different sectors have their specificities regarding the supply chain, and it is necessary to take that fact into account. This study included companies from different sectors, so the results can be viewed as general without taking into account the specifics of individual business sectors. One of the limitations is the number of companies that responded to this questionnaire.

Having in mind the limitation of this study, the recommendation for future research is to provide structured research that will determine the possible difference in ranking criteria for selecting viable suppliers in different sectors and industries. Our assumption after conducting research is that companies operating in different sectors have different priorities when choosing viable suppliers. Therefore, it would be interesting to conduct similar analyzes in individual sectors, especially those that were most affected by supply chain disruptions over a long period. This research provides a good basis for future similar research that will introduce additional specifics about the selection of viable suppliers.

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