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DEVELOPMENT OF AN INTELLIGENT DECISION-MAKING SUPPORT SYSTEM FOR THE SELECTION OF RAW MATERIAL MANUFACTURERS TO BE SUPPLIERS IN HEALTHY FOOD PRODUCTION COMPANIES IN THE CONTEXT OF GLOBAL SUPPLY RISKS

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Abstract

Like the entire food production industry, the market for producing and trading healthy food products faces uncertainty. These days it has a direct relationship with global challenges such as instability of energy prices, breakdown of supply chains, lack of raw materials necessary for food production, climate change and its consequences, and other difficult-to-predict aspects, that have a considerable impact not only on the price of finished products but also on the possibilities of realization on the market. Consequently, to ensure at least the minimum stability of the market for the production of healthy products, companies need an academic support tool, the application of which can help absorb the challenges posed by global markets. This article analyzes the main risks arising for this market due to the unstable raw material supply market. Moreover, it analyzes possible alternatives when choosing supply channels and suppliers. Hence, it raises a dilemma: Is it indispensable to follow all the main principles of sustainable development to manage risks and ensure the production of healthy food products? The research aims to develop and practically test a methodological tool as an intelligent decision support system for healthy food production companies to help select the most suitable raw material suppliers in the context of global supply chain risks.

The authors of this article, using an expert assessment method and multi-criteria mathematical modeling SAW, provide a tool with the help of which companies can make decisions related to the choices of raw material suppliers to adapt to emerging global risks while minimally violating the principles of sustainable development. The novelty of this research stems from the fact that it is rare research that uses a comparative analysis of simple additive weighting to show the value and the cost of each alternative for the selection of raw material suppliers in healthy food production companies. Consequently, research fills a knowledge gap and presents a tool to help companies make informed decisions. To create a practical tool for the evaluation of the best suppliers under multicriteria evaluation, it must be possible to adapt that evaluation to specific conditions for risk management under changes in the global market.

In the research, the most important task solved was the selection of appropriate criteria for the assessment of raw materials suppliers. The SAW method for multicriteria evaluation is recognized as the most suitable method of evaluation of companies when you need to select the most suitable one to prevent the main risks in the context of global challenges. After systematizing the basic information about the process of raw materials supplier selection for the healthy food production industry and developing an evaluation tool, it was tested practically in a healthy food production company in Kaunas town (Lithuania). After performing an expert evaluation according to the criteria and after multi-criteria evaluation calculations, the priority list of the most suitable suppliers was created to prevent risk in the future if the situation in the global market changes in negative aspects.

The scientific potential of evaluating and selecting the most suitable raw materials suppliers for healthy food production companies is critical in the context of global risks that apply under situations of energy crisis, war, pandemic, economic risks, and other global challenges. Only by using an intelligent support system for the selection of the most suitable ram materials suppliers and having prepared a list of alternatives ones, healthy food production companies make sure to manage main risks and successfully compete in the global market. The proposed intelligent decision-making tool has been tested in real business conditions, and its suitability is fully justified.

***Key words**: Risks, Supply Chain, Healthy Food Production, Decision Making, SAW.*

1. Introduction

Like the entire food production industry, the market for producing and trading healthy food products faces uncertainty. The poorly designed food supply chain is considered a root cause of the industry. Since all processes and stages in the supply chain are connected, a slight delay or glitch can trigger a butterfly effect resulting in significant socioeconomic losses [1]. Moreover, Lillford and Hermansson stated that achieving many sustainable development goals has a critical reliance on the food chain at both a global and local level [2].

Moreover, the covid-19 has caused considerable damage to various industries worldwide. Therefore, the availability and supply of a wide range of raw materials, intermediate goods, and finished products have been seriously disrupted [3]. These days it has a direct relationship with global challenges such as instability of energy prices, breakdown of supply chains, lack of raw materials necessary for food production, climate change and its consequences, and other difficult-to-predict aspects that have a considerable impact not only on the price of finished products but also on the possibilities of realization on the market. According to Glencross *et al.*, [4], using any raw material introduces a suite of risks that need to be considered to enable the production of safe, sustainable, and functional feeds to underpin this sector.

According to the works of Xu *et al.*, [5], and Abdel-Basset *et al.*, [6], disruption risks in supply chain management have a tremendous negative influence on the performance of supply chain members. Moreover, Due to increased uncertainty, the significant risk considerations have grown. Furthermore, risks become a critical part of our lives since they involve everything we do and participate in. As stakeholders increasingly hold firms accountable for environmental and social performance in their supply chains, the importance of understanding how firms can be more sustainable becomes more prescient [7 - 11].

Increasingly health-conscious consumers demand better food quality, such as improved food safety, nutritional value, freshness, and flavors [12]. Furthermore, Cavallo and Sacchi [13], and Bracale and Vaccar [14] in their research underline a vital opportunity to advance the understanding of changing consumer behavior. Moreover, the increase in the consumption of some types of food is linked to their symbolic value and their tendency to carry on at home some external socialization habits. On the other hand, Misra and Mention [15], Granato *et al.*, [16], and Santeramo *et al.*, [17], underlined that great interest is devoted to the changes in consumers' preferences and expectations as well as to the analysis of food innovations and their impact on the global market.

Furthermore, in the research by Grunert [18], Kearney [19], and Bigliardi and Galati [20], the food industry has been facing technical and economic changes both in society and in manufacturing and food processing, that in turn had a significant impact on the entire food supply chain, up to the distribution of food to end consumers, and forced companies to pay great attention in food products that meet the consumers' demand for a healthy lifestyle. Moreover, in recent years, consumers have been demanding convenient and healthy foods with 'fresh-like' characteristics while still being safe and having a long shelf-life [21].

Transforming the current food system simultaneously towards providing healthy diets and environmental sustainability constitutes one of the grand challenges of current times [22]. Moreover, Sharma *et al.*, [23], and Duan *et al.*, [24], claimed that fundamental changes in agriculture and food production are inevitable. Besides, food systems are complex and keep changing over time. Hence, the current set-up of food supply chains is an important cause of inefficiencies in food production. These inefficiencies should be reduced to guarantee food security for a growing world population and improve the future responsible production and consumption of food products [25]. Lastly, according to Panghal *et al.*, [26], and Van Ruth *et al.*, [27], expanding the food industry within and beyond national borders has resulted in complex collaborative networks and supply chains.

The research by Hobbs [28], Parfitt *et al.*, [29], and Ahumada and Villalobos [30], discusses the effects of demand-side shocks on food supply chains, including consumer panic buying behaviors concerning essential items and the sudden change in consumption patterns away from the food service sector to meals prepared and

consumed at home. Moreover, food supply chains impact the quality of the end product and the vitality of the businesses involved. Therefore, using blockchain-based systems to manage a supply chain offers significant benefits, such as faster and more reliable traceability [31].

Risk management plays a vital role in effectively operating supply chains in the presence of various uncertainties [32]. Moreover, risk management refers to implementing strategies and plans to manage supply chain networks through constant risk assessment and reducing vulnerabilities to ensure supply chain resilience [33]. According to Wicaksana *et al.*, [34], contemporary supply chains face myriad types of risks caused by unprecedented risk factors. This condition motivates us to develop a contemporary supply chain risk typology to help identify and monitor newly surfaced risks and reveal emerging topics and research collaborators to help foster impactful research in supply chain risk management. Besides, supply chains have eliminated most non-value-adding activities and have become leaner. However, lean supply chains without much inventory are more vulnerable to disturbances in logistic processes, which means that they might be less consistent in their performance [35]. The article aims to provide a support system for the selection of food suppliers for healthcare institutions.

The aim of the research- is to develop and practically test a methodological tool as an intelligent decision support system for healthy food production companies to help select the most suitable raw material suppliers in the context of global supply chain risks.

2. Materials and Methods

For the evaluation of suppliers of raw materials, a Lithuanian food production company was selected, which has 4 factories in Lithuania and exports its products to 40 countries of the world. Given the unstable market situation and global challenges of recent years, the company pays great attention both to social responsibility and to the ability to quickly respond and adapt to global challenges. This company agreed to participate in the study and chose to analyze flour suppliers as a pilot study. It is necessary to note that the company's raw materials suppliers include the countries of Lithuania, the Baltic States, Europe, and East Asia. For priority work, the determination of the significance of the criteria was carried out.

To provide scientific assistance in decision-making in choosing the right suppliers of raw materials for producers of healthy foods, it is necessary to delve into the content of the decision-making tasks in light of national and global challenges. The selection of suppliers of raw materials is classified as a multi-criteria task by Aissaoui *et al.*, [36], Ho *et al.*, [37], and Sanayei *et al.*, [38], which, depending on the management of risks, must be solved as a complex task consisting of a set of partial tasks. The assessment assesses not only the supplier as a natural person but also its resistance to risks and the impact of emerging risks both on the reliability of the raw material supplier and on the stability of the food manufacturer's activities. Common in the scientific literature and a variant of three tasks is the search for suppliers, their evaluations, and negotiations [38, 39]. They are sometimes accompanied by a monitoring of the execution of supply contracts [37]. In this article, the authors also add a risk management component as mandatory because of modern challenges.

Summing up the options for managing the supplier selection process studied in the scientific literature, highlighting the interrelationships between the tasks to be solved, and integrating the risk management component, we see a meaningful approach to the selection of suppliers of raw materials as an eight-step process (Figure 1). It's a good idea to reveal both the content of the selection and the chain of this multidimensional process by introducing the risk management component.

The process begins with the search for suppliers of raw materials. This step of s consists of identifying the object of the search and identifying signs and sources of searching for information. Potential suppliers of raw materials are called subjects of economic activity and are identified by different signs: legal form, nature of activity, specialization in the geography of activity, etc. [40]. From the point of view of the validity of the search, the most important characteristic is the identification of the object of supply itself - the raw material. From the point of view of food production, the search for validity is carried out for each object of supply separately. The specificity of the object of supply as a feature of the search is individual in each case since also each healthy food production company can be distinguished by the specifics of food production [41]. The choice may depend not only on the nature of the object of supply but also on certain conditions of the buyer and his potential commercial situation and the global challenges affecting the market. The potential sources of information for the search for raw materials suppliers also differ in various attributes: the content of the information, the accuracy, and reliability of the data, the form of presentation, the possibility of obtaining it, the cost, the price, etc. This is methodically a seemingly uncomplicated task, without a clear system, it presents a lot of difficulties for practitioners. One of the possible options is the decision to make public the search for suppliers in the form of a tender and thereby analyze the possibilities of the market to meet the needs of enterprises engaged in the production of healthy food.

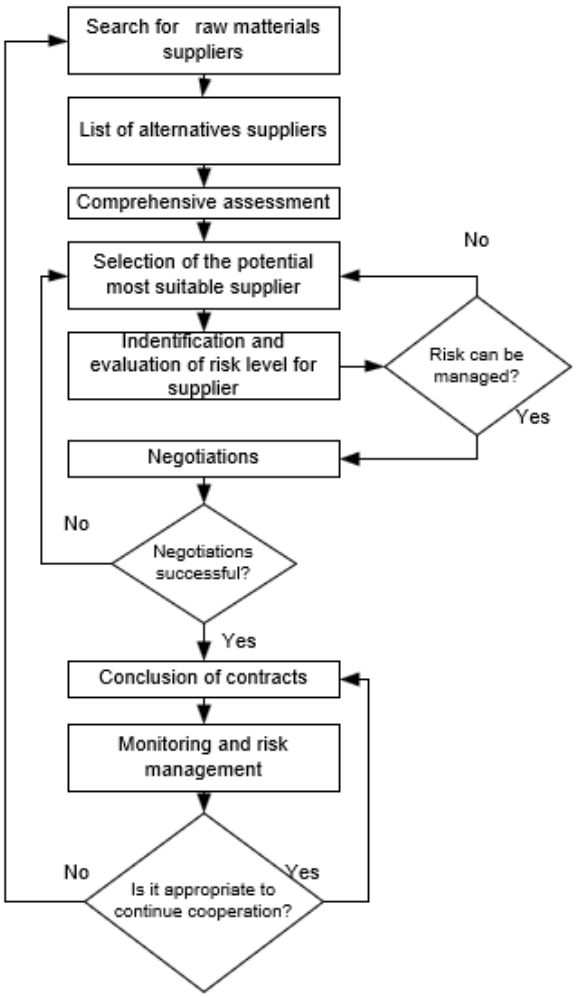

Figure 1. The process of selecting suppliers of raw materials in the context of risks

Compilation of a preliminary list of suppliers of raw materials is the systematization of the data accumulated after the first phase, distinguishing suppliers that meet the main characteristics posed and can meet the needs of the company. The complexity of this step is - first of all, there is a variety of possible solution options. The most problematic aspects of this task for decision-makers are as follows: a wide variety of information about the three types of main objects (supplier, object of supply, component of the supply object) in terms of content and attributes, the establishment of limits on the suitability of the characteristics of the supply objects, the assessment of the similarity of the supply objects in conditions of uncertainty and the management of existing risks. Properly organized preliminary selection will make it possible to reduce the unproductive costs of selecting suppliers of raw materials, which would be necessary for further evaluation processes.

The assessment is complex. Researchers argue that, from the point of view of content, the range of criteria must be sufficient to evaluate suppliers of raw materials in various aspects that affect the quality of future supplies in a broad sense. It is for this reason that the task of evaluating suppliers of raw materials is assigned to the category of multi-criteria tasks. This task is dealt with by answering two questions: what set of criteria and what rules for their application can ensure the necessary validity and objectivity of the assessment.

The complexity of the solutions for the selection of suppliers of raw materials and the significance of their results cause great attention from researchers in the context of especially global challenges. In the scientific literature, perhaps, many proposals for the evaluation of suppliers are beginning to be found, based on various methods [37, 42]. Although various assessment methods are applied to the assessment of suppliers, they are all characterized by multi-criteria. The formation of a set of evaluation criteria with the formation is named the second most important task of this step. The proposals for such sets vary widely, from a few to several dozen criteria, both quantitative and qualitative [37].

The generalized criteria for the selection of food suppliers for healthcare enterprises based on the sources of different authors are presented in Table 1.

Table 1. Criteria for the evaluation of raw materials suppliers [16] [17]

No.	Criterion	Explanation
k1	Reliability	Experience, financial situation, risk factors
k2	Ability to ensure quality products	Possibilities of application of modern technologies of food storage, processing, and transportation to ensure proper quality of food products
k3	Possibility to deliver goods on time	Adherence to delivery deadlines from order to delivery of fresh food
k4	Flexibility and productivity	Possibility to change fresh food order quantities and themes, possibility to supply fresh food in the required (required) quantity and frequency
k5	Price	The price that corresponds to the quality of service and satisfies the customer
k6	Traceability	Traceability is provided to manage risks on the part of the supplier under global regulation and sustainability.
k7	Additional guarantees and commitments	Guarantees and obligations are provided to manage risks on the part of the supplier.

Research has justified and clarified the importance and the need for the criteria provided to select the most suitable suppliers for food businesses [43, 44] (Table 1).

The presented criteria are emphasized by the above authors as essential for the selection of the most suitable suppliers of food raw materials in various contexts of global challenges that most serve the interests of healthy food producers and help to manage risks. Multi-criteria assessment methods help to choose not only the best but also the most reliable supplier of raw materials from the available alternatives, sort by importance, and rank from the most suitable and reliable to the least reliable [45, 46].

To determine the influence of the criterion on the choice of supplier of raw materials for food products, it is necessary to determine the significance of the criteria. Usually, it is done by expert assessment. Subjective or objective assessments can be used to determine the significance of the criteria. Mostly assessment is used to determine the significance of the criteria in the strictest way, i.e. when the significance of the criteria is determined by professionals in the required field, experts, and mathematical statistical methods are used to carry out the calculations [37]. Experts are considered to be middle and top managers of food production enterprises who have at least 5 years of work experience in the organization and implementation of the supply of raw materials for the production of food products.

The formed group of experts carries out the determination of the significance of the selected criteria. The criteria are different in terms of their weight for decision-making and have different estimates. After selecting the criteria scores η_1, η_2, η_3.....η_n for each row of the table, the value W_i representing the total significance estimate is calculated and calculated according to the formula:

$$W_i = \sum_{e=1}^{m} W_{ie} \ , i = 1, m \qquad (1)$$

Where: W_i Sum of the evaluations for criterion i:

$$\eta_i = \frac{W_i}{\sum_{i=1}^{m} W_i} \ , i = 1, m \qquad (2)$$

Where: η - overall significance estimate.

The significance matrix of the criteria is presented in Table 2.

After the determination of the significance of the criteria, the method of the sum of the products of the values of the criteria and the sum of the products of significance is applied to the assessment of the choice of suppliers (Simple Additive Weighting - SAW). In the scientific literature as mentioned by Nakat and Bou-Mitri [21], the most commonly applied is the SAW method. The criterion for this method S_j is the sum of the values of the weighted indicators:

$$S_j = \sum_{i=1}^{m} w_i \tilde{r}_{ij} \qquad (3)$$

Where: w_i - the weight of the i-th indicator; $\tilde{r}_{ij}$ - the *normalized* value of the i-th indicator *for the j-th* object.

Based on the mathematical calculation of the SAW method and the assessment of the significance of the criteria, an assessment of the selected alternatives is carried out according to the decision evaluation matrix presented in Table 3.

After the calculations, it is determined which supplier scores the most points and continues to follow the selection stage.

The fourth phase of the cycle is designed to select a supplier from the list of potential suppliers considering the results of the evaluation of suppliers. After selecting a supplier from the list of compiled alternatives, a risk assessment takes place. Risk assessment is a consequence of an ever-changing economic environment and cannot be called into question. Therefore, each potential supplier is evaluated in the context of existing challenges. Does it not entail corresponding risks and can ensure a constant supply of raw materials to the enterprise? After the assessment

Table 2. Matrix for determining the significance of the criteria

Experts / Criteria	j_1	j_2	j_3	J_i	Overall significance estimate
	j_1 expert's assessment of the significance of criterion (η_1)	j_1 expert's assessment of the significance of criterion (η_1)	j_1 expert's assessment of the significance of criterion (η_1)	j_1 expert's assessment of the significance of criterion (η_1)	
k_1	...	...	...	...	...
k_2	...	...	...	...	...
k_3	...	...	...	...	...
...	...	...	...	...	...
k_n	...	...	...	...	..

Table 3. Decision evaluation matrix

Primary evaluation criteria	Index	Significance	Alternatives under consideration					
			1	2	...	j	...	n
			Evaluations of the alternatives under consideration					
j_1	1	w_1	v11	v12	...	v1j	...	v1n
j_2	2	w_2	v21	v22	...	v2j	...	v2n
j_3	...	...	...	...	...	...	...	...
j_i	i	w_i	vi1	vi2	...	vij	...	vin
...	...	...	...	....	...	...	...	...
j_n	n	w_m	vm1	vm2	...	vmj	...	vmn
		SAW	S_{j1}	S_{j2}	...	S_{jj}	...	S_{jn}

of risks, a phase of rejection or confirmation takes place. If the supplier of raw materials is rejected - the process returns to the list of selected suppliers, if approved - proceeds to the next phase.

After the selection and assessment according to the possible risks, there is a transition to the negotiation phase. The negotiations are aimed at improving the supply conditions offered by suppliers. At the same time, negotiations can also take place with several potential suppliers, but negotiations are held with each of them individually and following the priority order. The proposals of the negotiating parties, much less their reaction to the proposals of the other party, cannot be defined in advance, since they depend on many factors, among which are the decisions made during the negotiations. Uncertainty arises during the negotiations. These are certain nuances of the proposal to conclude a contract and the uncertainty of the obligation to conclude a contract. They are especially characteristic when negotiating with more than one potential supplier. In the contract-making phase, two things are the most problematic.

After negotiations, there is a phase of rejection or approval. If a potential supplier is rejected due to an unsatisfactory result of the negotiations, the process is returned to the phase of choosing a potential supplier. The process cycle is repeated until a satisfying result of the negotiations is obtained. After the negotiations give a positive result, the transition to the next - *the phase of the conclusion of the contract*. The conclusion of the contract is the formal formalization of obligations.

The last phase - the monitoring of supply - breaks down into four tasks of different content: accounting, control, analysis and evaluation, and decisions on interventions. The purpose of accounting is to create a base of objective information about the state of performance of supply contracts. The essence of the control procedures in this case is the comparison of the actual and contractual supply statuses and the identification of inconsistencies. The last step is to justify decisions that are purposeful in the situation that has arisen.

Possible solution options are as follows:
1) Do not change anything;
2) Eliminate deviations in the actual state;
3) Change the terms of contracts;
4) Change supplier.

Even according to the variants of solutions, this is the most difficult from a methodological point of view, the task of this phase. Labor costs are high, and quantitative approaches use primary information of reliability [41], so in practice such decisions are based on expert assessments, often quite simplified.

3. Results and Discussion

As mentioned before, for the evaluation of suppliers of raw materials, a Lithuanian food production company was selected, which has 4 factories in Lithuania and exports its products to 40 countries of the world.

For the determination of significance, experts at the level of managers were selected who work in the food production sector, but in different enterprises. The requirements for experts are that they have been working in food production plants for more than 5 years, with more than three years of experience in the selection of food suppliers. The study applied an individual method of expert survey. The experts assessed the significance of the criteria for the selection of suppliers of raw materials for the production of food products. The results of the expert assessment of the significance of the criteria are presented in Table 4. Experts gave the highest rank to the criterion „the ability to ensure the supply of only quality products“ (significance 0.23). It should be noted that the criterion

Table 4. Assessment of the significance of the criteria

Parameters	Significance of the criteria							
	E1	E2	E3	E4	E5	E6	Overall Significance	
k 1	15%	17%	15%	13%	15%	17%	15.33%	0.15
k 2	25%	23%	20%	23%	24%	23%	23.00%	0.23
k 3	11%	10%	11%	12%	8%	9%	10.17%	0.10
k 4	8%	7%	9%	10%	9%	11%	9.00%	0.09
k 5	12%	14%	13%	11%	12%	13%	12.50%	0.13
k 6	17%	19%	21%	18%	19%	18%	18.67%	0.19
k 7	12%	10%	11%	13%	13%	9%	11.33%	0.11

Table 5. Assessment of food suppliers in case of purchase of raw flour at the food production plant

Criterion	Significance	Suppliers					
		MB Miltai Jums	**ŽŪB Auginam**	**UAB AgroBE**	**UAB AgroBeta**	**ŽŪB EcoLT**	**UAB AugaAuga**
k1	0.15	9	9	9	9	9	8
k2	0.23	10	9	10	10	9	8
k3	0.10	8	10	9	8	8	7
k4	0.09	7	9	8	9	6	7
k5	0.13	6	8	7	9	8	8
k6	0.19	9	8	9	10	8	9
k7	0.11	8	9	8	8	9	8
SAW (S_j)		8.4600	8.7900	8.7767	9.2017	8.3167	7.9950

of, traceability' (0.19) has played a very large role, which can be emphasized as a consequence of the need for risk management in this sector.

An evaluation questionnaire was submitted to the food manufacturer, who chooses the suppliers of raw materials, as well as the criteria according to which all 6 suppliers participating in the procurement were scored according to the established seven evaluation criteria. According to the results of the evaluation, an assessment of all suppliers was carried out using the SAW method. The results of the assessment are presented in Table 5.

According to the assessment of food suppliers, the most suitable supplier is UAB Agrobeta, which scored 8.7767. Based on the calculations made, a priority ranking of suppliers has been established. Based on that, further negotiations with suppliers of raw materials can be carried out - based on the supplier selection process presented in Figure 1. It should be noted that UAB AgroBE was rejected from the list of potential suppliers since the evaluation criteria are good, but the company has links with a country that is subject to European Union sanctions and, as a result, may also affect the company's performance.

4. Conclusions

- Research by scientists on the choice of suppliers of raw materials to food production companies is carried out from time to time, and the context of global risks is minimally analyzed. The support tool is necessary for businesses to apply prevention in the context of risks on time while ensuring the effective operation of the company.

- The multi-criteria approach presented in the article and the established evaluation criteria create the prerequisites for increasing the efficiency of the selection of suppliers of raw materials for food producers in the context of national and global challenges. The presented supplier selection support system consists of 8 steps and 3 decision-making points, as well as the content of the system components.
- The developed tool, tested in practical food production activities using the SAW method of multi-criteria analysis, allows for the compilation of a priority list of suppliers of raw materials, considering the identified criterion and the possibility of eliminating the unsuitable ones if they pose a risk to the efficiency of the company's activities. In this way, the process of selecting and evaluating suppliers is optimized and

can be applied both in the national and international context in the departments of food production enterprises responsible for the supply of raw materials.

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