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Examination of the selection of logistics service providers

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Abstract: The selection of logistics service providers plays a crucial role in the success of an organization's supply chain management. The new industrial revolution taking place today provides solutions that prioritize the issue of quality and also raise reliability to a new level, both on the service provider's and user's sides. As businesses grow and expand, the need for efficient and reliable logistics services becomes increasingly important. This study examines how to determine the criteria for the selection of logistics service providers in the current technological environment. The choice of logistics service provider has significant implications for an organization's operations and overall performance. Optimum selection can lead to enhanced customer satisfaction, cost savings, improved efficiency, and a competitive advantage. However, poor selection can result in logistical inefficiencies, decreased customer satisfaction, increased costs, and negative impacts on organizational reputation. Hence, careful consideration and evaluation of potential service providers are crucial. The digitized environment offers a solution for accessing large-scale databases, which provide well-founded decision evaluation plans based on a large number of samples. The quality characteristics influencing the logistics parameters were examined and weighted from the perspective of customer requirements. By exploring various aspects, we aim to shed light on the intricacies of this process and provide insights that can assist organizations in making informed decisions. We attempt to make the indices that appear as bottlenecks in the specified order more efficient using an optimization procedure.

1 Introduction

Today, as a result of globalization, especially the significant cooperation of economic organizations, market competition is becoming increasingly global. Companies' competitive strategies go beyond the opportunities provided by the market within national borders and expand their production processes, strategies, and relationship systems. In the 21st century, it has become indispensable for companies to individually formulate future orientation and foresight strategies [1]. In addition, companies face new challenges such as the demand for high-quality standards, constantly changing consumer habits, a transformed market environment, and technological innovations. Taking all of this as a basis, it can be stated that essentially those companies can survive and belong to the leading edge of the competitive market, and they do not regret investing in continuous development and improvement [2]. As a result of increasing competition, both the micro and macro environments of companies have changed [3]. The assessment of business performance depends not only on internal company activities but also on their results. Currently, the recognition that supply chains, supply networks, and networks compete in the economy is becoming increasingly accepted. Excellent individual performance is in vain if a company's business partners, suppliers, subcontractors, intermediaries of its products or services, and other related actors in the supply (sales) chain do not perform adequately [4]. Based on practical knowledge, it can be established that the material flow processes taking place within the network have a strategic role; therefore, sufficient emphasis must be placed on their performance, or, in other words, their quality. The question of choosing the right service provider is detailed in this section. After reviewing the literature, it can be concluded that many researchers and professionals address the topic of logistics service provider selection methods. The multidisciplinary logistics field is supported by the fact that the process is based on mathematical methods that can be implemented to achieve effective results for the delimited topic area. Numerous proposals have been made on this topic, which examine the given issue from different perspectives. The digitization environment is important because, by providing a technological background, it generates a huge amount of data that must be usefully used during the evaluation and selection process. However, owing to the complexity of different customer needs, it can be difficult for logistics service companies to effectively understand the different ways customers value the service elements they offer. In this context, the task can be approached in such a way that, on the one hand, the available dataset and developed decision-making method help the company using the service in choosing the right service provider, and the service provider is also a benchmark point, which provides feedback on its performance and the parameters within which the intervention should be made to maintain its market position. To judge the success of a process, we inevitably run into the requirement of measurability. In general, it can be stated that a well-developed method for the evaluation of the logistics service provider can increase the possibility of success. In many cases, the unmanageability of the large available data and information set and the lack of a measurement system can lead to an incorrect assessment of consumer or end-user expectations, which is why it is important to develop and apply a correct and well-applied criteria system. It is also necessary to develop a model that immediately reflects the impact of changes, although this impact only shows the degree of importance of the criteria. Therefore, the developed model must cover all sectors, including production and services, and measure them efficiently and effectively [5].

2 Creation of a model suitable for evaluating and choosing a logistics service provider based on multi-criteria decision-making methods

When choosing logistics service providers today, the following are the basic aspects:

- a wide range of activities provided by the logistics service provider (R-S-T activity, creation and dismantling of unit loads, product identification, collection and classification, etc.),
- the customer's expectations of the service provider regarding the provided activity, which include the quantity, quality, and cost-related expectations of the service,
- goals formulated by customer.

Having explored the literature and learned about the task to be solved, it can be stated that the solution must be approached and examined as a multi-criteria decision-making task. The steps of multi-criteria decision modelling can be found in the literature dealing with decision processes [6-8]. These consist of the following steps:

- delimitation of the decision-making task,
    - defining the general model from the point of view of service seekers,
    - to define a general model from the perspective of service providers (alternatives).
- solving the decision task.

To define a decision task, it is necessary to develop a general model and its mathematical scheme [9].

2.1 *Definition of the general model*

To determine the decision goal, it is necessary to know what objective functions can be used to describe the needs of a company looking for logistics services. The decision task means that we find the best service alternative for the user of the service using an optimization method based on the given objective functions. For management objectives, each applied objective function must be characterized by a specific set of parameters. When defining a general model, the first step is to record the elements that constitute the model. In this model, we considered two typical building elements: users of logistics services and logistics service providers.

Users of logistics services are interested in the logistics services available in the globalized market and their technical and economic parameters. The company that uses the service determines the objective functions, considering that it attempts to find the right service providers. These objective functions can differ according to a company's interests. Logistics service providers are characterized by the activities they provide and their technical, economic, and logistical aspects [10,11]. The logistics activity provided by the logistics service provider is characterized by various logistics parameters. Based on the above, we define the structure of the service seeker model as follows. In the first step, those looking for a logistics service are characterized by the objective functions they formulate for the service they are looking for.

Based on these results, the following conclusions can be drawn:

- the company looking for the i-th logistics service has special needs specific to the company,
- he searching company requires different logistics services, the maximum number of which is n_i, where i refers to the company searching for the i-th service,
- each requested logistics service is classified based on objective functions,
- different objective function numbers are typically used for each service, where $k_{i,j}$ represents the maximum number of objective functions for the j-th logistics service of the company seeking the i-th logistics service.

This proves that it is an extremely diverse general model that is complicated by additional factors to be considered. When managing the objective functions, it is essential to specify the parameters that characterize the given objective function. In general, it can be said that an objective function named C is characterized by a parameter with the number of P_c pieces. We select the k-th objective function for the j-th logistics service of the company seeking the i-th logistics service. Figure 1 illustrates the relationship between the service seeker, given service, given objective function, and parameters of the objective function.

The symbols in Figure 1 are as follows:

- *CF* - Objective function describing the given logistics service.
- *P* - Number of parameters characterizing the given objective function.

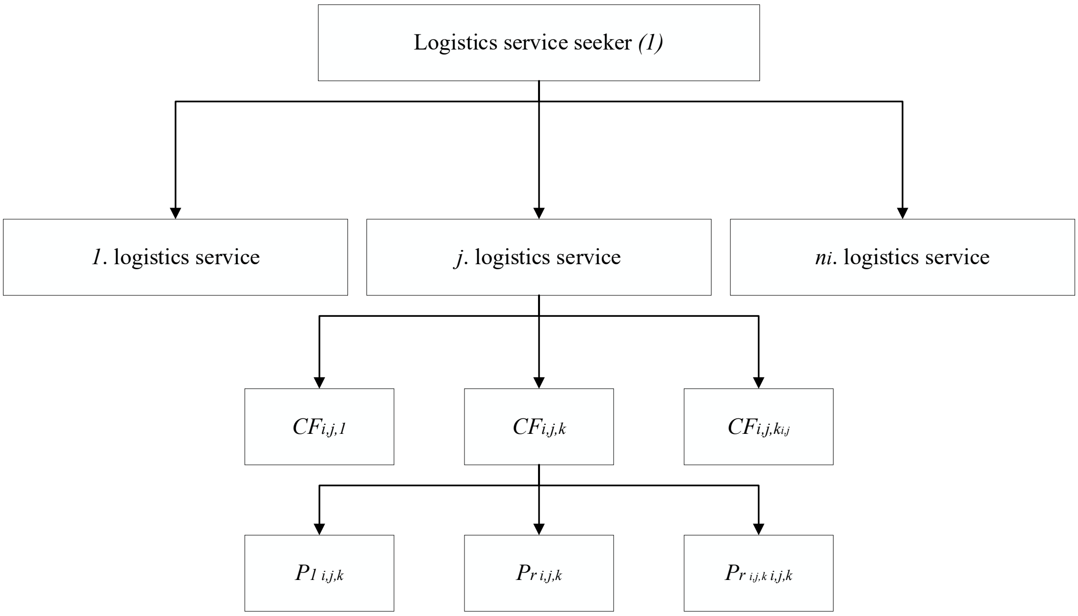

Figure 1 Characterization of companies looking for services

In the following, we supplement the model given in Figure 1 by specifying the maximum number of parameters as well as the connection system of the service finder, the service sought, and the maximum number of pieces of the given objective function. This is illustrated in the model shown in Figure 2.

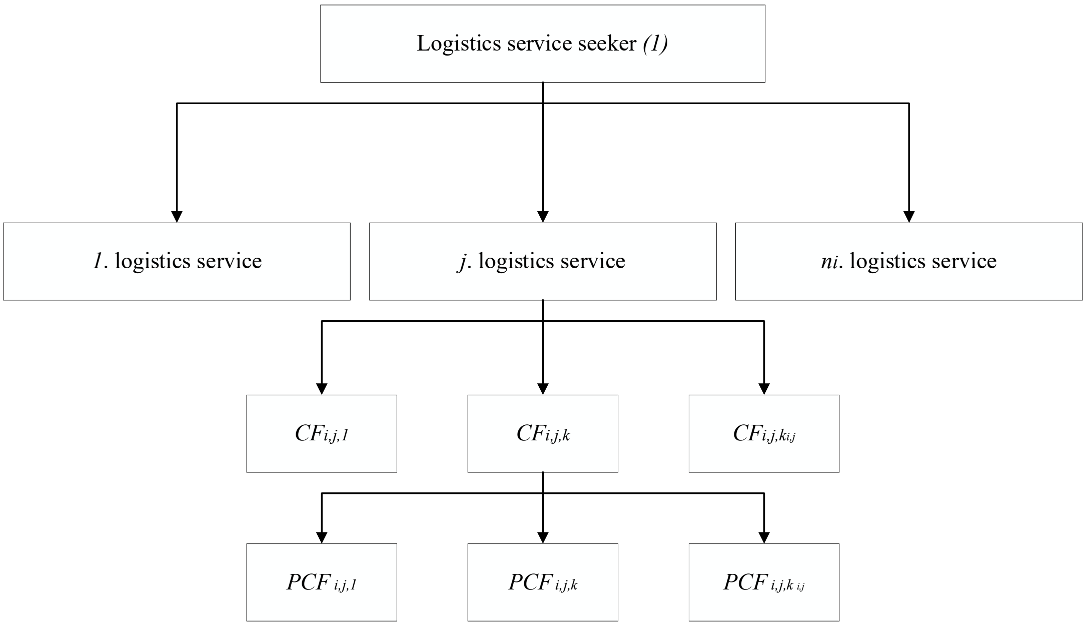

Figure 2 Specifying the parameter versions

In the Figure 2 the parameter versions of the objective functions are contained in the $PCF_{i,j,k}$ module, which is characterized by the following parameters:

- the *i*-th service seeker,
- for the *j*th requested service,
- in the case of the *k*th objective function,
- $r_{i,j,k}$ maximum number of parameters.

Using Figure 1 and 2, we provide the relationship system of companies looking for logistics services based on the requesting company, the requested service, the objective functions for the service, and the parameters for the objective function. In the basic model, we took into account two building blocks: those looking for logistics services (consumers and buyers) and logistics service providers [12]. Previously, we defined those looking for logistics services, and now we define those who offer the service. In the following, we define the connection structure of logistics service providers, the service aspects they provide, and their parameters. During the investigation, a logistics service company was treated as a possible alternative solution. Logistics service providers can be classified according to various development levels (1Pl, 2Pl, 3Pl, 4Pl, 5Pl, etc.), these development levels represent the complexity of the offered service [13,14]. The range of services requested by the customer will determine the level of service companies that can be considered and involved in the evaluation [15]. Since several logistics service providers can be considered as solution alternatives in the competitive market, we consider m alternatives in the model. Each alternative has a different service aspect. These aspects and their specific numbers usually differ as alternatives. Figure 3 shows this.

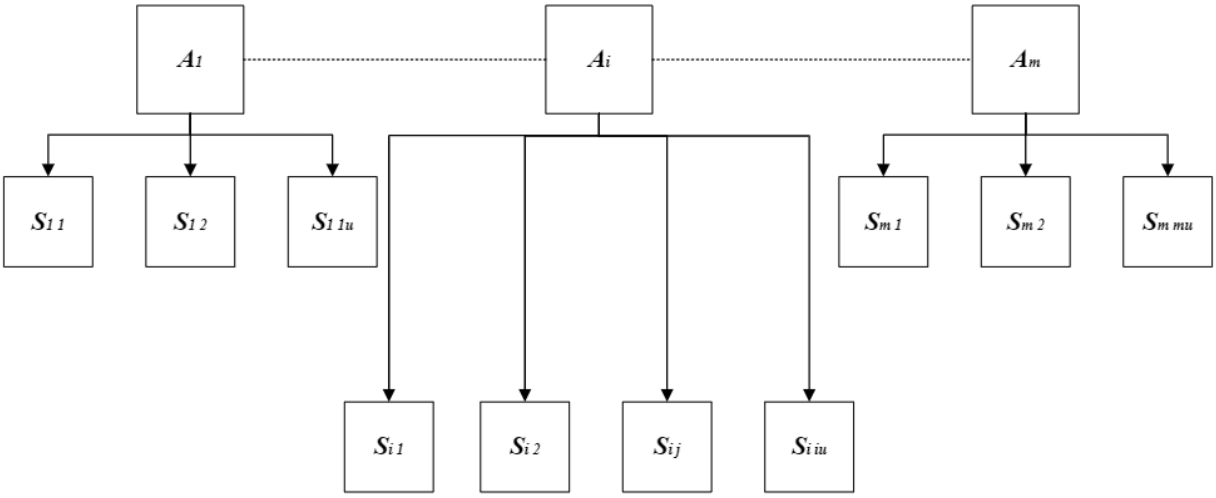

Figure 3 Offered alternatives and their aspects in relation to logistics service providers

The notations introduced in Figure 3 are as follows:

- A_i - the *i*-th service alternative, where $i=1,2,...m$.
- S_{ij} - the *j*-th service aspect of the i-th service alternative, where $j=1,2,...u_{ij}$, and where u_{ij} is the last service aspect for the *i*-th alternative.

The connection system of the individual supply alternatives and the service aspects that characterize them (Figure 4) needs to be subjected to further investigations. Based on Figure 4, we cannot yet characterize the service aspects with sufficient accuracy, only the connection system is defined. For this reason, in the case of an *i*-th alternative, additional characteristics must be taken into account. This is illustrated in Figure 5.

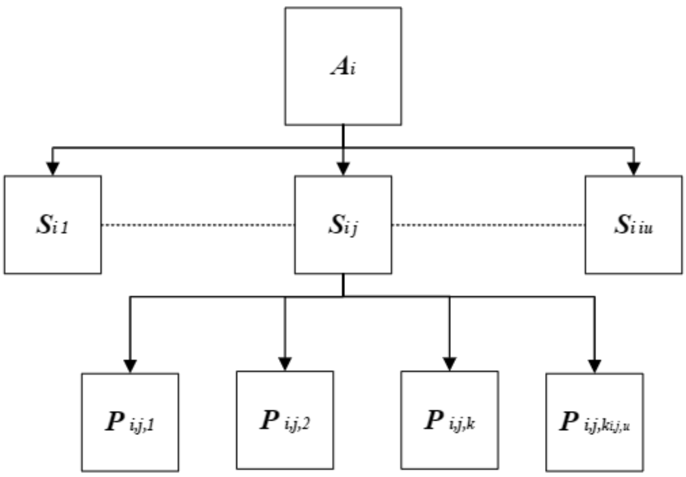

Figure 4 Offered service alternatives of i., the connection of parameter systems of $P_{i,j,k}$ defining the j. service aspect

The meaning of the notation used in Figure 5 is as follows: $P_{i,j,k}$ is the value of the kth parameter for the jth service aspect of the ith service alternative, where $k=1,2,...k_{i,j,u}$ is the maximum number of parameters for the jth service aspect of the ith service alternative.

Using the results of Figure 3 and Figure 4, we can provide the supply side of our investigations, that is, the general model that can be used to characterize logistics service providers, the relationship system of the alternatives (service providers), the service aspects as our alternative and the characteristic parameters for all aspects of each alternative number and their associated values. Figure 5 describes this.

Based on the characteristics described above, the approach and principle course of the task takes place according to the following steps:

- defining the decision goal,
- exploring and recording the aspects necessary for the decision,
- defining the parameter system related to the decision criteria,
- exploring and characterizing the system of service providers (alternatives) that can be considered for the decision,
- statement of results.

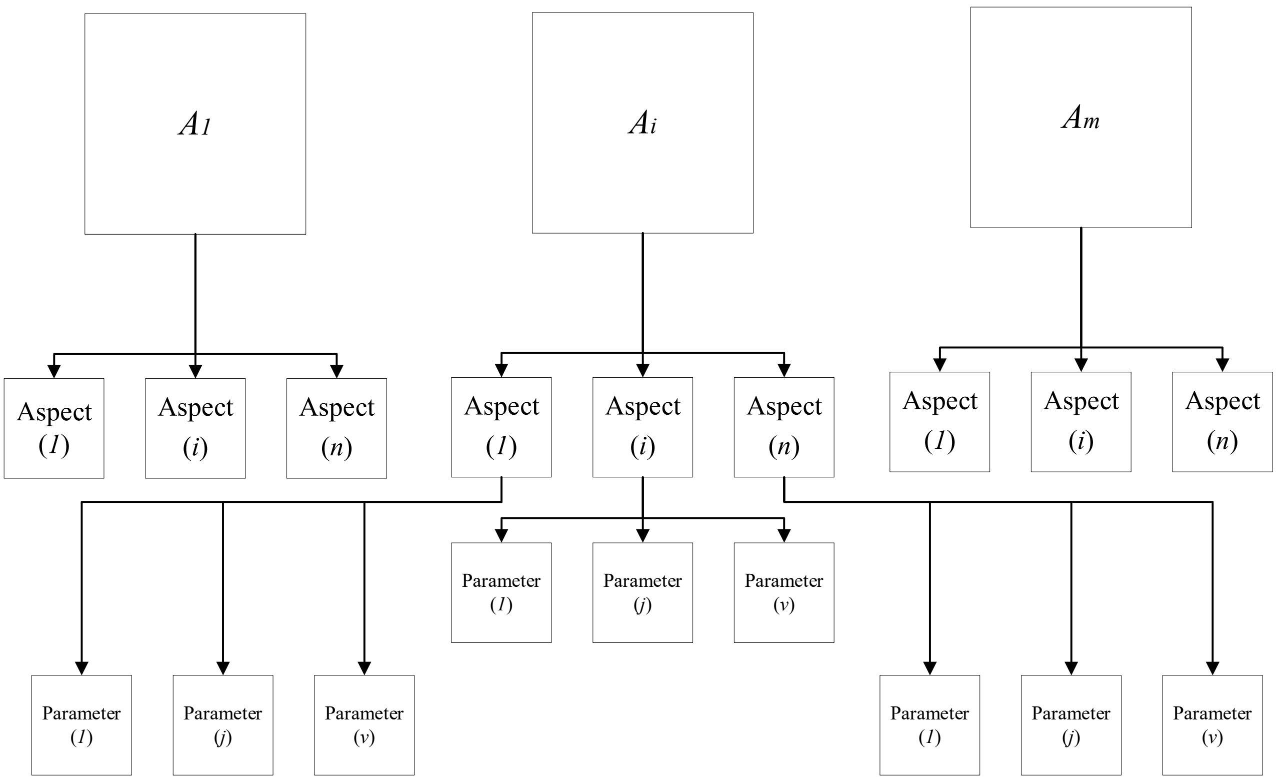

Figure 5 A general model for characterizing service providers

The outline of the solution to the decision task is as follows:

- evaluation of each possible service provider (alternative) based on all parameters of each aspect,
- defining the mathematical model of the evaluation,
- development and selection of the criteria-parameter weighting method required for evaluations,
- evaluation of the alternatives using the weighting factors for the parameters,
- using the multidimensional scaling method (MDS) to decide the number of dimensions and display the obtained values.

2.2 Determination of decision goal, decision criteria and related parameter system

Based on the above, it can be seen that several goals can be defined along a given objective function in order to find the result of the decision task. In our case, the goal that appears at the end of the task is the choice of the optimal logistics service provider for the user of the service based on given criteria. In practice, the tested parameters can be recorded taking into account the effective combination of price-value and quality [16,17]. The basic task is to develop a mathematical model or models suitable for solving the defined task by jointly applying the two proposed models (Figures 2 and 5).

In all cases, it is the task of the customer or consumer to define the criteria necessary for the decision. The term aspects are the collective name for a given set of parameters. With regards to the predefined objective function, we can define the relevant aspects and assign the characteristic parameters to these aspects. Setting up the system of criteria is the task of the organization using the given service, which must strive to record the essential aspects and alternatives - this can also be done with the involvement of an expert. Experts are all persons who are involved in the consequences of decisions at some level. Decision theory distinguishes between individual and group decisions in terms of the number of decision makers.

In all cases, the creation of the related parameter system is necessary for the defined decision criteria [18]. The definition of the main evaluation criteria is task-specific since the goal to be achieved can always change along the given objective function. We can describe a given aspect with a set of parameters in order to achieve the desired result. A specific aspect may have a different number of parameters, depending on the weight of the given aspect compared to the others. Depending on this, it is possible to determine the number of characteristic parameters. The relationship between the aspects is shown in the following diagram with a tree structure (Figure 6).

2.3 Connection system of service providers (alternatives), aspects, parameters that can be used in the decision

By alternatives, we mean the service providers in question, from which the buyer or customer may be able to decide depending on the evaluation of the aspects and their associated parameters. The general model of the election is illustrated in the following Figures 6 and 7. For the model to be developed, we took as a starting point the relationships previously defined in Figures 1 and 2, which actually describe the objective functions defined by the companies looking for the service. Using these two Figures (Figures 1 and 2), we created Figure 6, which illustrates the relationship between service seekers (*SK*) and their related objective functions (*C*). On the other hand, it can be said that it is also necessary to develop a relational system that assigns different alternatives to individual objective functions. This is illustrated in Figure 7, on which we specifically examine the goal to be achieved along a single objective function, but as Figure 6 shows, this connection system must be examined for each objective function of the service finder. Regarding the objective functions, it can be said that an objective function is composed of several descriptive aspects, which can be further detailed with the parameters specific to each aspect. In this case, there are several possible alternatives (service-providing organizations), therefore, for each alternative, it is necessary to enter a specific value for each descriptive aspect and their parameters. This connection system is illustrated in Figure 7. Knowing the above, the goal is that the values included in the developed mathematical model provide us with the opportunity to optimally satisfy the given need based on various aspects. The goal is to create a matrix in which the elements offer a solution to the ideal solution of the given task during various mathematical procedures and by applying various optimization methods.

The developed model is characterized by the following:

- The goal to be achieved is defined.
- Related to the given goal, we record $i=1,2,...n$ aspects that we will take into account.
- We define the number of descriptive parameters for all given $i=1,2....n$ *aspects*. Of course, the number of parameters for each aspect can differ. In case of the first aspect the number of parameters is $P=1,2,....v_1$; thus the marking of the parameters belonging to the first aspect is $P_{1,j}$ where 1 indicates the first aspect and j to parameter j. The first aspect's maximum number of parameters is v_1. This can be marked similarly for every parameter for every aspect. The number of parameters for aspect i is $P=1,2,......v_i$; where v_i indicates the maximum number of parameters for aspect i. After defining the parameters for the final aspect we see that the number of parameters for aspect n (last) is $P=1,2,....v_n$; meaning that the last aspect's maximum number of parameters is v_n. The different alternatives are connected to the goal defined aspect system's parameter system. The number of possible alternatives is $k=1,2,....m$; so the number alternatives is m. $A_{i,j,k}$ marks the connection of a j parameter for an i aspect for a selected k alternative. These connections are visualized by Figure 7.
- Connection matrix A: $A[i,j,k]$, where
  - i is the running index of aspects in $i=1,2,....n$ is where n is the number of maximum aspects,
  - j is the running index of parameters in $j=1,2,...v_i$ where v_i is the $i=1,2,...n$ aspects' maximum number of parameters,
  - k is the running index for alternatives in $k=1,2,...m$ where m is the maximum number of alternatives.

Basically, three principles are applied when solving the process:

- Defining the decision problem,
- Comparative evaluation of the parameters,
- Synthesis of established results.

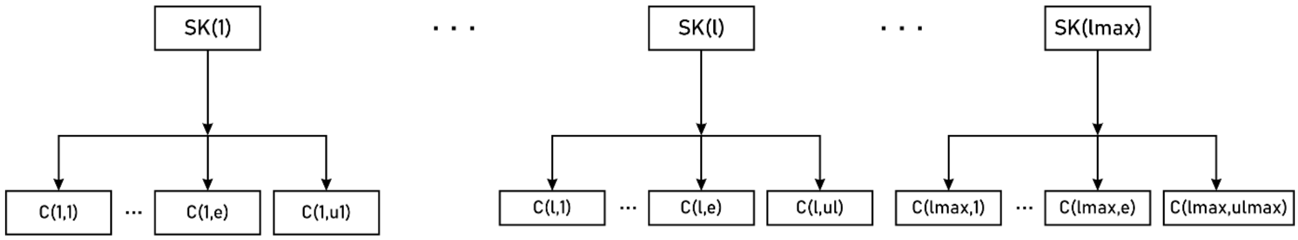

Figure 6 The systematic relationship of the objective functions defined by the service seekers

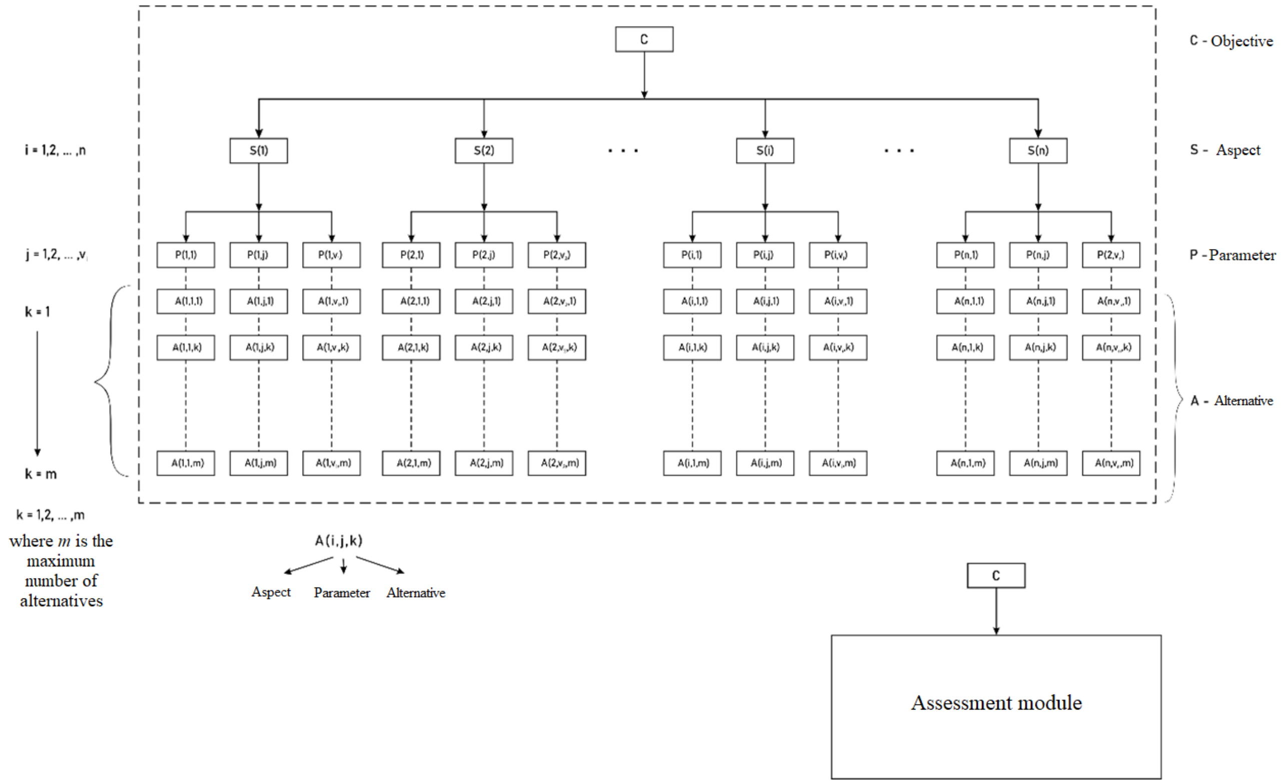

Figure 7 The relationship system of alternatives, parameters, aspects

2.3.1 The mathematical model of the evaluation

It is the responsibility and competence of the service user to define the best suiting target diagram with which it can start the examination. A goal supporting aspects system must be defined according to which the selection task can be successfully executed. The defined aspects must be evaluated with specific parameters with the use of input data and background databases. Input data means the priority defined by the company and the differences in priority between aspects. Databases can provide the data on previous evaluation results, different statistical reports, and information in the form of questionnaires. The used database must confirm to the buyer's goal's and to the characteristics of the aspects and aspect defining parameters. The established data structure and the primary connection system of the evaluated data can be introduced with the $a_{i,j,k}$ matrix where the components of the matrix are:

- the aspects to be considered according to the goal ($i=1,2,....n$),
- all evaluated aspect can be defined by the determined parameters and their given values,
  - the number of needed defining parameters are usually different for each aspect ($j=1,2,....v_i$),
  - used parameters usually have different dimensions,
- the evaluated alternatives generally give different solutions and values for a given aspect's parameter.

The datasets created this way show the solution offered by a given goal's *i* aspect's *j* parameter's *k* alternative. The evaluated dataset gives us basis for the following optimal tasks:

- defining the optimal alternative for reaching a defined goal using the matrix's data,
- defining the improvement methods of solution parameters provided by a given alternative with the use of digitalization methods and according to market aspects (costs, quality improvement of parameters, improvement of market competitive position).

Taking the following parameter set into consideration and with the use of the developed model we will demonstrate the method of finding the optimal. In the first step of the evaluation we will define the $a_{i,j,k}$ three dimensional matrix. Starting form the A =[$a_{i,j,k}$] matrix, we define the *i*th aspect's *j*th parameter's *k*th alternative, which has the value of $a_{i,j,k}$. The result will be defined by the evaluated alternative. According to the evaluated parameter's properties this can be a maximizing of minimizing value. If the parameter is maximizing (1) then we search for the maximum of the $a_{i,j,k}$ based on the alternative's (*k*) parameter (*j*) where the appropriate objective function is:

$$P_{max\ i,j,k} = \max_i\{a_{i,j,k}\} \tag{1}$$

In the next step we define the relative value (2) of the $a_{i,j,k}$ according to the following:

$$P_{i,j,k} = \frac{a_{i,j,k}}{P_{max\ i,j,k}} \tag{2}$$

where

$$0 \leq P_{i,j,k} \leq 1 \tag{3}$$

In case the parameter is minimizing (4) then we search for the minimum of the $a_{i,j,k}$ based on the alternative's (*k*) parameter (*j*) where the appropriate objective function is:

$$P_{min\ i,j,k} = \min_i\{a_{i,j,k}\} \tag{4}$$

In the next step we define the relative value (5) of the $a_{i,j,k}$ according to the following:

$$P'_{i,j,k} = \frac{P_{min\ i,j,k}}{a_{i,j,k}} \tag{5}$$

where

$$1 \leq P'_{i,j,k} < \infty \tag{6}$$

For the proper handling of $P'_{i,j,k}$ we define $P_{i,j,k}$ which provides the use of relative parameters (there is no ∞ value). $P_{i,j,k} = \frac{1}{P'_{i,j,k}}$ in this case $0 < P_{i,j,k} \leq 1$ then we get the *j*th value of the *i*th aspect's relative *k*th alternative ($P_{i,j,k}$) where $i=1,2,\ldots n$. If we perform this for all parameters of a given *k*th alternative, we get the relative parameter matrix for the that *k* alternative. This step must be repeated for all k=1,2,….m alternative to get m number of similarly built matrixes. This three dimensional matrix P = [$p_{i,j,k}$] will be the base for the execution of possible optimal methods.

2.3.2 The method of weighting

The first possible solution finding method is the weighting of evaluated parameters. Because of this it is essential to properly define the aspect's/indicator's weighting scale for the effectiveness of the model. In reality, when searching for a solution (alternative) each parameter has different importance for the buyer. We can validate the differences in importance by introducing weighting formulas (7). In the case of the kth alternative's *i*th aspect's *j*th parameter, the weighting formula's value is $w_{i,j,k}$; where

$$0 < w_{i,j,k} < 1 \tag{7}$$

assuming that $j=1,2,\ldots.v_i$.

In regard to the weighting formulas (7), it is a given that

$$\sum_{j=1}^{v_i} w_{i,j,k} = 1 \tag{8}$$

where i and k are constant.

When defining the $w_{i,j,k}$ values we must take the above written into account. In these correlations $j=1,2,\ldots v_i$ must always be fulfilled for all values of $i=1,2,\ldots.n$ and $k=1,2,\ldots m$. Based on these we can define the W = [$w_{i,j,k}$] matrix, which contains the weighting formulas value.

We evaluate the appropriateness of the *k*th alternative (9). The *k*th alternative's *i*th aspect's evaluation indicator is the following:

$$e_{i,k} = \sum_{j=1}^{v_i} w_{i,j,k} \tag{9}$$

where i and k are constant.

This $e_{i,k}$ evaluation indicator gives how appropriate the *k*th alternative is for the *i*th aspect. If we perform the above summarization for a given alternative's every evaluation aspect (9) then we get the *k*th alternative's result indicator (10). The result indicator for the *k*th alternative is the following:

$$e_k = \sum_{i=1}^{n} e_{i,k} \tag{10}$$

through this we get the result indicator for the kth alternative. Since the maximum number of alternatives is *m*, we must define the result indicator for every $k=1,2,\ldots m$ alternative. Afterwards, according to correlation (10) we get the e_{opt} (11) and the

$$e_{opt} = \max_k\{e_k\} \tag{11}$$

which gives e_{opt} and the ralting $k=k_{opt}$ value.

2.3.3 Application of the multidimensional scaling (MDS) method

The literature on multidimensional scaling (MDS) is now quite extensive, well known, and often uses statistical procedures. With its help, the 2- or 3-dimensional representation of multi-dimensional objects becomes possible, where, based on the resulting Figure, hidden relationships may exist between the evaluation and certain properties of the categories. Thus, the magnitude relationships of the distances between the points of the original set of points are also preserved. The essence of the procedure is that we are given n objects, of which p properties are observed one by one, from which we can create an n×p data matrix, in which the n rows of the matrix represent the objects (points) and the p columns represent the observations given to the points. Our goal is to embed objects in Euclidean space. If two of our elements are far from each other in a certain sense in our original p-dimensional space, then we want them to be far from each other in this k-dimensional Euclidean space, that is, our elements are equally far from each other in the reduced space, within a certain margin of error.

Examining the literature, the method is mainly used in the field of sociology, where properties have to be scored on a specific scale; however, in our case, it can also be used effectively as a decision support method for selecting a logistics service provider. The MDS method can be used as a part of the general model presented above and the mathematical procedures of the evaluation process. The justification for using this method was the fact that in today's digital environment, many service providers offer themselves as potential options on the competitive market, the number of evaluation criteria and descriptive parameters is increasing, and the handling of the resulting datasets is becoming increasingly complicated. Using this method, it is possible to reduce a large number of criteria such that it provides an exact easy-to-understand solution for the person responsible for the decision [19].

Various statistical software packages are available for the application of the MDS method. In our case, we used the Statistical Product and Service Solutions (SPSS) software developed by IBM. In the case of the initial configuration in the procedure, there are usually no distance matrices available but raw data. This usually means that we have information about each object and evaluate it along some dimensions. The distance matrix should then be obtained from this information [20].

3 Example

In this section, the practical use of the previously presented procedure is introduced. In this example, aspects and their descriptive parameters were defined. The numerical values were also the result of random assignments (Table 1).

Table 1 Service provider evaluation board

	Name of aspects/parameters	Weight factor	Value (1-100)									
			A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
S_i	**Delivery**	0.2										
Sz_1	By on-time delivery	0.08	55	53	97	25	60	52	42	33	71	21
Sz_2	Accounting and invoicing accuracy	0.04	76	8	72	55	37	19	42	54	32	24
Sz_3	Condition of vehicles	0.05	10	35	75	42	35	43	42	62	43	98
Sz_4	Loading and unloading	0.03	77	75	7	16	17	13	42	58	81	93
R_i	**Storage and inventory**	0.15										
R_1	The characteristics of the order process	0.01	93	70	65	16	43	67	85	6	48	32
R_2	Accuracy of order fulfillment	0.06	70	65	16	43	67	85	8	48	32	76
R_3	On-time storage	0.03	69	95	30	78	51	39	60	26	25	4
R_4	On-time pick-up	0.03	63	75	61	59	40	90	86	26	67	75
R_5	Appropriate regulation of stocking	0.02	43	10	33	16	30	60	87	59	23	40
M_i	**Service level and quality**	0.25										
M_1	Availability of tools and resources	0.08	81	85	62	84	55	91	36	45	27	48
M_2	Problem-solving ability	0.06	55	37	44	11	56	24	8	40	10	38
M_3	Quality of the transport and warehousing service	0.07	97	83	62	39	66	18	4	8	47	69
M_4	Financial stability of the company	0.02	15	72	59	16	19	23	43	40	44	90
M_5	Market reputation	0.01	91	19	66	53	36	38	59	92	88	75
M_6	Ability to operate on a global scale	0.01	13	84	28	55	34	35	83	83	50	87
K_i	**Costs**	0.3										
K_1	The (specific) cost per transport unit	0.005	6	68	12	63	21	46	30	19	45	36
K_2	Storage cost per storage unit	0.005	13	9	64	12	28	66	76	81	9	52
K_3	Service cost	0.02	61	57	82	79	96	37	73	69	77	43
T_i	**Applied technique and technology**	0.1										
T_1	Application of tracking systems	0.05	32	17	47	44	20	64	23	48	57	7
T_2	Provision of electronic data exchange (EDI)	0.01	23	48	57	7	41	46	99	20	71	26
T_3	Provision of Internet and e-commerce	0.02	55	80	63	50	40	22	37	23	70	60
T_4	Willingness for process improvement	0.01	44	33	67	87	85	22	63	71	18	29
T_5	Willingness to develop technology	0.01	33	21	10	67	43	95	65	39	79	81

After the weighting is done, the table takes the following values, as shown in Table 2.

Table 2 Weighted indicators of the evaluation of the service provider

	Name of aspects/parameters	Weighted value									
		A1	*A2*	*A3*	*A4*	*A5*	*A6*	*A7*	*A8*	*A9*	*A10*
S_i	**Delivery**	10.25	8.56	14.60	6.78	8.54	7.46	8.40	9.64	11.54	10.33
R_i	**Storage and inventory**	9.95	9.9	5	7.17	7.78	10.84	7.45	5.68	5.62	8.05
M_i	**Service level and quality**	17.91	17.3	14.06	11.51	13.46	11.17	5.92	9.11	8.31	14.37
K_i	**Costs**	1.315	1.525	2.02	1.955	2.165	1.3	1.99	1.88	1.81	1.3
T_i	**Applied technique & technology**	3.7	3.47	4.95	4.81	3.49	5.27	4.16	4.16	5.93	2.91
		43.13	40.76	40.63	32.23	35.44	36.04	27.92	30.47	33.21	36.96

The color marking illustrates the obtained result, the service providers marked in green performed the best and those marked in red performed the worst. The next step is the multidimensional scaling procedure (MDS), which we use in the example using the SPSS software. In the first step, with the help of the program, we create a distance matrix from the received weight values of the aspect (Table 3), which illustrates the Euclidean distance of the points measured from each other in the 5-dimensional space (Table 4).

Table 3 Criteria weight values received as a service provider

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Delivery	10.25	8.56	14.60	6.78	8.54	7.46	8.40	9.64	11.54	10.33
Storage and inventory	9.95	9.9	5	7.17	7.78	10.84	7.45	5.68	5.62	8.05
Service level and quality	17.91	17.3	14.06	11.51	13.46	11.17	5.92	9.11	8.31	14.37
Costs	1.315	1.525	2.02	1.955	2.165	1.3	1.99	1.88	1.81	1.3
Appl. technique and technology	3.7	3.47	4.95	4.81	3.49	5.27	4.16	4.16	5.93	2.91

Table 4 The measured distance of the dimensions included in the study

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
A_1	0.000									
A_2	1.824	0.000								
A_3	7.766	8.569	0.000							
A_4	7.898	6.792	8.508	0.000						
A_5	5.311	4.433	6.853	3.010	0.000					
A_6	7.515	6.554	9.698	3.832	4.437	0.000				
A_7	12.414	11.672	10.551	5.863	7.580	6.453	0.000			
A_8	9.827	9.309	7.086	4.073	5.007	6.098	3.855	0.000		
A_9	10.853	10.684	6.619	6.048	6.802	7.264	4.700	2.719	0.000	
A_{10}	4.095	3.938	5.684	5.059	2.278	5.642	8.805	5.972	7.313	0.000

The mathematical quality of the MDS procedure in SPSS is characterized by the following two fit indicators, s-stress and RSQ. The s-stress indicator is nothing but an indicator calculated from the difference between the coordinates of the plotted and the original points. Therefore, the smallest values of s-stress are desirable, because they correspond to the smallest possible distortion (Table 5).

Table 5 The value and quality of the S-stress indicator (based on my own editing [9])

S-Stress	Quality	Comment
<0.05	Excellent	It probably contains all the relevant information.
0.05<0.1	Good	Correct, the results are interpretable.
0.1<0.15	Medium	The results stand their ground in relation to the task.
0.15<0.2	Acceptable	It's worth dealing with. The result is still mostly interpretable.
0.2<	Inadequate	For the given dimension number, it can only be represented with a large loss of information. It is worth using a larger dimension number.

RSQ (R SQUARED) - another fit indicator calculated by SPSS - is simply the square of the correlation coefficient calculated between the corresponding elements of the plotted and the original matrices, which directly indicates what proportion of the total variance can be explained by the given MDS model [21]. For this indicator - in contrast to the previous one - of course, lower values indicate a

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worse fit. *RSQ> 0.6* is the acceptable value range. In the example, with regard to the given data set:

- Stress = 0,06053 → Takes a "good" value.
- RSQ = 0,98481→ Appropriate value.

The next step of running the program is to determine the coordinates of the points in the space transformed to 2 dimensions (Table 6).

Table 6 Coordinates of points in 2D space

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
Dim1	1,8428	1,6511	0,2819	-0,3506	0,3707	-0,1066	-1,8942	-1,1131	-1,3914	0,7094
Dim2	-0,053	0,383	-1,7974	0,7314	0,2296	1,1807	0,5191	-0,2404	-0,7195	-0,2333

The next step is to determine the distance of the points located on the transformed projection. In the last step, the dot plot reduced to two-dimensional space is shown. This mapping means mapping the five-dimensional (point of view) space into two dimensions, where in fact all 5 original dimensions appear to a greater or lesser extent. From the point diagram and the standard deviation of the alternatives, we can deduce where the original dimensions appear in the new coordinate system. Deciphering the *X*-axis was quite clear, since the points are scattered mostly along the service level dimension (Table 7).

Table 7 The distribution of the standard deviation of each descriptive aspect

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	*Deviation*
Delivery	10.25	8.56	14.60	6.78	8.54	7.46	8.40	9.64	11.54	10.33	***2.14***
Storage and inventory	9.95	9.9	5	7.17	7.78	10.84	7.45	5.68	5.62	8.05	***1.90***
Service level and quality	17.91	17.3	14.06	11.51	13.46	11.17	5.92	9.11	8.31	14.37	***3.66***
Costs	1.315	1.525	2.02	1.955	2.165	1.3	1.99	1.88	1.81	1.3	***0.32***
Appl. technique and technol.	3.7	3.47	4.95	4.81	3.49	5.27	4.16	4.16	5.93	2.91	***0.89***

Regardless, the other dimensions also make their impact felt in the reduced space, for example two original dimensions are close to the *y* axis: transportation and storage and inventory. The reason for this is that these original dimensions also correlate (negatively) with each other (Table 8).

Table 8 The magnitude and direction of the linear relationship between the two aspects

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Correlation
Delivery	10.25	8.56	14.60	6.78	8.54	7.46	8.40	9.64	11.54	10.33	-0.5715
Storage and inventory	9.95	9.9	5	7.17	7.78	10.84	7.45	5.68	5.62	8.05	

Among the original dimensions, the 4^{th} (applied technique, technology) and 5th (costs) dimensions are also included in the reduced space, but their position is more difficult to determine, as they are less differentiated in the initial five-dimensional space. After the investigation, as a result of the conclusion, it can be concluded that the best correlating aspect during the transformation is the level of service and quality (M_i) displayed on the horizontal (x) axis, the next two best correlating aspects along the vertical (y) axis are transportation and storage and inventory. The axes depicted in the diagram are oriented according to the display shown in Figure 8. Along the x-axis, the neighborhood of the minus value can be interpreted as the "lower" service level, and in the direction of the positive value, the "higher" service quality can be seen. Along the y-axis, the minus value is represented by service providers focusing on the "delivery aspect", and the positively oriented value is represented by the service providers focusing on the "warehousing and stocking" aspect.

The essence of the technique used lies in the fact that we can display the service providers qualified in the complex evaluation system in a two- or three-dimensional coordinate system where the axes represent various properties and the service providers are scattered along these trends. This makes it clear to the decision-makers what the individual service providers are stronger than their competitors, as well as what the strengths and weaknesses of the individual service providers are and which is the best service provider in the comparison.

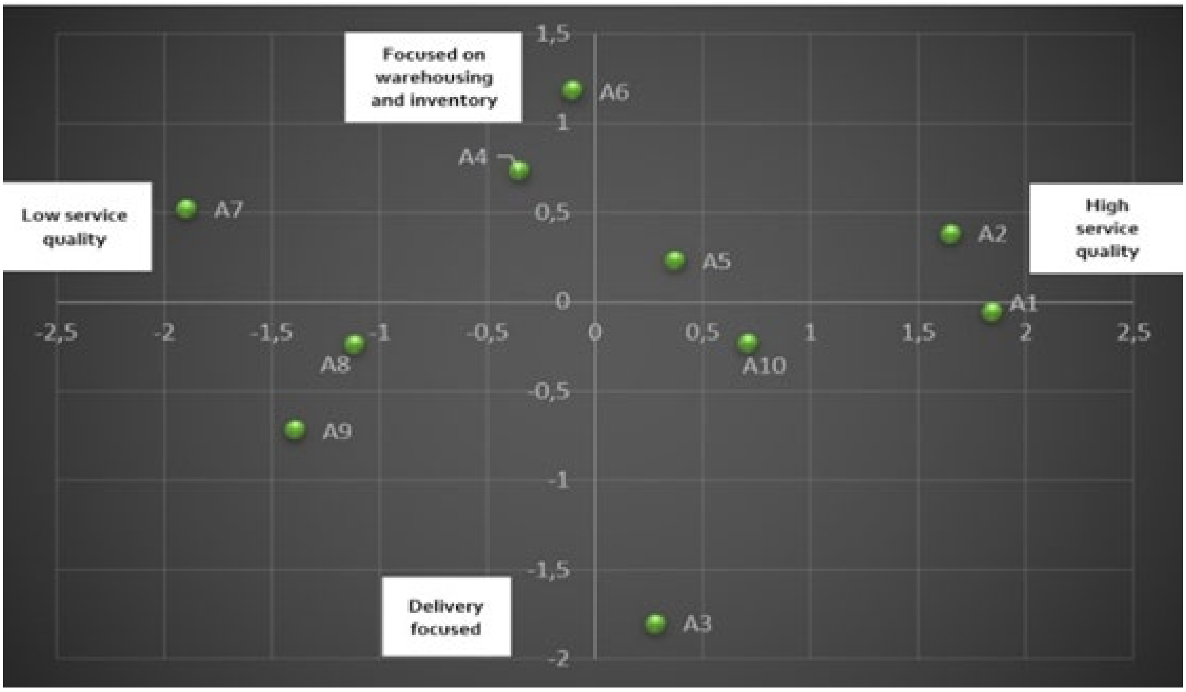

Figure 8 Scattering of alternatives in the transformed dimensional space

4 Conclusion

The choice of the topic of the article was justified by our experience gained in company practice, as well as the possibilities inherent in the complexity of the evaluation and selection process. The selection of logistics service providers is a complex process that requires careful consideration of numerous factors [22]. By examining cost factors, service quality and reliability, operational capabilities, geographical coverage, and technological advancements, organizations can make informed decisions that align with their unique supply chain requirements [23]. Ultimately, selecting the right LSP can lead to enhanced operational efficiency, improved customer satisfaction, and increased competitive edge in the marketplace. In this study, research directions related to more efficient operation applicable to the evaluation and selection of service providers were formulated. We explore today's service offerings of the logistics sector, present their portfolios in detail, and outline the multi-level evaluation-preference indicators illustrating the overall evaluation of these service providers. The presented results give practice the opportunity to evaluate the service provider providing added value primarily from the perspective of the service user, i.e. the buyer/consumer. The test method was specifically presented as a decision support method for the evaluation process of companies providing logistics services; however, with minimal correction, it can be used for all evaluation-selection processes. The achieved selection ranking can also be considered a benchmark evaluation for the service provider, with which it can position itself in a competitive market. In relation to the task, the limitations indicate how relevant the aspects describing the objective function and the parameters characterizing the aspects are to the objective function. Therefore, in practice, it is necessary to involve experts with sufficient competence to determine the necessary aspects for this task. These experts can also be internal employees of the company or, if necessary, external specialists specializing in this task Several additional development possibilities can be mentioned, among them the extension of the test model by the service provider to the evaluation of the consumer, as well as the development of a computer web application suitable for the application of the testing methods at the company level be highlighted.

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