

EVALUATION MODEL OF THE COMPANIES OPERATING WITHIN LOGISTIC NETWORK

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Abstract: *In the paper authors presented concept of evaluation of complex systems such as logistic companies which operate in competitive environment. Authors also highlighted the importance of the evaluation problem in operational activity, particularly in the properly prepared procedures to be followed, consisted of several stages adapted to currently conducted research. Properly executed evaluation of companies enables customers to take right decisions on contracting services and stimulate the development of those companies. It should be noted that the proposed algorithmic model of assessment may be particularly useful for assessment of complex logistics systems. Characteristics of the respective phases developed procedure allowed to indicate that it is important to select of appropriate criteria and evaluation methods. It was pointed out that particularly useful for assessing of logistics companies are multi-criteria analysis methods, because they allow to examine objects in a holistic manner, taking into consideration various aspects of activities such organizations. For the practical realization of assessment of logistics companies there was proposed Bellinger method, which contains quite transparent procedures. The results obtained from that method are consistent with those carried out by means of other, more complex multi-criteria methods. Also there was presented the problem of selection of weighted factors for the criteria in the context of their impact on the end result of evaluation. It was pointed out that the choice of an appropriate procedure for determining weights depends on the nature of the evaluated problem and form of criteria.*

Key words: *evaluation, logistic companies, multi-criteria methods*

1. Introduction

Modern look at the economy, caused by the transition from the manufacturer market to the consumer market, indicates that the conditions have changed under which companies must conduct their business. The current operation of the enterprise is primarily a process of interaction with the environment within which the feedback occurs of the predetermined force. This is due to the fact that operators are very dependent on their environment, which requires greater sensitivity to the changes taking place in it. Thus, they can function and evolve only by developing (continuous improvement) its activities in connection with extensive knowledge, imagination and flexibility in responding to the challenges of the environment. It should however be noted that the company not only passively adapts to the environment, but it can also shape it according

to its own interests and expectations. Along with the development of enterprise, there also increases the scale of its impact on its own environment, and its creative possibilities grow. This is particularly evident in supply chains and logistical networks, in which the companies play different roles (Jacyna, 2008). The literature describes logistic network as a group of independent companies competing and cooperating in order to improve the efficiency and effectiveness of the flow of goods and accompanying them information in accordance with the expectations of customers (Svahn, Westerlund, 2007, Harland, Lamming, Zheng, Johnen, 2001). It should be noted that in the activities of companies, there are many practical reasons for which the evaluation is needed. Overall, the assessment is an evaluative statement of the evaluator, expressing approval or disapproval of the state of the evaluated

object in the context of the accepted criterion (criteria) formulated based on a certain system of values (Górny, 2004). Evaluation of the logistic system (of the company), depending on the adopted method of the study and the extent to which it refers, may take the following forms (Kempka, 2015):

- functional assessment - involving studying separate elements of the logistic system, phenomena and processes occurring in the operation of the system. Thanks to this assessment it is possible to include various features of the company in a given period;
- systemic evaluation - allowing a holistic approach to the analyzed company. The system under scrutiny is arranged according to the adopted scale of importance. This type of evaluation also takes into account the system environment and its relationships and interactions;
- decision-making assessment - involving the fragmentary analysis of processes and conducting the research, grouped around pursued decision. The number of components of the system being analyzed depends on the type (decision rank) and the time at which the operations are proceeding. Elements of the system are examined in their mutual relationships, but only in the area of the decision being made.

Each evaluation includes a cognitive element contributing the additional information to the collection, which the evaluator has in its disposal or is putting the collection of information about the system in the orderly manner. The importance of the evaluation is evidenced by the fact of it being used to make decisions (Caplice & Sheffi, 1995, Zak & Jacyna-Gołda, 2013).

The evaluative situation depends on many different aspects, which include a number of systems being assessed (one, two or more), the nature of evaluation - whether it is an absolute evaluation, relative to a standard or to some other system. Important is also the extent to which the information held is reliable, thus the assessment itself can be certain or uncertain. The evaluation is therefore dependent on many factors and typically it is expressed as the probability of its credibility.

The evaluation of logistic systems is closely related to uncertainty, which applies when making decisions without having full knowledge of the tested object. Uncertainty of the decision situation is partly due to the phenomenon of indeterminacy of

the system. In connection with the issue of evaluative uncertainty, there are three states of knowledge of the evaluator of the evaluative situation, with which associated is a widening range of uncertainty (Bojarski, 1984):

- 1) evaluator knows what he is certain of and what he does not know ;
- 2) evaluator knows that he does not have a precise diagnosis of the situation, but is not aware of what he does not know;
- 3) evaluator is not aware that he is not well versed in the evaluative situation and remains convinced that he knows everything.

The importance and range of uncertainty increases with the increase of the scope of the phenomenon studied and the lengthening of the period in question of its functioning. The most common is becoming a belief that smaller error is being made by taking into account this uncertainty in the estimations than by ignoring it completely.

In summary, the complexity of logistic systems (logistical companies) requires multi-dimensionality and relativity of the evaluating, which in turn determines in the first place conducting the identification and selection of criterion characteristics. The selection or designing of appropriate evaluation methodology creates a need for analysis and verification of the available methods and then adapting them according to the type of system under assessment. Depending on the purpose of evaluation, evaluative studies are conducted using various methods.

2. The algorithm of evaluating logistical companies

In order to establish a model for evaluating logistic companies it is possible to use the following research rationale:

- model should refer to complex problems requiring a comprehensive approach;
- the model form must be accompanied by awareness of the purpose for which it is created;
- model should reflect the components and their properties, the processes occurring in it and the relationship between the elements and its surroundings;
- the model should be internally consistent and consistent with the information that formed the basis of its construction;

- construction of the model should enable the efficient use of its tools, and procedures in practice;
- model should be susceptible to algorithmization in the use of computer software to facilitate the

- preparation of options when making decisions and assessing the activities carried out;
- all the measurements and indicators should be quantified for the numerical verification to be possible and the development of synthetic measures.

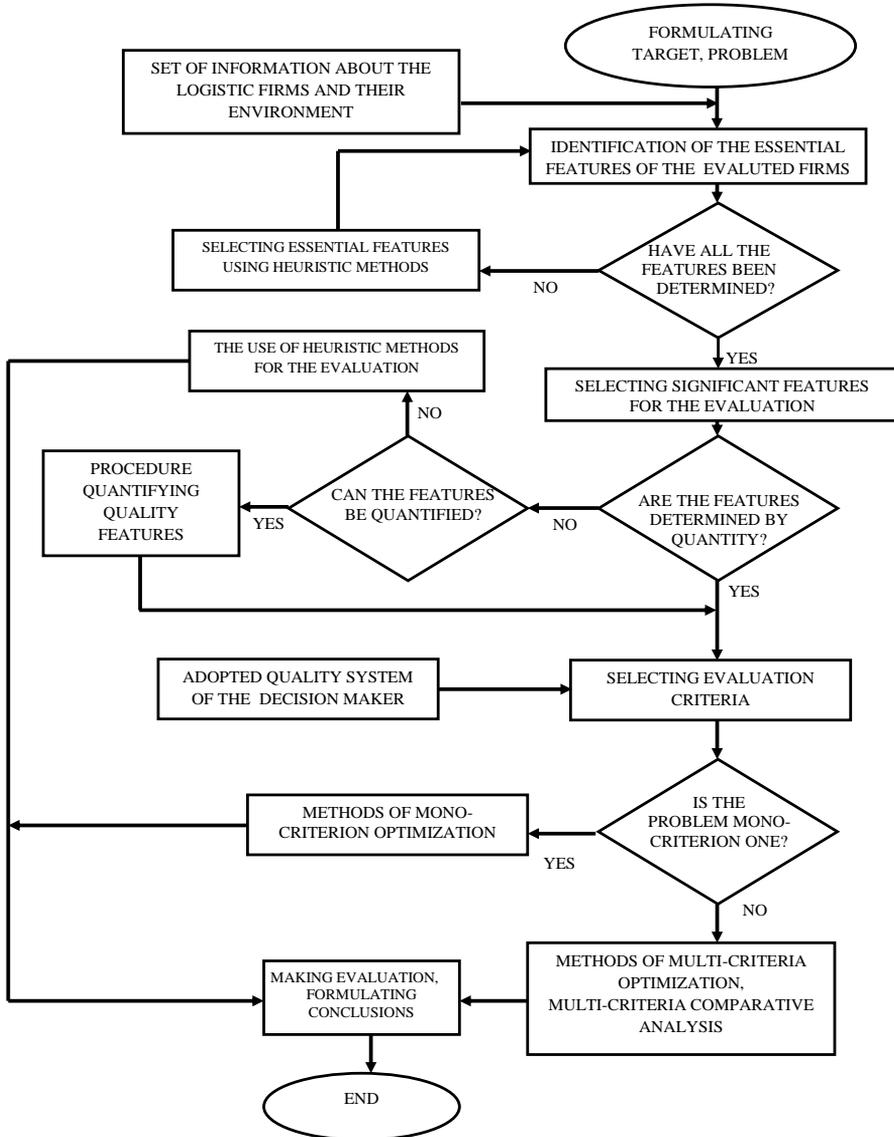


Fig. 1. Algorithmic model for the assessment of logistic companies. Source: Own compilations.

A correct assessment of a complex system, which certainly a logistic company is, requires the development of algorithmic model that was presented in Figure 1. The starting point of the correctly defined evaluative situation of the companies is setting the appropriate targets which this assessment is to serve. The objective is commonly understood as a particularly desirable state of a specific object or part of the reality, freely and consciously chosen by the operator to carry out as a result of its activity. It is also possible to believe that the aim of the activity is to cause, in the given fragment of the reality, such a change, that as the result of which, the particularly desirable condition of it, will be achieved. As the aim may also be defined event, achieving a certain state, the implementation of the process, or playing a selected role (Bojarski, 1984). The subject literature, as essential objectives of the evaluation of companies regards mainly (Brzeziński, 2007):

- comparing two or more companies,
- defining the requirements for newly developed systems,
- verifying the degree of compliance with the requirements,
- selecting the best option in accordance with established evaluation criteria.

Another element of the proposed scheme is to formulate the evaluative problem. Due to many demands facing the system, its complexity and the criteria taken into consideration during the evaluation, the evaluative problem may have different degrees of difficulty:

- simple evaluative problem - its solution is made possible by having adequate knowledge or after a simple evaluative studies;
- complex evaluative problem - requires an additional commitment of additional resources to allow in-depth analysis of the system, it requires advanced knowledge and practical skills;
- very complex evaluative problem - to solve it is necessary to resort to the help of others, additional financial resources.

Often, unfortunately, it turns out that errors made in the phase of formulating the problem of the assessment are detected too late and can no longer be effectively remedied at this stage, much less at the stage of its implementation. Problem situations occur quite accidentally, based on certain symptoms. Therefore, it is very important to focus on the

initialization stage and identification of the problem to avoid such a situation in subsequent steps of troubleshooting the assessment problems.

The correct definition of the evaluative problem allows to specify objects of comparison - logistic systems (companies) including identification of a set of vested relevant features that distinguish it from other objects. It is the features that characterize the object under consideration (system) in some respects and decide that in this respect it is just the way it is. The differences in the state of the features can help distinguish different states of the same subject and various subjects (Bojarski, 1984).

According to the ontological categories, the feature is a reliant component, differentiated by the intellectual analysis in the things we are getting acquainted with. It's a dependent being, which must necessarily coexist with things that are its carriers (Stachak, 2006). It is an attribute that of necessity a certain object is entitled to and without which this subject would be been unthinkable, impossible to describe and present (Prechtel, 2009). The feature is any measurable or un-measurable, but verbally describable element, that allows to make an opinion on the given object or its properties.

With regard to logistic systems, there are two types of features (Bojarski, 1984, Brzezinski, 2007):

- own characteristics (properties) defined solely based on the knowledge about the system, which it is really entitled to and regardless of its current relations with other systems. Due to the set of properties, the differences between the systems are primarily quantitative;
- the relative qualities (properties) defined about the system based on its relationship with the environment or with respect to any other specified object. The property is therefore a specific feature for the given system, which qualitatively distinguishes it from all other things.

Due to the ability to be measured, the features can be divided into:

- measurable (magnitudes), which are expressed using the appropriate unit of measurement;
- un-measurable (attributes) that can be described only in words in a two-stage or multi-stage scale.

Measurable qualities are more valuable with respect to the information than the immeasurable characteristics because they provide continuous information. In turn, the advantage of the un-measurable features is the ease of measurement

because it is less time-consuming and does not require precision instruments.

It should be noted that companies operating in logistic networks with the identical purpose are characterized by similar features. These features are often determined by policy-makers or specialists. Identifying the features is itself a process that requires the use of heuristic methods. The use in this case the method of "brainstorming" or using the advice of specialists, using the Delphi method allows to determine exactly which properties should characterize the logistic system under scrutiny.

After determining the abundance and variety of features that the logistic systems are entitled to, one should, in the next stage of the evaluation, choose only those features that, in the light of substantive knowledge are most important to make the evaluative process. The basic substantive criteria are among the others: importance of the characteristics in terms of the systems being evaluated, holistic character of the assessment, the logic of interconnections and maintaining proportionality of representation of the partial evaluations. When creating such a set of attributes one should use heuristic methods (e.g. A brainstorming session or Delphi method).

The developed list of characteristics must subsequently undergo formal verification with particular regard to the following properties: a quantitative nature, availability, completeness and cost effectiveness (acquisition costs). Further the fixed set, based on the merit & formal criteria, should undergo further verification due to the informative value of the features. This is done using statistical procedures due to the following basic criteria (Panek, 2009):

- discriminative ability, that is their variability with respect to the tested systems,
- capacity (information potential) of the features, that is the degree of their correlation with other properties.

After defining characteristics, one ought to make sure that they are measurable, i.e. if they have been set out in a quantitative manner, giving the opportunity to present in numerical form. If the characteristics are not shown in this way, one ought to check the possibility of their quantification. If the case when it is impossible to change the un-measurable characteristics into the measurable ones, an evaluation of the logistic system can be

performed only by means of heuristic methods. The evaluation result depends on the competence and the subjective preferences of people involved in the individual methods (Rafele, 2004).

After bringing the features to the quantitative state one ought to define evaluative criteria. They form the basis for the calculation of each method and provide a view of the capabilities of the surveyed logistic companies.

Proper selection of the criteria, which is the most important features that allow an objective verification of assets of the systems considered, is the most important and most difficult part of the assessment process. Asking about the evaluation criterion is the question about decision preferences. These can include the following questions (Bojarski, 2001):

- what quantitative and qualitative aspects are of interest to the decision-maker in reality; the existing situation in the reference scenario, in the process of implementing the project and its outcome?
- what weights does the decision maker attach to the individual aspects of reality; what evaluations and economic weights would he be willing to attribute to the changes of specific aspects?
- what material and subjective extent of the real variable is of interest to him and in what time range (horizon)?

Answering such formulated questions enables to create a certain structured system of values of the decision maker, allowing the evaluation of solutions at each stage of the systems evaluation process.

The term of evaluation criteria determines factors and their functional relationships which have a significant impact on the studied object. As the criteria, one may adopt different un-measurable or measurable characteristics, figures determining the property of the system, thus useful to describe the state the studied object is in. The most relevant assessment criteria seem to be the requirements that are placed on the studied systems, as they include the state desired by the end user (Caplice & Sheffi, 1994).

Poorly chosen assessment criteria make it impossible to obtain information about significant disruption in achieving the set its requirements. Selection of criteria can be made for current needs, or systematically for the analyses repeated at certain intervals. In order to choose a suitable criterion for

assessing logistic systems one should take into account requirements imposed on them (Kolman, 2009):

- criterion should be defined unequivocally;
- the criteria cannot be qualities of sameness or synonymous;
- as criteria, if possible, one should adopt qualities or features suitable for the up-sloping values;
- criteria, in the adopted a set, should complement each other;
- the number of a set of criteria should not be less than three.

The number of criteria in the set should be greater than one, because the greater the number of criteria, the more thorough the evaluative procedure. One however should note, that an excessive number of criteria makes an analysis difficult and reduces its transparency. In order to finally select the form of criteria one ought to consider their meaning and check whether it is adequate to the evaluative problem in question. A set of criteria should be a complete collection and therefore one in which one criterion is not dependent on the others.

The final step is to determine whether the given problem is of mono-criterion type, or has more than one evaluative criterion. In case of the mono-criterion type of problems, evaluating logistic system is reduced to the use of e.g. linear optimization method. An example of this is Simplex method, in which the maximum of the function is sought with equality constraints. When we deal with a number of criteria, to solve the problem we need the method of multi-criteria comparative analysis. The use of methods such as numerical taxonomy method, AHP or the Bellinger method, allows in holistic way to look at the system in question in terms of conducting its in-depth analysis and making a best selection according to the imposed requirements.

3. The selection of methods for evaluating logistic companies

Choosing the right method of assessment is not easy and obvious. The multifaceted nature of the functioning of logistic systems often requires complex evaluative solutions. The available qualitative methods require experts to put in the right order the systems attributes, namely the making a decision whether a given property precedes the others, taking into account the given criterion. The

quantitative methods, however, in addition to properly arranging the features, provide information, by how much one value is superior to the other. The basic requirements posed for the logistic systems evaluation methods may include (Kempka, 2015):

- the truth of the statements and evaluations - information must reflect the facts resulting from the records; the data should be subject to verification; numerical values are selected in such a way as to representatively depict the studied elements of the logistic system;
- conciseness in the formulation of the results – the evaluative studies should be as synthetic as possible, and the documentation should present the results obtained;
- little effort needed for analytical steps – the assessment methods should be chosen to require the smallest possible amount of work in the preparation and conducting the tests;
- comprehensible form of the results - the information contained in the assessment should be diversified in terms of brevity of the formulation of results and tailored to the level and preparation of the recipient (user of the results of the evaluation);
- the speed of obtaining study results – duration of evaluative studies should be as short as possible and quickly lead to the result; the rate of testing is often more important than their precision, not all problems require detailed examination but require taking prompt remedial measures.

It should be noted that particularly useful to assess the logistic systems are the multi-criteria analysis methods. The essence of the multi-criteria studies is their comparative approach, which means that the level of a complex phenomenon is dealt with in different objects (Kukuła, Jędrzejczyk, Fiddler & Wilkosz, 2002). The multi-criteria evaluation of a given phenomenon involves determining the value of this phenomenon due to the specific set of the criterion characteristics.

Amongst the multi-criteria methods we can identify ELECTRE method, which gives opportunity to choose the best system from the set of alternative variants based on ordering relations (equivalence, preferences, incomparabilities) (Roy & Bouyssou, 1993). General Algorithm consists of the following consecutive stages: determining the initial and final set of evaluation criteria, building graphs of

preference for each of the criteria, assigning weights to each criterion, calculation of indicators of compliance and non-compliance, calculating the degree of outranking, creating a synthetic graph preferences based on degrees the outranking, drawing up the ranking (Roy 1985).

Another method belonging to this group is the AHP analysis, which basing on pairwise comparisons method allows to introduce the relative scale of assessment - priorities for countable and uncountable criteria (Saaty, 1990). This method leads evaluators to identification of a set of core criteria and precisizing of the dominance relationship between them (definition of hierarchy of priority criteria, hierarchy of the given variant's priority in relation to respective criteria). In the final stage, they are aggregated base on the before designated partial values. In case of occurring only hierarchical dependencies, aggregation is based on a weighted sum of partial results (Saaty, 1980).

In this case, to solve the problem, that the evaluation of logistic companies is, the Bellinger method was applied, that organizes objects based on the value of the total assessment determined from the set of partial criteria adopted. This method, compared to methods of multiple criteria (such as, for example ELECTRE method, AHP), however, is more transparent and the analyses carried out using it are consistent with the results of other methods that are more complicated. Furthermore, using this method, is supported by the ability to apply appropriate weights to the criteria by which it is possible to take into account the preferences of the decision maker regarding the choice of a given logistic system.

The Bellinger method involves bringing the evaluation decision variants, with respect to all criteria adopted, to the state of comparability, for further aggregation (Bellinger, 1979). A characteristic feature of the method is that for each analyzed evaluation criterion there is determined the most and least desirable status and the direction of these changes. For each available decision-making variant there is determined assessment with respect to each criterion, as a fraction of the so-called "path" which is the difference between these states. The best decision-making variant is the variant for which the total "path" is the longest, thus it receives the cumulative rating of the highest value (Wolny, 2007). The algorithm in the Bellinger method consists of eight successive stages (Górny, 2004):

- 1) Defining the requirements and restrictions for the future possible alternatives of solutions in the analyzed problem. Selection of criteria.
- 2) Determining the decision-making variants available.
- 3) Clarification of the adopted assessment criteria consistent with the purpose of comparing objects. Adoption of the measurement units, the desired direction of change within a given criterion, as well as upper and lower limit of the changes in individual sub-criteria.
- 4) Creating a semantic hierarchy of the various criteria by determining weights, attributed the by the decision maker to the adopted evaluation criteria.
- 5) Building a matrix containing the actual values of the criteria corresponding to the individual variants.
- 6) Building a matrix containing the actual values of the criteria corresponding to the individual variants.
- 7) The results obtained in step 6 are multiplied by the weights adopted in step 4.
- 8) Determining the best variant based on summing up of the ratings granted to individual variants from the point of view of the analyzed criteria.

4. Example of the use of Bellinger method

In order to practically present the possibilities of Bellinger method to assess companies the following set of criteria was adopted (Eurologistic, 2014):

- 1) The scope and assessment of logistic services in the evaluation of the key customers of the given company's (K_1) - the result of a given company is the percentage of the total number of this company's key customers completely satisfied (8-10 evaluation on 10-element scale) of the most common logistic services conducted by this company.
- 2) Implementation of the adopted standards for logistic services in the assessment of key customers of the company (K_2) the result shows the percentage of core customers evaluating the implementation of all the adopted norms of logistic services by this company very highly (rating of 8-10 on the 10-element scale). Included standards are: delivery on time, supply completeness, accuracy of deliveries.
- 3) The market position in the assessment of key customers of the company (K_3) – the indicator

- determines how often a logistic company is indicated by its key customers as the best company on the market in the given areas of operation, taking into account the importance attributed by the clients to the given field. The result quoted is an average rating for fifteen studied categories of customer service.
- 4) The market position in the assessment of the total number of customers of the company's (K_4) - indicator shows how often a given logistic company is generally indicated by the clients of the surveyed companies as the best in customer service. This result is the average number of indications for fifteen investigated categories, taking into account the importance attached by customers to particular fields of service.
 - 5) The loyalty of key customers of the given company (K_5) – the result shows how often a given logistic company is indicated by its key customers as a company that they would

- recommend without reservations or dissuade from using its services, or it would be indifferent to them. The result is the difference between strong supporters and critics of the given company.
- 6) The market leader in the evaluation of key customers of the given company (K_6) – the indicator shows how often a given logistic company is indicated by its key customers as the best logistic company on the market.
 - 7) The most competitive company in the assessment of all customers (K_7) – is defined as the quotient of the total number of customers that recognize a given company as the best on the market to the number of its key customers tested.
- In the second step of the method, as the decision variants, we adopted the first 20 companies in the ranking “Logistic Operator of the year 2014”. The business data with appropriately assigned values of the criteria is summarized in Table 1.

Table 1. Values of the criterion for selected logistic companies (Eurologistic, 2014)

No.	Criterion [j] Evaluated system [i]	K_1	K_2	K_3	K_4	K_5	K_6	K_7
		[%]	[%]	[%]	[%]	[%]	[%]	
1	Maszoński Logistic	28,30	100,00	78,70	2,69	100,00	88,90	0,889
2	TNT Express Worldwide (Poland)	38,11	92,60	76,89	3,36	81,40	64,80	1,167
3	DHL Express	33,40	78,40	68,93	5,70	72,50	74,50	4,608
4	Raben Polska	24,81	61,80	70,18	3,51	80,00	70,90	2,164
5	General Logistic Systems Poland	30,29	76,90	64,67	2,27	80,80	53,80	0,827
6	Hellmann Worldwide Logistic Polska	23,64	100,00	57,24	2,47	85,80	50,00	0,929
7	arvato Polska	25,75	66,70	62,03	1,91	83,30	83,30	1,000
8	General Logistic Systems Poland (e-commerce)	18,67	86,50	68,14	2,34	77,00	65,40	0,769
9	FM Logistic	24,16	70,60	56,73	2,81	52,90	64,70	2,235
10	Geodis Calberson Polska	22,77	80,00	53,21	2,70	100,00	40,00	1,400
11	Diera	25,73	90,00	60,59	1,85	68,00	56,00	0,580
12	Fiege	30,28	75,00	60,71	2,01	50,00	50,00	0,750
13	DHL Supply Chain	26,65	55,60	57,54	5,47	44,40	44,40	1,444
14	C. Hartwig Gdynia	23,08	80,40	58,83	1,90	74,50	45,10	0,549
15	Panalpina Polska	23,29	66,70	54,55	1,98	71,10	51,10	0,844
16	DPD Polska (e-commerce)	14,26	68,80	64,17	2,23	45,20	53,10	1,281
17	DPD Polska	27,69	64,70	42,11	1,94	52,90	45,10	0,902
18	Allport Cargo Services Poland	22,80	77,20	59,75	1,69	63,20	43,90	0,456
19	Poczta Polska	21,49	72,00	57,16	1,51	59,00	46,20	0,482
20	IFB International Freightbrigade (Poland)	19,57	72,50	56,88	1,84	64,70	39,20	0,392
Lower limit		38,11	100	78,7	5,7	100	88,9	4,608
Upper limit		14,26	55,6	42,11	1,51	44,4	39,2	0,392

In addition, Table 1 presents in the header, units of measurement in which the criteria is specified. For the criteria $K_1 - K_6$ the data is expressed as a percentage, while K_7 is a dimensionless quantity. In the defined set of criteria, depending on the nature of the characteristics, there may be:

- stimulant that is a variable, whose increase in the value indicates an increase in the assessed level of the complex phenomenon;
- destimulant or a variable, whose decline in the value indicates an increase in the assessed level of the complex phenomenon

The data presented shows that the criteria summarized in Table 1 are stimulants – i.e. the characteristics for which big value are desirable, but there are no destimulants – i.e. the characteristics for which smallest values desires are desirable.

For the purpose of the analysis we assumed that the lower and upper limits of the changes for each criterion will be the smallest and highest value from the set of j -th criterion. These values are given in the last two lines of Table 1.

In the fourth step the weights to the criteria were specified. It should be noted that the criteria can be treated with this method in an equivalent manner, which means assigning to them equal weight coefficients (equal to 1) or be considered as non-equivalent, which means assigning to them different weighting factors.

Weighted factors have various interpretation depending on structure and context of situation to be evaluated. That is why their estimation could be processed in many different ways. The frequent approach bases on using of the opinion of expert(s) or/and decision maker(s), the second approach takes into account mathematical operations on data collection in terms of evaluation of their informational value. The first approach could be applied to quantitatively or qualitatively weighted criteria, since it takes into consideration preferences of the decision maker or/and expert, which are resultant of its informational value, experience, and perception (Bottomley, Doyle & Green, 2000). The second approach to estimation of weights is processed mainly taking into consideration statistic and algebraic operations on data collection. It means that criteria shall be measurable and represented in form of real numbers (Diakoulaki, Mavrotas & Papayannakis, 1995).

Selection of concrete method amongst available variety of tools is extremely difficult. However it is viable to develop of recommendation which enable decision maker to select appropriate procedure of estimation of weighted factors, well-tailored to structure of executed analysis. It is worth to note that choice of concrete method of selection of weighted factors is derivative of familiarity of respective procedure, quality of data collection and ability of applying. Good solution could be also selection of weighted factors using different methods and then compare them.

To determine the weights values the points method was used, whose algorithm may be presented in the following steps (Panek, Zwierzchowski, 2013):

- 1) Adoption of the assumptions:
 - We have p points to be shared by experts between m criteria (where p is a positive number),
 - by p_{hj} we denote non-negative number of points awarded by h -th expert to the j -th criterion, when the equality is met:

$$\sum_{j=1}^m p_{hj} = p, h=1,2,\dots,k \tag{1}$$

- 2) Based on the results of the assessment of all the experts we build a matrix of criteria ratings of the form:

$$P = [p_{hj}], h=1,2,\dots,k; j=1,2,\dots,m \tag{2}$$

- 3) Calculate the mean score for each criterion:

$$\bar{p}_j = \frac{\sum_{h=1}^k p_{hj}}{k}, j=1,2,\dots,m \tag{3}$$

- 4) Because $\sum_{j=1}^m \bar{p}_j = P$, the we define weight factors as:

$$w_j = \frac{\bar{p}_j}{P}, j=1,2,\dots,m \tag{4}$$

In order to present this method for determining the weighting factors, each of the seven criteria was assigned a positive number of points from a pool of 20 points.

The results are summarized in Table 2, while the weighting coefficients determined according to the presented method's procedure are also included in the last line of the table.

The fifth stage is to create a table with the values of criteria for each logistic company (Table 1).

In the next stage, any number from Table 1 must be presented as a percentage of a covered "path" from the state of the least to the most desirable. The evaluation of the *i*-th company based on the *j*-th criterion (o_{xij}) is determined according to the relationship:

- for the stimulant:

$$o_{xij} = \frac{\max X_j - x_{ij}}{\max X_j - \min X_j} \cdot 100\% \tag{5}$$

- for destimulant:

$$o_{xij} = \frac{x_{ij} - \min X_j}{\max X_j - \min X_j} \cdot 100\% \tag{6}$$

where :

- x_{ij} is an assigned value of the *j*-th criterion for a company of *i*-th number,
- $\max X_j$ is a maximal value from the set of the *j*-th criterion,
- $\min X_j$ is a minimal value from the set of the *j*-th criterion.

The values determined in this stage size should be multiplied by predetermined weights.

The last stage is the final assessment of logistic company determined based on the relationship taking into account the weight of a given criterion:

$$O_{xi} = \sum_{j=1}^m w_j \cdot o_{xij} \tag{7}$$

where:

- O_{xi} is a final assessment of the *i*-th company,
- w_j is a weights values for *j*-th criterion,
- o_{xij} is a partial evaluation of the *i*-th company based on the *j*-th criterion.

In table 3 there was showed the final evaluation of the logistic companies together with its ratings. Column 3 presents final assessment taking into consideration equal weights, while column 5 presents weighted final assessment which takes into consideration assigned values of weighted factors with using of points method.

The evaluative analysis shows that from the point of view of the adopted criteria and preferences of the decision maker (the weighting values) the total highest score was achieved by DHL Express, then, Maszoński Logistic, TNT Express Worldwide (Poland). The remaining rankings are given in column 3 and 6. Table 3. The analysis of final grades of the logistic companies, taking into account the

same and different weightings, shows that they have similar values.

Table 2. Point values assigned to the criteria (Zelkowski, 2015)

Expert's number	Assigned points for criteria [point]						
	K ₁	K ₂	K ₃	K ₄	K ₅	K ₆	K ₇
1	3	6	3	1	2	3	2
2	3	5	4	3	2	2	1
3	3	2	2	3	5	3	2
4	2	3	2	2	3	3	5
5	4	3	2	2	2	4	3
6	3	4	3	4	1	3	2
7	4	3	3	1	2	3	4
8	4	3	4	4	1	2	2
9	4	3	4	3	3	2	1
10	3	2	5	3	3	1	3
11	3	2	2	6	1	3	3
12	2	4	2	2	4	3	3
13	2	4	2	3	3	2	4
14	2	4	3	2	3	4	2
15	2	4	4	3	2	3	2
16	2	2	4	1	1	5	5
17	3	2	3	2	4	3	3
18	4	4	3	2	2	2	3
19	2	2	4	3	3	2	4
20	2	3	3	3	1	4	4
21	2	5	3	4	2	2	2
22	4	4	2	3	2	2	3
23	2	5	4	3	3	1	2
24	4	5	3	2	3	2	1
25	2	3	2	4	3	2	4
26	2	4	4	3	2	2	3
27	3	3	5	1	4	2	2
Average	2,815	3,481	3,148	2,704	2,481	2,593	2,778
Weighting coefficient of the criterion	0,141	0,174	0,157	0,135	0,124	0,130	0,139

Table 3. Total ratings of the logistic companies acquired by Bellinger method

No.	Evaluated company [i]	Final grade	Ranking	Weighted final grade	Ranking
1	2	3	4	5	6
1	Maszoński Logistic	4,988	2	0,723	2
2	TNT Express Worldwide (Poland)	4,590	3	0,670	3
3	DHL Express	5,265	1	0,747	1
4	Raben Polska	3,525	4	0,492	4
5	General Logistic Systems Poland	3,001	7	0,433	7
6	Hellmann Worldwide Logistic Polska	3,125	5	0,464	5
7	arvato Polska	3,103	6	0,432	8
8	General Logistic Systems Poland (e-commerce)	2,993	8	0,439	6
9	FM Logistic	2,566	11	0,368	11
10	Geodis Calberson Polska	2,749	9	0,391	10
11	Diera	2,649	10	0,396	9
12	Fiege	2,139	14	0,319	13
13	DHL Supply Chain	2,241	12	0,316	14
14	C. Hartwig Gdynia	2,176	13	0,322	12
15	Panalpina Polska	1,908	15	0,271	16
16	DPD Polska (e-commerce)	1,577	17	0,237	17
17	DPD Polska	1,263	20	0,180	20
18	Allport Cargo Services Poland	1,818	16	0,273	15
19	Poczta Polska	1,509	18	0,226	18
20	IFB International Freightbrigade (Poland)	1,451	19	0,217	19

5. Summary

The presented procedure for the selection criterion features combined with multi-criteria comparative analysis allows a rational evaluation of selected logistic companies with respect to meeting a number of criteria, for example, respective service standards, compliance with imposed logistic standards. The presented course of the proceedings, depending on the needs and the requirements imposed by the decision makers, can be supplemented by indirect procedures (surveys, interviews), by which a detailed analysis of the criteria adopted is carried out.

It should be noted that the Bellinger method applied is clear and the analyses made by it are consistent

with those from other more complex methods. This method can be supplemented by other complementary techniques such as, for example, experts method. Accordingly, an important problem is the selection of appropriate course of action according to the needs of ongoing evaluative studies. This will then increase the credibility of the results of the logistic companies' assessment obtained.

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