Multicriteria Evaluation of Designing Transportation System within Distribution Sub-Systems

Dariusz Pyza
Warsaw University of Technology, Faculty of Transport, Warsaw, Poland

The paper presents the problem of designing transportation system for goods distribution with usage of multicriteria decision supporting method. The general characteristic of transportation system as an element of distribution system was presented. Moreover, the distribution system was identified as a one of the most important elements of supply chain which aims in making products available in place and time matching client needs. In further part the problem was mathematically formalized to optimization task. Analyzing the problems of modeling conveying system forces claim that decisions taken within area of transport organization consist in solving complex decision problems. Complexity follows from the demand of best decision according to many aspects. Solution must ensure othe best realization of all partial criteria (aims) taken into account during decision making process. The article contains characteristics of methods of multicriteria evaluation with regard to short literature review. The emphasis was placed on ELEKTRA and MAJA methods which can be applied in the evaluation of complex decision problems in transportation systems. The last part of the article is verifies of presented issues by tneans of numerical experiment.

Key words: Transportation system, transportation services schedule, distribution system, multicriteria evaluation.

1. INTRODUCTION

Transportation is a system whose purpose is to move people and/or cargo between different geographical locations. The necessity for movement implies the demand for the transportation services. This is because the companies need to be supplied with materials (elements, semi-finished products) that are necessary for production, or other resources, such as transportation of employees to work etc. The demand for transportation services can also result from the diversification in the spatial and assortment structure of the production as well as from the directional structure of the transportation and from the changes in the market supply and products distribution [11], [27]. Achieving goals in the production, trade-production, or trade businesses implies the need that the product that is to be sold reaches the retail sale and the consumer in the proper quantity and quality in the right place at the right time and at reasonable prices[1], [2], [19].

Distribution is one of the most important element in the logistic chain as it makes the product available at the time and place corresponding the customer needs and expectations.

In the literature [3], [11], [26], [27] you can meet many definitions and approaches of the concept of distribution (from Latin distributio - means the division, section). In economics, the distribution means the division of goods in the society. This can takes place by the conclusion of purchases and sales transactions, namely in the form of market exchange, as well as other forms of benefits paid on the basis of established criteria. From a macroeconomic perspective distribution means a process and structure of goods distribution from the manufacturers to the target audience [26]. It constitutes a distinct set of market channels and links one with another. The existing economical distribution systems of a certain organizational structure and equipped in material-technical factors help to choose the best way of product movement from the production to the consumption zone. The features of these systems cause that in short term, they become an external factor for the development of methods of distribution. In micro-economic, distribution is often identified with the process of selling and delivering products to final customers. Decisions related to the choice of how to sale a product, are in every company strategic decisions, because they ultimately affect the achieved efficiency of markets and economic results. From the point of view of the company, distribution means a set of actions and decisions related to offering the product at the place and time corresponding to the needs of the customers. An integral part of the distribution system is the transport system whose goal is the optimal – in terms of accepted criteria - meeting, reported in the area, transport tasks through the implementation of the transport process. In order to meet this objective it is necessary that this system has a defined structure that the characteristics of its components are set, that the size of the tasks is given and a specific organization is defined. The zoning problems on a macro scale, particularly the physical movement of goods between multiple shipment sites to multiple destination sites require consideration of many criteria in choosing the organization of transport.

The problem of optimal planning of the spatial links between the shipment and destination places for the goods is a routing problem and belongs to the essential issues for management of the means of transport, as an issue for the the transport enterprises. The routing task is to identify patterns of movement of transport units in such a way that each customer is served (receiving or delivering of the cargo), and that the vehicle capacity is not exceeded.

It can be assumed that the problem of scheduling the movement of transport units is a complex optimization problem. Its complexity stems from the fact that the decision has to be the best in terms of several aspects. The decision should therefore ensure the best implementation of all partial criteria (objectives) considered in the decision-making process. The ability to make decisions that consider different criteria is possible with the multicriteria optimization, often called as well polioptimization. It is worth noting that when the sub-objectives are consistent and have a hierarchical nature, then multicriteria decision problem can be replaced one-criterion problem with weights.

This article concerns the optimization of the transportation systems that perform the transportation tasks. Its assessment is analyzed in multicriteria aspects.

2. TRANSPORT OPTIMIZATION IN THE DISTRIBUTION SUBSYSTEMS

The issue of multicriteria assessment of the schedules of the transport service in the distribution subsystems can be considered in two steps.

The first step is to formulate the task that optimizes the project for transportation system of goods, the second step is the multi-criteria assessment of the variants of proposed solutions.

2.1. TO FORMULATE THE OPTIMIZATION TASK

The optimization task of the transportation services for distribution of goods is as follows. There exists a set $\boldsymbol{I} = \left\{ i^m : m = \overline{0, M} \right\}$ of numbers of the cities where there is a demand for goods and the center of distribution $\left(i^0 \right)$. The cities are described by the scale of demand for that good r^k- tego of this type $\boldsymbol{R} = \left\{ r^k : k = \overline{1, K} \right\}$, presented in the form of a matrix $\mathrm{B}=\left[b\left(i^m, r^k\right) \equiv b_{i^m}^{r^k} \in \Re^+ : i^m \in \boldsymbol{I}, r^k \in \boldsymbol{R} \right]_{M \times K}$.

The transportation services of the distribution system have a transportation firm that has a set $\boldsymbol{S} = \left\{ s^n : n = \overline{1, N} \right\}$ of means of transport. Each mean of transport can be defined by: payload $q\left(s^n\right) \equiv q_{s^n} \in \Re^+ : s^n \in \boldsymbol{S}$, volume $g\left(s^n\right) \equiv g_{s^n} \in \Re^+ : s^n \in \boldsymbol{S}$ and average driving speed $v\left(s^n\right) \equiv v_{s^n} \in \Re^+ : s^n \in \boldsymbol{S}$. The load delivered to the clients is taken from a distribution center (DC) within a specified period of time: $\Phi\left(i^0\right) \equiv \Phi_{i^0} = \left\langle \varphi'\left(i^0\right), \varphi''\left(i^0\right) \right\rangle; \varphi'\left(i^0\right) \in \Re, \varphi''\left(i^0\right) \in \Re;\ \varphi'\left(i^0\right) < \varphi''\left(i^0\right)$. In addition, customers accept the cargo within a specified time range $T\left(i^m, r^k\right) \equiv T_{i^m}^{r^k} = \left\langle t'\left(i^m, r^k\right), t''\left(i^m, r^k\right) \equiv t_{i^m}^{'r^k}, t_{i^m}^{''r^k} \right\rangle; t_{i^m}^{'r^k} \in \Re^+, t_{i^m}^{''r^k} \in \Re^+$. The time range may be equal for all customers, or individual customer requirements can be taken into account. We assume that the time of loading r^k- tego of the cargo $\Delta\Phi(s^n, r^k, i^0) \equiv \Delta\Phi(s^n, i^0)$,

$s^n \in \boldsymbol{S}$, $r^k \in \boldsymbol{R}$, $i^0 \in \boldsymbol{I}$ to s^n- ty the mean of transport in the DC, and the time of unloading r^k- tego the cargo $\Delta T\left(s^n, r^k, i^m\right) \equiv \Delta T\left(s^n, i^m\right)$, $s^n \in \boldsymbol{S}$, $r^k \in \boldsymbol{R}$, $i^0 \in \boldsymbol{I}$ from s^n- tego the mean of transport in i^m- tym the entry point. Distances of direct connections between the cargo entry points, and the DC are presented in the form of a matrix $\mathrm{D} = \left[d\left(i^m, j^m\right) \equiv d_{i^m j^m} \in \Re^+\right]_{(M+1)\times(M+1)}$. Furthermore the cost $c\left(s^n, r^k\right) \equiv c\left(s^n\right) \equiv c_{s^n} \in \Re^+ : s^n \in \boldsymbol{S},\ r^k \in \boldsymbol{R}$ of transport r^k- tego of this cargo s^n- tym by the mean of transport within one kilometer is also given.

The value of **decision variables** need to be determined for this data: $x^{s^n}_{i^m, j^m}$, where: $x^{s^n}_{i^m, j^m} = 1$ for $i^m \in \boldsymbol{I},\ j^m \in \boldsymbol{I},\ s^n \in \boldsymbol{S}$ – if $\left(i^m, j^m\right)$ is included in the route s^n- tego of the mean of transport, 0 in the opposite case meeting the **constrains**:

- $\sum_{i^m: m=0}^{M} \sum_{s^n: n=1}^{N} x^{s^n}_{i^m j^m} = 1, \forall j^m : m = 0, 1, 2, ..., M$ (2.1)
- $\sum_{j^m: m=0}^{M} \sum_{s^n: n=1}^{N} x^{s^n}_{i^m j^m} = 1, \forall i^m : m = 0, 1, 2, ..., M$ (2.2)
- $\sum_{i^m: m=0}^{M} x^{s^n}_{i^m p^m} - \sum_{j^m: m=1}^{M} x^{s^n}_{p^m j^m} = 1,$
  $\forall s^n : n = 0, 1, 2, ..., N; \forall p^m : m = 0, 1, 2, ..., M$ (2.3)
- $\sum_{i^m: m=0}^{M} \sum_{r^k: k=1}^{K} b^{r^k}_{i^m} \cdot \sum_{j^m: m=1}^{M} x^{s^n}_{p^m j^m} \le q_{s^n}$,
  $\forall s^n : n = 0, 1, 2, ..., N;\ \forall r^k : k = 0, 1, 2, ..., K$ (2.4)
- $\sum_{i^m: m=0}^{M} \sum_{r^k: k=1}^{K} b^{r^k}_{i^m} \cdot \sum_{j^m: m=1}^{M} x^{s^n}_{p^m j^m} \le g_{s^n}$,
  $\forall s^n : n = 0, 1, 2, ..., N;\ \forall r^k : k = 0, 1, 2, ..., K$;
  $\forall p^m : m = 0, 1, 2, ..., M$ (2.5)
- $\sum_{i^m: m=0}^{M} T^{s^n}_{i^m} \cdot \sum_{j^m: m=1}^{M} x^{s^n}_{i^m j^m} + \sum_{i^m: m=0}^{M} \sum_{j^m: m=0}^{M} a^{s^n}_{i^m j^m} x^{s^n}_{i^m j^m} \le T_{s^n}$,
  $\forall s^n : n = 0, 1, 2, ..., N$ (2.6)
- $z_{i^m} - z_{j^m} + M \cdot \sum_{s^n: n=1}^{N} x^{s^n}_{i^m j^m} \le M - 1$
  $0 \le i^m \ne j^m \le M, \quad z_{i^m}, z_{j^m} \in \Re^+$ (2,7)
- $x^{s^n}_{i^m j^m} \in \{0,1\}$, $\forall i^m, j^m : m = 0, 1, 2, ..., M$,
  $\forall s^n : n = 0, 1, 2, ..., N$ (2.8)
- $\varepsilon^{s^n}_{j^m} = x^{s^n}_{i^m j^m} \cdot max\left\{\varepsilon^{s^n}_{i^m} + a^{s^n}_{i^m j^m}, t'^{s^n}_{j^m}\right\} + \Delta T^{s^n}_{j^m}$,
  $\forall i^m, j^m : m = 0, 1, 2, ..., M$,
  $\forall s^n : n = 0, 1, 2, ..., N$ (2.9)
- $\varepsilon^{s^n}_0 \ge t_0, \forall s^n : n = 0, 1, 2, ..., N$ (2.10)
- $t'_{i^m} \le \varepsilon^{s^n}_{i^m} - \Delta T^{s^n}_{i^m} \le t''_{i^m}$, $\forall i^m : m = 0, 1, 2, ..., M$,
  $\forall s^n : n = 0, 1, 2, ..., N$ (2.11)

  which guarantee the **minimum** cost of transport to the customers recorded as:

$$f(X) = \sum_{i^m: m=0}^{M} \sum_{j^m: m=0}^{M} \sum_{s^n: n=0}^{N} d_{i^m j^m} x^{s^n}_{i^m j^m} \longrightarrow min \quad (2.12)$$

2.2. THE MULTICRITERIA ASSESSMENT OF THE TRANSPORTATION SYSTEM

Increasingly it is stressed that the decisions taken in the organization of transport depend on solving complex decision-making problems. This complexity stems from the fact that the decision taken has to be the best in terms of many aspects. At the same time we should seek to ensure that the best solution adopted implement all partial criteria (objectives) considered in the decision process, even if sometimes they contradict each other for example the decision in transport service should be dependent on costs of transport, quality of the service provided and the time needed to carry out the transport. This possibility gives the multicriteria optimization called also polioptimization. It is worth mentioning that if the sub- goals are compatible and can be fulfilled in one point, then the multicriteria decision process can be replaced by a one-criterion problem. The multicriteria decision problems are based on two basic postulates [6], [7], [10], [14], [17], [23], [25], [28]:

- **Domination postulate** – if there are two possible solutions, we assume that one of them is better then the other because of at least one criterion, and worse because of the rest of criteria. We should choose the first solution.
- **Transitive postulate** – if as results of comparisons, we decide that option A is better than B, and B for better than C, then we should consistently consider that option A is better than C.

From this postulates it can be observed that the adopted evaluation system in multicriteria optimization needs to be followed. This means that for the subjective valuation no reference system is created.

Arguments for the accuracy of solutions are based on the strength of the person who is giving the arguments, and not on the principles of logical inference.

In the multicriteria optimization set of solutions we can distinguish [14], [17], [23], [25], [28]: non-dominant solutions (optimal in sense of Pareto), weakly non-dominant solutions and dominant solutions (so called dominant in the ordinary sense – maximum elements) and weakly dominant solutions. Regarding the way of preferences expression by the decision maker we can divide the decision-making methods into [5], [6], [10], [14], [17], [24], [25], [28]:

- Methods, where the preferences are expressed in the a priori way: in the form of utility function, in the form of hierarchy of objectives, and in the form of level of target realization;
- Methods, in which preferences are granted gradually, so-called interactive programming (dialogs, conversations);
- Methods, in which preferences are expressed a *posteriori***:** the choice of compromise function.

One of the dialog methods is the method of variant sorting ELECTRE, which is based on the outranking concept. The result of the application in the model the ELECTRE method is the ranking and sorting of variants from the most preferable to the least preferable. This ranking and sorting is the result of the outranking relation which construction is based on so called compatibility and non- compatibility tests regarding the preferences for each pair of variants. This means that the ELECTRE method may be applied for the problems with finite and countable number of solution variants. A similar approach in determination of the optimal solution (also for the countable number of options) in the application used for optimization of transport is presented by the Authors of articles [7], [10] and [24]. In the presented method, $\boldsymbol{Y}$ is the finite set of variants w, so:

$$\boldsymbol{Y} = \{Y(1), ..., Y(w), ..., Y(W)\} \qquad (2.13)$$

However $\boldsymbol{\Psi}$ is a set of k sub-criteria evaluation of transport systems, ie:

$$\boldsymbol{\Psi} = \{\psi_1(\boldsymbol{Y}), ..., \psi_k(\boldsymbol{Y}), ..., \psi_K(\boldsymbol{Y})\} \qquad (2.14)$$

For evaluations of the options we assume that the Cartesian product $\boldsymbol{Y}\times\boldsymbol{\Psi}$ we have μ, as:

$$\mu : \boldsymbol{Y}\times\boldsymbol{\Psi} \longrightarrow \Re^+,$$

for which $\mu(w,k) \equiv \mu_{w,k} \in \Re^+$ has the interpretation of the w transportation system option variants $Y(w)$, through the k sub-criterion ψ_k.

Furthermore, for some of the sub-criteria, $k\in\boldsymbol{K}$, the ξ_k figures were assumed, interpreted as their relative validity . For such formulated problem the rate of compliance of variants assessments in the w and w' variants was defined by the formula:

$$z_{w,w'} = \frac{1}{\xi} \sum_{k\in \boldsymbol{K}:\, \mu_{w,k} > \mu_{w',k}} \xi_k \qquad (2.15)$$

where:

$$\xi = \sum_{k=1}^{K} \xi_k \qquad (2.16)$$

However the dependence of the incompatibility of the variant w and variant w', can be expressed as follows:

$$n_{w,w'} = \frac{1}{\lambda} \max_{(w,k):\mu_{w',k} > \mu_{w,k}} \{\mu_{w',k} - \mu_{w,k}\} \qquad (2.17)$$

where:

$$\lambda = \max_{\{(w,k)\}} \{\mu_{w,k}\} - \min_{\{(w,k)\}} \{\mu_{w,k}\} \qquad (2.18)$$

The next step of the multi-critera method is to assume the compliance threshold α and non-compliance threshold β. These thresholds help to define the outranking relation. It was set that the variant $Y(w)$ outranks the variant $Y(w')$, when for $Y(w), Y(w') \in \boldsymbol{Y}$:

$$z_{w,w'} \geq \alpha \wedge n_{w,w'} \leq \beta \qquad (2.19)$$

Based on the outranking relation a domination matrix is made, following the rule where:

$$m_{w,w'} = \begin{cases} 1, & \text{gdy } z_{w,w'} \geq \alpha \wedge n_{w,w'} \leq \beta \\ 0, & \text{w przeciwnym przypadku} \end{cases} \qquad (2.20)$$

This assumption helps us define in the set of possible conclusions the non-dominant variants, i.e. optimal Pareto, that are the solution to the problem. The full formulation for the multicriteria task can be found inter alias in publications [1],[10].

3. OPTIMIZATION OF TRANSPORT SERVICES IN THE DISTRIBUTION SUBSYSTEMS

Using a computer program "OPTIMIZATION of DELIVERY ROUTES" an experiment was performed for the transport service of distribution system. Input to the optimization problem formulation of the transport service distribution system:

- The number of means of transport used to operate in the considered network:
- Trans Logistic[1] Company uses all together 5 means of transport – 3 Volvo trucks and two tractors with Scania trailers.
- The number of collection centers and working hours of these points.
- The collection centers constitute 9 collectors. Collectors are working 24/24.
- Number of cargo loading places and their working time:
- The loading place is the distribution center located in Mszczonów. The DC works 24/24.
- Cargo handling time:
    - For both the recipient and the cargo loading place the time of loading and unloading is 60 minutes. This time includes all activities related to cargo handling
- Recipient demands: in this case customers are dealers located in the distribution system of the Trans Logistic company. Table 1 lists the average monthly recipient demand[2].
- Distances and driving times between particular points:
    - The distances (km) and times (min) have been presented in the table 2 and table 3. It was assumed that the average speed of transport is 50 km/h. Distances between the recipients were determined with the Via Michelin program.

Using the computer program „Optimization of the delivery routes" following results have been obtained (table 4).

The average utilization of means of transport is 58%; the accumulated unused transport carrying capacity: 23694 kg; total working time of the means of transport: 4164 minutes; total transport cost: 3 894, 24 PLN.

In further analysis of the distribution system following variants of transportation organization were proposed for following assumptions:

- **Option II** – reducing one of the Volvo trucks and leave unchanged the number of Scania tracktors. As a result, the total number of vehicles is 4;
- **Option III** – reduction by two the number of Volvo trucks leaving unchanged the number of Scania tractors. As a result, the total number of vehicles is 3;
- **Option IV** – to use only the Scania tracktors. Because there are no Volvo trucks involved in the process the number of Scania tracktors increases by one.
- **Option V** – reduction by one of the tracktors. In this option the total number of means of transport is 4;
- **Option VI** – to use only the Volvo trucks for the distribution network. In this case there will be 4 trucks needed.

3.1. CRITERIA OF SOLUTION ASSESSMENT

The proposed solution options can be assessed with the following criteria:

1. The average use of all means of transport (this parameter has a direct influence on the solution flexibility in case if one of the means of transport has an unexpected failure).
2. Cumulated unused load of the means of transport (based on this parameter it can be estimated if the possible demand increase is related with the changes in transport organization).
3. Total working time of the means of transport.
4. The operating costs of the means of transport (this parameter is set by the intersection of the kilometers made and the average cost of 1 kilometer).

---

[1] The name of the company was changed because of formal reasons.

[2] The data were prepared with the consideration of the cargo weight and cubature volume.

Table 1. Average number of monthly recipients demand

Name of town	The Load (kg)	Number of cargo pallets units (cpu)
1 – Tomaszów Mazowiecki	10200	28
2 – Jarosty	8500	23
3 – Wolbórz	6700	18
4 – Chorzów	9800	26
5 – Warszawa	8800	24
6 – Ożarów	1800	5
7 – Błonie	2500	7
8 – Gdańsk	9900	27
9 – Poznań	7800	21

Source: own work based on the available data

Table 2. Distances between particular recipients and DC

Name of town	Mszczonów	Tomaszów	Jarosty	Wolbórz	Chorzów	Warszawa	Ożarów	Błonie	Gdańsk	Poznań
Mszczonów	-	63	92	77	252	49	46	29	371	301
ToMaszów	63	-	31	16	191	111	108	91	435	277
Jarosty	92	31	-	19	166	140	137	120	391	247
Wolbórz	77	16	19	-	178	125	122	105	449	263
Chorzów	252	191	166	178	-	299	296	279	553	373
Warszawa	49	111	140	125	299	-	16	29	346	322
Ożarów	46	108	137	122	296	16	-	13	356	306
Błonie	29	91	120	105	279	29	13	-	341	294
Gdańsk	371	435	391	449	553	346	356	341	-	310
Poznań	301	277	247	263	373	322	306	294	310	-

Source: own work based on the available data

Table 3.The driving times between particular recipients and DC

Name of town	Mszczonów	Tomaszów	Jarosty	Wolbórz	Chorzów	Warszawa	Ożarów	Błonie	Gdańsk	Poznań
Mszczonów	-	76	110	92	302	59	55	35	445	361
ToMaszów	76	-	37	19	229	133	130	109	522	332
Jarosty	110	37	-	23	199	168	164	144	469	296
Wolbórz	92	19	23	-	214	150	146	126	539	316
Chorzów	302	229	199	214	-	359	355	335	664	448
Warszawa	59	133	168	150	359	-	19	35	415	386
Ożarów	55	130	164	146	355	19	-	16	427	367
Błonie	35	109	144	126	335	35	16	-	409	353
Gdańsk	445	522	469	539	664	415	427	409	-	372
Poznań	361	332	296	316	448	386	367	353	372	-

Source: own work based on the Via Michelin program

Table 4. The results of optimization of the transport service in the distribution system

No. of the mean of transport	The use of the mean of transport (%)	No. of kilometers made (km)
1	35	169
2	70	741
3	36	281
4	55	506
5	94	923

Source: own work based on the data driven from the program: „Optimization of the delivery routes”

Table 5. Juxtaposition of the results of all options with the assessment criteria

OPTIONS	**CRITERIA**			
	Means of transport utilization (%)	**Unused load of the means of transport (kg)**	**Total working time of the means of transport (min)**	**Total operating cost (PLN)**
I *after optimization*	58	23 694	4 164	3 894,24
II	66	13 494	3 805	3 574,47
III	86	20 791	3 695	3 575,73
IV	78	10 591	3 348	3 724,05
V	73	6 197	4 193	3 743,40
VI	69	9 100	4 973	4 057,05

Source: own work based on data from the „Optimization of the delivery routes" program

3.2. IMPLEMENTATION OF THE COMPUTER METHOD FOR THE ASSESSEMENT OF THE MULTI-CRITERIA METHOD

For the multi-criteria evaluation of the transportation system a computer program EKSPERT has been used. The program is an important element in the decision-making process concerning the organization of transport systems in the distribution of goods. After defining the criteria (Section 3.1), and variants of the organization of transport systems (Table 5) the evaluation of different options with *k*-th criterion has started. Ensuring comparability of variants evaluated their normalization has been made. This means the values of assessment criteria has been set $f(w,k)$ using the formula put in the position of [10]:

for the maximilized criteria:

$f(w,k)=\dfrac{o(w,k)}{\max\limits_{w\in W}\{o(w,k)\}}$, for the minimalized criteria $f(w,k)=\dfrac{\min\limits_{w\in W}\{o(w,k)\}}{o(w,k)}$,

where: $o(w,k)$ means the assessment for the *w*-th variant towards the *k*-criterion. In the next step a number of particular criterion have received some figures assigned ξ_k interpreting the relative importance of the *k*-th criterion. For the purposes of the analyzed decision-making situation it can be assumed that the value ξ_k of the relative importance of each criterion is a number from the interval $\langle 0,1\rangle$, but the higher is their value ξ_k the *k*-th criterion is more important. The dialog window for data input into the program and for the calculation of compliance indicators (2.15) and non-compliance indicators (2.17) of the evaluation options w with the option w' are illustrated by the pictures 3.1 ÷ 3.2.

In further analysis the thresholds of compliance $\alpha = 0,6$ and non-compliance assessments $\beta = 0,28$ have been set. Their are necessary to choose the effective option of the transportation system for the analyzed decision problem [1], [10]. [10]For the analized problem, regarding the multi-criteria assesement the final solution has been obtained. The best solution is the 5th option (picture 3.3).

The 5th option is better then the 1st, 2nd and 6th option and is not dominated by any other options. Other variants are worse, they have a smaller number of dominations or are being dominated.

4. SUMMARY AND CONCLUSIONS

There were 5 possible options proposed for the solution of the the transport organization problem. The most important was to find the best solution using the set assessment criteria. The best option meeting the expectations of the decision maker is the 5th option. Comparing the 5th option with the 1st (primary) option the use of the vehicles increased by 25,86% and is now 73,6% (figure 4.1).

The unused load capacity of the means of transport decreased by 17 497 kg, so ca.73,85%, which means that the use of accessible rolling stock was better used and planned (figure 4.2).

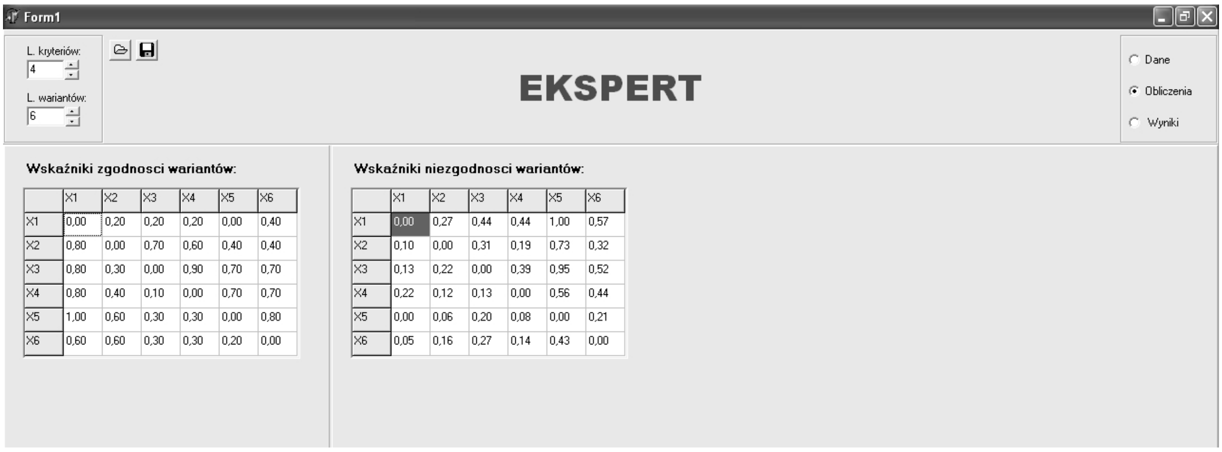

Figure 3.1. Dialog window for the data input

Source: own work

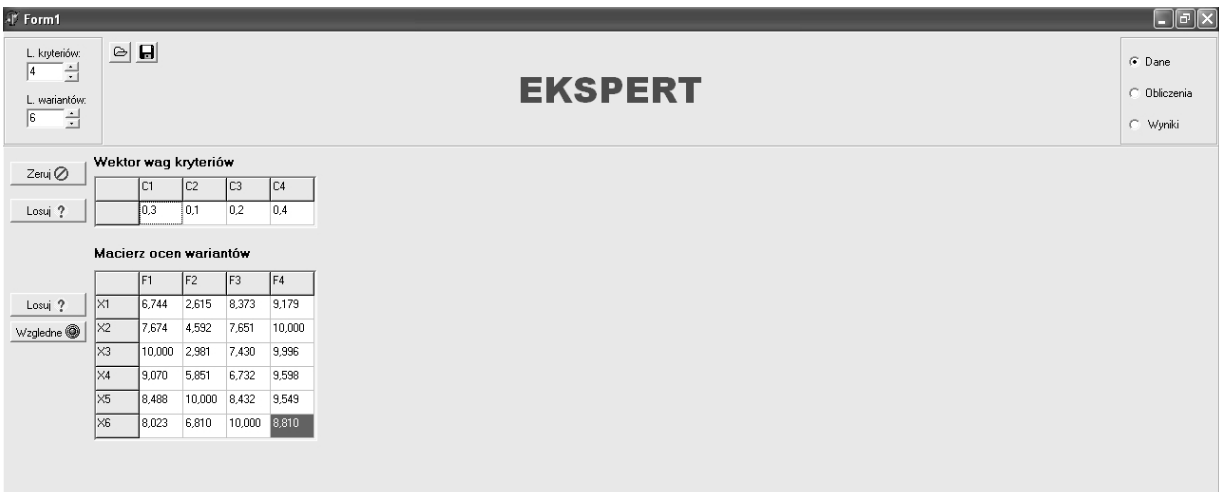

Figure 3.2. Dialog window with the calculation of compliance and non-compliance indicators

Source: Own work

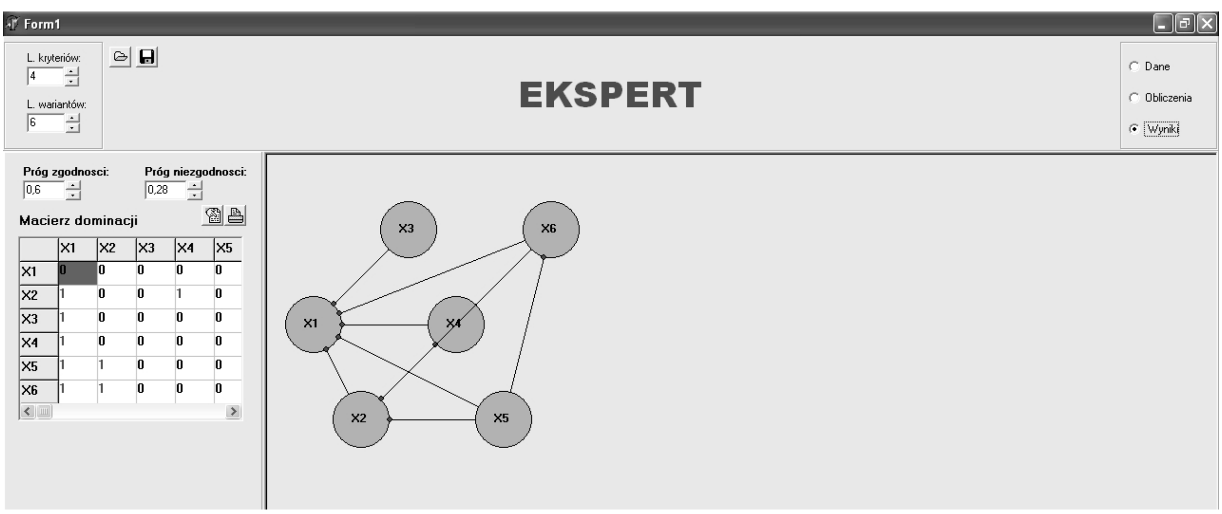

Figure 3.3. The dialog window with the problem solution

Source: Own work

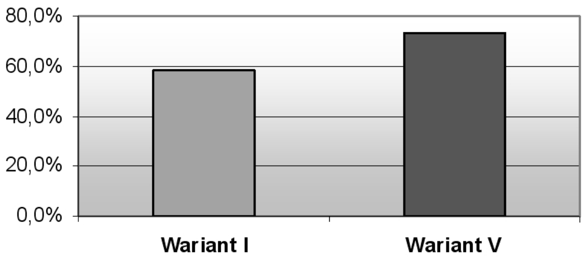

Figure 4.1. Comparison of the use of means of transport
Source: Own work

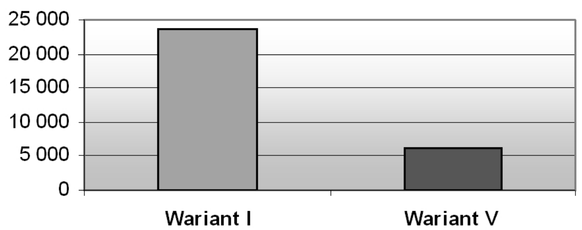

Figure 4.2. Comparison of the usues load capacity of the means of transport
Source: Own work

The operation cost in the solution proposed is smaller by 150,84 PLN/day than the current one after optimization (figure 4.3).

Figure 4.3. Comparison of the total operation costs of the means of transport
Source: Own work

The monthly cost will be reduced by 3,016.80 PLN, while the annually costs decreases by 36201,60 PLN. The cost reduction by about 5% makes the company more attractive for the customers and more competitive on the market. Concluding, the existing transport organization can be certainly changed. By reducing the number of the means of transport and by changing the way of transport organization the company can achieve better values in the indicators considered. This can definitely increase the financial performance of the company. In addition, the computer software EXPERT significantly reduces the time of decision-making and makes it possible to consider the problem on the multicriteria basis.

ACKNOWLEDGMENTS

This article is the result of the development project „Model of logistics system of Poland a way to the transport comodality in the European Union" No R10 0027 06/2009. Project Manager - Marianna Jacyna.

BIBLIOGRAPHY

[1] Ambroziak T., Pyza D., *O pewnym podejściu do oceny operatora usług logistycznych. Wybrane Zagadnienia Logistyki Stosowanej*. Rocznik 2007 nr 4, Komitet Transportu PAN, ISBN: 978-83-60560-07-5, Kraków 2007.

[2] Ambroziak T., Pyza D., *Selected aspects of* transportation *system modeling, Total Logistic Management*, AGH University of Science and Technology Press, Krakow 2008, ISSN 1689-5959

[3] Beier F., Rutkowski K., *Logistyka*, Wydawnictwo Szkoły Głównej Handlowej, Warszawa 2004

[4] Całczyński A., Metody optymalizacyjne w obsłudze transportowej rynku, OWPW, Warszawa 2001.

[5] Ignasiak E., *Optymalizacja projektów* inwestycyjnych, Państwowe Wydawnictwo Ekonomiczne, Warszawa 1994.

[6] Ignasiak E. (red), *Badania operacyjne*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2001

[7] Jacyna M., *Modelowanie wielokryterialne w zastosowaniu do oceny systemów transportowych*, Rozprawa habilitacyjna, Prace Naukowe seria Transport z. 47, Oficyna Wydawnicza PW, Warszawa 2001.

[8] Jacyna M., Multicriteria Evaluation of Traffic Flow Distribution in a Multimodal Transport Corridor, Taking into Account Logistics Base Service Archives of Transport, Polish Academy of Sciences, Com. of Transport, vol. 10 iss.1-2, Warsaw 1999;

[9] Jacyna M., Multicriteria Evaluation of Traffic Flow Distribution in a Transport Corridor, Railway Engineering, London 2001

[10] Jacyna M., *Modelowanie i ocena systemów* przewozowych, Oficyna Wydawnicza PW, Warszawa 2009.

[11] John J. Coyle, Edward J. Bardi, C. John Langley Jr., *Zarządzanie logistyczne*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2002.

[12] Krawczyk S., *Zarządzanie procesami logistycznymi*, PWE, Warszawa 2001.

[13] Leszczyński J., *Modelowanie systemów i procesów transportowych*, PWE, Warszawa 1994.

[14] Nykowski I., Galas Z., Żółkiewski Z., *Programowanie wielokryterialne*, Państwowe Wydawnictwo Ekonomiczne, Warszawa 1987;

[15] Nykowski I., *Dwukryterialny liniowy zbilansowany problem transportowy*, Przegląd Statystyczny, t. 33, z. 1, 1986;

[16] Nykowski I., *Programowanie liniowe*, Państwowe Wydawnictwo Ekonomiczne, Warszawa 1980;

[17] Nykowski I., *Rozwiązanie kompromisowe w wielokryteriowym programowaniu liniowym*, Przegląd Statystyczny, t. 24, z. 1, 1977;

[18] Ortúzar J. de D., Willumsen L. G., *Modeling transport*, second edition, John Wiley & Sons West Sussex, England 1998;

[19] Pyza D., *Selected Aspects of Modelling OF Conveyance Systems at Random Supply*, Archives of Transport volume 20, issue 3, ISSN 0866-9546, Polish Academy of Sciences Committee of Transport, Warsaw 2008.

[20] Pyza D., *Metoda oceny czynników jakościowych w decyzjach typu make or buy, w Teoria i praktyka modelowania systemów logistycznych*. Monografia Wydziału Ekonomii i Zarządzania nr 99. Wydawnictwo uczelniane Politechniki Koszalińskiej, ISSN 0239-7129, Koszalin 2004.

[21] Pyza D., *Modelowanie procesów logistycznych w przedsiębiorstwach transportowych*. Prace Naukowe Politechniki Warszawskiej serii Transport, zeszyt nr 63 (2007)

[22] Roy B., Present M., Silhol D., *A programming method for determining witch Paris metro stations should be renovated*, European Journal of Operational Research, vol. 24, 2 (1986).

[23] Roy B., Vincke P., *Multicriteria analysis: survey and new directions*, European Journal of Operational Research, vol. 8, 3 (1981);

[24] Roy B., *The outranking approach and foundations of ELECTRE methods*, W: Bana e Costa C. A. (ed.): Readings in multiple criteria decision aid. Springer-Verlag, Berlin 1990.

[25] Roy B., *Wielokryterialne wspomaganie decyzji*, Wydawnictwo Naukowo Techniczne, Warszawa 1990.

[26] Rutkowski K. (red.), *Logistyka dystrybucji*, Wydawnictwo Difin, Warszawa 2002

[27] Sikora W., *Modele i metody optymalnej dystrybucji*, Zeszyty Naukowe – seria II, Akademia Ekonomiczna w Poznaniu, Poznań 1993.

[28] Słowiński R., Przegląd metod wielokryterialnego wspomagania decyzji. Część I, Przegląd Statystyczny, t. 31, z. 1/2, 1984.