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THE USE OF MULTIPLE-CRITERIA RANKING METHODS FOR DESIGNING PUBLIC TRANSPORT SYSTEMS

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Summary

The aim of the paper was an attempt at application of multiple-criteria analysis for planning public transport system. Methodological rules of an assessment of public transport systems were presented, including: defining variants and coherent family of criteria. Modelling decision-maker's preferences and seeking the most desirable solution. The problem of an assessment of public transport systems was formulated as a multiple-criteria problem of variants ranking. Schemes of appropriate communication connections (routes) were developed in the work using GIS technology and subjected to the assessment by means of a coherent family of criteria using the decision maker's preferences.

Key words: multiple-criteria assessment, ranking methods, Analytical Hierarchical Process, public transport

INTRODUCTION

Socio-economic development of any area is to a considerable degree conditioned by an efficiently functioning transport system which should guarantee proper services for passengers. In most cities transport is usually associated with arduous traffic jams, noise and environmental pollution. These phenomena are mainly caused by individual vehicle transport development which is the main competitor for city transport. In this situation one should strive to seek alternative solutions on one hand meeting the expectations of customers regarding travelling standards, on the other reducing the level of pollution and noise. Easy access to the transport system, appropriate travelling comfort, proper road infrastructure and reliable, comfortable trams and buses should be provided in order to encourage city dwellers to use public transport means. The interest of potential passenger is also significantly affected by the tariff policy. The level of payments for transport services in public transport should be adjusted to financial abilities of the society and competitive for the costs of using a car (Gadziński 2010).

For decades people have been facing a problem of making decisions. Both private persons and financial empires feel increasingly stronger pressure, awareness of risk and anxiety about assuming responsibility (Korenko et al 2014). Choosing a wrong solution may lead to lower profits or even inhibition of a city or commune development. A process of seeking the tools which would make the decision making process more efficient and faster was initiated, which would allow to reduce the risk to minimum (Adamus, Szara 2000).

In order to ensure a proper process of planning the public transport infrastructure investments, its projects should be consulted not only with local authorities but also with the inhabitants. Creating a new public transport network and the transport logistics based on existing connections and solutions are crucial elements in the management of infrastructure in a given area (Gadziński 2000).

AIM AND SCOPE OF WORK

The paper addresses the issues of a multiple criteria selection and problems associated with public transport, discusses the essence of multiple criteria decision support, as well as presents the concept, functions and development of public transport. The methodology adopted for designing and selecting the best transport solution were presented in detail. Five various transport solutions in the area of Słomniki commune were designed and subjected to a multiple-criteria assessment. The assessment of discussed variants of commune public transport used a set of criteria comprising: accessibility of the system, travel time, the size of served area, population number, accessibility of public facilities and integration with railway transport.

DEFINITION AND CONCEPT OF MULTIPLE CRITERIA DECISION SUPPORT

Each subject functioning in a complex economic reality, while making a choice is driven not by one, but many criteria. Therefore the problem is multiple criteria by nature. Multiple Criteria Decision Support (MCDS), called multiple criteria analysis or multiple criteria decision making is a discipline originating from operational research. The disciple aims to provide a decision maker with procedures, tools and mathematical – information methods enabling him to solve complex decision processes. Contradictory points of view must be very often taken into consideration while solving these problems (Adamus, Gręda 2005). According to B. Roy (1990), multiple criteria decision support is the activity of an analyst who in a decision making process helps a decision maker to find answers to questions connected with seeking the most desirable solutions regarding the multiple aims which the decision maker sets.

B. Roy (1990) defines decision support as: "the activity of the person who on the basis of clearly expressed but not necessarily fully formalized models helps to find elements of the answers to questions posed by an intervening party in the decision making process, elements clarifying the decision and usually recommended or just privileging certain behaviours in order to increase their coherence with the process evolution on one hand and objectives and intervening party's system of values on the other."

In other words, MCDS serves to solve multiple criteria decision problems, i.e. the situation when, possessing a defined set of activities and criteria family, a decision maker aims at (Żak 2005):

- determining the sub-set of activities regarded the best in view of considered family of criteria (the problem of choice),
- dividing set of activities into subsets, in compliance with certain standards (the problem of classification or sorting),
- ordering the set of activities from the best to the worst (the problem of ranking).

In the first place decision support should be divided into four categories of decision problems (Spronk et al. 2005):

1. "The description issue" – the problem is making description of potential actions and identification of a criterion or a family of criteria. This category comprises for example characteristics of financial condition of a set of enterprises,
2. "The problem of choice" – supporting a decision-maker focuses on a selection of a small number of good proposals. There is no requirement of choosing the best (optimum) variant. The choice targets the best option from the considered sub-set. This category comprises the problems of e.g. choosing investment projects.
3. "The assignment issue " – the problem of assigning an alternative to one of the available categories. This category comprises such problems, as forecasting a potential bankruptcy of an enterprise (on the basis of financial condition analysis).
4. The ranking issue – making a ranking of decision variants according to defined criteria (and determined superiority relationships). Variants may be mutually better, worse, incomparable (or indiscernible).

This category comprises the problems of e.g. making comparative analysis and ranking of company's shares on the stock market.

These issues result from determined aspect of planned decision and the aim which is expected of the supported process.

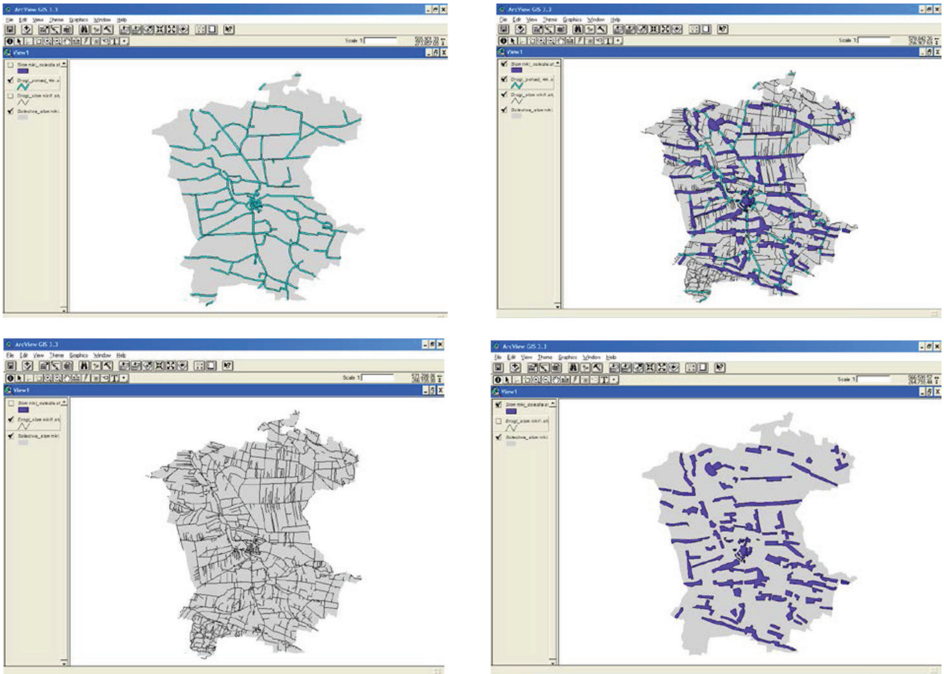

Figure 1. Thematic layers with individual factors determining localisation of new transport routes

RESULTS

Schemes of suitable transport connections (routes) were developed in the paper using GIS technologies (ArcView, Emapa Transport Plus). In order to enable transporting passengers as close as possible to the most important facilities in the commune area, the following factors were taken into consideration in route designs:

- buildings location,
- population (population density),
- distribution of road network,
- existing transport connections (railway, public city transport, public local transport, private transport firms).

The above mentioned factors played a crucial role in planning alternative transport solutions. New routes were marked out along the existing roads which have bituminous surface and are at least 3m wide. The other roads were not taken into consideration due to high costs of their adaptation for everyday exploitation.

The routes design considered also population density in a given area. By limiting to the minimum passages through uninhabited areas, among others the route lengths were shortened and the fuel costs were reduced, which in consequence contributed to lowering the transport costs. The existing public transport network was taken into consideration at designing the route variants. Area of Slomniki commune was chosen as a case study.

For each of the above mentioned criteria thematic layers were developed using ArcView programme (Fig.1). Combining all thematic layers of each criterion allowed to mark out the areas which should be taken into consideration in designing new routes.

CHARACTERISTICS OF DISCUSSED VARIANTS

Variant 1 (V1)

The first variant is a single route, 58.85 km long. The route passes through 21 localities situated in the area of Słomniki commune. It is the simplest solution, with an advantage of a possible using only one means of transport. However, the time of waiting and travelling along this route without stopping at bus stops is 1 hour and 40 minutes. From the passenger's point of view it is an arduous solution because a passenger getting on at the beginning of the route, who wants to travel just for a short distance would have to travel throughout whole commune area and loose plenty of time. Moreover, the solution gives no possibility to use train connection.

Variant 2 (V2)

Two routes were marked out in variant two. One passes through the northern part of the commune, the other through the southern one. The northern route (blue) is 40.9 km long and the travel time along it is 1 hour and 13 minutes. The southern route (red) is shorter. It is 27.4 km long and the travel time necessary to cover it is 44 minutes. In relation to variant 1 it shortens the travel time and therefore improves the travel comfort. Moreover, using this solution a passenger is able to use train connection.

Variant 3 (V3)

For the next variant (variant 3) four routes were marked out. Each differs from the other by its length and travel time. The first route (green) is the longest – 30.2km and serves the north-western part of the commune, the travel along it takes 55 minutes. The subsequent route (purple) serves the north-eastern part of the commune and is 24.5km long. The distance may be covered in 33 minutes. The south-western route (red) is the shortest (18.9km) and can be covered in 28 minutes.

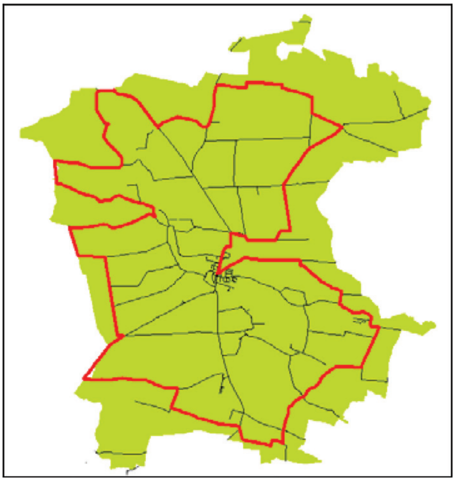

Figure 2. Variant 1 route

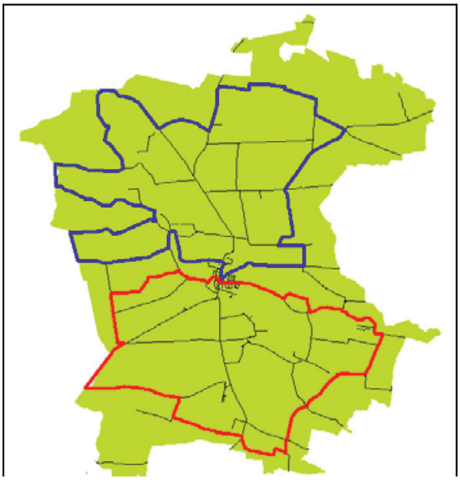

Figure 3. Variant 2 routes

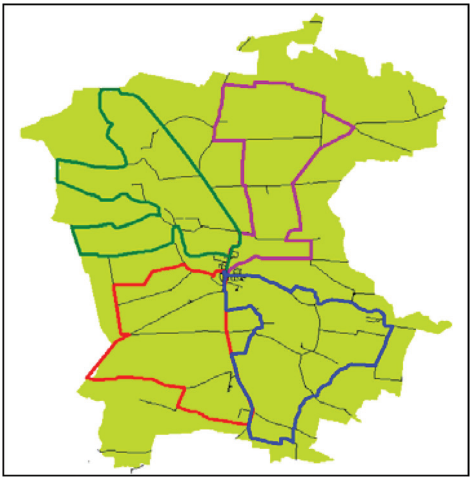

Figure 4. Variant 3 routes

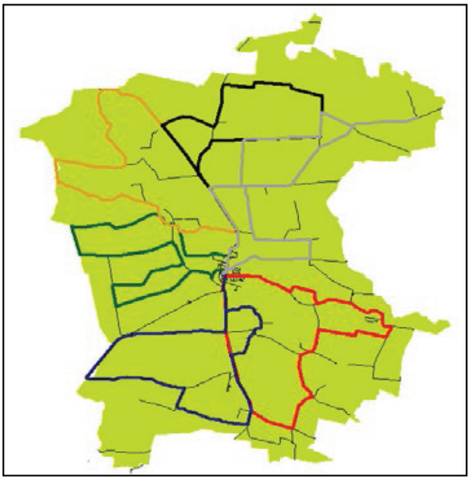

Figure 5. Variant 4 routes

Variant 4 (V4)

Variant 4 presents 6 routes (fig.5). The travel times along them are approximate. A disadvantage of this solution involves a means of transport passing through uninhabited areas which incurs higher fuel consumption. Moreover, it is associated with a necessity to use several means of transport. There is also a possibility that one minibus would serve several routes, however in such situation, a passenger's waiting time at a bus stop would get longer. Both in variant 2 and 3, a travelling person may use two railway stations. Moreover, a number of public facilities, such as sports facilities, health centres or libraries are situated along the routes.

Table 1. Lengths of routes for public transport in variant 4

Route no.	Length [km]	Travel time [min]
1	20.48	32
2	19.62	28
3	19.81	39
4	23.37	36
5	21.65	29
6	25.07	36

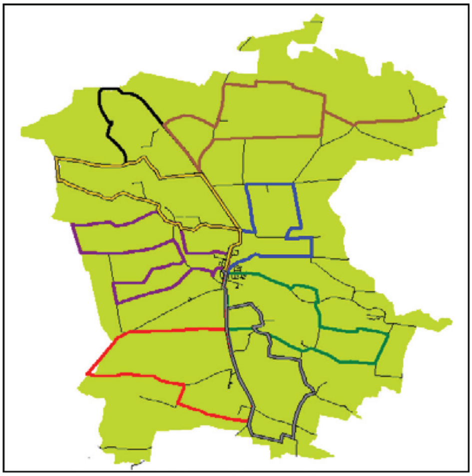

Figure 6. Variant 5 routes

Variant 5 (V5)

A greater number of routes i.e. 8 was suggested for variant 5. The shortest (outlined in blue) measures approximately 12 km, whereas the longest (brown) almost 28. Table 2 presents detailed characteristics of this solution. It is possible to develop more than ten or even several dozen of different communication links in the area of Słomniki commune. Each solution involves a necessity to use higher number of means of transport, different length of the routes and travel time.

Owing to increased number of routes it was possible to shorten the travel time and distance. A minibus would not pass through uninhabited (agricultural) areas, as it was planned in variant 4. Shortening of travel time would improve travel comfort, which from the travelling persons' perspective greatly affects a choice of the means of transport. A traveller is able to use each railway station situated in the commune area, which makes this solution more attractive.

Table 2. Lengths of public transport routes in variant 5

Route no.	Length [km]	Travel time [min]
1	18.12	26
2	27.88	39
3	11.54	17
4	14.81	23
5	15.21	29
6	17.99	29
7	19.81	39
8	18.12	26

Table 3. Final ranking of variants

	Priorities	System accessibility	Travel time	The area served	Population number	Public facilities accessibility	Integration with railway transport
1	0.1105	0.2810	0.2810	0.4091	0.2810	0.3752	0.4091
2	0.1298	0.3752	0.3752	0.4091	0.3752	0.2810	0.5438
3	0.1982	0.5383	0.5383	0.5438	0.5383	1.0000	0.7665
4	0.2688	0.7654	0.7654	1.0000	0.7654	0.7665	0.7665
5	0.2928	1.0000	1.0000	0.7665	1.0000	0.5383	1.0000

RANKING OF VARIANTS AND THEIR ASSESSMENT

A computational experiment conducted by means of AHP method revealed that the best preferred solution is variant 5. On the basis of conducted calculations, the final ranking was developed, presented in Table 3.

SUMMARY AND CONCLUSIONS

The paper presented possible applications of multiple criteria decision support for planning, construction and assessment of public transport systems. Five alternative variants of public transport system in the area of Słomniki commune were designed using GIS tools. The variants were subjected to an assessment by means of a coherent family of criteria using the decision maker's preferences. Computational experiments leading to ranking of variants were conducted using AHP method. Conducted analyses have demonstrated the following:

1. Requirement and techniques assumed in the process of planning transport connections led to developing five variants of public transport systems with various lengths and travel time.
2. The use of AHP method allowed to estimate the priorities for individual solutions and to establish a ranking based on them. The best solutions proved to be variant 5, composed of eight routes with the total length of 143 km.
3. The main criteria affecting the assessment of public transport system are social and infrastructural criteria.
4. The applied methodology may be used for an assessment of transport systems not only in the commune area, but also in a county or voivodship.
5. Multiple-criteria methods translate the dependencies and mechanisms formulated as a theory into concrete solutions supported by computations.

REFERENCES

Adamus, W., Gręda, A. (2005). Wspomaganie decyzji wielokryterialnych w rozwiązywaniu wybranych problemów organizacyjnych i menedżerskich. *Badania Operacyjne i Decyzje*, (2), 5-36.

Adamus, W., Szara, K. (2000). Zastosowanie Analitycznego Procesu Hierarchicznego AHP do racjonalizacji zarządzania i organizacji gospodarstw (przedsiębiorstw). *Zagadnienia Ekonomiki Rolnej*, (4-5), 20-41.

Gadziński, J. (2010). *Ocena dostępności komunikacyjnej przestrzeni miejskiej na przykładzie* Poznania. Poznań: Bogucki Wydawnictwo Naukowe, ISBN 978-83-62662-36-4.

Korenko, M., Földešiová, D., Máchal, P., Kročko, V., Beloev, C. (2014) 5s method as a set of measures to improve quality of production in the organization. *Agricultural, forest and transport machinery and technologies* (1/1), 27-32.

Roy, B. (1990). *Wielokryterialne wspomaganie decyzji*. Warszawa: WNT.

Spronk, J., Steuer, R., Zopounidis, C. (2005). Multicriteria Decision Aid. Analysis in Finance. In: *Multiple Criteria Decision Analysis: State of the Art Surveys (VII). International Series in Operations Research & Management Science (VII/78)* pp 799-848. New York: Springer.

Żak, J. (2005). *Wielokryterialne wspomaganie decyzji w transporcie drogowym*. Poznań: Wyd. Politechniki Poznańskiej.

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