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IDENTIFYING CRITERIA FOR EVALUATING THE LOCATION OF RAILWAY STATIONS

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Abstract**:** *Planning of the railway station locations in integrated passenger transport is a multicriteria problem. By analyzing previous research on that subject it has been observed that in most of the cases researchers are using optimization method with just one criterion in order to determine the railway station location. The goal of this research is to find a methodology capable of solving this problem from a multicriteria perspective. The solutions that are obtained by an optimization method using just one criterion can be compared and evaluated by another method and an additional set of criteria defined by the stakeholders involved in the process of railway station location planning. The selection of the interested parties mostly depends on the relationship between the government, infrastructure manager and railway operators. In this research the interested parties are users, infrastructure manager and railway operators. For multicriteria evaluation it is possible to use the analytic hierarchy process since it can compare the qualitative and quantitative criteria. Using AHP it is possible to rank the relevance of each criterion considering the goal of the research. Defined criteria can be compared regarding solutions obtained by the optimization method. The output of the evaluation process is a rank of solutions – such as railway station locations and stops obtained by the optimization algorithm. Sensitivity analysis regarding criteria priorities and their number has been conducted on the output of the evaluation process.*

1. INTRODUCTION

The construction of an urban public transport system, and particularly of the separated rail systems, such as the railways, requires long-term planning and harmonization with other transport modes, as well as substantial investments. It is necessary to plan a transport system which currently corresponds to the needs of the population for mobility, but that will at the same time, in 10, 15, or 20 years still be running and satisfying the newly arisen needs. The stakeholders in the process of planning the urban public transport system (traffic planners, engineers, users, carriers, local authorities) do not necessarily have to agree on the goals and restrictions during the planning process. The available data may be unreliable, and the construction costs often exceed the planned budgets. All this makes the planning process, i.e. the problem regarding the design and shape of the urban public transport network an extremely complex one.

According to Vuchic [1], railway stations represent a constant infrastructure which requires high investments and, consequently, their location in space has a significant impact on the environment. Also, the number and the distribution of stations on the line significantly influence the speed of transport, time of travelling, comfort during transport and operative costs.

2. DEFINING THE CRITERIA FOR THE EVALUATION OD THE SOLUTIONS REGARDING THE LOCATION OF RAILWAY STATIONS

Defining the criteria for the evaluation of the solution of the stations location depends strongly on the government (at state and local level) – infrastructure manager – carrier relation. This aspect of planning the station location should be approached depending on the mentioned relation in the country in which the construction of the railway line and the accompanying stations is planned. Therefore, some of the criteria applied in this research would not be taken into consideration in some other country, but there would be other criteria important for the specific local conditions. The research was done for the case when the transportation activity is separated from the infrastructure management. Therefore, the starting point is that the criteria for determining the station location are brought and evaluated by the infrastructure manager, carrier and the immediate infrastructure users. The number, arrangement and precise location of the station affect both the infrastructure manager and the carrier. Apart from the manager and the carrier, the current and potential users of railway transport play an important role, so that they also need to be included in the process of evaluating the solutions for the station locations.

2.1. SYSTEM USERS' CRITERIA

From the aspect of the transportation system users, the criteria that affect the station location refer to:

- total travelling time;
- station accessibility.

In this case the total *travelling time* is considered from the aspect of the travelling time by the means of public transport and it consists of:

- time of travelling from the trip origin to the station (t_p');
- time of transfer (t_t) and time of waiting for the transport means ($t_č$)[1];
- time of riding by the transport means (t_v);
- time from the destination station to the trip destination (t_p'').

The time of travelling from the origin to the station of public transport depends on the method of arrival to the station. According to [2], it is precisely this segment of the overall travelling time which is very important from the aspect of the user as the deciding factor in the selection of the transport mode. *The time of waiting* for the transport means is related to the frequency of the transport means; the higher the frequency the shorter the average waiting time. *The time of riding* by the transport means depends on the respective public transport system. In this way the systems can be divided into those that are physically separated from the rest of the traffic system (rail transport systems) and those that share the traffic surface with individual transport. In this study the time of riding on a train is relevant. This time depends on the permitted maximal speed on the railway line or certain railway line sections and on the possibility for the train to reach this speed which has been determined by the minimal distance between the two adjacent stations. *The time of travelling from the destination station to the trip destination itself* can be defined in the same way as the travelling time from the origin to the origin station; that is, depending on the method of

[1] Usually the total transfer time is defined, which contains the mentioned times.

arriving to the station, i.e. departure from the station. The only difference is that if part of the trip t_p' is done by a passenger car, then probably part of the trip t_p'' will have to use some other mode. Eventually, the total travelling time, t_{up}, can be written as follows:

$$(1)\ \sum t_{up} = \sum(t_p' + t_{\check{c}} + t_v + t_p'') = \sum(\frac{l'}{v'} + \frac{h}{2} + \frac{l_p}{v_v} + \frac{l''}{v''})\ [min]$$

where

l', l'' – distances that a user covers on arrival from the trip origin to the station and in departure from the station to the end destination;

l_p – length of the railway line section travelled;

h – train headway;

v', v'' – velocities of arrival to the station, i.e. departing from the station;

v_v – train running velocity.

The accessibility as a criterion affects the system user as well as the carrier. The system user is affected regarding the location of the station. It is partly related to the criterion of the travelling time, i.e. the component of the travelling time from the origin to the station itself t_p' and it depends on the method of arriving to the station. If the station can be accessed only by walking, then from the users' aspect such a station is poorly accessible since it is accessible only to certain few people who live or work in the close vicinity of the station. On the other hand, if the station can be accessed also by bicycle, passenger car and/or some other transport mode, then such a station is accessible to a larger number of users. The catchment areas of a station regarding the different methods of arriving to the station has been presented in Figure 1.

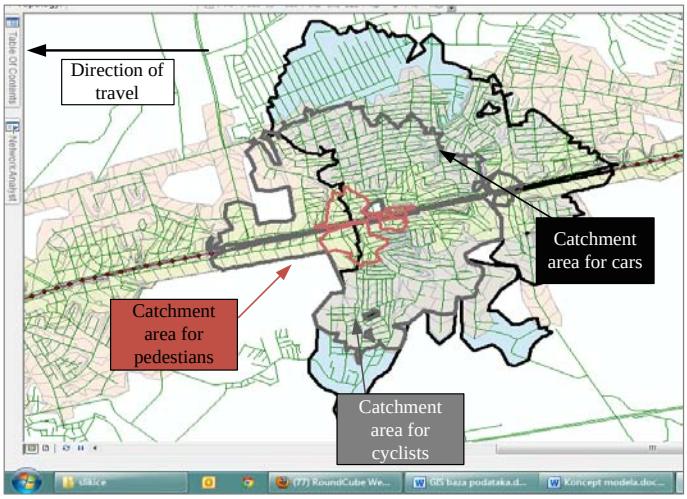

Figure 1 - Catchment area for rail station

2.2. INFRASTRUCTURE MANAGER'S CRITERIA

Within the context of defining the station location the infrastructure manager has a set of criteria that result from the obligations defined by the legal acts. In this study the criteria of the infrastructure manager in defining the station location are based on the legal acts of the Republic of Croatia. Based on this it is possible to define the criteria of the infrastructure manager that are usually of financial nature. These criteria are:

- station construction costs;
- station maintenance costs;
- operative costs.

Station construction costs are certainly one of the major items in the process of station location planning. The amount of station construction costs is affected by many factors, and they depend on the precise location at which the station will be built. Thus it may happen that

the costs of station construction of the same category at two different locations are different (e.g. if one station is in the vicinity of the residential buildings and additional protection against noise is required). These costs are known only after the precise location of the station construction is known, and they include:

- costs of land acquisition;
- costs of preparing the land for the station construction (levelling, complexity of construction depending on the type, loading capacity and property of soil);
- station construction costs that depend on the station category (existence of P&R system, urban public transport stops);
- costs of connecting the station to the existing traffic network (connecting to the road, bicycle and pedestrian network);
- costs of connecting the station with the existing electrical grid, utility network, etc.

Apart from building the infrastructure, the infrastructure manager also has to maintain and modernize the infrastructure. The *maintenance costs* include all the costs related to station (building) maintenance and costs of maintaining the devices and equipment on the station. In the first years of exploitation the maintenance costs will not be high if the facilities, devices and equipment are new, but over the years these costs will increase. According to [3], there is a distinction between the investment maintenance and the current maintenance. Investment maintenance means in advance planned works that exceed in their scope the current maintenance and require technical and material preparations. Current maintenance means works on maintaining the infrastructure for normal flow of traffic. The task is to maintain the infrastructure and to protect it against damaging so that it can endure the planned service life. The costs included here are the cost of material, mechanisation and hours spent by the staff on maintenance. The cost of station maintenance depends also on the station category and it will increase proportionally to the level of the station category. If two stations are compared, of which one has the P&R system, and the other does not, then one may expect that the former will have higher maintenance costs for the item of P&R system maintenance. The *operative costs* include all the costs of current station operation, such as the overheads, costs of the employed personnel, costs of the office materials, and information technology equipment as well as other costs. Operative costs also depend on the number and category of the station. The higher the category of the station, the higher the requirements regarding station operation, including costs.

2.3. RAILWAY CARRIER'S CRITERIA

From the aspect of the carrier the criteria for evaluating individual solutions for the station location can be:

- riding time;
- operative costs.

Riding time from the carrier's aspect overlaps partly with the riding time contained in the travelling time from the user's aspect. If a station, namely, from which the ride starts is not at the same time a depot, then this riding time has to be increased by the part of the trip from the depot to the station. Also, at the end station certain time for resting and personnel shift/change has to be provided, as well as for the schedule adjustment. Thus, from the carrier's aspect the travelling time t_v^p can be defined as follows:

(2) $t_v^p = t_{dt} + t_v + t_t \; [min]$

where:

t_{dt} – running time from the depot to the station at which a certain railway line starts the transport;

t_v – running time between end stations of a considered railway line;

t_t - time spent at the end stations.

Running time is a technological parameter which depends on the velocity. In railway traffic, among others, the commercial[2] (v_k) and technical velocity[3] (v_t) are distinguished and they are interconnected. These velocities are under exclusive jurisdiction of the railways, i.e. they depend on the fixed railway transport means (railway lines) and mobile means (train) [4].

Operative costs represent the operational costs of a certain railway transport line. According to Vuchic [1], the carrier's operative costs include the following items:

- salaries of the operative staff with bonuses;
- costs of fuel and propulsion energy;
- maintenance costs, including the employees, premises and equipment for the maintenance;
- costs of transportation documents;
- informing, promotion and marketing;
- train licensing and registration;
- insurance costs;
- costs of administration, including staff, office premises, and other costs related to the operation of the transportation agency.

With the increase in the number of stations the carrier has higher costs of material, equipment and devices that have to be installed on the stations.

3. EVALUATION OF THE CRITERIA USING AHP METHOD

The problem needs to be presented through the hierarchical structure. In the first variant the problem was defined by having three main criteria (users, infrastructure manager and railway carrier) and their subcriteria. If the problem is structured in this way, it is necessary first to compare the three main criteria and an obvious question is asked: To which extent are the users' requirements more important than the requirements of the carrier or the infrastructure manager? There is no answer to this question that would represent a general conclusion of this research. It is possible to make simply several different versions and in the first version to give greater significance to the user, in the second – to the carrier, etc. Also, not in all railway systems are there stakeholders taken into consideration. This depends on the organization of the railway transport system itself and the relations to the local and government authorities. There is also another way, and that is that the problem is not structured in the described way, but rather the subcriteria of the stakeholders become criteria that are mutually compared. The problem of defining the station location structured in such a way is presented in Figure 2. The versions available for selection are different solutions of the railway station locations on a line.

The next step is the comparison and evaluation of criteria regarding the goal. The process of comparison and evaluation is to be done by using the Saaty scale, and the results are presented in Figure 3.

[2] Commercial velocity is obtained from the relation of the travelled distance and the total time of travelling which consists of the riding time and the time of staying of the train.

[3] Technical velocity is obtained from the relation of the travelled distance and the riding time.

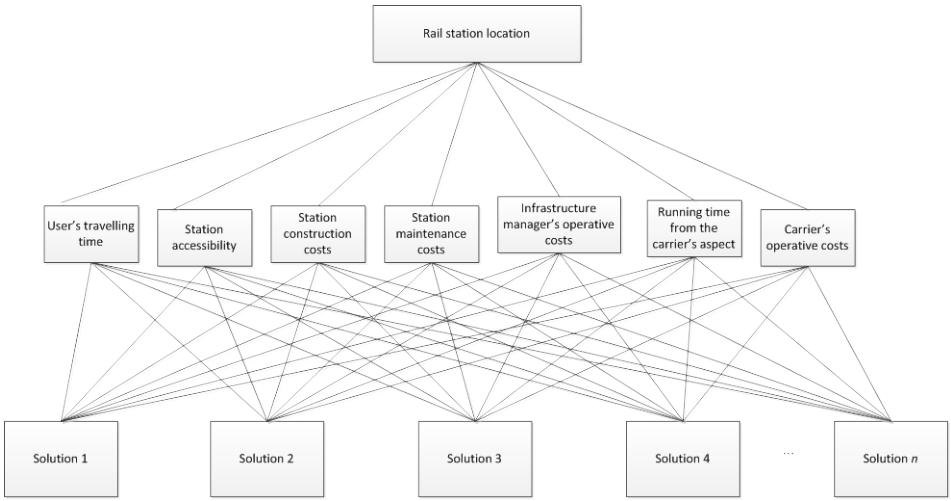

Figure 2 – Hierarchical structure of the AHP method

Figure 3 – Evaluation of criteria regarding the goal

The decision-maker has the freedom to assign other different priorities to certain criteria than shown in Figure 3. There is also a possibility of group evaluation of the solution, so that several interested parties participate in the evaluation procedure, in which the parties do not have to agree regarding the criteria priorities. The acceptability of the obtained solution can be assessed by carrying out the **sensitivity analysis,** i.e. by the change of value of the critical parameters of the model. The critical parameters are those variables whose variations, either positive or negative, can have the highest impact on the financial or economic results of the project. The criteria for assessing the efficiency of the project start from the assumption that all the taken parameters in the calculation are real, both at the moment of the calculation, and in perspective. However, it is very difficult to evaluate individual input parameters for the close, and particularly for further future, i.e. during the evaluation of the project efficiency, which is a period from 10 to 30 years. Therefore, additional analysis of the project efficiency is carried out, i.e. an analysis of sensitivity and sensibility. In case of AHP method the sensitivity analysis is carried out by changing the criteria priorities in relation to the initial model. This allows making of a calculation and presentation of the relations of the changes in the priorities of the alternatives as function of the criteria significance. Therefore, it is possible to change the criteria priorities and to analyse the impact of these changes on the final solution.

4. CONCLUSION

The problem of defining the railway station location is a multicriteria problem. The decision-making procedure includes several stakeholders who do not necessarily have to agree on the criteria nor about their priorities. The goal of this study was to enable all the stakeholders to define the criteria that have influence on the location of the railway stations and to rank these criteria. This can be achieved by the application of the AHP method. The alternatives or versions among which the selection is to be made in the structure of the AHP

method are the proposed solutions of the locations of the railway stations on a single line. Following the evaluation of the solution a ranking of the solutions is obtained. The feasibility of the obtained solutions can be assessed by carrying out the sensitivity analysis.

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УСТАНОВЯВАНЕ НА КРИТЕРИИ ЗА ОПРЕДЕЛЯНЕ НА МЕСТАТА НА ЖЕЛЕЗОПЪТНИТЕ ГАРИ

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Ключови думи: *планиране на местоположение, железопътни гари, мултикритериен анализ*

Резюме**:** *Планирането на местата на железопътните гари в интегрирания пътнически транспорт е мултикритериен проблем. Чрез анализ на предишни изследвания на тази тема е установено, че в повечето случай изследователите използват метод за оптимизация със само един критерий за да определят местоположението на железопътната гара. Целта на това изследване е да намери методология, която да реши този проблем с множество критерии. Решенията, които са получени чрез метод на оптимизация с използване само един критерий могат да бъдат сравнявани и оценявани по друг метод с допълнителен набор от критерии, формулирани от заинтересованите страни, участващи в процеса на планиране на местоположението на железопътните гари. Изборът на заинтересовани страни най-вече зависи от взаймоотношенията между правителството, инфраструктурния управител и железопътните оператори. В това изследване заинтересованите страни са ползвателите, инфраструктурния управител и железопътните оператори. За мултикритериална оценка е възможно да се използва аналитично йерархичен процес /AHP/, който може да сравнява качествени и количествени критерии. Използвайки AHP е възможно да се класифицира общественото значение на всеки критерий, с оглед целта на изследването. Дефинираните критерии могат да бъдат сравнени по отношение на получените решения чрез метод за оптимизация. Резултатът от процесът на оценка е класиране на решенията – като местоположение на железопътните гари и спирки, получени с алгоритъм за оптимизация. Анализът на чувствителността относно критериалните приоритети и техния брой се управлява в резултат на изчисленията в процеса на оценка.*