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Park & Ride facility planning

Authors:

Davor Krasić, Ph.D., traff.eng.
The Institute for Tourisam
davor.krasic@iztzg.hr

Zdenko Lanović, M.Sc., traff.eng.
Elipsa - S.Z.
zdenko.lanovic@elipsa.hr

Preliminary note

Davor Krasić, Zdenko Lanović

Park & Ride facility planning

Park and ride facilities are places where passengers transfer from passenger cars to public transport vehicles (railways, light urban railways, buses). Although park & ride systems have been developing for many years in a number of cities, there are still many communities in which a much smaller significance is accorded to such systems. As the construction of R&R facilities is financially demanding, these systems should be planned in a rational manner. Principal criteria to be used in planning development of P&R facilities are presented in the paper, based on critical analysis of past experience and original research conducted by the authors.

Key words:
transport infrastructure planning, Park & Ride facilities, planning criteria, facility ranking

Prethodno priopćenje

Davor Krasić, Zdenko Lanović

Planiranje Park & Ride objekata

Park&Ride objekti su mjesta na kojima se ostvaruje transfer putnika između osobnog automobila i vozila javnog prijevoza (željeznice, lake gradske željeznice, tramvaja, autobusa). Dok se u nekim gradovima Park&Ride sustavi razvijaju dugi niz godina u drugima se ovim sustavima pridaje znatno manje značenje. S obzirom da je izgradnja P&R objekata financijski zahtjevna, potrebno je njihovom planiranju pristupiti na racionalan način. U ovom su radu na temelju kritičke analize prethodnih iskustava i vlastitih istraživanja definirani glavni kriteriji koje je poželjno primijeniti u planiranju razvoja P&R objekata.

Ključne riječi:
planiranje prometne infrastrukture, Park & Ride objekti, planerski kriteriji, rangiranje objekata

Vorherige Mitteilung

Davor Krasić, Zdenko Lanović

Planung von Park & Ride Objekten

Park & Ride Objekte sind Anlagen, auf denen der Transfer von Passagieren zwischen dem PKW und öffentlichen Verkehrsmitteln (Bahn, leichte Stadtbahn, Straßenbahn, Autobus) durchgeführt wird. In einigen Städten werden Park & Ride Systeme seit vielen Jahren entwickeln, während anderweit diesen Systemen wesentlich weniger Bedeutung zugesprochen wird. Da der Bau einer Park & Ride Anlage finanziell anspruchsvoll ist, sollte ihre Planung auf eine rationale Weise vorgenommen werden. In dieser Arbeit sind, auf einer kritischen Analyse vorheriger Erfahrungen und auf eigenen Forschungsaktivitäten basierend, grundgelegene Kriterien definiert, die in der Planung von Park & Ride Objekten angewandt werden sollten.

Schlüsselwörter:
Planung von Verkehrsinfrastruktur, Park & Ride Objekte, Planungskriterien, Rangierung von Objekten

1. Introduction

First Park & Ride (P&R) locations emerged in the 1920s in the USA, initially always spontaneously, and later on as facilities planned by competent transport authorities wishing to form integrated P&R systems. This planned approach has been applied for decades in the USA and Canada, as evidenced by comprehensive guidelines for the planning and design of P&R facilities [1, 2]. At the same time, European countries have tackled this combined form of transport in a variety of ways. The reason for this difference could lie in the fact that the development of American cities has not been hindered by space limitations to the extent experienced by European cities, and hence they have not been so much faced with the scarcity of free zones suitable for development of larger-size P&R facilities.

An another aspect to be mentioned at this point is the difference in the evaluation of efficiency of P&R systems. Thus, they are considered preferable by a number of exerts, while others neglect this option when seeking solution to congestion problems in urban areas. One of examples is the Netherlands which attributes a minor role to P&R transport solutions, although at the same time it boasts one of the Europe's best public transport systems. An another example is Germany which actually favours this form of transport, although not equally in all of its cities.

Unlike other European countries, the development of P&R systems in British towns has primarily been linked with bus service. As from 1970s, the P&R system based on bus transport has been systematically implemented in British cities. At that, many new bus lines have been introduced as an exclusive service to P&R systems. Great Britain has passed through four phases in the development of this system: establishment of the P&R transport mode, acceptance of this mode on the national level, encouragement and promotion of the P&R system, and elimination of national level subsidies [3].

The city of Zagreb with approximately 800,000 residents has placed in many of its documents a great emphasis on the significance of P&R systems in the context of finding an integrated solution to transport problems in this city. This was mainly a declarative support to the development of this system, without an objective appraisal of its advantages and weaknesses, needs and limitations, and practical implementation possibilities. As Park & Ride facilities are not inexpensive, and as they take up a lot of valuable urban land, their planning and construction should be approached in a rational manner, without an upfront and hasty definition of priorities. At that, it is very significant to define a set of criteria according to which investment decisions will be made, which does not mean that their number will a priori guarantee a successful planning.

The decision was made to use the AHP (Analytic Hierarchy Process) method in this paper as it provides a good basis for consistent multicriteria evaluation and ranking of potential Park & Ride facilities. The AHP method is generally favourable for transport planning in cases when pure economic criteria can not be considered sufficient for final decision making [4]. There are many examples in which the AHP method has been successfully applied in the resolution of various transport planning problems such as: selection of the most favourable travel route to work, determination of the most favourable alternative for linking city centre with the airport, choice between tunnel or bridge for connecting two shores [5], evaluation of alternative urban railway networks [6], and determining priorities for investing in forest roads [7]. Some authors consider that the AHP method is the most favourable multicriteria method for evaluation of transport projects [8] and, in that respect, they cite successful projects including: selection of best public transport systems, evaluation of various methods for privatisation of public transport in urban areas, determination of priorities in the modernization of rural roads, etc.

2. Some characteristics of European P&R systems

European experience greatly varies as to the planning and evaluation of Park & Ride systems. Individual countries have not much in common with respect to concepts applied so far except, of course, for the main principle: park your passenger car and resume travel with public transport. There are several possible classifications of P&R facilities. One of them is based on the mode of public transport and so we differentiate:

- P&R facilities near railway transport systems
- P&R facilities near bus transport systems
- P&R facilities near combined rail and bus transport systems.

Table 1. Properties of P&R systems used in Europe

City	Number of residents	Number of P&R locations	Number of parking spaces
Amsterdam	743.000	5	1.278
Vienna	1.682.000	6	6.226
Budapest	1.696.000	25	3.384
Berlin	3.423.000	44	4.947
Hamburg	1.773.000	49	9.409
Helsinki	568.000	27	3.163
Koln	995.000	28	5.570
Luxembourg	86.000	5	4.116
Ljubljana	279.000	1	217
Munich	1.315.000	24	7.128
Oslo	566.000	5	3.000
Paris	2.166.000	28	5.849
Prague	1.195.000	17	3.196
Rome	2.708.000	31	12.880
Sheffield	530.000	8	1.754
Stockholm	795.000	22	3.000
Geneva	447.000	19	4.854

Source: euroTest Study on Park & Ride. ADAC, 2009

It can be seen from the above information that individual European cities greatly differ as to development of P&R systems. Thus, on the one side we have a great tradition in planning and realization of P&R systems, with a relatively great number of P&R facilities, while on the other we have a sporadic presence of P&R systems on a small number of locations. These differences are best expressed through the number of P&R parking spaces par thousand of inhabitants, with an average of 3.81 for all seventeen cities. The cities of Luxembourg and Geneva are well above this average, and the former can hardly be surpassed by the level of development of this system, as it has over four thousand P&R parking places for no more than 86,000 inhabitants, i.e. almost 48 parking places per one thousand of inhabitants. The cities like Ljubljana, Berlin, Amsterdam and Budapest are at the very bottom of this list with up to two parking places per one thousand of inhabitants. German cities (with the exception of Berlin) are characterized by relatively high values of this parameter, situated somewhere around 5.5.

The data about an average size of P&R parking facilities show that cities have based their concept on the concentration of parking lots on a smaller number of locations, or they opted for a dispersed system with a greater number of smaller P&R facilities. An average capacity of a parking lot operating as a part of the P&R system, based on the information for all cities, amounts to 232 parking places. The group of cities with concentrated parking capacities includes the cities such as Vienna (with more than one thousand parking places on an average), Luxembourg, Oslo and Rome. Cities with the highest dispersion (and smallest size) of parking facilities are Berlin and Helsinki where an average parking lot has a little more than one hundred places.

A single standard does not exist even with regard to the design of P&R facilities, primarily as to maximum acceptable distance between P&R parking lots and public transport stations. While in terms of an European average we could speak about a distance of 300 metres, the distance of 100-200 metres is considered acceptable in Koln, while in Berlin this distance is as many as 800 metres.

All these features and differences influence the success of P&R systems in individual cities. For instance, the statistics for German cities show that the reduction of passenger car transport due to introduction of P&R systems amounted to about four percent. It is interested to note here that 80 percent of P&R system users are commuters travelling to or from their work place [9].

The P&R systems are not inexpensive and so they must often be subsidised, just like traditional public transport systems. Because many particularities about the effects of P&R systems have not as yet been cleared out, some authors [3] consider that further research is needed instead of an a priori investment in such facilities.

Contrary to these opinions, the city of Vienna has established an extensive program for the construction of P&R facilities over the oncoming period. According to the planning documents, ten new locations with some eight thousand parking places will be built, and the municipal authorities support realization of this program with interest-free loans covering eighty-five percent of the investment, with an eighty year repayment time [10].

3. Park & Ride facilities in Zagreb

The use of the Park & Ride system has emerged spontaneously in Zagreb, just like in many other cities of Europe. People living in distant parts of the city, and residents of satellite towns and towns near Zagreb, have recognised the possibility of parking their vehicles along a public transport station, and resuming their travel by public transport. Today it is hard to establish whether their motives were connected to time savings or financial reasons.

Over the past ten years, first plans have been made in order to encourage drivers to use Park & Ride facilities, primarily through realization of a number of parking lots at locations situated next to public transport stations. Facilities built so far have enabled realization of the first study on P&R facility use in the city of Zagreb. The study was conducted in November 2009 at two typical Park & Ride locations in Zagreb: Vrapče and Dubrava, figure 1 and 2.

The facility built in Vrapče district is the first structure of this type that has been built in Zagreb in accordance with all recommendations for P&R facilities. It is situated at the west leg of the suburban railway, some 6.5 km away from the city centre. Although the Vrapče location has always existed as a railway station, it is only after the rehabilitation that it has gained all attributes of a modern P&R location, with extended platforms for the reception of trains, with platform sheds for passengers, with amenities for disabled persons, and with parking places for passenger cars and bicycles. Passengers can use an underpass to pass under the railway. There are no attractive destinations near this P&R location, and so it is exclusively used as the point of transfer between passenger cars and public transport facilities, figure 1.

Figure 1. Park & Ride facility at Vrapče – urban railway station

In many of its aspects, the Park & Ride location in Dubrava is quite different from the one in Vrapče. While the Vrapče location is located next to two large and compact urban settlements, the location in Dubrava is relatively distant from densely populated areas. It has been built in the scope of a tram depot situated some 5 km to the east of the city centre. Parking areas are formed of two parking lots. Passengers can leave their cars at any one of these parking lots and can then resume their travel by tram to the centre of the city, or in an another direction toward the city periphery. The location also has commercial amenities that are not connected to transport, figure 2.

Figure 2. P&R location in Dubrava – parking lot next to tram depot

The survey was conducted on a working day on a sample comprising fifty percent of P&R users on each location. In addition the survey comprised analysis of parking lot occupancy in several time frames. The information was gathered about:

- origin of travel
- destination of travel
- purpose of travel
- need for additional transfer (change of transport mode),
- frequency of parking lot use
- duration of parking lot use
- occupancy of parking lot
- level of occupancy upon arrival at the P&R parking lot.

These two P&R locations on which the survey was made can reasonably be considered as typical examples of P&R locations in Zagreb, but also in other cities as, according to their features, they comprise:

- two different modes of public transport, one of which is much faster but unable to penetrate many parts of the city (suburban railway), while the other is slower and features greater frequency of starts during the day, and a much more developed network (tramway)
- two different types of urban districts from which P&R facility users are attracted: Vrapče location is a compact and densely populated urban community, while Dubrava is a sparsely populated community with widely dispersed housing developments
- different distance from the centre of the city: the difference is 1.5 km which is not negligible for the city the size of Zagreb.

Survey results show that the occupancy of parking lots on both P&R locations amounts to about 90 percent on a working day from 8 a.m. to 4 p.m. In late afternoon or evening hours, also on a working day, the occupancy is much lower and amounts to 37 percent for Vrapče and 22 percent for Dubrava. Such low occupancy of parking lots outside of working hours reopens the question of whether it is justified to build P&R locations that are exclusively used by commuters travelling to and from the workplace.

On Saturdays, during day hours the occupancy of the Dubrava parking lot is twice as high as that of the facility in Vrapče, which is a clear indication that the P&R transport is used even for non-work related travel at the facility that has a better public transport service (as to the frequency of service and extent of the network).

Most users of the P&R services travel to the centre of the city. It can be concluded from this information that the transfer to public transport is not motivated by faster arrival to distant destinations in other parts of the city, and that users of the P&R transport mostly originate from the population whose selection of the mode of transport is highly influenced by the prices of parking (which are high) in the centre of the city. Weaknesses of the suburban railway arise from the need to additionally change the mode of transport in order to arrive to the final destination, while in case of tram transport this need has been registered for a relatively small number of users.

Table 2. Results of survey conducted on two P&R locations in Zagreb (working day – morning peak)

Indicator	P&R facility in Vrapče	P&R facility in Dubrava
Distance for the centre of the city	6,5 km	5,0 km
Population density in the area around the P&R location	high density	low density
Mode of public transport	suburban railway	tramway
Average length of travel to P&R facility	1,6 km	2,9 km
Utilisation rate (occupancy) of P&R facility	88 %	70 %
Proportion of travels to centre of the city	73 %	71 %
Proportion of travels to work	100 %	93 %
Need for additional transfer to reach the destination	30 %	10 %
Proportion of every day users of P&R facilities	83 %	65 %
Average vehicle occupancy	1,29 persons	1,36 persons

Although it could reasonably be expected that the use of the Park & Ride system should be guided by rational criteria, behaviour pattern of Zagreb residents does not confirm this premise. In fact, it was registered that an average occupancy of vehicles used to reach P&R locations does not differ from the occupancy of other vehicles. Results obtained in the course of this survey were quite helpful for the elaboration of plans for new P&R facility locations in Zagreb [11]. Some significant indicators are shown in Table 2.

4. Criteria for determining priorities with regard to P&R facility planning

Based on the study of experience gained in P&R facility planning in Europe and North America, it can be concluded that the method for determining priorities with regard to P&R facility planing, applicable to most cities, has not as yet been developed. Thus, various criteria are nowadays used for the definition of priorities for realization of P&R facilities.

4.1. Presently applied criteria

It is indicated in almost all papers and studies on P&R that one of the most significant criteria for the selection of priority P&R locations is the size of the gravitating zone. In fact, the gravitating zone determines a potential number of users of P&R systems. A general method for determining demand for P&R locations has not as yet been accepted. According to the study conducted by Morall [12], only 55 percent of cities in the USA and in Canada have tried to estimate future demand for P&R locations until 1990s. Empirical methods were used in 88 percent of all cases. The estimation was successful in 65 percent of cases, which means that out of cities having the P&R systems only 34 percent had relevant information about demand, while other either did not make prognoses, or these prognoses proved incorrect. The American national manual for planning and shaping P&R facilities, issued in 2004, cites several methods for determining demand for P&R facilities, separately for rural and urban areas [1].

However, the size of the area gravitating to a P&R facility is just one of criteria that can be used for the determination of priorities with regard to realization of P&R facilities. Burns [13] is one of the first authors that attempted to introduce a system of criteria for P&R locations. He divided the criteria into three main groups, and each of them consisted of a number of subcriteria rated from 1 to 10. Main groups of criteria are: location of P&R facilities, location considerations, and economic considerations. The total number of subcriteria is 19, and the expert team attributes to each P&R location, based on subjective evaluation, and appropriate rating for each criterion, and the final ranking of potential P&R facilities is obtained by summing up all ratings. The expert team is accorded the possibility to attribute different weightings to individual criteria.

The Athens Clarke County Planning Department prepared in 1998 the study of locations of P&R facilities along the bus lines organised by the Athens Transit System [14]. The aim of the study was to identify potential P&R facilities and to determine priorities for their realization based on the following criteria: location, visibility, adequacy of use, traffic volume, accessibility, and price/availability of land. After the first evaluation in which the group of eligible locations was obtained, the second evaluation step was made to determine high-priority P&R facilities that could be realized within 5 years. The following criteria were also used: potential demand, distance to principal workplace locations, road traffic congestion points, availability of public transport, land acquisition possibilities, and relationship to other road projects in the state of Georgia. Each criterion was rated from 1 to 5 and six priority locations (out of possible ten) were selected by simply summing up the ratings.

The Center for Urban Transportation Research, University of South Florida, defined in 2001 a number of criteria for evaluation of potential P&R locations [15]. The evaluation procedure is conducted in two steps. The first step involves identification of zones that are suitable for one or several P&R facilities based on the following criteria: spontaneous P&R locations, population density, concentration of workplaces, distance between main habitation and workplace zones, and level of service on main roads. The second step involves evaluation, based on identification made in the preceding step, of potential P&R locations based on the following criteria: price of land, safety and environment, size of facility, noticeability, accessibility, quality of public transport service, congestion of access road, and design requirements relating to public transport vehicles. Individual criteria are weighted based on evaluation made by the expert team.

Basic and preference criteria were used for the selection of P&R facilities in the 2030 Park and Ride Plan [16]. Basic criteria were: level of service, vicinity of main transport corridors, vicinity of main intersections, access for vehicles, size of facility with regard to current demand, and additional local requirements. In cases when two potential P&R locations receive similar rating based on basic criteria, additional nine criteria (preference criteria) are used to select a better location.

In the Chitenden County Park-and-Ride & Intercept facility Plan [17], the determination of priorities is based on classification of criteria into three categories: demand, location, and readiness for realization. The first category comprises criteria that are related to the traffic volume on roads near the P&R location, frequency of public transport service, and possibility of access by bicycles and pedestrians. The second category comprises criteria that take into account accessibility of the P&R location with respect to main roads and vicinity of centres of activity, while the third category comprises criteria that are related to the possibility of rapid realisation of the project (ownership of land, public-private partnership, building permit). The rating method is adapted

to the estimated importance of each individual criterion, and so the criteria do not participate in the rating with an equal maximum number of points. Thus, while maximum 10 points may be attributed for a particular criterion, maximum 8 or 5 points can be attributed for an another criterion, etc. Potential P&R locations are ranked by summing up points that have been allocated according to all criteria.

Seven criteria were used in the evaluation of P&R locations for Canberra [18]: availability of land, noticeability of the location, passive surveillance of the location, possibility of access by vehicle, construction cost, influence of P&R facility on its surroundings (noise and pollution), and quality of public transport service. Each criterion was given a weight ranging from 5 to 20, which defines its relative importance. Potential P&R locations that obtained more than 80 points (out of maximum 100 points) were considered highly suitable for realization, locations with 75 and 80 points were considered suitable for realization, while those with a smaller number of points were rejected.

According to recommendations given by the British Parking Association for the selection of P&R locations [19], such locations should be located at city edges, near main roads, outside of residential areas, on sufficiently large land plots, with good public transport connections, at multiple use locations.

4.2. Criteria applied for the city of Zagreb

Although a considerable number of criteria has been used in some studies, the authors of this paper have limited their attention to several crucial criteria, taking into account limitations recommended in [20, 21, 22] (these limitations are not directly related to the AHP method but rather to limitations in human perception and capacity to compare a great number of data). Consequently, five main criteria were selected for the evaluation of P&R locations in Zagreb. The evaluation included potential locations but also existing locations, which are scarce and which require additional investment in order to meet adequate standards.

These criteria are:

- size of area gravitating to the P&R location
- multifunctional character of the P&R location
- ease of realization from technical and financial standpoints
- quality of public transport service
- access to P&R locations

The *Size of the area gravitating to the P&R location* is the criterion that is formed of spatial, urban planning, and transport components. The spatial component is primarily related to the physical extent (size) of the zone from which potential P&R users originate. The urban planning component takes into account the dominant type of construction/development in the area around the P&R location. Studies conducted in Zagreb show that an area gravitating to a P&R location depends on the type of urban development and, what is often connected to it, the quality of the competing modes of transport. Densely populated areas benefit in most cases from developed transport infrastructure and from equally developed public transport services, which competes with P&R locations as the latter depend on a single mode of transport only. An oppolocation example would be a sparsely populated area with dispersed habitations and other developments, which is usually accompanied with a more modest transport network and poorer supply of alternative transport services. In such circumstances, the competing position of P&R locations is much more favourable.

In case of Vrapče P&R location, most users come from nearby residential districts while, in case of Dubrava P&R location, the distribution of distances from which users are reaching the location is much more uniform, with a relatively big proportion of distant locations. Ninety percent of users come to Vrapče P&R location from locations not exceeding 2 km, while only 53 percent of users come to the Dubrava P&R location from such nearby locations. An average length of travel by passenger car to Vrapče location and Dubrava location amounts to 1.6 km and 2.9 km, respectively. The transport component reflects properties of demand for this type of transport, which gives an additional possibility for ranking locations with similar properties when measured according to two previously described components.

The *multifunctional character of P&R locations* is the criterion that answers the question of whether the parking lot at the P&R location will be used during the day and week exclusively for parking aimed at moving on to public transport to reach the workplace, or for other purposes as well (shopping, business activity, visit to cultural institution, eating out, etc.). As the cost of building a parking lot or parking garage is high, the mono-functional character of the location reduces rationality of investment as capacities are used for no more than 8 – 10 hours during working days, and even less so on weekends. Thus, it would be much more cost-effective to invest in those P&R locations whose parking lots will also be used for other purposes. Construction of P&R locations on such locations could also be partly financed from private sources, through some form of a public-private partnership.

The *ease of realization from technical and financial standpoints* is the criterion that is used for evaluating the location with respect to the time period in which it can be realized. In this respect, the existing P&R locations have an initial advantage as they mostly require additional development or extension of capacities, unlike new location where the process of realisation starts with preparation of planning documents and land acquisition. Some locations have greater spatial constraints than others, which makes them more costly and technically complex. In the scope of this criterion, an advantage should be given to those locations that can rapidly be included into the P&R system, as compared to those requiring several years of preparation and construction efforts.

The *quality of public transport service* is the criterion that is composed of three components: speed and comfort of travel, frequency of transport service bringing passengers to P&R locations, and significance of P&R locations within the transport network. The speed and comfort of travel characterize various modes of public transport (bus, tramway and railway). Even within the same subsystem this component does not need to give the same rating to two different P&R locations as urban development and traffic conditions on the route are not identical, which results in different speeds of travel and different levels of comfort. The frequency of transport service bringing passengers to P&R locations is an important component for the evaluation and ranking of such locations as it influences the total time of travel from origin to destination. Similarly, this has a psychological effect on potential users through impression on "pleasantness" of travel which is much lower for the location with rare departures where the user must come at a strictly specified time, usually much earlier, so as not to miss the departure/passage of the public transport vehicle. The significance of P&R locations within the transport network is the third components which contains the following elements for the evaluation of P&R locations: possibility/impossibility of direct arrival to the destination due to the number and penetration of transport services (providing transport to/from P&R locations) into other parts of the city, and connection with other modes of public transport.

The *access to P&R locations* is the criterion that evaluates P&R locations on a micro level, primarily as to the level of harmonization of locations to simpler, safer and more comfortable use by the passengers. Due to their spatial constraints some locations can not meet this criterion in an optimum way. In this respect, the analysis focuses on the spatial harmonization between the parking lot and public transport areas, distance between them, and possible vertical obstacles hindering movement of pedestrians. As to safety, the analysis focuses on potential conflicts between vehicular and pedestrian flows of traffic, P&R accessibility by passenger cars (dependent on the position of P&R locations with respect to road network), and quality of road network that is used to reach the P&R location.

5. Multicriteria evaluation using the AHP method

As shown in previous two sections, the development of P&R systems is a procedure during which a number of different and often conflicting requirements must be taken into account and, at that, different compositions and evaluations may lead to different solutions (priorities). The P&R system development belongs to the category of "ill-defined" problems, i.e. problems that do not have a generally accepted and clearly, or at least approximately, defined algorithmic structure. That is why it can reasonably be said that the use of multicriteria evaluation respects the very nature and structure of the P&R problem, regardless of whether it is related to the establishment or further development of a P&R system.

The aim of the document [11] was to evaluate 22 locations in order to determine possible influences of the P&R facility construction, and provide to authorities in charge of transport policy development a proper basis for strategic decision making.

The authors have initially opted for a "mild" approach so as to promote criteria given in their proposal and to convince all transport policy operators that desired results can only by achieved through the use of several criteria (measurable, clear and acceptable for the city of Zagreb). According to this mild approach, the locations were first evaluated according to criteria that have been defined as being of equal weight (significance). Ten locations were selected and rated with points 1 (worst) to 3 (best). In the first round of evaluations, the authors have deliberately avoided a greater range of points so as to force evaluators to critically consider all options, including some les know locations. A greater range of points could have resulted in the allocation of excessively high ratings to some widely known locations that have been in use for many years now.

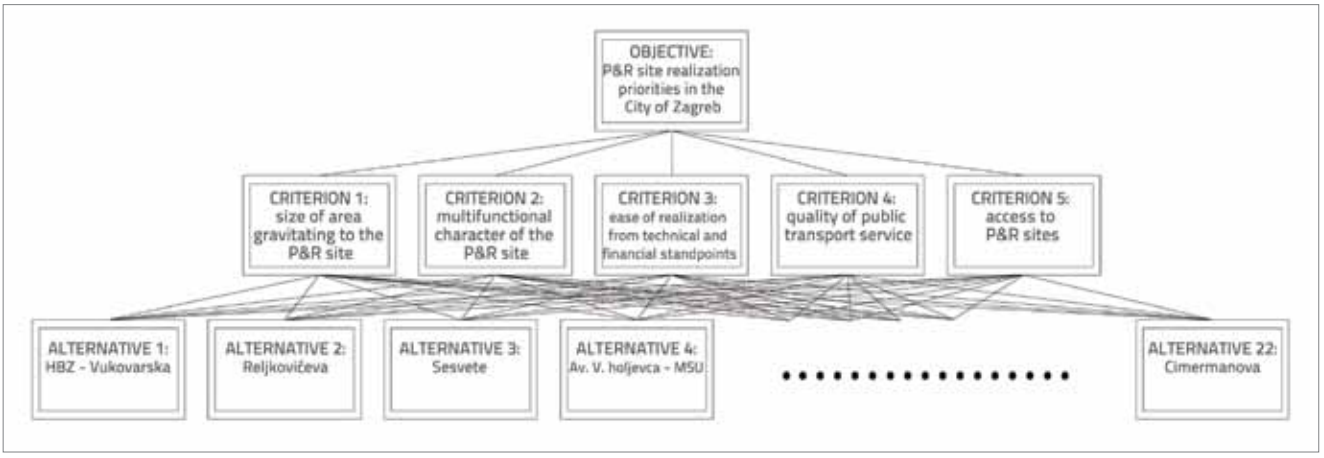

Figure 3. AHP model for determining construction priorities for P&R locations in Zagreb

Even this simplified approach has pointed to some locations that deserve a greater attention instead of others that have been considered for years as potentially the most appropriate. This surprising position of some of the new locations (HBZ – Vukovarska, Reljkovićeva ulica, Avenija V. Holjevca – Modern Art Museum) proves that the idea about a reduced number of points has been quite correct. It soon became clear that the use of several criteria is an advancement in the Zagreb P&R system planning, and so this concept was strictly applied in the second round of evaluations, based on the AHP method.

The decision on its use was partly founded on its advantages when compared to other multicriteria methods [23]. Some of these advantages are: widespread use, availability of software, possibility of verifying consistency, easily understood by decision makers, although some specific reasons were primarily responsible for final adoption of the AHP method. The city of Zagreb has been theoretically supporting the P&R system, but without an objective analysis of its advantages and weaknesses, needs and limitations, use of municipal land, and financial possibilities in particular. In some situations, the P&R system has been mentioned as the best solution to municipal transport problems. The authors of this paper were aware that they can be asked to give additional economic evaluations based on different criteria: as inexpensive as possible, as fast as possible, as fast as possible up to a certain cost limit, as inexpensive as possible with maximisation of the number of P&R parking places, etc. The AHP method, with all its known advantages and limitations, also opens up the possibility of making subsequent economic evaluations in the course of the decision making process.

As the P&R location evaluation process involves several criteria and a number of alternative solutions (potential locations), the procedure must be carried out with the greatest deal of attention. Experience has shown that the conduct of surveys in which the experts are given a detailed questionnaire with many questions, is not a good solution. When decisions are made on the basis of a multicriteria analysis, the results should be the consequence of consistent conclusions, and should at the same time be valid. In order to achieve greater consistency it is advisable to have a reasonable number of elements for comparison, as human brain has a limited perception capability, and can not consistently make conclusions if it compares a great number of elements. But, on the other side, a greater number of elements provide for better validity as conclusions are based on a greater number of data. Therefore, as consistency and validity requirements are opposed to each other in the multicriteria analysis, it has been established via mathematical analyses for the AHP method that an optimum number of elements to be analysed is seven [22]. This rule is applicable to the pairwise comparison, which is a way of measuring and comparing criteria and alternative solutions in the AHP method.

The structure of the AHP model applied for potential P&R locations in the city of Zagreb is shown in Figure 3. The objective was to define construction priorities for 22 potential Park&Ride locations (alternative solutions), taking into account five criteria described in the preceding Section.

The above survey has greatly facilitated the process of weighting criteria according to their significance. Although the AHP method permits a wide range of relationships (Saatyev scale), i.e. from 1 – equally significant to 9 – extremely more significant, the evaluators actually applied a smaller range of points. Weight relationships for individual criteria are resented in Table 3.

If, as in our case, there is a large number of alternative solutions, then an absolute measurement must be applied for their ranking, which means that ratings must be given separately for each alternative solution, with has to be related to a standard or a reference value. This standard may be real (meaning that it exists in real life) or imaginary. That is why this type of multicriteria analysis can be conducted by experts only. In brief, if we have many alternative solutions, the AHP method is implemented in two steps: in the first step weight relationships between the criteria are obtained through

Table 3. Weight relationships for individual criteria

Criteria	Graviting area	Multifunctional character	Ease of realization	Quality of public transport service	Access to P&R location
Gravitating area		2,0	1,0	4,0	4,0
Multifunctional character			3,0	2,0	3,0
Ease of realization				-2,0	4,0
Quality of public transport service					6,0
Access to P&R location					

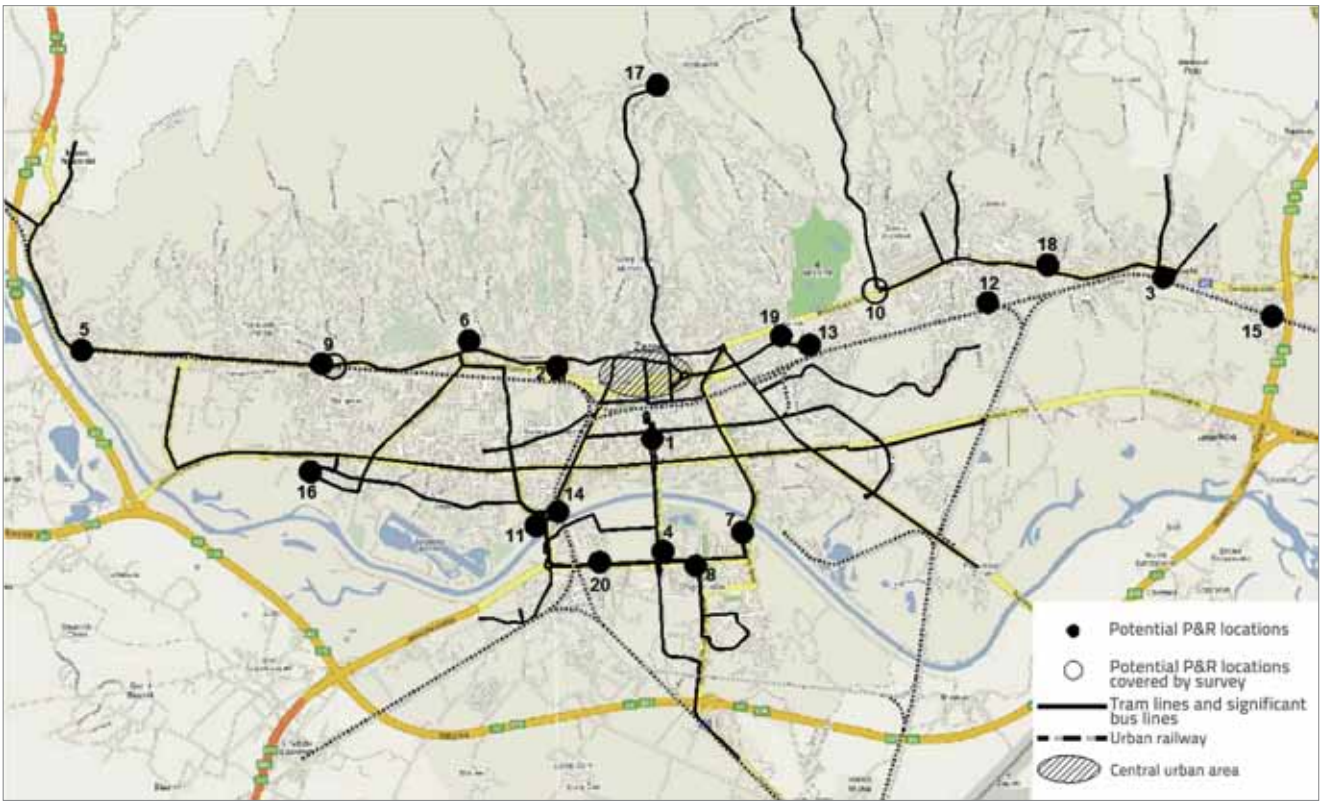

Figure 4. Potential and surveyed P&R locations in Zagreb

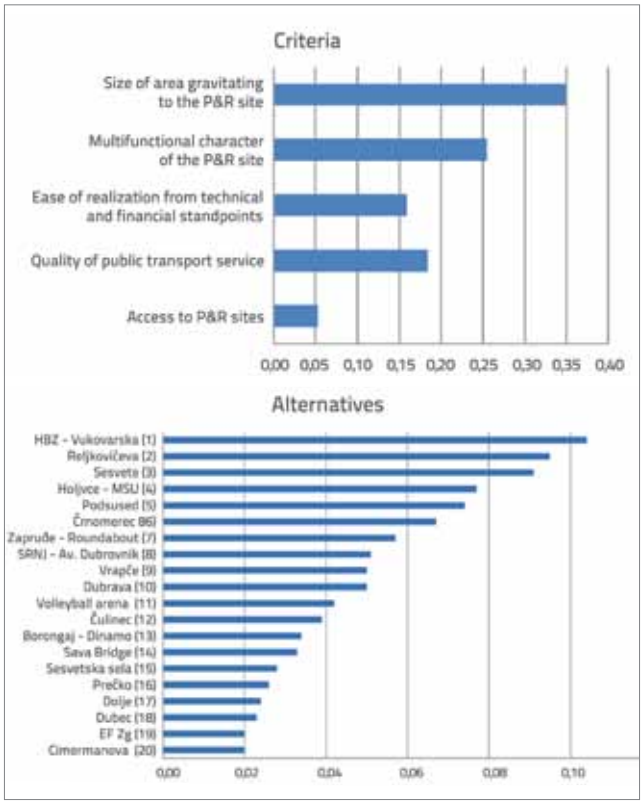

Figure 5. Ranking results for P&R locations in Zagreb

comparison by pairs as described earlier in this text, while in the second step ratings by each criterion are given for each alternative solution separately, by comparing it to a defined/ imaginary standard, or reference value.

An entire weighting range has been suggested for evaluation of alternative solutions by each criterion. In this way, the authors have motivated the evaluators to clearly express personal opinions within a particular criterion. The results for the most significant criterion, i.e. extent of the area gravitating to the P&R location.

Final AHP evaluation results for potential P&R locations in Zagreb are presented in Figure 5. The results show that the most significant criterion is the extent of the gravitating area, while the least significant one is the access to P&R facility. It should at that be noted that the criterion "Multifunctional character of P&R location" which, according to available information, has so far never been used in surveys, is ranked at the very high second position by significance.

As the city of Zagreb does not have a developed P&R system (except for several locations), it can reasonably be expected that a "global" criterion will have the highest significance, while a "local" will be of the lowest importance. It is interesting to compare the "multifunctional character" and "quality of public transport" criteria. Although the quality of public transport is of crucial significance for introduction of P&R systems, the "multifunctional character" criterion has proven to be more significant for the city of Zagreb as the low cost of investment,

occupation of space, and usability of location, are its strong points, when compared to a location that would exclusively be destined to P&R service.

The position of potential P&R locations within the public transport network of the city of Zagreb is shown in Figure 4. The numbers given in this figure correspond to the order of locations after the ranking (Figure 5).

Results pointing to construction priorities in Zagreb are a mixture of expected and unexpected outcomes. The location in the zone of the HBZ – Ulica grada Vukovara crossroads has come up as the most adequate although it has not been favoured before the multicriteria evaluation. After the first presentation of results to the public, this choice has been somewhat criticized, but recent opening of a new similar purpose parking lot to the north of this crossroads has confirmed adequacy of the multicriteria ranking. In fact, that parking lot has a high level of occupancy during the day because of the vicinity of the tramway line and train station, court and administrative institutions, and the concert hall. The value of this location has been fully confirmed, especially from the standpoint of its multifunctional character.

The AHP also enables conduct of simple economic evaluations. Potential P&R locations in Zagreb can be classified into four types of facilities: at-grade parking lot, two-level prefabricated parking lot, above-ground parking garage, and an underground parking garage. The knowledge of specific needs of each of these locations, and the data about other elements needed for implementation of the system, enable proper evaluation of the total investment. Available data and experience have enabled a credible evaluation of construction time for each P&R location, and for the entire system. It is precisely because of excessive cost of the entire system (€25 billion) that the following realization scenarios were subsequently requested:

- S1: invest minimum sums for equipping the already developed (existing) locations,
- S2: invest as little as possible to build a P&R sysem to the level corresponding to an average of the Europe's cities,
- S3: build locations that will locally provide the most P&R parking places,
- S4: buld as many P&R parking places as possible within the shortest time period,
- S5: build locations in stages based on the AHP method.

The standardised cost of individual P&R locations is the relationship between investment needed for a particular location and the total investment into the P&R system. The investments vary from € 30,000 for equipment of the already existing locations, to as many as € 6 million for the most expensive location that has to be built from the scratch and properly equipped. The standardisation results in establishment of a weight relationship between individual locations which, in combination with the weight relationship obtained by the AHP method, gives a rough cost – benefit indicator (relationship between the standardised cost of the location and usability according to the AHP).

Two (S2 and S4) out of four one-dimensional scenarios have shown that with no more than twenty percent of the total investment it would be possible to achieve in the city of Zagreb the number of P&R parking places that corresponds to the Europe's city average (4 parking places per 1000 residents). The scenario S3 requires 39 percent of the investment to reach that figure. However, this is not sufficient. The question should be asked as to where are these places and whether or not they will be used, and whether all these effects expected by users and transport policy makers will be achieved? The AHP implementation results have enabled the authors to show how a simplified approach (economic or time-related) can be erroneous, although such scenarios are very often the most interesting ones to decision makers: low-cost or rapid realisation of the project. Piling up P&R parking places in zones where satisfactory transport demand for this type of service does not exist, or where expensive parking facilities have only one function (which means that they are unused for 14 hours within a working day and during the entire weekend), can not be considered a good solution for the urban transport system.

6. Conclusion

Many issues faced by engineers when planning construction of transport facilities require some form of multicriteria evaluation and decision-making. Planning development of Park & Rides systems and the corresponding facilities is a good example of such multicriteria approach. Unlike previous investigations, this paper points to some novel perceptions that have to be taken into account in the P&R facility planning. The study conducted by authors of this paper have pointed to some specific aspects that have to be taken into account when analysing potential locations for P&R facilities. One of them is the extent of the area gravitating to the facility as it is greatly dependent on the type of urban community, population density, and development of transport infrastructure in a wider area. The example of two locations covered by this study in Zagreb has shown how the difference in the extent of the gravitating area influences different types of urban communities, primarily from the standpoint of population density and competing forms of transport. The area with a great population density attracts P&R system users whose origin of travel (place of living) is relatively close to the P&R location. The area characterised by dispersed housing and low population density, generates travel to the P&R location from greater distances. Such behaviour of users is further enhanced by the supply of competing forms of transport, which in the area with a grater population density is almost always available, unlike areas with low population density, and so it is quite understandable that people living in the latter areas are willing to travel a longer distance to the P&R location. Therefore, instead of analyzing the extent of the gravitating area by means of the presently predominant geometrical

procedure based on a recommended radius, it would be more suitable to make a separate analysis of the above mentioned influence factors for each location, so as to determine the real boundaries of the area.

The quantity of criteria according to which the multicriteria evaluation is made should be reduced to a reasonable number, so that the expert team that makes decisions can consistently analyse the significance and influence of each criterion. Although a large number of criteria has so far been used in studies focusing on P&R facilities, the consistency element in conclusion making has unfortunately not been checked.

The authors of this paper place a particular emphasis on the multifunctionality criterion of P&R facilities which has so far not been used, and which has shown its usefulness and weight (significance) on the example of the city of Zagreb. The multifunctionality of P&R facilities contributes to the rational use of such locations, i.e. it increases the level of soundness of the investment. In addition, possibilities are thus opened to include financing by private investors who could find their interest in the development of such facilities. Monofunctional P&R locations that are used exclusively for the transfer of passengers (passenger car – public transport) for going to the workplace, are insufficiently used, not only on Saturdays and Sundays, but also during most of the working days.

When planning transport infrastructure facilities (motorways, bridges, railways, airports, etc.), the number of alternative solutions is in most cases limited to no more than seven (this number is limited for proper use of the pairwise comparison in AHP method). However, some dilemmas might arise during development of infrastructure facilities, for instance in determining P&R location realization priorities, where a much greater number of potential locations may be considered. In this paper, the AHP method is used to show what procedure should be applied when decision is made about ranking a considerable number of alternative solutions. The AHP method has enabled verification of consistency of decisions made by experts that participate in the determination of significance of individual criteria, and in potential P&R location ranking. In addition, several possible P&R system realization scenarios were considered, both as to funding needed, and also as to expected results. This has greatly reduced the possibility of making erroneous investment decisions that are based solely on selection of the lowest cost alternative.

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