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*Original Article*

# EVALUATING THE SUCCESS FACTORS OF INTEGRATING THE RAILWAY INTO THE PUBLIC URBAN–SUBURBAN TRANSPORT

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**Highlights:**
- success of integrating the railway into the public urban and suburban transport;
- determination of relevant factors;
- clustering factors;
- design an Analytic Network Process (ANP);
- case study in the City of Rijeka (Croatia).

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**Abstract.** The success of integrating the railway into the public urban and suburban transport depends upon a range of internal and external factors, with challenges arising in their number and complex interdependence. Furthermore, the significance and impact of some factors are uneven in cities. There is a necessity for the right mix of different factors that drive significant use of railway into the Public Transport System (PTS). The research problem is finding and defining factors needed to assess the success of railway implementation into public urban and suburban transport. An efficiency analysis of the factors that impact the level of the planned transport system use was conducted in a hierarchical or network system. The 1st step of research is to the determination of relevant factors. In this research 27 factors were determined. Based on the determining factors and their connection it is possible to design an Analytic Network Process (ANP) to evaluate the importance of factors. Factors are divided into 4 clusters: (1) user features, (2) road transport features, (3) services features, and (4) city and corridor features. Testing was carried out by group decision-making process by members of an expert panel. According to the testing, the most important factors according to their weight are: (1) frequency with 0.11651, (2) employment level with 0.10146, (3) ticket price with 0.09714, (4) reliability with 0.07256, and (5) integration of services with 0,07065. Using the weight of each factor it is possible to evaluate the success likelihood of a concrete project. In this research case study was oriented on integrating the railway into the public urban and suburban transport in the City of Rijeka in Croatia. For this purpose, the relevance of the determined weight factors was used for the concrete project of integration in the City of Rijeka that resulting in 67.17% fulfilment of the successful integration railway into the public urban and suburban transport.

**Keywords:** railway, integration success, urban public transport, analytic network process (ANP), City of Rijeka.

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## Notations

AHP – analytic hierarchy process;
ANP – analytic network process;
DANP – DEMATEL–ANP;
DEMATEL – decision-making trial and evaluation laboratory;
ISM – interpretive structural modelling;
PTS – public transport system;
PROMETHEE – preference ranking organization method for enrichment of evaluation.

## Introduction

For the last few decades, numerous cities have been implementing urban rail systems (trams, metros, light urban and suburban rail), believing them to be optimal for incentivising the use of public transport and facilitating sustainable mobility of the growing urban population. Several motives encourage this renewed interest in rail systems: (1) a reduction in traffic congestion, (2) an improvement of the public transport, (3) better access to city center, (4) environmental protection, (5) reduction in energy expenditure, (6) an increase in safety, (7) and an incentive for economic and residential growth.

Of course, the success of integrating the railway into the public urban and suburban transport depends upon a range of internal and external factors, with challenges arising in their number and complex interdependence. Especially when implementing the railway system into urban and suburban areas it is crucial to find and define factors that are influencing the implementation process. Therefore, in research is necessary to incorporate a mix of different factors. Each factor must be understandable on a conceptual level and afterwards on a modelling level.

The researcher can use different approaches to find and define factors in their research. The more effective scientific approach is the AHP. The AHP is one of the most popular and widely employed multi-criteria methods. In the AHP, the processes of rating alternatives and aggregating to find the most relevant alternatives are integrated. The AHP seeks to rank a set of alternatives or select the best in a set of alternatives. The ranking/selection is made concerning an overall goal, which is broken down into a set of criteria. A more general form of AHP is ANP. ANP models the dependencies and influences between decision-making elements. A network contains much more information on the decision-making problem than the hierarchy. Applying the ANP, obtaining more accurate results at the end of the decision. For implementing the railway system into the public urban and suburban transport, this research is used different factors, to be precisely 27, each of these factors after finding them was mandatory to define an importance measure. In this research, the overall goal is to get a concrete decision so that why is used ANP.

This article is organized as follows: (1) literature review, (2) the methodology of evaluations, (3) assessing the factor importance of sustainable railway integration into urban–suburban transport, (4) case study of the City of Rijeka, and (5) conclusion. The chapter "Literature review" has investigated the most important articless in the research field and the research gap is defined. In the chapter "The methodology of evaluations" is defined research methodology. The next chapter is "Assessing the factor importance of sustainable railway integration into urban–suburban transport" is crucial for defining the importance of the factors. In the chapter "Case study of the City of Rijeka", the theoretical approach is tested in the area of the City of Rijeka in Croatia. In the last chapter "Conclusions", the most crucial finding is summarized for this research.

## 1. Literature review

Public transport project is usually financially challenging and politically demanding. In such projects, there are always a large number of conflicting stakeholders who are trying to use their influence to pull the project in their favour. Thanks to modern decision-making methods that contain conflicting criteria, it is possible to evaluate each individual criteria and the project as a whole and make an unbiased assessment of the feasibility of the project. The most famous scientist in developing different decision-making models is Saaty (2004a, 2004b). Saaty (2004a) made an introduction to multi-criteria decision-making using the AHP and its generalization the ANP. In his work explain involves individual and group decisions both with the independence of the criteria from the alternatives as in the AHP and also with dependence and feedback in the entire decision structure as in the ANP. ANP become a very useful tool for decision-making in different situations in the PTS. Nuhodzic *et al.* (2018) used fuzzy ANP for the organizational design of a rail company. In this article authors used fuzzy ANP as a solution for making a decision, which alternative was optimum, considering the variety of data, and their uncertainty, interactions and feedback. Fuzzy ANP was applied as a tool for choosing the optimal organizational structure, and it was presented as a numerical example based on the data from the Montenegro Railway. In order to gain an overall view on all relevant connections of the elements in a public transportation system Duleba *et al.* (2013) proposes a different approach: AHP–ISM, which aims to keep the AHP hierarchy, but simultaneously to amend that with the non-hierarchical types of linkages within the structure. The additional ISM procedure is suitable because the most influential elements of the AHP structure can be selected, and moreover also direct and indirect impacts of element improvement might be followed in the structure by considering both types of connections within the system. In the article by Stoilova (2018) an integrated approach of fuzzy linear programming method and multi-criteria analysis that includes 3 steps. In the 1st step is defined the schemes of transport of intercity trains and optimized different operational aspects using the fuzzy linear programming method. The 2nd step determined the additional technological criteria to assess the variant schemes by applying the fuzzy AHP method, and the last 3rd step is to present the optimal choice of transport applying the PROMETHEE method. The objective of the research done by Rao (2021) was to examine the impacts of intercity railways passenger transport service in Taiwan. By using the DEMATEL and DANP based method, the research analysed the degree of mutual influence to find the causality between indicators and identified the weight of individual indicators and the dimension. Besides, an empirical analysis was conducted to collect the performance of various sustainable indicators of Taiwan intercity railway transport, including different railway services, and calculated the individual and integrated synthetic sustainability indices.

Overall, rail systems are proposed and implemented as pillars of traffic load in public urban–suburban transport (Vuchic 2017). The rail systems have 3 significant advantages: (1) speed, (2) capacity, and (3) comfort. On average, the train reaches twice the commercial speed of buses, and the train has at least 50% greater capacity, and comfort is significantly higher. However, numerous research initially carried out in the US and later in Europe doubts the success of implementing rail systems in public transport. The 1st such research by Pickrell (1992) claimed that planners could reduce the magnitude of errors by adopting various technical improvements in the forecasting process, the structure of transit grant programs, while dedicated funding sources provide little incentive for local officials to seek accurate information in evaluating alternatives. 1st, confirmations that the problem is not only "american" were made by Flyvbjerg *et al.* (2002). Based on a sample of 258 transportation infrastructure projects worth 90 billion $, representing different project types, geographical regions, and historical periods, it was found with overwhelming statistical significance that the cost estimates on whether such projects should be built are highly and systematically misleading. Underestimation cannot be explained by error and is best explained by strategic misrepresentation – lying. The policy implications are clear: legislators, administrators, investors, media representatives, and members of the public who value honest numbers should not trust cost estimates and cost-benefit analyses produced by project promoters and their analysts (Flyvbjerg 2007). Significant research was made by Litman (2018) in his report "Evaluating public transit criticism…". It examined claims that rail transit is ineffective at increasing public transit ridership and improving transportation system performance. It claimed that rail transit investments are not cost-effective and that transit is an outdated form of transportation. But it did find that critics often misrepresent issues and use biased and inaccurate analyses. Rail transit investments can be an appropriate way to create more efficient and diverse urban transport systems that better respond to consumer demands and future economic conditions. Rail transit is not justified everywhere, but it is often a cost-effective way to improve urban transport systems, considering all impacts and objectives. Also, Litman (2007) done straightforward research about evaluating rail transit benefits. It summarized some of the findings of more detailed analyses of transit benefits and suggested that there is abundant evidence that high quality, grade-separated transit does reduce urban traffic congestion and that urban transit improvements can be cost-effective investments when all economic impacts are considered. He concluded that this is not to say that every rail transit project is optimal or that transit investments alone will solve every transport problem. However, various studies indicate that considering all impacts and planning objectives, rail transit is often a cost-effective investment. Edwards & Mackett (1996) examined 11 new and planned systems in the UK. The authors defined a number of key factors considered during the decision-making process: (1) forecast demand, (2) image, (3) deregulation of buses, (4) technological innovation, (5) private sector involvement and (6) the funding mechanism. They concluded that although transport planners make rational decisions within the current political framework, some decisions are not rational. In another research (Mackett, Edwards 1998), the authors point out that there has been increasing concern about the dependence on the automobile and the need to improve the environmental conditions in many cities in the last decades. Therefore, one of the approaches is to construct new PTSs. Concerned with the way in which decisions are made about such systems, in particular the rationale underlying the decision-making process and the implications for the city in terms of travel demand, urban development, and the environment, the authors concluded that it seems the impacts of many of the new urban PTSs are much smaller than those anticipated by those promoting them. However, it is very important that the investment in urban PTSs must be made in a rational way. Otherwise, even if the present irrational methods do produce new systems, the maximum benefits will not be obtained, and the procedures will become discredited. There is a need for both theoretical and empirical research to ensure that a sound investment procedure is put into place and that new urban PTSs are appropriate and cost-effective.

The Cohen-Blankshtain & Feitelson (2011) examines whether the seemingly more technical light rail transit routing decisions are instrumentally rational. They underlined the following rationales: providing service for the most heavily travelled and congested corridors and inducing development, and subsequently demand, in areas perceived to be underdeveloped or distressed and in areas that have deteriorated. Babalik (2000) in his doctoral thesis, tackles the issue of how to explore ways of making new urban rail systems more successful. He developed a methodology for analysing the success of systems, identifying the factors behind their success, and enhancing success.

Based on the analysis of new generation urban rail systems, a planning framework was developed. The framework is a policy-based approach to help planners and operators to increase the success of their systems. It has 2 main functions: it predicts the success of new systems and makes recommendations on how their success can be enhanced. Taylor *et al.* (2009) concluded that public subsidy of transit services had increased dramatically in recent years but with little effect on overall ridership. Quite obviously, a clear understanding of the factors affecting transit ridership is central to making decisions on investments in and the pricing and deployment of transit services. They found out that most of the variation in transit ridership among urbanized areas – in both absolute and relative terms – can be explained by factors outside of the control of public transit systems: (1) regional geography, (2) metropolitan economy, (3) population characteristics, and (4) auto/highway system characteristics. Models in the research are explained by service frequency and fare levels. The observed influence of these 2 factors is consistent with both the literature and intuition: frequent service appeals to passengers, and high fares drive them away. Ibrahim *et al.* (2020) made a detailed literature review about rail-based public transport service quality and user satisfaction. They examined the factor of user satisfaction concerning rail-based public transport with the aim of discovering precisely, which factors have a significant effect on user satisfaction and the uptake of rail travel. The research focused on a total of 9 possible factors affecting passenger satisfaction with rail travel: (1) availability of service, (2) accessibility of service, (3) ticket or pass, (4) punctuality, (5) clarity of information, (6) quality of customer service, (7) comfort, (8) safety, and (9) image. Those factors are most worth investigating if the quality of this crucial means of transport is to be raised and users be satisfied with the quality of service provided. Mathias & Kim (2019) investigated new night train services between the US cities. Interestingly, they found that the new service needs to be: (1) cost-effective and (2) time-efficient. Train transport is the most cost-effective method of transporting passengers (users), and a time-efficient approach can be regulated by the coordination of departure or departures times of trains.

However, transport planners face many problems – from the irrationality of the decision-making process to a great number of factors and the impossibility of analysing the impact on the success of using rail systems in urban–suburban transport. The latter is the central issue of this article: assessing the factors of successful and sustainable integration of the railway into the public urban and suburban transport in Croatian cities that aims to evaluate how justified proposed projects are, thus increasing the likelihood of their success. In this article is examined the case study of the City of Rijeka.

## 2. The methodology of evaluations

The decision on constructing a rail system is often made based on the perception of its benefits. Plans to integrate the railway into the urban and suburban transport of Croatian cities by using existing infrastructure usually follow the same principle – the railway has been preselected as an alternative. In such a context, all activities are related to improving the likelihood of project justification and success.

As in most cases, the railway integration decision was premade, and the issues arise with regard to the applicability of the decision-making theory. The theory of decision-making can serve as an estimation for the justification of such decisions, that is, as an assessment of the success of integrating the railway into the urban–suburban transport.

Since the adequacy of the railway as a solution depends on numerous internal and external factors whose values change over time, the question of how much the likelihood that railway is adequate to the solution to the problem increases if some factors are altered can be answered. The underlying assumption is that an increase in the value of one criterion ensures the same success rate of the system as with lower values of other criteria. For instance, a city's great regional importance that means a greater inflow of passengers from suburban zones can make up for lower population density (fewer users) with the railway in the urban area and vice versa.

A further prerequisite for success is, for instance, the above-average satisfaction of a smaller number of main criteria, but also the average satisfaction of a greater number of factors. Therefore, the assessment of the concrete project could be the classic school-grading assessment, which means the final assessment would be made based on the assessment of individual criteria that were deemed important for success.

What poses a problem is deciding on the importance of a criterion since not all have the same impact on project success, that is, the final assessment. This problem is vividly described by Taylor *et al.* (2009): "Even a casual observer can guess the reasons behind different success rates of the urban–suburban transport: population density, car ownership, topography, motorway network, parking availability and cost, network scope, service frequency, ride times, safety, cleanliness – all this plays a role". However, the relative significance of such variable factors and how they interact is far from clear (Saaty 2004b). Therefore, the method of evaluating a project 1st and foremost must enable us to determine the significance of factors by taking into consideration their mutual interaction. An ANP can be used as a method that meets said demands.

The ANP method is the latest method in decision-making. It is an upgrade to the AHP method. ANP ensures the modelling of a functional interaction between criteria and alternatives in a model, thus ensuring greater result stability. In other words, the structure of feedback loops that exist in the ANP ensure a network definition of problems. Feedback loops enable a more precise determination of element priorities and a more quality solution to a problem (Begičević 2008).

In a hierarchy, criteria weight is used to evaluate alternatives and determine their priorities. In a network, each component can depend on another component. Therefore, ANP is a useful and practical tool for determining element significance when significance depends on values of other elements in the system, as is the case with factors of successfully integrating the railway into the urban–suburban transport.

This method also indirectly helps to model group work. Decision-makers and members of the railway integration project come from different environments, which in a way determines or models their attitudes (transport experts, urbanists, politicians with greater and lower understanding of the transport system, railway operators, and others). Therefore, using a method that ensures teamwork and makes mutual communication and understanding easier is both desirable and practical. The 1st step in the methodology is a selection of relevant criteria (factors) that are key elements for evaluation. After this 1st step follows splitting the step into 2 pillars: (1) determining the criteria importance, and (2) determining criteria values. To determine a criteria importance, it is necessary to devise an ANP model. To assess the importance of each selected criteria must be determined pool of experts that are suitable for assessing the importance of criteria. Experts evaluate criteria using Satty's scale and the result is a weighted coefficient of each criterion. According to the criterion coefficient weight, it is possible to determine significance for evaluation. A determination of criteria values is divided into two: (1) objective, and (2) subjective. Objective criteria values are possible to determine using different measurement scales, but on the other hand, subjective criteria values need to be determined using different questionnaires. Then follows a step that joins objective and subjective criteria by assessing criteria values. Overall assessment of the project can be

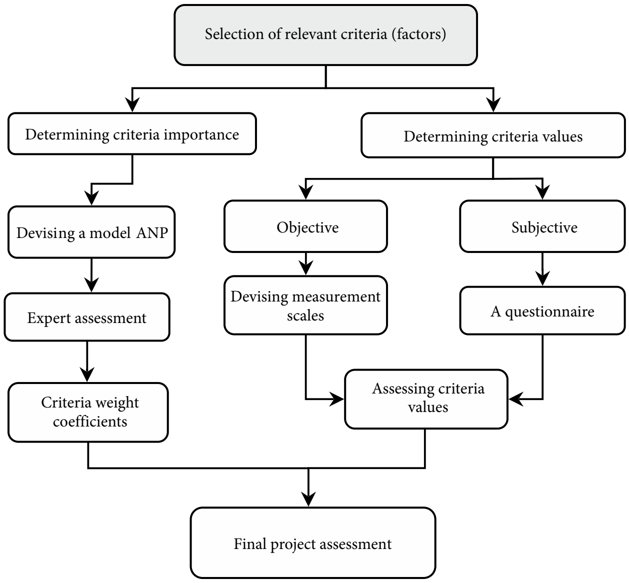


**Figure 1.** The methodology of project assessment

achieved by combining criteria weight coefficients and criteria values. Figure 1 illustrates the proposed methodology of assessing a project proposal for integrating the railway into urban–suburban transport.

## 3. Assessing the factor importance of sustainable railway integration into urban–suburban transport

The objectives of constructing rail systems can vary, which means that the number of transported passengers is not the only measure of success. Nevertheless, in the Croatian context and the plan of using existing rails, emphasis is placed on the so-called greater interests in terms of facilitating urban growth, improving the economy of deteriorating urban areas or centers, and improving a city's image. The number of passengers is a sensible measure of success because it directly defines objective completion in terms of reduction of congestion, environmental protection, mobility increase, and others.

Determining factors and their mutual interdependence that are of importance for sustainable integration of railway into the urban–suburban transport can be carried out by taking the following steps:

- estimating future transport demand;
- analysing anticipated journey frequency;
- modal distribution.

Based on the research by Hirnig (2018), the criteria are defined and their interdependencies are determined, taking into account the direction of action. The criteria were put in a relationship only in terms of a positive effect on the total number of potential beneficiaries. Negative action is not included as this would change the perspective and create circular interdependence. The negative effect can be most easily explained by the characteristics of the new transport service. The service is being introduced to affect, among other things, the road system, primarily in order to reduce congestion. Therefore, each qualitative attribute of the service increases the probability of its use or "attracting" car users. However, such dependencies are contained directly in the hierarchy with respect to the goal – a high level of utilization. Indirect impact through congestion criteria is in fact negative because by attracting users from the road system, congestion is reduced, which in turn loses its importance in potentially attracting new passengers. On the other hand, for example, the low availability of parking in the center directly motivates some drivers to use the PTS, but also, indirectly, by influencing other criteria attracts additional users. Low availability of parking means looking for free space and more circular rides, which increases congestion in the center and fuel costs and thus indirectly, through these factors, attract new users. This consideration of the direction of action of the criteria reduced the number of described impacts and imposed the need to develop the model on 2 levels. This approach is shown in Figure 2.

With that in mind, a set of 27 factors was selected that represents clusters in the ANP model. They also encompass the features of potential users, the road system, the urban area – rail corridors and the railway service. This also represents the clusters in the ANP model. It shows what needs to be done to make the model clear, the result analysis, and especially the reduction in the number of comparisons that need to be made simultaneously while considering cognitive restrictions.

### 3.1. Devising an ANP model

Clusters – the basic network elements – consist of nodes that are mutually linked based on interdependence. The link (loop) between nodes that shows impact is marked by an arrow. Nodes that impact one another are linked via a feedback loop. If nodes within the cluster are mutually linked regardless of their features, they are internally dependent, and this is marked by a loop. These dependencies are, for simplicity, usually illustrated as dependence between clusters or network components (Figure 3).

The key is to recognize when the interaction between elements is essential for modelling a problem. The network contains arches, which can be unconstrained, indicating an incomplete interdependency process between the elements, especially if there is a feedback loop between the elements. Therefore, factors are placed in an interrelationship only if they positively impact the total number of potential users. This direction reduces the number of identified impacts and results in a two-level assessment methodology. Namely, as stated earlier, greater factor values that describe the planned service affect the objective, that is, the level of the system using only directly (AHP). However, interdependencies, both external and internal (ANP), exist between factors that describe urban, corridor, road, and user features. Given that the initial clustering was conducted solely due to cognitive restrictions at assessment, the attribution of weight to individual clusters

| Goal | Evaluation of criteria for successful integration of rail into urban–suburban transport | | | |
|---|---|---|---|---|
| Clusters (AHP) | Deployment location features | | | Service features |
| Clusters (ANP) | City and corridor features | Road transport features | User features | |
| Nods | ▪ city population density;<br>▪ orientation of the railway towards the center;<br>▪ regional significance of the city;<br>▪ accessibility (pedestrian accessibility) of the railway;<br>▪ economic, social and retail attractiveness of the corridor;<br>▪ number of inhabitants in the gravity zone;<br>▪ relief;<br>▪ climate | ▪ availability of parking in the center;<br>▪ serviceability of alternative roads in the corridor;<br>▪ traffic congestion in the center;<br>▪ parking price in the center;<br>▪ fuel cost | ▪ motorization level;<br>▪ employment level;<br>▪ percentage of retirees;<br>▪ usage culture of PTS;<br>▪ percentage of young people;<br>▪ ecological awareness | ▪ integration of services;<br>▪ park and ride;<br>▪ comfort;<br>▪ travel speed (time);<br>▪ reliability;<br>▪ ticket price;<br>▪ frequency;<br>▪ safety |

**Figure 2.** A general model for evaluating the importance of criteria

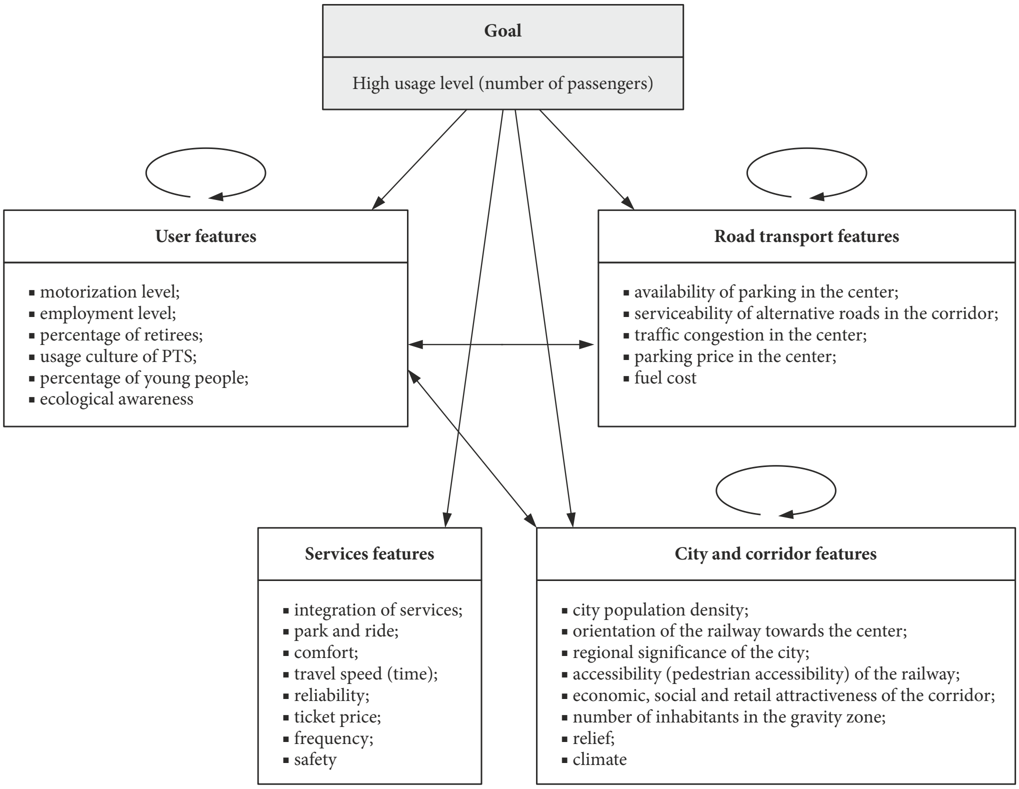


**Figure 3.** ANP model for assessing the importance of criteria in sustainable railway integration into the urban–suburban transport

on the network level was not planned. It was done only on the hierarchical clusters – service features and location features. Based on these loops, an assessment model was devised using *SuperDecisions* software (*https://www.superdecisions.com*), as shown in Figure 3.

## 3.2. Model testing

Model testing was carried out by group decision-making. The result was a synthesis of individual responses made by members of the expert group. This was done to ensure the consideration of potentially different opinions that arise when including participants with various skills and knowledge. On the one side, this ensured a multidimensional approach, and on the other, it avoided the potential domination of authoritative group members. Furthermore, the members put forward their ideas freely, having been freed from assuming responsibility. The decision-making process included various experts from the railway system, PTS of the cities of Split, Rijeka and Osijek, and higher education, overall was 10 experts. The distribution of experts was as follows: 2 participants from HŽ Passenger Transport Limited Liability Company (*https://www.hzpp.hr* – in Croatian: *HŽ Putnički prijevoz d.o.o.*), currently the only passenger railway operator in the Republic of Croatia, 6 participants from the public urban transport system, 2 from each of the companies that perform public urban transport in the cities where the integration of the railway in the Republic of Croatia is planned, and 2 participants from higher education – experts in the field of urban–suburban transport. They were asked to assess the importance of one factor compared to another (pair-wise comparison). The comparison was ranked on a scale of 1 to 9 using the Satty's scale for pair-wise comparison. Each participant made a total of 128 comparisons. Before the decision-making process, they were warned about a potential response inconsistency, which was continuously monitored and recorded to be acceptable. The result included unpondered, pondered, and restricted super matrices, that is, attribution of weight to certain criteria. In the end, the obtained priorities were shown to the participant for result-confirmation purposes (procedure representativeness).

The next step was a synthesis of individual estimations done by calculating the geometric mean. Aczél & Saaty (1983) have mathematically proven that if reciprocal estimations are used, the geometric mean is the only way to combine individual estimations. If A is significantly more important than B and B is moderately more important than C, then C cannot be anything more important than A. The result was presented to each respondent in order to examine whether it reflects his views on the importance of the considered criteria, and the confirmation obtained also confirms the correctness of the model.

After importance, that is weight, was determined for all elements based on the model shown in Figure 3, they were unified. For that purpose, the clusters of location features and service features were included, and the priority vector was obtained through the paired comparison by assessment participants.

Finally, the global importance (weight) of all criteria was calculated by multiplying the values of the respective weights, determined using the super matrices and the weight of the cluster they belonged to (Table 1). For clarity and assessment purposes, the obtained values were 1st pondered to $\sum = 1$.

**Table 1.** Global significance of factors of sustainable integration of the railway into the urban–suburban transport

| Factor | Weight | | | | |
|---|---|---|---|---|---|
| | of the cluster | | of the factor | | globally |
| | basic | ponderation | basic | ponderation | |
| Parking price in the center | 0.43578 | 0.47492 | 0.02596 | 0.02892 | 0.01373 |
| Availability of parking in the center | 0.43578 | 0.47492 | 0.08058 | 0.08978 | 0.04264 |
| Fuel cost | 0.43578 | 0.47492 | 0.01945 | 0.02167 | 0.01029 |
| Serviceability of alternative roads in the corridor | 0.43578 | 0.47492 | 0.03507 | 0.03907 | 0.01856 |
| Traffic congestion in the center | 0.43578 | 0.47492 | 0.10510 | 0.11710 | 0.05562 |
| Number of inhabitants in the gravity zone | 0.43578 | 0.47492 | 0.02270 | 0.02530 | 0.01201 |
| Accessibility (pedestrian) of the railway | 0.43578 | 0.47492 | 0.02538 | 0.02827 | 0.01343 |
| Economic, social and retail attractiveness of the corridor | 0.43578 | 0.47492 | 0.05108 | 0.05692 | 0.02703 |
| City population density | 0.43578 | 0.47492 | 0.11461 | 0.12770 | 0.06065 |
| Climate | 0.43578 | 0.47492 | 0.00901 | 0.01004 | 0.00477 |
| Regional significance of the city | 0.43578 | 0.47492 | 0.03842 | 0.04281 | 0.02033 |
| Relief | 0.43578 | 0.47492 | 0.01450 | 0.01616 | 0.00768 |
| Orientation of the railway towards the center | 0.43578 | 0.47492 | 0.02854 | 0.03180 | 0.01510 |
| Ecological awareness | 0.43578 | 0.47492 | 0.00992 | 0.01105 | 0.00525 |
| Usage culture of PTS | 0.43578 | 0.47492 | 0.02910 | 0.03242 | 0.01540 |
| Percentage of young people | 0.43578 | 0.47492 | 0.02866 | 0.03193 | 0.01517 |
| Percentage of retirees | 0.43578 | 0.47492 | 0.03717 | 0.04141 | 0.01967 |
| Motorization level | 0.43578 | 0.47492 | 0.03052 | 0.03401 | 0.01615 |
| Employment level | 0.43578 | 0.47492 | 0.19174 | 0.21364 | 0.10146 |
| Travel speed | 0.48179 | 0.52508 | 0.10478 | 0.12380 | 0.06501 |
| Ticket price | 0.48179 | 0.52508 | 0.15657 | 0.18500 | 0.09714 |
| Frequency | 0.48179 | 0.52508 | 0.18780 | 0.22190 | 0.11651 |
| Integration of services | 0.48179 | 0.52508 | 0.11388 | 0.13455 | 0.07065 |
| Park and ride | 0.48179 | 0.52508 | 0.05641 | 0.06665 | 0.03500 |
| Reliability | 0.48179 | 0.52508 | 0.11696 | 0.13820 | 0.07256 |
| Safety | 0.48179 | 0.52508 | 0.05284 | 0.06243 | 0.03278 |
| Comfort | 0.48179 | 0.52508 | 0.05709 | 0.06745 | 0.03542 |
| | | | | Sum: | 1.00000 |

Given that the ponderation of factor values amounted to 1, the obtained data can be interpreted as a percentage share of a factor in the success of the project, or the percentage share of the impact it has on the expected level of system use, i.e., the number of transported passengers.

3 factors dominate with over 30% of impact: train frequency, fares, and employment level. The following group of important criteria is related to service because next to the city's population density, the service includes train reliability, service integration, and train journey speed. These 4 criteria hold 25%, which together with the 1st 3 dominant ones make it 60% of the success. This group has factors that can significantly impact passenger behaviour, that is, appeal. The 1st group has a more dominant effect on user behaviour but is more closely related to available funding, in other words, the city's ability to subsidize transport. On the other hand, reliability and service integration are organizational and planning issues, which means that planners and operators can and should use them. Train speed is a more complex issue because besides depending on infrastructure and funding, it also depends on a variety of other factors.

## 4. Case study of the City of Rijeka

Rijeka is the center of the Primorje – Gorski Kotar County and the 3rd-largest city in Croatia. It is also the country's greatest seaport, the development of which facilitated the railway link between Rijeka and its hinterland. In 1873, 2 rails were set up connecting Rijeka and Pivka (with Ljubljana and Vienna), and Karlovac (with Zagreb and Budapest). Using these rails to establish urban and suburban transport has for long been of interest to the city and was anticipated in the "General urban plan of the City of Rijeka". Also, it is considered, accepted, or developed as part of other scientific or professional efforts, directly or as part of a larger project. Currently, the most detailed and examined source that serves as basis for the infrastructure is the "Study of feasibility of constructing a second track of the railway line Škrljevo – Rijeka – Šapjane" (HŽ Infrastruktura 2014a, 2014b). This study aims to examine the possibilities of adding a 2nd track to the section, including a reconstruction of existing terminals and stops, and construction of new ones for suburban transport. The plans put forward containing information on the number and location of stops, allowed speeds, and other information were used in this study.

In the 1st step, the factors were classified into either objective or subjective, depending on the way their value was determined. The division of factors into objective and subjective is only in terms of assessing their value in this case study. Valuation is the input for the model and the valuation methodology does not affect the model itself. On the contrary, most criteria can be classified into one or another group, and the decision depends on the availability of data for a particular case. The availability of parking can be measured and assessed exactly by putting the number of available parking spaces in relation to the demand expressed by the number of vehicles in the city, the number of inhabitants, the area of the center, so this is objective. More accurate information about parking is possible due to the possibility of parking in places not in the billing system, so this is subjective.

The objective group described or defined the existing features of urban spaces and the population, and the features of the city's transport system and the proposed railway corridor – population density, city's regional significance, number of residents in the corridor, the percentage of youth and pensioners, employment rate, the culture of using urban and suburban transport, the level of motorization, road service in the rail corridor, the direction of the rail towards the center, and the economic and retail appeal of the corridor (Hirnig 2018).

The subjective criteria 1st and foremost represented the individual perception of users – their assessment of the current and planned system. This included assessment on pedestrian access, fuel costs, accessibility and parking fees in the center, road traffic congestion, service accuracy and reliability, journey time, fares, train frequency, comfort, safety, service integration, park and ride options, and eco-awareness. This classification was done to assign a ranking/value in this project. Assessing subjective factors was carried out using a questionnaire. The questionnaire was conducted online using the *LimeSurvey* tool (*https://www.limesurvey.org*). *LimeSurvey* can prepare and conduct a questionnaire via the internet. A total of 348 questionnaires were collected to be used in the analysis (Hirnig 2018).

On the other side, objective factors were assessed using measurement scales, an example of which is given in Table 2. For example, in Table 2, the lower limit is the value from the "Methodology for defining the coverage of urban areas in the Republic of Croatia", which makes it relevant for projects in the Republic of Croatia but not universally representative. The value of all factors was ranked on a scale of 1 to 7. The obtained results are listed in Table 3.

After determining the values of individual factors, the importance was for the project success was determined by unifying their established significance using the ANP model. The 2nd column (A) included the calculated global criteria weight by using the proposed ANP model based on the expert assessment. The 3rd column (B) contains criteria values in the City of Rijeka obtained by using measurement scales and potential polling users (questionnaire), turned into scaled values (1–10) in the 4th column (C). By multiplying the criteria weight (value) by their scaled value, is obtained their global (B) importance in the project. The result and criteria assessment are presented in Table 4.

The Table 4 also includes an average assessment of the entire project and the likelihood of its success, considering the observed criteria. In the case study, the average assessment was 0.67166, which can be interpreted as having a 67.2% chance of success or a 67% fulfilment of successful integration criteria. Naturally, the maximum value

**Table 2.** The measurement scale for the city's regional significance

| The percentage of all commuters residing in the gravitational zones of units of local self-government that gravitate towards Rijeka | Assessment |
|---|---|
| <30% | 1 |
| 30…34% | 2 |
| 35…39% | 3 |
| 40…44% | 4 |
| 45…49% | 5 |
| 50…55% | 6 |
| >55% | 7 |

**Table 3.** Assessment of the values of "A case study of the City of Rijeka" factor

| Factor | Assessment |
|---|---|
| Parking price in the center | 6 |
| Availability of parking in the center | 5 |
| Fuel cost | 6 |
| Serviceability of alternative roads in the corridor | 1 |
| Traffic congestion in the center | 6 |
| Number of inhabitants in the gravity zone | 4 |
| Accessibility (pedestrian) of the railway | 4 |
| Ticket price | 2 |
| City population density | 6 |
| Climate | 3 |
| Regional significance of the city | 5 |
| Relief | 4 |
| Orientation of the railway towards the center | 6 |
| Ecological awareness | 4 |
| Percentage of young people | 6 |
| Usage culture of PTS | 5 |
| Employment level | 6 |
| Motorization level | 2 |
| Percentage of retirees | 5 |
| Travel speed | 5 |
| Economic, social, and retail attractiveness of the corridor | 4 |
| Service frequency | 4 |
| Integration of services | 4 |
| Reliability | 6 |
| Park & Ride | 4 |
| Safety | 6 |
| Comfort | 6 |

(100%) can hardly be expected in practice as it would require the maximum value of every criterion. Therefore, a result above 80% can be seen as an excellent prerequisite for implementing the railway into urban and suburban transport.

This project assessment based on criteria value and importance is quite practical because it models well-known relationships – several prerequisites or criteria (factors) need to be meet for the project to be successful. If they have great importance, even if other factors are left out. Similarly, projects can succeed even if they do not have clear basic prerequisites or high values of key criteria, under the condition that they are well-supported by a variety of other factors. Furthermore, changes in the system can be simulated as can their impact on using the planned version. For instance, if users were satisfied with fares, frequency, and integration in this project, the success probability rate would increase by around 10%.

## Conclusions

Public transport is one of the most important services offered in today's cities. Especially, keeping in mind the process of decarbonization the position of public transport in overall transport system becoming more and more important. Very often, there is an idea to incorporate railway into the public urban and suburban transport without a more comprehensive picture of what are advantages and disadvantages of that solution. So, there is a necessity to use different decision-making models to make a reasonable and enforceable decision. The more effective scientific approach is the AHP. The AHP is one of the most popular and widely employed multi-criteria methods. A more general form of the AHP is ANP. Applying the ANP, obtaining more accurate results at the end of the decision. Numerous factors affect the use of railway systems and thus the success of planned railway integration into urban and suburban transport. Apart from the numerousness of such factors, another issue is their varying significance in terms of success and complex interaction among them.

This article has examined the possibility of assessing factor importance using an ANP. Based on 27 factors that were selected as relevant in terms of ensuring anticipated (assumed) level of use of the planned service and their links, an ANP model was devised using a decision-making support software SuperDecisions. Model testing was conducted through group decision-making by experts from various fields and various systems related to planned service integration of railway into the public urban and suburban transport. Factors are divided into 4 clusters: (1) user features, (2) road transport features, (3) services features, and (4) city and corridor features. Testing was carried out by group decision-making process by members of an expert panel. According to the testing, the most important factors according to their weight are: (1) frequency with 0.11651, (2) employment level with 0.10146, (3) ticket price with 0.09714, (4) reliability with 0.07256, and (5) integration of services with 0.07065. The existence of dominant criteria that together hold over 30% of impact was determined – train frequency and fares. The next group of factors was related to service itself – (1) urban density, (2) train reliability, (3) service integration, and (4) train speed. Together, these 4 factors hold over 25% and together with the dominant group comprise around 60% of project success.

**Table 4.** Global assessment of the case study

| Factor | | Global weight (A) | Assessment | | |
|---|---|---|---|---|---|
| | | | Basic (B) | Scaled (C) | Global (D) |
| City and corridor features | City population density | 0.06065 | 6 | 0.85714 | 0.05199 |
| | Regional significance of the city | 0.02033 | 5 | 0.71429 | 0.01452 |
| | Number of inhabitants in the gravity zone | 0.01201 | 4 | 0.57143 | 0.00686 |
| | Orientation of the railway towards the center | 0.01510 | 6 | 0.85714 | 0.01294 |
| | Accessibility (pedestrian) of the railway | 0.01343 | 4 | 0.57143 | 0.00767 |
| | Economic. social and retail attractiveness of the corridor | 0.02703 | 4 | 0.57143 | 0.01545 |
| | Relief | 0.00768 | 4 | 0.57143 | 0.00439 |
| | Climate | 0.00477 | 3 | 0.42857 | 0.00204 |
| Road transport features | Serviceability of alternative roads in the corridor | 0.01856 | 1 | 0.14286 | 0.00265 |
| | Fuel cost | 0.01029 | 6 | 0.85714 | 0.00882 |
| | Parking price in the center | 0.01373 | 6 | 0.85714 | 0.01177 |
| | Traffic congestion in the center | 0.05562 | 6 | 0.85714 | 0.04767 |
| | Availability of parking in the center | 0.04264 | 5 | 0.71429 | 0.03046 |
| User features | Usage culture of PTS | 0.01540 | 5 | 0.71429 | 0.01100 |
| | Motorization level | 0.01615 | 2 | 0.28571 | 0.00461 |
| | Percentage of young people | 0.01517 | 6 | 0.85714 | 0.01300 |
| | Percentage of retirees | 0.01967 | 5 | 0.71429 | 0.01405 |
| | Employment level | 0.10146 | 6 | 0.85714 | 0.08697 |
| | Ecological awareness | 0.00525 | 4 | 0.57143 | 0.00300 |
| Services features | Integration of services | 0.07065 | 4 | 0.57143 | 0.04037 |
| | Reliability | 0.07256 | 6 | 0.85714 | 0.06219 |
| | Park and ride | 0.03500 | 4 | 0.57143 | 0.02000 |
| | Frequency | 0.11651 | 4 | 0.57143 | 0.06658 |
| | Travel speed | 0.06501 | 5 | 0.71429 | 0.04644 |
| | Ticket price | 0.09714 | 2 | 0.28571 | 0.02775 |
| | Comfort | 0.03542 | 6 | 0.85714 | 0.03036 |
| | Safety | 0.03278 | 6 | 0.85714 | 0.02810 |
| | | | | Sum | 0.67166 |

After determining the weight of each criterion, it was possible to assess the justifiability of implementing the railway in a city by pondering the actual factor value with their calculated weight. For this purpose, the questionnaire was done to determine people's opinions in the catchment area. The questionnaire results were used with the weight of the model's factors to calculate the new value of the importance of factors. At the same time, it was possible to simulate the changes of existing criteria weight revealed that the success likelihood would increase by around 11% of users were happy with fares, service frequency, and planned integration. On the other hand, the road system's impact would be reduced parking availability and increased parking fees, increase in fuel cost and higher traffic congestion in the city center and the corridor would have a limited impact – a 4% chance for project success.

Using the weight of each factor, it is possible to evaluate the success likelihood of a concrete project. This research case study was oriented on integrating the railway into the public urban and suburban transport in the City of Rijeka in Croatia. For this purpose, the relevance of the determined weight factors was used for the concrete project of integration in the City of Rijeka, resulting in 67.17% fulfilment of the successful integration railway into the public urban and suburban transport.

Future research steps can examine other criterias that were not incorporated in this research more deeply. For sure, one of the new criteria is equity of using public transport services and within that railway. Another improvement of the current model can go in the direction of doing the expert assessment in different countries, and from that, results make a benchmarking of factors weights.

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