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ENHANCING MULTIMODAL CONNECTIVITY BETWEEN AIR AND RAIL TRANSPORT: A CASE STUDY OF FRANJO TUĐMAN AIRPORT

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***Abstract**:*

Connecting airports with rail transport infrastructure is increasingly emerging as a strategic priority in the context of sustainable development, improving passenger mobility and strengthening multimodality. Such integration contributes to better connectivity of urban and regional areas with airports, expands the airport's catchment area, reduces traffic congestion and emissions, assists with the logistical supply of the airport (especially fuel), and increases the overall efficiency of the transport system. Research efforts to date include analyses of modal shift between road, air, and rail transport, assessments of the economic viability of investments in rail infrastructure, and the development of methodologies for evaluating transport projects and selecting optimal solutions using multi-criteria decision-making (MCDM) methods. The analysis of selecting the best option for connecting an airport to rail transport infrastructure includes four basic criteria: financial, traffic, environmental and availability criteria. For this purpose, the following options have been defined: (A) a direct railway line to the airport, (B) a connection to the existing railway line with organised shuttle transport, and (C) an extension of the tram line or the construction of a new tram line. The scientific contribution of the research is reflected in the systematisation of knowledge about the multimodal integration of air and railway hubs, and the method of using the approach for selecting connection options. The proposed methodology is based on the Step-wise Weight Assessment Ratio Analysis (SWARA) method, which assesses the weighting factors of the main criteria in the process of selecting the offered options for connecting an airport, where the connection of Franjo Tuđman Airport in Zagreb to the railway transport infrastructure will be used for the case study. Given these challenges, the aim of this paper is to analyse the possibilities and criteria for connecting airports with railway infrastructure and to identify key factors that influence the development of such integrated transport solutions. Special attention is paid to the evaluation of criteria relevant for planning railway connections to airports by applying multi-criteria decision-making methods.

Keywords: *airport connectivity, multimodality, air transport, land transport, railway, SWARA*

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1. Introduction

In modern transport planning and the concept of sustainable development, the need for the integration of different modes of transport, especially air and rail, is increasingly emphasised. Such integration is a key prerequisite for increasing the efficiency of the transport system, reducing negative environmental impacts, and improving the availability and competitiveness of airports. Despite the growing interest in the integration of air and rail transport in the European and global context, such solutions have not yet been implemented in the Republic of Croatia. Currently, no airport in Croatia is directly connected to railway transport infrastructure, which represents a significant limitation for the development of intermodal transport and for reducing dependence on road transport in accessing airports. The existing dominance of road transport in accessing airports faces a number of challenges, such as traffic congestion, air pollution, high energy consumption and limited infrastructure capacities. In this context, the integration of rail transport as a sustainable, reliable and energy-efficient alternative is becoming an increasingly relevant topic for transport experts, urban development planners, and decision-makers.

Unlike previous studies that primarily focus either on technical feasibility, cost-benefit analysis, or isolated modal integration indicators, this study develops an integrated decision support framework specifically tailored to airport rail connectivity planning in emerging multimodal transport systems. The scientific contribution of the research does not lie solely in the application of the SWARA method, but in:

(1) the development of a structured evaluation framework for airport rail integration that simultaneously incorporates transport, accessibility, financial and environmental dimensions;

(2) the adaptation of SWARA weighting to the specific context of airport accessibility planning, where stakeholder priorities are highly heterogeneous;

(3) the integration of sensitivity analysis into the decision-making process in order to evaluate the robustness of infrastructure prioritisation under changing strategic preferences; and

(4) the application of the framework to a real-world case study of Franjo Tuđman Airport, representing one of the first systematic evaluations of airport–rail integration options in Croatia.

In contrast to conventional infrastructure appraisal approaches based primarily on economic indicators, the proposed framework enables a transparent comparison of alternative airport access solutions under multiple and conflicting criteria. The methodological approach is transferable and can support strategic planning for secondary and medium-sized European airports facing similar multimodal integration challenges.

Therefore, the novelty of the study is methodological and contextual: methodological in combining SWARA-based weighting with robustness-oriented sensitivity analysis for airport access planning, and contextual in addressing the underexplored problem of rail integration for airports in Southeast Europe.

2. Literature Review

European strategic documents, such as the Trans-European Network – Transport (TEN-T), strongly promote the development of multimodal transport, with the integration of rail transport with air hubs playing a key role in improving mobility and environmental sustainability (European Commission, 2011, 2014, 2015, 2024; European Parliament and Council of the European Union, 2024; Publications Office of the European Union, 2021). Furthermore, numerous research and studies (Borsati & Albalate, 2020), (Buire et al., 2020), (Rus et al., 2023), (Dobruszkes, 2025), (Lauda & Novotný, 2022), (Nash, 2015), (Rail Baltica, 2019), (Rattanakijsuntorn et al., 2024), (Rodrigue, 2024), (Šarić et al., 2025) confirm that high-quality rail connectivity of airports can significantly increase the share of passengers using public transport, contribute to the decarbonisation of transport, and enable better spatial and economic connectivity of regions. In the Croatian context, the issue of integrating airports with the national railway network has been the subject of expert analyses and public debates for years, but concrete infrastructural developments are still lacking (Grad Zagreb, 2024), (Mihetec et al., 2010), (Ministry of Maritime Affairs, 2016), (Šarić et al., 2023). The Transport Development Strategy of the Republic of Croatia for the period 2017–2030 highlights the need to complete the existing and build new railway infrastructure and network in order to improve accessibility to airports, create the prerequisites for optimal passenger and freight transport, and reduce transport time and costs (Republic of Croatia, 2017). A direct rail connection between the airport and the city centre

would certainly contribute to increasing the modal split in favour of public transport, reducing traffic congestion, and improving regional and local connectivity. Investing in multimodal connectivity with urban and regional transport represents a strategic step towards a sustainable transport system, enabling a simple transition between air and rail transport without the need for additional road transfers.

In the European context, the LAirA (Landside Airports Accessibility) project and numerous strategic studies and papers (Buire et al., 2023), (Gharehgozli et al., 2019), (Janić, 2011), (LAirA Project, 2020), (Rosik et al., 2022), (SESAR Joint Undertaking, 2025), (Šipuš et al., 2022) indicate a clear need and potential for the development of such solutions. However, implementation depends on political will, financial capacity, and coordination between transport, urban and environmental policies. Integrated air-rail systems enable simple, fast and comfortable passenger transfer between urban areas and airports, reducing the need for private cars and taxi services. The purpose of this research is to analyse and evaluate possible options for connecting the Franjo Tuđman Airport in Zagreb with the railway transport infrastructure, using the multi-criteria decision-making method SWARA.

Within the field of MCDM, (Durmaz et al., 2024), (Jia et al., 2023), (Kamber et al., 2026), (Macharis & Bernardini, 2015), (Šarić & Abramović, 2025), (Taherdoost & Madanchian, 2023), (Thakkar, 2021) highlight that transport infrastructure evaluation increasingly requires multi-actor and multi-criteria approaches due to conflicting stakeholder objectives. Nevertheless, the application of MCDM methods specifically to airport rail integration remains relatively limited. Existing studies often rely on conventional weighting techniques such as AHP, which may introduce inconsistencies in pairwise comparisons and become less practical when expert judgments are uncertain or criteria are closely interrelated.

Recent studies show the growing application of SWARA and hybrid MCDM approaches in transport and airport planning (Šarić & Abramović, 2025), applying the SWARA technique to determine the weights of criteria for airport and railway integration, while a study (Durmaz et al., 2024) combines SWARA and WASPAS (Weighted Aggregated Sum Product Assessment) methods to assess the sustainability of airports in relation to sustainable development goals. Recent review studies further confirm the increasing role of MCDM techniques in sustainable transport planning, especially under conditions of uncertainty and conflicting stakeholder goals. Moreover, recent studies increasingly integrate fuzzy logic and hybrid MCDM frameworks to improve robustness and reduce subjectivity in infrastructure evaluation processes.

Compared with these approaches, the SWARA method offers several advantages for airport connectivity planning. It enables direct expert-based prioritisation of criteria, reduces the complexity of pairwise comparisons, and provides greater transparency in situations where strategic infrastructure priorities must be evaluated under limited data availability. However, previous research rarely combines SWARA weighting with robustness-oriented sensitivity analysis in the context of airport accessibility planning. This study attempts to address that gap by developing a structured and transferable framework for evaluating airport rail connection alternatives.

Despite the growing body of literature on air-rail integration, there is still a lack of research addressing medium-sized airports in transition economies, particularly in Southeast Europe, where institutional constraints, infrastructure gaps and financial limitations significantly influence the selection of optimal connectivity solutions.

The results are expected to confirm the justification for developing the Franjo Tuđman Airport railway connection as a strategic element of a sustainable transport system, with a clear emphasis on the key criteria that influence the selection of the optimal option. The paper should provide an expert basis for future infrastructure decisions but also point out the limitations and challenges of implementing such projects within the Croatian transport and institutional framework.

3. Methodology

The SWARA technique was used to determine the weights of the criteria for the evaluation of land transport infrastructure for the purpose of connecting airports. This is a multi-criteria decision-making (MCDM) technique designed to determine the weights of different criteria based on expert opinions using a sequential approach (Durmaz et al., 2024), (Jia et al., 2023), (Kamber et al., 2026), (Macharis & Bernardini, 2015), (Taherdoost & Madanchian,

2023), (Thakkar, 2021). Based on the research conducted using the SWARA technique (Šarić & Abramović, 2025), the results of the evaluation of the criteria and sub-criteria will be applied to the case of Franjo Tuđman Airport in Zagreb, with the evaluation of three options for connecting the airport to the railway transport infrastructure. The Stepwise Weight Assessment Ratio Analysis (SWARA) method was applied to the case study of Franjo Tuđman Airport with the aim of defining a framework for objective and transparent decision-making. Based on the assessment of the weighting factors of the selected criteria, this method allows for a structured evaluation of the connection options. The research methodology can be illustrated by the following steps, as shown in Figure 1.

By defining multiple solution options (A, B, C), their comparative analysis is enabled in relation to the parameters and criteria set for selecting the optimal option. The key parameters for selecting the best connection option, as well as the distance between the Main Railway Station – Zagreb and the airport passenger terminal, depending on the connection option, are shown in Table 1.

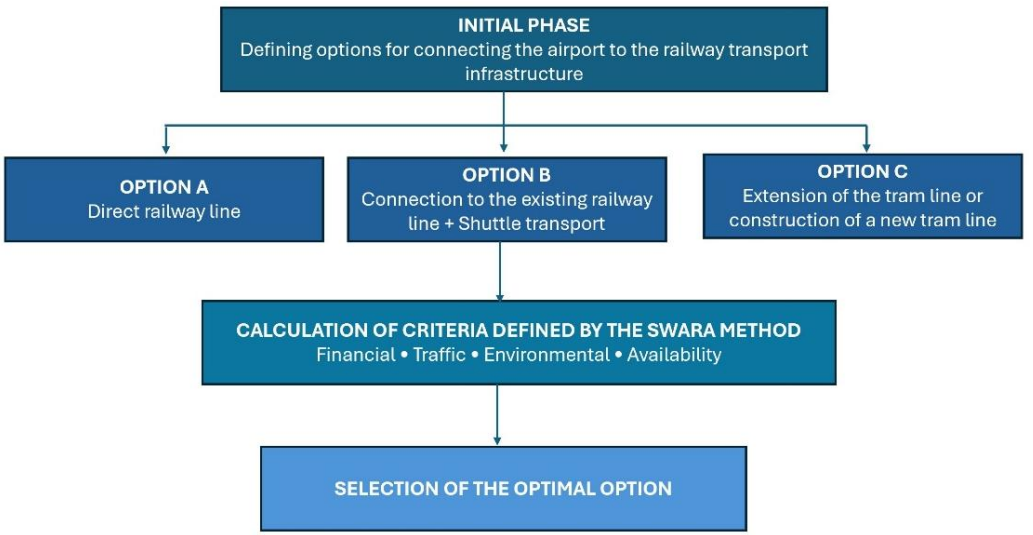


Fig. 1. Defining the steps in selecting the optimal option for connecting the airport to the rail transport infrastructure. Source: Authors

Table 1. Key parameters for choosing a connection option. Source: Authors

Parameter	A) Direct railway line	B) Railway line + Shuttle	C) Tram line
Distance to airport	15 km	7 + 6 km	15 to 18 km
Travel time	15-20 min	30-40 min	30-45 min
Transfers	No	Yes	No
Comfort	5	4	3
Capcity	High	Medium	Medium
Implementation cost	High	Low	High
Traffic dependency	Low	Medium (Shuttle)	High

Option A, which involves a direct rail connection to the airport passenger terminal, proves to be the simplest in terms of transport and the most operationally reliable. The absence of transfers reduces the total travel time and increases the predictability of arrival and the level of travel comfort, which is in line with the practice of large European airports. However, the high infrastructure requirements and the need for a new rail route pose a significant challenge in terms of investment costs and spatial planning.

Option B, which combines rail transport and shuttle bus service, has the advantage of faster implementation and lower initial investments. However, the additional transfer phase increases the complexity of the journey and reduces the comfort and reliability of the system, especially in conditions of road congestion. Such a solution may be acceptable as a transitional measure, but in the long term it does not provide the same level of service as a direct rail connection.

Option C, based on the extension of the existing or the construction of a new tram line, stands out for its good integration into the existing urban transport network and greater spatial accessibility for urban users. However, a greater number of stopovers and lower average speeds result in longer travel times, which may reduce the attractiveness of this option for travellers whose primary destination is the airport.

In order to ensure the comparability of the results, all options are evaluated on a single numerical scale, where a point scale of 0 to 100 is applied. This approach allows for more detailed differentiation between the options and a more precise presentation of their relative advantages and disadvantages.

Furthermore, in the study (Šarić & Abramović, 2025), the following criteria were evaluated: (1) traffic, (2) availability, (3) financial, and (4) environmental.

The obtained scores for the criteria are then weighted using the weighting coefficients determined by the SWARA method. The weights reflect the relative importance of individual criteria in the decision-making process, with the traffic and availability criteria having the greatest weight, while the financial and environmental criteria, although ranked somewhat lower, still have a significant impact on the final score. Weighting ensures that the criteria of greater importance have a proportionally stronger influence on the overall evaluation result. If the order of the options remains unchanged or changes only to a minor extent, it can be concluded that the decision-making model is robust and resistant to subjective variations in the assessment of the importance of the criteria.

4. Results and discussion

Decision-making is part of the process of solving problems related to infrastructure and includes identifying problems that exist in an urban area and that can be solved by building new infrastructure, reconstructing existing infrastructure, or improving management. As previously stated, the results of the study (Šarić & Abramović, 2025) were used as a reference framework for the purpose of evaluating the criteria for connecting Franjo Tuđman Airport to the railway infrastructure. In the aforementioned study, the SWARA method proved to be practical and transparent in the multi-criteria decision-making process. As a result of the study, the traffic criterion (26.3%) was given the greatest importance, followed by the availability criterion (25.6%), while the financial (24.6%) and environmental (23.5%) criteria are also present, but with a smaller impact. The results emphasise that in the process of multimodal integration of airports, it is crucial to ensure traffic flows and accessibility, while also taking into account financial sustainability and environmental requirements. Based on these results, the SWARA method will be applied to select the optimal option for connecting Franjo Tuđman Airport to the railway transport infrastructure.

4.1. Mathematical model of option valuation with SWARA method results

The total weighted score of option *(j)* is calculated according to the expression:

$$S_j = \sum_{i=1}^{n} \left(w_i \cdot s_{ij} \right) \tag{1}$$

where:

w_i – weight of criterion **i** obtained by SWARA method

$s_{i,j}$ – score of criterion **i** for option **j** (0 – 100)

n – number of criteria (in this case 4)

and SWARA weights:

- Traffic: $w_1 = 0{,}263$
- Availability: $w_2 = 0{,}256$

– Financial: $w_3 = 0{,}246$
– Environmental: $w_4 = 0{,}235$

where:

$$\sum_{i=1}^{4} w_i = 1{,}000 \tag{2}$$

4.2. Valuation of connection options

When evaluating connectivity options, three options are considered:

A. Direct Rail Line
B. Rail Line + Shuttle Transport
C. Light Rail (Tram)

The values of the standardised point rating of the individual considered options for connecting Franjo Tuđman Airport with the railway transport infrastructure are shown in Table 2. The ratings are the result of an independent expert assessment by selected experts in the field of transport planning and the railway system, carried out in accordance with predefined and transparently established evaluation rules. Each option was evaluated according to a set of previously defined criteria, where the experts, based on their professional judgment, experience and available technical data, assigned point values, which were then standardised to ensure mutual comparability of the results. The point ratings are expressed on a numerical scale from 0 to 100, where the value 0 indicates an extremely unfavourable rating in relation to the observed criterion, while the value 100 represents the most favourable possible rating. Higher point values indicate better fulfilment of the given criteria and a higher level of efficiency, justification and quality of the observed option in relation to the other analysed options. The results obtained in this way enable a more objective comparison of the considered solutions and serve as a basis for further analysis and decision-making in the process of selecting the optimal option for connecting the airport to the railway network.

Table 2. Standardised point ratings of selected options. Source: Authors

Criterion	Option A	Option B	Option C
Traffic	95	70	80
Availability	90	80	70
Financial	60	90	70
Environmental	90	65	80

4.3. Calculation of weighted score

The model uses a weighted sum approach. Each option is evaluated against the same set of criteria, and the overall score for the option is the sum of the criteria scores multiplied by the corresponding criterion weights. This approach assumes that the criteria are congruent (same direction and scale) and that the trade-offs between the criteria are linear and compensatory. Weights are assigned as a vector representing the relative importance of each criterion. The model keeps the weights normalised so that their sum equals one. This makes the overall score a true weighted average and ensures comparability when assumptions about importance are changed. Below are the calculated scores for each individual option.

Option A

$$S_A = \sum_{i=1}^{4} (w_i \cdot s_{iA})$$
$$S_A = 0.263 \cdot 95 + 0.256 \cdot 90 + 0.246 \cdot 60 + 0.235 \cdot 90 = 83.935 \tag{3}$$

Option B

$$S_B = \sum_{i=1}^{4} (w_i \cdot s_{iB})$$
$$S_B = 0.263 \cdot 70 + 0.256 \cdot 80 + 0.246 \cdot 90 + 0.235 \cdot 65 = 76.305 \tag{4}$$

Option C

$$S_C = \sum_{i=1}^{4} (w_i \cdot s_{iC})$$
$$S_C = 0.263 \cdot 80 + 0.256 \cdot 70 + 0.246 \cdot 70 + 0.235 \cdot 80 = 74.980 \tag{5}$$

The results obtained represent a weighted average of the option ratings, with each option achieving a total value as the sum of the products of the ratings by criteria and the associated weighting coefficients, as shown in Table 3. The analysis of the results shows that Option A achieves the highest total value, which is a consequence of the high scores in the traffic and availability criteria, which have the greatest relative importance in the model. This confirms that the model consistently reflects the defined decision-making priorities.

Table 3. Order of options based on calculation results. Source: Authors

No.	Options	Total S
1.	Option A	**83.935**
2.	Option B	76.305
3.	Option C	74.980

4.4. Sensitivity analysis

A one-way is performed by varying the weight of a single criterion across its feasible range, while adjusting the remaining weights proportionally to maintain a total of one. Proportional reassignments preserve the relative shares among the criteria that are not varied and are the standard assumption when there is no alternative information about how to redistribute importance. For each sampled value of the varied weight, the total score for each option is recalculated. After the calculation, breakpoints are displayed where the ranking between the options changes. Graphically, these are the intersections of the option score curves on the score-versus-weight plots, and algebraically they correspond to the weight values that equalise the weighted sums of the two options. Tracking these breakpoints shows what changes in preferences (weights) would result in a different preferred option, helping decision-makers understand critical thresholds. The analysis summarizes the one-way results by reporting the minimum and maximum total scores that an option can achieve when the weight of each criterion is varied. Plotting these ranges side by side highlights which criteria have the greatest impact on the results. Those with the largest range of scores are the most influential and indicate where efforts should be focused to reduce uncertainty. The visualisation below shows the scores against the weight for each criterion (illustrating how the overall score of each option changes as that weight changes). If the preferred option remains at the top despite large variations in weight, the choice is robust; if small changes in one weight prevail, the decision is sensitive and requires deeper analysis (for example, better measurement of that criterion or more discussion of the actual preferences of stakeholders). One-way sensitivity and breakpoints indicate which criterion is driving that sensitivity.

Figures 2–5 below provide an intuitive visual insight into robustness. Straight, non-intersecting score lines indicate robustness against that criterion's weight, while changes in the relative positions of the linear lines on the graph indicate sensitivity.

The change in the overall scores of the three options (A, B and C), depending on the increase in the weight of the traffic criterion (Weight for Traffic), is shown in Figure 2.

- **Option A:** The score increases continuously with increasing traffic weight (approximately 79 to 95). This means that this option is the most favourable when traffic is the most important criterion.
- **Option B:** The score decreases (approximately 78 to 69) as the importance of the traffic criterion increases, which shows that this option performs poorly in the traffic aspect.
- **Option C:** The score increases slightly (approximately 72 to 79), but more slowly than Option A.

Conclusion: The more important the traffic criterion becomes, the more Option A stands out as by far the best choice, while Option B becomes the least favourable.

The change in the overall score of the three options (A, B and C), depending on the increase in the weight of the availability criterion (Weight for Availability), is shown in Figure 3.

- **Option A:** The score increases continuously (approximately 81 to 90), indicating that it achieves the best results in terms of availability.
- **Option B:** Also shows slight growth (approximately 75 to 79), but much slower than Option A.
- **Option C:** The score decreases (approximately 76 to 69) as the importance of availability increases, indicating poorer performance in this criterion.

Conclusion: As the importance of the availability criterion increases, Option A becomes the most favourable, while Option C becomes the least favourable.

The change in the overall score of the three options (A, B and C) with the increase in the weight of the financial criterion (Weight for Financial) is shown in Figure 4.

- Option A: The score decreases significantly (approximately 90 to 60), which shows that it is financially less favourable.
- Option B: The score increases continuously (approximately 71 to 89) and becomes the best

option when financial considerations are the most important.
– Option C: The score decreases slightly (approximately 76 to 69), showing moderate sensitivity to the financial criterion.

Conclusion: As the importance of the financial criterion increases, Option B becomes the most favourable choice, while Option A loses its advantage.

The change in the overall score of the three options (A, B and C) with increasing weight of the environmental criterion (Weight for Environmental) is shown in Figure 5.

– Option A: The score increases continuously (approximately 81 to 90), which indicates very good environmental performance.
– Option B: The score decreases (approximately 79 to 65), which means that it is the least environmentally friendly.
– Option C: Shows slight growth (approximately 73 to 79), but at a slower rate than Option A.

Conclusion: As the importance of the environmental criterion increases, Option A becomes the most favourable, while Option B loses its competitiveness.

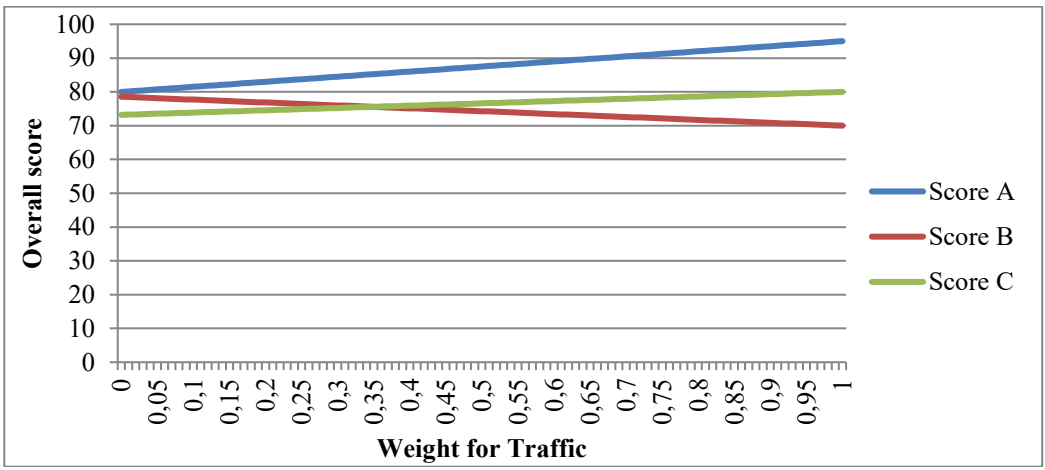


Fig. 2. Scores vs weight for Traffic

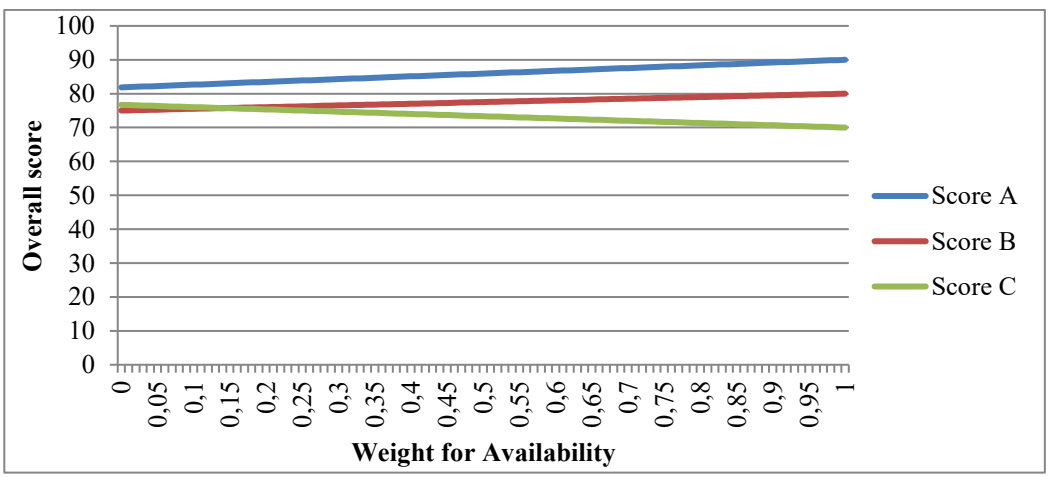


Fig. 3. Scores vs weight for Availability

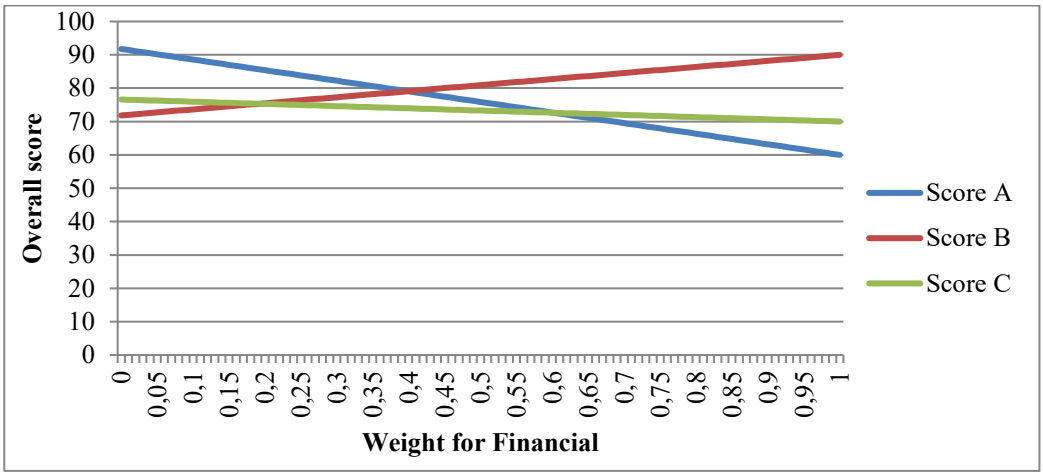


Fig. 4. Scores vs weight for Financial

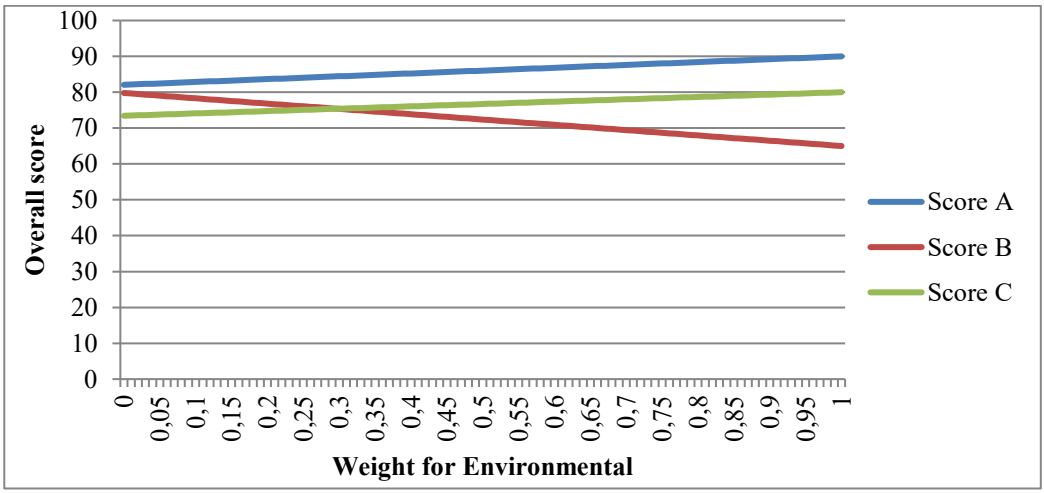


Fig. 5. Scores vs weight for Environmental

The ranges of values for the four analysed criteria, traffic, availability, financial and environmental, are shown in Table 4.

Table 4. Value ranges of analysed criteria. Source: Authors

Criterion	Min Score	Max Score	Range
Traffic	70.00	95.00	25.00
Availability	70.00	90.00	20.00
Financial	60.00	91.74	31.74
Environmental	65.00	90.00	25.00

The analysis of the range of values for the four criteria shows the different levels of influence of individual factors on the final result of multi-criteria decision-making. The financial criterion has the largest range, indicating its dominant role and the model's high sensitivity to cost changes. The traffic and environmental criteria show moderate variability, which means that they significantly influence the ranking of options, but not to the same extent as finance. In contrast, availability has the smallest range, which indicates a relatively stable influence on the final decision. Overall, the results confirm

that, in order to select the optimal option, it is necessary to balance financial aspects with traffic and environmental requirements, with a smaller but not negligible contribution from availability.

5. Discussion

The results obtained in this study are applicable to Franjo Tuđman Airport and can be used as a tool for evaluating the justification of investments in strengthening multimodal connectivity at other airports, or for connecting them to the railway transport infrastructure. By applying the SWARA method to the example of Franjo Tuđman Airport, it was concluded that connecting the airport to the direct railway infrastructure is justified, which is confirmed by the weighted result of Option A (83.935) compared to Option B (76.305) and Option C (74.980). When analysing the ranges of values of the analysed criteria, the financial criterion has the largest range (31.74). This criterion has the greatest impact on changes in the overall score and is the most sensitive in the analysis, while the traffic and environmental criteria have a medium range (25), indicating a moderate impact on the final result. The availability criterion has the smallest range (20) and has the least impact on changes in the overall score. In conclusion, the financial criterion is the most dominant and critical in decision-making, while availability is relatively the least influential. The results of the analysis showed that the option of a direct rail connection to the passenger terminal achieves the most favourable results in terms of travel time, reliability and simplicity of the travel process, as it eliminates the need for transfers and reduces the impact of road congestion.

The results further indicate that the financial criterion represents the most sensitive component of the model. The largest score range associated with this criterion confirms that relatively small changes in the perceived importance of investment and operating costs may significantly affect the ranking of alternatives. In practical terms, if financial constraints become dominant in the decision-making process, lower cost transitional solutions such as the rail plus shuttle option (Option B) may become more competitive despite lower operational efficiency. Conversely, when transport efficiency, travel time reliability and passenger comfort are prioritised, the direct rail connection maintains a clear advantage.

The traffic and environmental criteria demonstrated moderate sensitivity, indicating that they substantially influence the final ranking while not independently dominating the model. This suggests that the selected methodology achieves a relatively balanced integration of operational and sustainability objectives. The availability criterion exhibited the smallest variability and therefore had the least influence on changes in the ranking order, indicating that all evaluated options provide a certain minimum level of accessibility improvement. Despite the methodological transparency and practical applicability of the proposed framework, several limitations of the applied methodology and obtained results must be emphasized. First, the SWARA method relies heavily on expert judgment in determining criterion importance. Although expert-based evaluation enables the inclusion of professional knowledge and practical experience, the obtained weights remain partially subjective and may vary depending on the composition and expertise of the selected expert group. Different stakeholder groups could potentially assign different priority levels to the analysed criteria.

Second, the analysis was conducted using a relatively limited number of evaluation criteria and alternatives. Although the selected criteria (traffic, availability, financial and environmental) represent the key dimensions of airport rail integration, additional criteria such as system reliability, service frequency, passenger demand forecasting, ticket integration, land use compatibility, institutional feasibility and social acceptance could further improve the comprehensiveness of the model.

Third, the applied weighted sum approach assumes linear and compensatory relationships between criteria. This means that weaker performance in one criterion can be compensated by stronger performance in another criterion, which may not always reflect real infrastructure planning conditions. In practice, certain criteria such as financial feasibility or spatial constraints may represent limiting factors that cannot be fully compensated through advantages in other categories. Another important limitation relates to the uncertainty of the input data and expert assessments. The evaluation scores assigned to individual options were based on standardized expert assessments rather than on detailed transport simulation models, economic feasibility studies or long-term operational analyses. Consequently, the

obtained results should be interpreted primarily as strategic planning guidance rather than as definitive investment recommendations.

In addition, the study represents a case-specific analysis focused on Franjo Tuđman Airport and the transport characteristics of the Zagreb urban region. Although the methodological framework is transferable, the ranking of alternatives may differ substantially for airports with different passenger volumes, spatial configurations, railway accessibility levels or governance structures.

6. Conclusion

The conducted analyses and interpretations confirm that high-quality rail connectivity between airports is a key factor in a sustainable, efficient and competitive transport system. The integration of air and rail infrastructure contributes to better airport accessibility, reduced road congestion and negative environmental impacts, and increased overall efficiency of the transport system. The application of the developed evaluation model, using the example of Franjo Tuđman Airport, has shown that it is possible based on clearly defined criteria and independent expert assessment to objectively compare different options for connecting airports to the rail network and identify the optimal solution in accordance with local spatial, traffic and development conditions. The results obtained confirm that the choice of the best option depends on the specific characteristics of each airport, rather than on a universal solution. The analysis shows clear differences between the criteria and options for connecting an airport to the railway transport infrastructure, where the financial criterion has the greatest influence (range = 31.74) and is key in changing the ranking of options. When financial considerations are a priority, lower-cost solutions (e.g., Option B) are preferred. The traffic and environmental criteria have a moderate influence (range = 25) and significantly contribute to the decision, but do not dominate to the same extent as finance, while availability has the least influence (range = 20) and represents a relatively stable criterion that affects the final outcome to a lesser degree. The choice of the optimal option strongly depends on strategic priorities there is no universally best option, but rather one that aligns with the assigned criterion weights. For future research, it is recommended to expand the set of criteria by including additional factors such as system reliability, line frequency, ticketing integration and user experience. In combination with the SWARA method, more advanced MCDM methods can be applied, and fuzzy approaches can be introduced to reduce uncertainty in the assessment. Stakeholder analysis could examine differences in preferences, taking into account the views of passengers, operators and decision makers, and link them to the goals of transport decarbonization, development of the TEN-T network and multimodal integration. The applied methodological approach represents a transferable and adaptable tool that can be used by other airports to make informed and transparent decisions on the development of their rail connectivity.

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