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MODAL SHIFT MODELLING ON THE TEN-T CORRIDOR IN BOSNIA AND HERZEGOVINA

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Abstract

In recent years, the European Union is a committed to sustainable development and has successfully integrated the sustainability dimension into many policy areas. The White Paper on Transport (2011) emphasises key objectives to ensure a sustainable European Union's transport system by 2050. In order to achieve these objectives, 30 % of road freight transport should be shifted to railway and water transport as environmentally friendly modes of transport, at distances greater than 300km by 2030, and even more than 50 % by 2050. Modal shift as a new paradigm of EU transport policy should be realized by the construction of efficient green freight corridors, requiring an adequate infrastructure and an efficient information and management system within the European multimodal transport network. Extension of the indicative TEN-T (Trans-European Transport Network) to Bosnia and Herzegovina offers an opportunity to become an integral part of the European multimodal transport network and to provide sustainable and effective transport rising the modal shift from roads to railways. In this paper, the modal shift on the TEN-T Corridor in Bosnia and Herzegovina will be modeled using a multi-criteria analysis focusing on the Analytical Hierarchy Process (AHP) software Expert Choice, to determine the weights of a range of criteria identified as influencing modal shift. The results obtained by this model will be discussed and an analysis of potential positive effects of modal shift in the economic, social and environmental aspects of sustainable transport will be given.

Keywords: modal shift, railways, Trans-European transport network, sustainability, analytical hierarchy process, expert choice software

1 Introduction

The rising transport demand, congestions, safety, climate changes are some of the issues that Europe and the world are facing. Road transport has the primacy in negative effects and that is a reason to make an idea of modal shift as a potential solution. Modal shift presents an important element of transport policy that has a goal to improve ecologic performances of transport, also better utilization of the existing capacities and increasing transport efficiency. Modal shift from road transport to rail or water could be helpful to decrease some of the external negative effects. Railway transport is responsible for just 0, 4 % of CO_2 emissions caused by transport, even it is taking part of 8, 1 % in passenger transport and 12 % of freight transport in Europe [1]. Sustainable development strategies in the EU promote the modal shift from road to less environmentally damaging modes. Except for the reduction of CO_2 emissions and positive environmental effects implementation of modal shift increases the level of safety, reduces transport costs and roads congestion. In this paper, the competitive analysis of the transport system in B&H is done, and the application of modal shift of oil and oil derivates is examined using the Expert Choice software tool based on the AHP method.

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2 Literature review

Recognizing the importance of modal shift, it has been the subject of numerous relevant studies. The researchers examined factors (costs, characteristics of goods, transport volume , transport distance, availability, CO_2 emissions, etc.) and their impact on the choice of mode of transport. In his research M. Gursoy [2] has developed a model for a combination of rail–road–sea transport. Shipping price, shipping time, safety, and accessibility are criteria included in AHP model. As a result, the preferred alternative with the highest probability for the given problem seemed to be combination of road and water transport. The analytic hierarchy process (AHP) model presented by Kumru and Kumru [3] is employed for a logistics company in selecting the most suitable way of transport between two given locations. The results indicate that railway transport received the highest priority. Alan Bury [4] used AHP method in his doctoral thesis to identify the key criteria in the modal choice decision-making process. He showed that delays and costs dominate the modal choice process. Analytic Hierarchy Process (AHP) methods were used by Raimondas Sakalys [5] for subjective weights of the five main criteria impacting synchromodality. The outcomes of the research have shown that service quality (transport time, service and waiting time, handling time, working hours, reliability and flexibility) is the most important indicator impacting synchromodality. The general model of selection transport mode using AHP for selecting the appropriate mode of transport from three potential transport modes is shown in Roman Hruška et al [6] research. It was found that under the given transport requirements and offers rail transport has an advantage. For multimodal route selection, Kwanjira Kaewfak et al [7] have developed a decision support framework for optimal route selection in a multimodal transport system which can reduce transport cost, time, and risks.

3 Modal shift as a new paradigm of EU transport policy

The total demand for freight transport is growing significantly. Modal share for freight transport has different values in EU countries and road transport has the highest share in total freight transport [8]. The modal share of inland freight transport in the EU-27 is shown in Table 1. It is a noticeable decline in the relative share of railways in inland freight transport in the EU-27 market. Therefore modal shift promotion has been identified as a political action to achieve a sustainable transport sector.

Table 1 Modal share of inland freight transport in the EU-27

Mode	2005	2010	2015	2019
Road	75.7 %	74.6 %	74.2 %	76.3 %
Rail	17.9 %	18 %	18.8 %	17.6 %
Inland waterways	6.4 %	7.4 %	7 %	6.1 %

Source: Eurostat data 2021

Promoting more efficient and sustainable modes of transport has been a key part of EU policy for the last 25 years. The European Commission (EC) intends to create a Single European Railway Area (SERA) to achieve a more competitive and efficient transport system. The main goal of the modal shift is to reduce the modal share of road traffic and reduce its negative impact on the environment by shifting transport from roads to rail, sea and inland waterway. EC has launched various projects such us Marco Polo, Shift2Rail. These projects aim to reduce congestion on roads and reduce environmental pollution by promoting and introducing new rail and water routes in the EU and encouraging the introduction of better trains on the

market, increasing reliability and accuracy and thus attracting users in rail transport. White Paper published in 2011. set a target value according to which 30 % of road freight over 300 km by 2030, should shift to other modes, such as rail or waterborne and more than 50 % by 2050, shifted on green freight corridors [9]. To respect environmental requirements and develop the internal market, the concept of the Trans-European Transport Network (TEN-T) was created. The main objectives of the TEN-T network are to improve economic and social cohesion by creating interconnected and interoperable national networks on land, sea, air and inland waterways; connecting isolated parts of Europe with the rest of the continent and thus promoting more environmentally friendly transport. On 14 December 2021, the European Commission proposed a revision of the current policy framework, notably to reflect the priorities of the European Green Deal, the Sustainable and Smart Mobility Strategy of the Commission and the Global Gateway Connectivity Strategy [10][10]. Modernizing the transport sector accordingly to this policy framework should increase connectivity and modal shift of passengers and freight on rail and inland waterways, supporting the rapid installation of chargers for electric vehicles, alternative refueling infrastructure, and new digital technologies, placing a strong focus on sustainable urban mobility.

4 Transport market analysis on TEN-T Corridor in Bosnia and Herzegovina

Western Balkans is an important transit area for the transport of European goods. In 2020, total trade between the EU and the Western Balkans was € 50.5 billion [10]. Pan-European Corridor Vc, has become an integral part of the TEN-T core and comprehensive network. Corridor Vc consists of the main north-south transit through B&H and it is a multimodal (road and rail) transport corridor connecting Hungary, Croatia and Bosnia and Herzegovina (Budapest - Osijek - Sarajevo – Ploče). In 2019. road transport performance of 2, 903 mils. tonne-kilometers was generated which is 2.7 % more than the previous year [11].

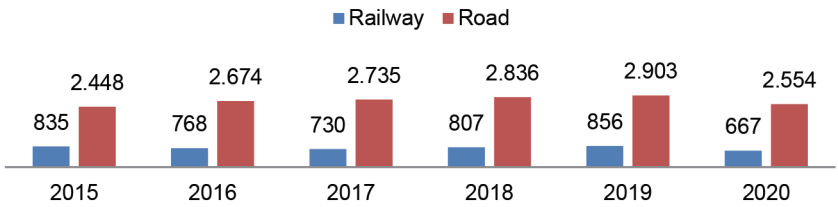

Figure 1 Road and railway transport performance in FB&H (mil. tonne-kilometres) [11]

Railway transport performance in 2019. was 856 mils. tonne-km (Fig. 1), which is an increase of 6.1 % compared to the previous year. Road transport is a serious competition to the railways, although the railways have a leading position in the segment of bulk cargo transport such as iron ore, bauxite, lignite, coking coal and coke.

5 Case study: Modal Shift modeling of oil and oil derivates transport

5.1 Analysis of the current situation on the TEN-T corridor

The transport of oil and oil derivatives in our country is mainly done by road. In the FB&H, there are oil terminals in the railway stations Čapljina, Mostar, Čelebić, Blažuj, Živinice, Bihać (owned by FB&H), Podlugovi (owned by Holdina d.o.o. Sarajevo) and Zenica (owned by Hifa-oil). Terminals of the FB&H managed by the company Operator - Terminali Federaci-

je d.o.o. has almost 200,000 of storage capacity in Bihać, Mostar, Živinice, Blažuj, Ploče and they are connected by road and rail.They were damaged by the war and need to be repaired and modernized in order to comply with the requirements and standards of B&H and the EU. Oil terminals have located in the area's four cantons and their functionality would have positive socio-economic effects. An overview of imports of oil and oil products in the FB&H in the period from 2017-2020 in tons is shown in Table 2. Energy balance in the FB&H is estimated at 1.1 mil. tons of oil, and the participation of railways in oil transport is almost negligible. In 2019. the railway in the FB&H was transported 60.671 tons of oil. The share of rail transport in total transport of oil in the last four years has ranged up to a maximum of 6 %.

Table 2 Overview of imports of oil and oil derivates in the FB&H in the period from 2017-2019 in tons

	2017	2018	2019	2020
Total imported	989.502	1.090.307	1.231.692	1.042.264
Road	931.524	1.025.329	1.171.021	1.015.330
Railway	57.978	64.978	60.671	26.934

5.2 Developing AHP model

Based on the analysis of the current situation, the possibility and positive effects of modal shift on the TEN-T corridor in B&H will be examined using multicriteria analysis focusing on the Expert Choice software tool, based on the Analytical Hierarchical Process (AHP) method. The goal to be achieved is at the top of the hierarchy, followed by criteria and at the bottom of the hierarchy are alternatives as shown in Fig. 2. The decision problem consists of the selection of the most suitable way for transport oil and oil derivates.

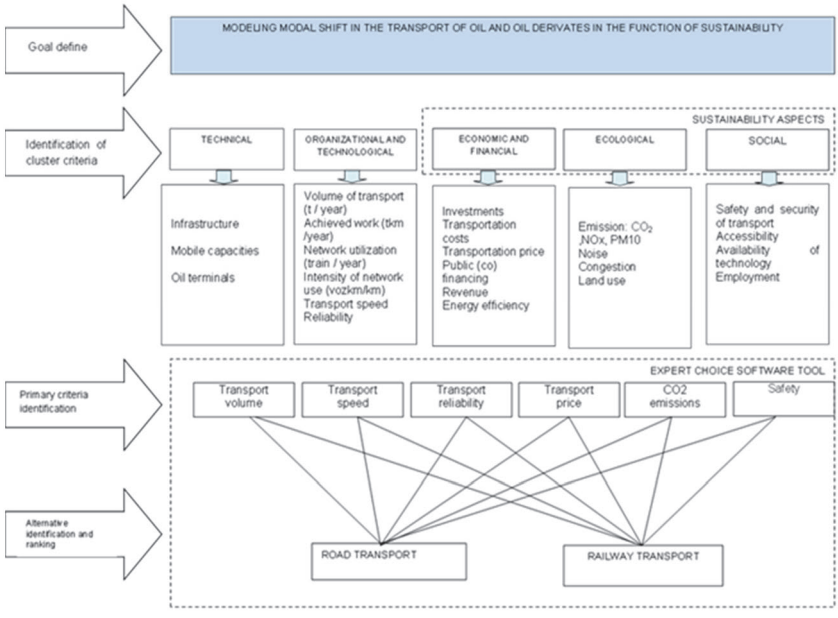

Figure 2 Hierarchy of decision problem modeling: Modal Shift of oil and oil derivates

To evaluate the alternative six criteria were taken into account transport volume, transport speed, transport reliability, transport price, CO_2 emissions and safety. AHP mathematical model calculates the weights of the elements. The importance of this method is based on comparing different alternatives in pairs using the Saaty scale where 1 is equal importance, 3 is moderate importance of one over another, 5 is strong or essential importance of one over another, 7 is very strong or demonstrated importance of one over another, 9 is extreme importance of one over another, 2, 4, 6, 8 are intermediate values, reciprocals are for inverse comparison [12]. Transport volume is the average transported quantity, measured by transport units. Transport speed is the average transport speed for road and rail vehicles. Transport reliability is defined by the number of transports delivered on time, 100 % is full reliability. Transport price is the average price over 12 months per transported tonnes per kilometer of transport distance. Based on a preliminary survey of road and rail transport prices for 2021, for routes on the B&H TER corridor, it was determined that the railway offers more favorable oil transport prices per tonne. CO_2 emission is the average CO_2 produced per tonne-kilometer (according to CER road 140 g/tkm, rail 16 g/tkm). Safety is the average number of accidents per year. Standard AHP forms and tables are used to determine priorities. An example of a comparison matrix in pairs for the case of two alternatives with one criterion is shown in the Table 3.

Table 3 Pairwise comparison matrix for criterion

C	A1	A2	Priority vector
A1	1	A1/A2	%
A2	A2/A1	1	%

In the next step, the normalized matrix is derived from the comparison matrix in pairs, and then the priority vector is calculated which gives the relative priority weights of the alternatives. The AHP also uses a consistency ratio (CR) to check the consistency of a judgment. Inconsistencies are likely to occur when careless mistakes or excessive judgments are made during the pairwise comparison process. A CR of 0.1 is considered an acceptable upper limit. If the CR is greater than 0.1, they must re-evaluate the comparisons in the matrix pairs until an acceptable ratio (‹ 0.1) is finally reached. The consistency index (CI) is used as a measure of consistency in achieving CR values:

$$CI = \frac{\lambda_{MAX-n}}{n-1} \tag{1}$$

If the matrix is perfectly consistent then CI=0. When dealing with the rising number of pairwise comparisons the possibility of consistency error is also increasing. So measure the CR (consistency ratio) that can be calculated. RI is represented by average CI values gathered from a random simulation of Saaty pair-wise comparison matrices CIs. The suggested value of the CR should be no higher than 0.1. The average RI of sample size is shown in Table 4.

$$CR = \frac{CI}{RI} \tag{2}$$

Table 4 Random consistency index values for n from 1 to 10

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

5.3 Evaluation of alternatives with the Expert Choice software tool

For the relative weight determining (or priorities) of each criterion, it is used Expert Choice Software tool. The values of the defined weight criteria are shown in Fig. 3. The results present defined weight criteria values, which are used to conclude that the "CO_2 emissions" (0.274) are the most important criteria. Also, it can be seen that consistency takes the value of 0.09 with the conclusion that the result is correct enough and that there is no need for corrections in comparison and conclusion repetition.

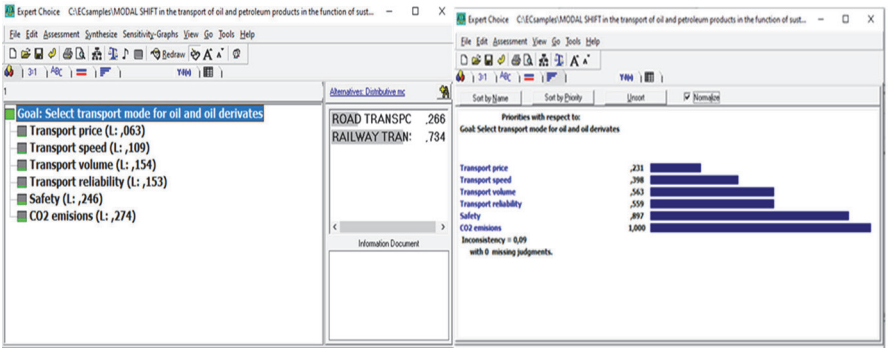

Figure 3 The values of the defined weight criteria

Analyzing the obtained results it can be concluded that, by defined criteria, railway transport presents a better choice for transport oil and oil derivates on TER corridor. Head-to-head sensitivity analysis represents the difference between the two alternatives in relation to the defined criteria (Fig. 4).

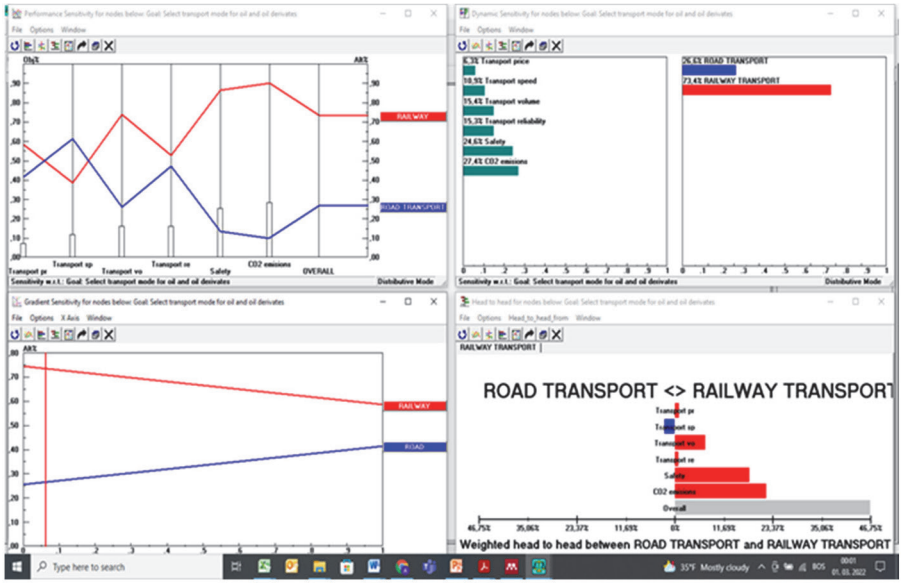

Figure 4 Alternative ranking

The head-to-head sensitivity analysis shows that "road" is better than "railway" in one defined criteria, transport speed and weaker in five criteria (price, reliability, safety and CO_2 emissions). The results have indicated that the railway or the transport is much more suitable than the road transport under the given conditions.

6 Conclusion

AHP model was employed for the selection of the most suitable transport mode for oil transport on the TEN-T corridor in B&H. Road and railway transport modes were evaluated to several criteria and results showed that railway transport received the higher priority. The TEN-T railway corridor in B&H, which connects the port of Ploče with Budapest, has the potential for an environmentally friendly and energy-efficient mode of transport and it could take over a large share of freight transport, as outlined in the White Paper. In order to achieve the goals of modal shift in accordance with EU transport policy and TEN-T standards, the national transport policy and strategy must give a significant impulse to the restructuring and modernization of the railway system, and intensify investment in railway infrastructure. Putting oil terminals into operation modal share of rail transport would be increased, and road transport, exclusively, will be used for the transport of oil products from terminals to petrol stations. This would directly affect the reduction of congestion in road traffic, increase safety and preserve the road infrastructure.

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