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Composite Transport Sustainability Index: Cross-country Assessment Towards Climate Neutrality in the Context of the European Green Deal Targets

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ABSTRACT

This study assesses the overall sustainability level of the transport sector in all European Union member states and the UK using the composite sustainability index methodology for cross-country comparison. The composite transport sustainability index included 15 different indicators grouped into 4 main dimensions – mobility, sustainability, innovation, and environmental. Results show high potential for increasing transport sustainability in all countries included in the study. Sweden and the Netherlands can be seen as benchmarks for achieving higher long-term sustainability. Most countries are lagging behind in innovating transportation systems by providing the necessary infrastructure for electric vehicles and alternative fuel cars. More emphasis should be placed on increasing the share of public transport in total passenger transport.

Keywords: transport sector, sustainability assessment, composite index, indicators, cross-country comparison

NONMENCLATURE

Symbols	
I_N^+	Normalized indicator of positive impact
I_N^-	Normalized indicator of negative impact
I_{act}	Actual value of an indicator in a specific country
I_{max}	Maximum value of an indicator from all the countries included in the study
I_{min}	Minimum value of an indicator from all the countries included in the study
I_D	Sub-index of a specific dimension
w	Weight of an indicator
n_I	Number of indicators in a dimension
CSI	Composite sustainability index
n_D	Number of dimensions

1. INTRODUCTION

The transport sector is one of the largest polluters and contributors to climate change globally and in the European Union in general. Greenhouse gas (GHG) emissions from the transport sector account for more than a quarter of total GHG emissions in the EU. The lack of adaptation of sustainable measures and innovations in the transport sector has led to an annual increase in greenhouse gas emissions and shows that no progress has been made towards achieving climate neutrality targets. Therefore, the transport sector is now considered one of the most critical cornerstones in the context of achieving the ambitious commitments Paris Agreement and targets European Green Deal. In order to achieve the ambitious goal of climate neutrality by 2050, the transport sector should reduce its GHG emissions by at least 90 % compared to 1990 levels [1]. Only a collective approach will lead to the necessary cumulative energy and GHG emission savings, which means an equal contribution and commitment from all European Union member states [2]. It is therefore necessary to examine which countries can be considered pioneers in sustainability and which lag behind. A cross-country comparison of sustainability levels is an effective tool to identify similarities and differences between different countries. It can be good to set the benchmarks and easily identify the bottlenecks that national governments should put more emphasis on in order to accelerate the implementation of more sustainable practices in the transport sector. The composite index method is a comprehensive and effective tool that is often used to make in-depth cross-country comparisons, as its competitive advantage is the integration of an unlimited number of indicators and the comprehensive interpretation of the results, which serves as a useful tool for decision-making and energy policy development [3].

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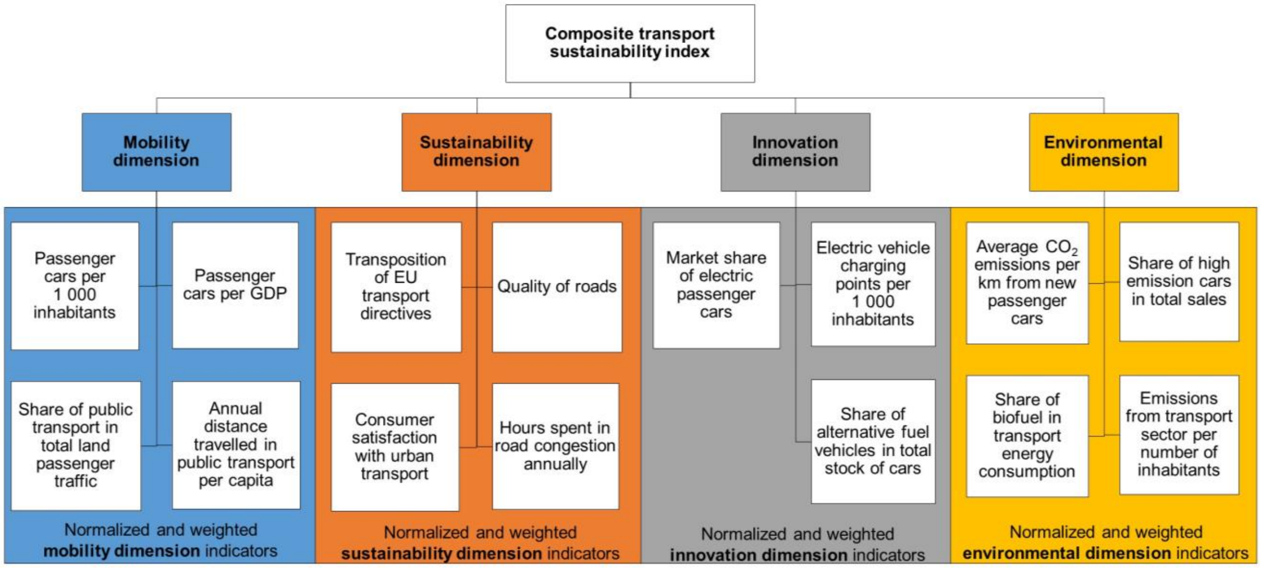

Fig. 1. Transport composite sustainability index construction hierarchy

2. METHOD AND DATA

The methodology of constructing the composite index in this study is based on the calculation procedure described in the studies of [4]–[6]. The overall calculation procedure for the construction of the composite sustainability index consists of the following steps: (1) selection and classification of the indicators, (2) indicator impact evaluation, (3) data normalization, (4) indicator weight assessment, (5) calculation of the sub-indices, (6) aggregation of the sub-indices into the composite sustainability index. Indicators were selected based on academic research and assessment reports on transport sector sustainability and data availability [3], [7]. The selected indicators were classified into four dimensions that characterize the long-term transition of the transport sector to a more sustainable and climate neutral system. The dimensions are - mobility, sustainability, innovation and environment. The indicators were selected for all the European Union countries (except for Malta) and UK, therefore the study makes a cross-country transport system sustainability comparison between 27 countries. Data were collected from the Eurostat, European Commission, Odysee-Mure databases. Figure 1 illustrates the basic construction hierarchy of transport composite sustainability index.

Further indicators are assessed according to their impact on overall sustainability, divided into two main groups - positive and negative impact indicators. If an increasing value of the indicator leads to higher sustainability, the indicator is classified as positive impact indicator. If, on the other hand, an increasing value of the indicator leads to a lower sustainability, the indicator is classified as negative impact indicator. For example, a higher share of public transport in total land passenger traffic leads to lower energy consumption and greenhouse gas emissions, and thus to greater sustainability. However, if the number of hours spent in road congestion annually increases each year, energy consumption during the journey also increases, with a negative impact on sustainability. Table 1 summarizes the selected indicators, which were classified into representative dimensions and assessed according to their impact on sustainability.

To make the units of measurement of the different indicators comparable with each other, the collected data are further normalized using Eq. (1) – Eq. (2).

$$I_N^+ = \frac{I_{act} - I_{min}}{I_{max} - I_{min}} \quad (1)$$

$$I_N^- = 1 - \frac{I_{act} - I_{min}}{I_{max} - I_{min}} \quad (2)$$

where I_N^+ is a normalized indicator of positive impact, I_N^- is a normalized indicator of negative impact, I_{act} is the actual value of an indicator in a specific country, I_{max} is the maximum value of an indicator from all the countries included in the study, I_{min} is the minimum value of an indicator from all the countries included in the study.

After normalizing the data, impact weights are assigned for both indicators and dimensions. In accordance with the sustainability framework, which envisages an equal distribution and balance between all dimensions and factors affecting sustainability, this study applies equal weighting to calculate sub-indices and final composite sustainability index. The indicators are first aggregated into sub-indices using Eq. (3). After calculating the values of the sub-indices for each dimension, the composite sustainability index is aggregated from all sub-index values using Eq. (4).

$$I_D = \sum w \times I_N^+ + \sum w \times I_N^- \ , \ w = \frac{1}{n_I} \quad (3)$$

where I_D is the sub-index of a specific dimension, w is the weight of an indicator, I_N^+ and I_N^- are normalized indicators in each dimension, n_I is the number of indicators in a dimension.

$$CSI = \sum w \times I_D \ , \ w = \frac{1}{n_D} \quad (4)$$

where *CSI* is composite sustainability index, w is the value of weight of a dimension, n_D is the number of dimensions.

Table 1

Selected indicators, data sources and impact evaluation

Indicator	Impact	Data source
Mobility dimension		
Passenger cars per 1 000 inhabitants	-	[8]
Passenger cars per GDP	-	[9], [10]
Share of public transport in total land passenger traffic	+	[11]
Annual distance travelled in public transport per capita	+	[11]
Sustainability dimension		
Quality of roads	+	[12]
Hours spent in road congestion annually	-	[12]
Transposition of EU transport directives	+	[12]
Consumer satisfaction with urban transport	+	[12]
Innovation dimension		
Market share of electric passenger cars	+	[13]
Electric vehicle charging points per 1 000 inhabitants	+	[13]
Share of alternative fuel vehicles in total stock of cars	+	[11]
Environmental dimension		
Share of biofuel in transport energy consumption	+	[11]
Emissions from transport sector per number of inhabitants	-	[14], [15]
Average CO_2 emissions per km from new passenger cars	-	[16]
Share of high emission cars in total sales	-	[11]

3. RESULTS AND DISCUSSION

Transport composite sustainability index incorporated 15 indicators grouped into 4 dimensions - mobility, sustainability, innovation and environmental dimension. First, the results for each sub-dimension are analyzed separately. Then, the aggregated index values are examined in detail. The advantage of the composite index methodology is that it allows a comprehensive interpretation of the results. The higher the indicator, sub-index and aggregated index value achieved, the higher the level of sustainability is in the respective country.

Fig. 2 illustrates mobility dimension sub-index values. Mobility dimension indicators describe socio-economic aspects of transport system sustainability including two categories of indicators: (1) passenger cars per thousand inhabitants and per GDP, and (2) the share and importance of public transport in total land passenger traffic.

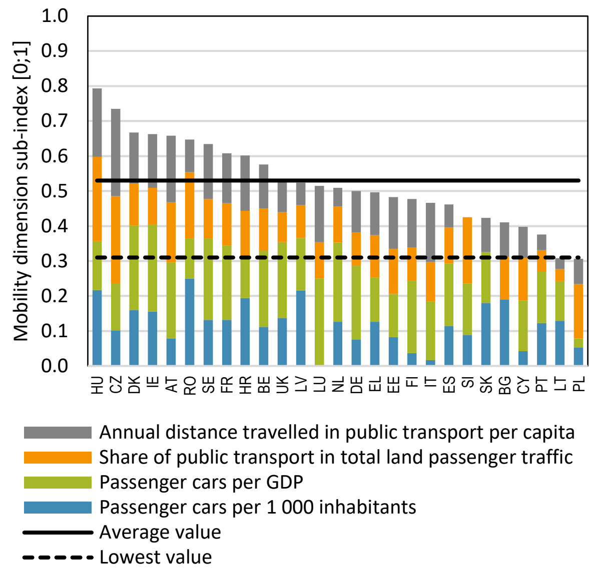

Fig. 2. Mobility dimension sub-index

The highest scores for the mobility dimension sub-index were obtained by Hungary, which scored high on all indicators included in the dimension. The results show that in Hungary the use of public transport is more developed and the share of private cars in total passenger transport is lower. High scores are also shown by the Czech Republic and Ireland, which scored high on almost all indicators, as did Hungary. On the other hand, the lowest values of the mobility sub-index are observed in Poland and Lithuania. Although Poland has a relatively high share of public transport in total land passenger transport, the high number of passenger cars per capita and GDP does not allow Poland to achieve higher and more competitive scores in this sub-index category. In turn, the critical positions for Lithuania are the low positions of public transport intensity, which prevent Lithuania from obtaining a higher score in the mobility sub-index.

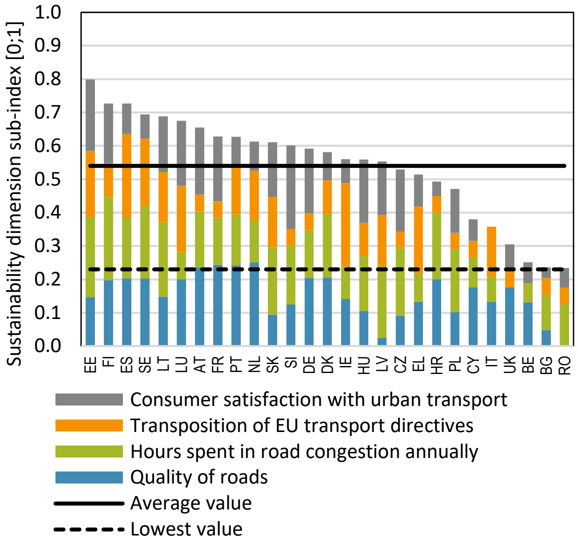

Fig. 3. Sustainability dimension sub-index

Fig. 3 shows the sub-indices of the sustainability dimension for all the countries studied. This dimension includes four sustainability indicators assessed by European Commission and the World Economic Forum - the quality of roads, the hours spent annually in congestion, the productivity of the implementation of EU transport directives and consumer satisfaction with urban transport.

The highest score on the sustainability dimension sub-index was achieved by Estonia, which scored high in all indicators except the quality of roads. Slovakia scored highest in consumer satisfaction with urban transport, but low scores for transposition of EU transport directives and quality of roads prevented it from achieving a higher sustainability sub-index score. For most countries, the indicator scores for consumer satisfaction with urban transport and the implementation of EU transport directives were the most critical, negatively affecting the overall score of the sustainability dimension sub-index. This suggests that countries should place more emphasis on improving consumer attitudes towards public transport use, which will help shift society's habits towards more sustainable travel measures. In addition, countries should be more proactive in adapting the framework of the EU transport directives, which aim to increase the energy efficiency, safety and sustainability of all transport infrastructure in all Member States.

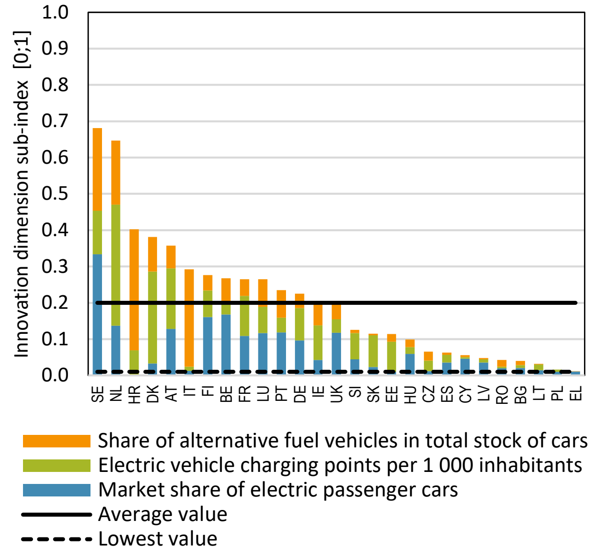

Fig. 4. Innovation dimension sub-index

Fig. 4 demonstrates the sub-index values of the innovation dimension. As it can be observed, the values of the innovation sub-index for all countries were on average significantly lower than the values of the other dimension sub-indices. Leading countries such as Sweden and the Netherlands are showing a greater pace of innovation in the transport sector and transformation to more environmentally friendly measures such as the use of alternative fuel vehicles and electric cars. While most other countries are just starting to build the necessary infrastructure for non-fossil fuel transport and are currently lagging behind the leaders in all indicator positions of the innovation dimension.

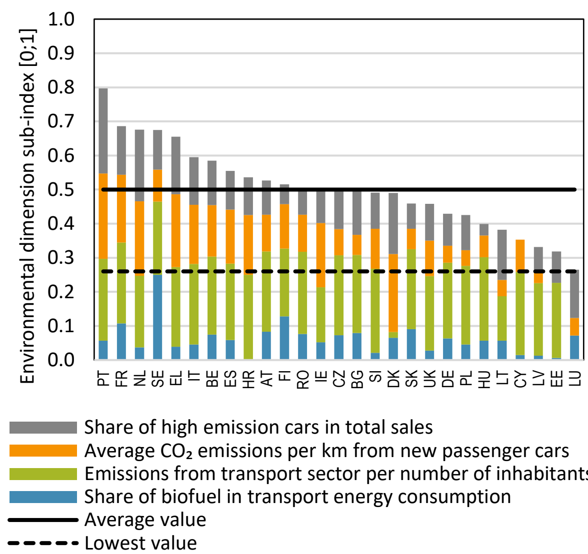

Fig. 5. Environmental dimension sub-index

Fig. 5 illustrates the sub-indices of the environmental dimension for all countries included in the study. All countries except Sweden have the lowest values for the indicator for the share of biofuels in transport energy consumption, which means that in most countries there is still untapped potential for replacing fossil fuels and increasing the volume of biofuel use. In a number of countries, such as Cyprus, Hungary, Finland, Slovakia, Latvia and Estonia, the share of high emission cars in total sales is still significant. This shows a negative trend in consumer behavior, which lowers the overall score for the sub-indices of the environmental dimension and the long-term sustainability of the transport sector as a whole.

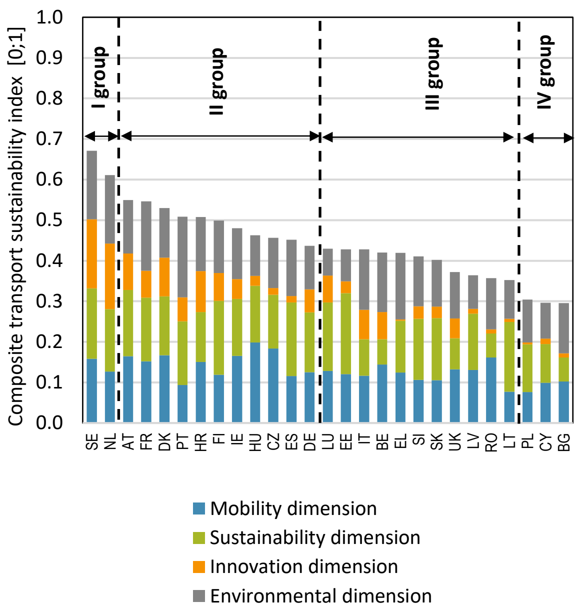

Fig.6. Composite transport sustainability index

Fig. 6 shows the results of the final transport composite sustainability index. Based on the results, it is possible to identify the most critical aspects for all countries that have an impact on a higher level of sustainability. In general, the innovation and environmental dimensions had the lowest scores compared to the mobility and sustainability dimensions. The leading countries in transport sustainability are Sweden, the Netherlands, Austria, France and Denmark. In all these countries, equal attention has been paid to all dimensional indicators, which has helped to achieve a higher level of sustainability. In general, however, a high level of untapped sustainability potential is found for all the countries studied, which is reflected in the overall score of the composite sustainability index. None of the countries achieved the highest possible score of 1, which means that even in the leading countries there are many positions that require greater efforts to transform the transport system towards more climate neutral and sustainable measures.

The final results of the composite transport sustainability index are classified into four groups of sustainability levels, as shown in Fig. 6. The first group includes countries with a high sustainability level such as Sweden (0.67) and the Netherlands (0.61), which have achieved values of the composite transport sustainability index values significantly higher than the average value. The second group includes countries with a moderate level of sustainability, whose composite transport index values ranges between 0.44 (Germany) and 0.55 (Austria). The third group includes countries with a low level of transport sustainability, whose composite transport sustainability index is below the average value of 0.44. The fourth group includes countries with very low levels of sustainability, with a composite transport sustainability index of 0.3. The fourth group consists of three countries - Poland, Cyprus and Bulgaria.

4. CONCLUSIONS

The results of the composite transport sustainability index show that there is a high potential for improving the level of sustainability in all member states of European Union and in the UK, represented by 15 indicator values grouped into 4 main dimensions - mobility, sustainability, innovation and environmental. Low scores on the innovation dimension sub-indices indicate that countries should make more investments and introduce support programs to develop sufficient infrastructure for electric vehicles and alternative fuel cars. A lack of innovation and proactivity in reducing fossil fuel consumption in the transport sector can be observed in all countries from Eastern European, which lag significantly behind innovation leaders such as Sweden and the Netherlands. More emphasis should also be placed on changing existing consumer behavior from the purchase and use of emission-intensive cars to greater use of public transport. This requires investment in improving the urban transport system and public transportation. Further research could expand the existing composite transport sustainability index by adding more significant indicators and thereby increasing the explanatory power of the index. In addition, different normalization (e.g. z-score normalization) and weighting (e.g. analytical hierarchy process) techniques could be applied to construct more tailored index.

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