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Preface

This CCIS volume presents selected articles from the 3rd edition of the IberoAmerican Congress on Smart Cities (ICSC-CITIES 2020), held on November 9–11, 2020 in Costa Rica as a virtual congress. This event continued the successful two previous editions of the congress, held in Soria, Spain in 2018 and 2019.

The main goal of the ICSC-CITIES 2020 congress was to provide a forum for researchers, scientists, teachers, decision-makers, postgraduate students and practitioners from different countries in Ibero America and worldwide to share their current initiatives related to Smart Cities. Articles in this volume address four relevant topics (energy efficiency and sustainability; infrastructures and environment; mobility and IoT; and governance and citizenship) covering several areas of research and applications.

The main program consisted of seven keynote talks, fourteen oral presentations and four poster presentations from international speakers highlighting recent developments in each of the areas. Over two hundred distinguished participants from 26 countries gathered virtually for this conference. The Program Committee of ICSC-CITIES 2020 received 99 manuscripts. 51 articles were accepted for oral presentation (21 selected for CCIS publication). All articles have undergone careful peer review by three subject-matter experts before being selected for publication.

We would like to express our deep gratitude to all the contributors of ICSC-CITIES 2020 and to the Conference Organizers, and also to the authors and reviewers for their endeavors that efficiently completed the paper-reviewing and publication process. We also thank the participants of the conference, our government and industry sponsors and the readers of the proceedings.

November 2020

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Performance assessment of the transport sustainability in the European Union

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Abstract. Based in the current growth rate of metropolitan areas, providing infrastructures and services to allow the safe, quick and sustainable mobility of people and goods, is increasingly challenging. The European Union has been promoting diverse initiatives towards sustainable transport development and environment protection by setting targets for changes in the sector, as those proposed in the 2011 White Paper on transport. Under this context, this study aims at evaluating the environmental performance of the transport sector in the 28 European Union countries, from 2015 to 2017, towards the policy agenda established in strategic documents. The assessment of the transport environmental performance was made through the aggregation of seven sub-indicators into a composite indicator using a Data Envelopment Analysis approach. The model used to determine the weights to aggregate the sub-indicators is based on a variant of the Benefit of the Doubt model with virtual proportional weights restrictions. The results indicate that, overall, the European Union countries had almost no variation on its transport environmental performance during the time span under analysis. The inefficient countries can improve the transport sustainability mainly by drastically reducing the greenhouse gas emissions from fossil fuels combustion, increasing the share of freight transport that uses rail and waterways and also the share of transport energy from renewable sources.

Keywords: Transport environmental performance · Data Envelopment Analysis · Sustainable Development.

1 Introduction

The interest in sustainability and sustainable development has been increasing in the past decades [1]. The rapidly growing population of the cities, their aging infrastructure and the environmental concerns continue to challenge and pressure policymakers. Providing the infrastructure and services to allow safe, quick and

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sustainable mobility of people and goods is increasingly challenging [2]. Investing in improving the quality and sustainability of the transport system will improve the productivity, attractiveness and quality of life of the cities. Therefore, the transport sector has become one of the main subjects with regards to sustainable development.

In the European Union (EU), the transport sector employs more than 11 million people and accounts for about 5% of Europe's Gross Domestic Product (GDP). Between 2010 and 2050, passenger transport activity is expected to grow by 42% and freight transport activity by 60% [3]. An effective transportation system should contribute positively to the economic growth, to social development through the fair use of the natural resources and to environmental protection [4].

Under this scenario, the European Commission's, 2011, White Paper on transport - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system [5] proposed strategies for deep changes in the European transport sector aiming at a more sustainable and efficient system.

The adoption of the United Nations' Sustainable Development Goals (SDG) also provided new targets to address the transport sustainability. These goals address global challenges in several areas such as poverty, inequality and climate change, in a total of 17 goals to be achieved in 2030 [6]. Some SDG targets are related directly to transport sustainability and others to areas where transport has an important impact, such as energy consumption and pollutant emissions.

The sustainable development of the transport sector has been put on the agenda of EU countries, making it clear the necessity of measuring and assessing the current transport performance towards achieving these targets. It is also evident the importance of analysing sustainable transport planning, as transport policy and planning decisions can have diverse and long-term impacts on sustainable development. A critical component of transport planning is the development of a comprehensive evaluation program that assesses the transport performance based on an appropriate set of sub-indicators.

In order to fulfill this objective, this study aimed at developing a composite indicator (CI) to measure the environmental performance of the transport sector in the EU countries, from 2015 until 2017, towards a more sustainable mobility. The CI is a practical approach that allows to summarize, compare and track the performance of the countries. It allows the measurement of complex and multi-faceted issues that cannot be captured completely by analysing individual sub-indicators [7]. To aggregate the different sub-indicators into the CI, a variant of the Benefit of the Doubt model, as proposed by Färe et al. in [8], was used.

This paper is organized as follows: the second section presents a literature review on the construction of composite indicator and the the variant of Benefit of the Doubt model proposed by Fare et al. [8]. Section 3 describes the sub-indicators selected to compose the CI. Section 4 analyses the data used and the results obtained. Finally, the conclusions from this work are presented in Section 5.

2 Literature review

2.1 Composite indicators

Composite indicators have been proven to be a useful method to synthesize masses of data, benchmark countries performance in relation to desirable states, demonstrate progress towards goals and to communicate current status to stakeholders leading to effective management decisions towards the established targets [9]. It is also a recognized tool for public communication, since they provide a big picture of a subject and often make it easier for the general public to interpret its results rather than having to identify common trends across many sub-indicators [10].

The essential purposes of the CI is to summarize a complex, multi-faceted phenomena in wide-ranging fields, e.g. environment, economy, society or technological development, enabling the performance comparison of several countries or the evolution of a country over time [11]. The CI comprises of several individual sub-indicators that measures different aspects with usually no unit of measurement in common. The sub-indicators are compiled into a single index on the basis of an underlying model [10].

The subjective judgment about the relative worth of each sub-indicator is modelled through the weight assigned to it [11]. The weight reflects the significance of the sub-indicator and assigns a value to it in relation to the others, and it has, usually, a great impact on the aggregation results [12]. The weights attributed to the sub-indicators can be derived through different methods. They can be based on opinions, such as expert judgment or public opinion poll results. When these information are unavailable, the easiest and most common approach is to use equal weights [13]. However, not all evaluated units will agree to be evaluated with equal weights, since each of them has different characteristics and preferences. Finally, to avoid the subjectivity in determination of the sub-indicators' weights, the preferred tools are the statistical methods that derive the weights endogenously, such as the Principal Component Analysis/Factor Analysis and the Data Envelopment Analysis [14].

2.2 Data Envelopment Analysis

The DEA is a linear programming method, proposed by Charnes et al. [15], that assesses the relative efficiency of several decision making units (DMU) that use multiple inputs to produce multiple outputs. Therefore, DEA measures the efficiency of each DMU, given observations on input and output values in a set of similar entities, without knowledge of the production or cost function [11]. By comparison with the best practices frontier, the DEA model enables the selection of weights that are the most advantageous for the DMU under assessment [7]. This means that the weights are derived from the data itself, avoiding *a priori* assumptions and computations involved in fixed weight choices [16]. Thus, DEA is a popular method in the CI literature as it can solve the problem of subjectivity in the weighting procedure. Another well-known property of the original DEA

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model is its unit invariance. This is very interesting for the construction of CI as its final value is independent of the measurement units of the sub-indicators which in turn makes the normalization stage redundant and unnecessary [17].

The application of DEA to the construction of CI, referred to as the Benefit of the Doubt model (BoD), was originally proposed by Melyn and Moesen in 1991 [18]. The BoD is equivalent to the original DEA input oriented model, with all sub-indicators considered as outputs and a single dummy input equal to one for all countries. The dummy input can be understood intuitively by regarding the model as a tool for aggregating several sub-indicators of performance, without referencing the inputs that are used to obtain this performance [19]. Since the BoD model only includes outputs it measures the country's performance rather than its efficiency.

In fact, the conventional BoD model derives the composite indicator, aggregating forward sub-indicators, which capture the positive aspect of a performance, where their increasing values are desirable. Frequently, the performance assessment has to manipulate anti-isotonic sub-indicators, which capture the negative aspect of a performance, where their increasing values are undesirable. There are many sub-indicators that fall in this category, for example, emission of a pollutant, traffic accidents, crime rate, etc. The data of these sub-indicator needs to be transformed, to allow them to be incorporated in the conventional BoD model and treated as the forward sub-indicators [8]. Previous approaches used to deal with these anti-isotonic sub-indicators were the use of data transformation techniques and of directional distance function models. One of the most common data transformation technique is the inversion of the value of the reverse sub-indicator [20]. The subtraction of the sub-indicator from a sufficiently large constant and the rescaling normalization using the maximum-minimum method are also approaches that can be found in the literature. Some of these techniques are presented and compared in [21] and [22]. Even though these transformation are simple, they can be problematic. Since the BoD model is derived from an input-oriented DEA model with constant returns to scale, it is not translation invariant for the output values. This means that, the use of translated or rescaled data will affect the CI results and, consequently, the ranking of the DMUs [8].

Färe et al. [8] proposed a new BoD model (FKHM), which directly incorporates the anti-isotonic sub-indicators without using any transformation. The model treats the anti-isotonic sub-indicators as reverse rather than as undesirable. This means that the model assumes that the reverse sub-indicators values can decrease or increase independently from the values of forward sub-indicators.

Given a cross-section of M sub-indicators and S countries, y_{ij} is the value of sub-indicator i for the country j , and w_i is the weight attributed to the i -th sub-indicator. The formulation for the FKH model is presented in Eq.(1), where y_{ij} ($j = 1, \dots, m$) are the forward sub-indicators (i.e., capturing positive aspect) and y_{ij} ($j = m + 1, \dots, M$) are the reverse sub-indicators (i.e., capturing negative aspect).

$$\begin{aligned}
 CI_{j_0} &= \max \sum_{i=1}^m w_i y_{ij_0} - \sum_{i=m+1}^M w_i y_{ij_0} \\
 \text{s.t.} \quad & \sum_{i=1}^m w_i y_{ij} - \sum_{i=m+1}^M w_i y_{ij} \leq 1 \quad \forall j = 1, \dots, S \\
 & w_i \geq 0 \quad \forall i = 1, \dots, M \\
 & \frac{w_i y_{ij_0}}{\sum_{i=1}^m w_i y_{ij_0} + \sum_{i=m+1}^M w_i y_{ij_0}} \geq 0.05 \quad \forall i = 1, \dots, M
 \end{aligned} \tag{1}$$

The main difference from the FKHM model to the conventional BoD model is that Eq.(1) maximizes the difference between the weighted average of forward sub-indicators and the weighted average of reverse sub-indicators. Additionally, the presence of forward sub-indicators does not imply the presence of reverse ones and, when there are no anti-isotonic indicators, model FKHM can be reduced to the formulation of the conventional BoD model [8].

The formulation given by Eq.(1) has three kinds of restrictions. The first restriction imposes that no country can have a CI value greater than one, to ensure an intuitive interpretation of the indicator. The second restriction imposes that each weight attributed to the sub-indicators should be non-negative, which implies that the CI is a non-decreasing function of the sub-indicators. The third restriction prevents the model from assigning zero weights to some sub-indicators, since zero weight means that the sub-indicator associated has no influence in the global performance. By adding a virtual proportional weight restrictions, as proposed by [23], each sub-indicator is required to have a minimum percentage of contribution in the assessed composite indicator. The value of 0.05 (or 5%) was chosen as it is sufficient to prevent the attribution of zero weights to any sub-indicator, thus, guaranteeing the contribution of all sub-indicators in the final composite indicator and have a higher countries' discrimination in the performance assessment. Consequently, the CI value obtained varies between zero and one for each assessed country j_0 , where higher values indicate a better relative performance [17].

3 Methodology

This paper intends to assess the transport environmental performance of EU countries through the aggregation of sub-indicators into a CI using the Fare et al [8] (FKHM) model. Therefore, the selection of these sub-indicators is of crucial importance to compute the countries overall performance while encompassing all the important subjects.

3.1 Data and variables

The selection of the sub-indicators was based on a literature review of CI with similar conceptual framework, the goals of transport sustainability mentioned in

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the Roadmap (EU's White Paper [5]) and the SDG [6], while also taking into consideration the data that was available for all the EU countries in the time span under analysis. Besides, each sub-indicator must be of easy interpretation and should measure a specific area of the performance, ensuring a minimal number of sub-indicators that assures that all dimensions are reflected in the calculation of the CI. All the data used in this work were gathered from the Eurostat database [24].

To assess the transport environmental performance of EU countries, the CI was constructed based in three forward sub-indicators (i.e., capturing positive aspect) and four reverse sub-indicators (i.e., capturing negative aspect). The forward sub-indicators are the share of buses and trains in total passengers transport, the share of energy from renewable sources in transport and the share of rail and inland waterways in total freight transport. The reverse sub-indicators are people dead in road accidents, GHG emissions by fuel combustion in transport, the average CO₂ emissions per kilometer from new passengers cars and the energy dependency on oil and petroleum products. These sub-indicators are described hereinafter.

The share of collective transport in total passengers transport (*public transport*) is expressed in percentage and measures the share of passenger's transport made by collective transport in the total inland transport. Collective transport refers to buses (including coaches and trolleybuses) and trains, while the total inland transport includes these facilities and also passenger cars. Trams and metros are not included due to the lack of harmonised data. The public transport sub-indicator is related to two Sustainable Development Goals, in which it is highlighted the importance of building resilient and sustainable infrastructure and the necessity to renew and plan cities so they offer access to basic services for all. This sub-indicator also relates to the necessity of improving the transport quality, accessibility and reliability, as discussed in the Roadmap.

The share of energy from renewable sources in transport (*renewable fuels*) is expressed as the percentage of renewable fuels in the total transport fuels. Energy by renewable sources consumed in transport is given by the sum of sustainable biofuels, renewable electricity, hydrogen and synthetic fuels of renewable origin and other reported forms of renewable energy [25]. With this sub-indicator it is possible to understand how extensive is the use of renewable energy in the transport sector and how much it has been replacing fossil fuels. The Renewable Energy Directive promotes policies for the production and promotion of energy from renewable sources in the EU, which states, in the revised version from 2018, the target of 32% share of renewable energy in the transport sector for 2030 [26]. The Roadmap also suggests a regular phase out of conventionally-fuelled vehicles from urban environments by halving their number in 2030 and phasing them out of the cities by 2050.

The share of rail and inland waterways in total freight transport (*freight transport*) is expressed in percentage. The total inland transport in the denominator of the sub-indicator includes freight on national territory made by road, rail and inland waterways transport. Sea and air freight transport are not represented

in the sub-indicator. The freight transport sub-indicator was not applicable for Cyprus and Malta since these countries did not present values for railways or inland waterways. As an effort to have a complete database without excluding these countries from the evaluation in this work the lowest values observed on the dataset were used for Cyprus and Malta for every year. This method avoid that these countries become unintended benchmarks, and therefore, it will not affect the location of the best practice frontier. This method has been suggested by Morais et al. [27]. The Roadmap mentions the objective of shifting 30% of the road freight to other modes, such as rail and waterways, by 2030 and more than 50% by 2050. This sub-indicator also reflects the progress toward the Sustainable Development Goals focused on innovation and on building resilient and sustainable infrastructure.

The people dead in road accidents (*road deaths*) sub-indicator measures the number of fatalities in road accidents per hundred thousand inhabitants. This sub-indicator includes passengers and drivers of motorized vehicles and pedal cycles, as well as pedestrians, that have died up to 30 days after the accident. This sub-indicator is aligned with two Sustainable Development Goals aiming at safer cities, health and well-being status. As highlighted in the Roadmap, EU aims to reduce fatalities close to zero by 2050 with initiatives in the areas of technology, enforcement and education.

The GHG emissions by fuel combustion in transport (*GHG emissions*) measures the transport's fuel combustion contribution in the total greenhouse gas emissions inventory. The values are originally expressed in thousand tonnes and were normalized using the countries' population on 1st January of each year, to take into consideration their dimension. Therefore, the sub-indicator's data is expressed in thousand tonnes per hundred thousand inhabitants for each country. The GHG emissions from the transport by road and inland waterways accounted for 22% of the total European Union emissions in 2017 and reached 27% when including international aviation and maritime emissions [28]. The Roadmap sets out a target of 60% reduction in the GHG emissions by 2050 compared to 1990 levels.

The average carbon dioxide (CO₂) emissions per kilometer from new passenger cars (*new car emissions*) is defined as the average CO₂ emissions per kilometer in a given year for new passenger cars and expressed in grams of CO₂ per kilometer. This is a target for the average of the manufacturer's overall fleet, meaning that cars above the limit are allowed in the market as long as they are offset by the production of lighter cars. The Regulation (EU) 2019/631 sets a mandatory target for emission reduction for new cars of 95 grams of CO₂ per kilometer by 2021 [29]. This sub-indicator reflects three Sustainable Development Goals related to ensuring environmentally aware consumption, to innovation in search of lasting solutions to environmental challenges and the call for climate action. The Roadmap also highlights the importance of the research and innovation on vehicle propulsion technologies and the improvement of energy efficiency performance of vehicles across all modes.

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The energy dependency on oil and petroleum products (*energy dependency*) sub-indicator monitors to which extent the countries economy relies on imports of oil and petroleum products to meet its energy needs. It is calculated by dividing the net imports by the gross available energy and it is used in a percentage basis. The net imports are the difference between the total imports and the total exports. The gross available energy is the sum of primary products, recovered and recycled products and imports, minus the sum of exports and stock changes. Regarding its metrics, energy dependency may be higher than 100% with regard to countries creating a stock in a given year or it can be negative, for oil exporter countries. A negative value occurred only once in the dataset, and the value was close to zero (-4.701%) for the exporter country. To achieve the best relative position of that energy exporter country regarding the other countries, the best score of 1% for this forward sub-indicator was assigned to the exporter country, to avoid handling negative data in the model. This sub-indicator shows how the EU countries progress toward more resource efficient policies. As oil becomes scarcer each year, the necessity of reducing EU dependency on oil imports, without reducing the transport system efficiency, is one of the objectives mentioned in the Roadmap. Imports exposes the economy to volatile world market prices and the risk of supply shortages.

These seven sub-indicators are used to assess the transport environmental performance of EU countries, as presented in the next section.

4 Results and discussion

4.1 Descriptive analysis of the variables

The transport environmental performance was assessed for the 28 EU countries, from 2015 to 2017. It was chosen to use the United Kingdom data, since during the time span of the assessment the country still integrated the European Union. Table 1 shows two descriptive statistics for the sub-indicators under analysis across countries for each year. The mean of the sub-indicators was calculated for each year, as well as the dispersion coefficient (DC). The DC measures the dispersion of the data around the mean and is given by the ratio between the standard deviation and the mean. It was calculated in order to facilitate the analysis among sub-indicators, since it allows the comparison of the degree of variation between different data sets even if they have different measurement units.

Analysing the forward sub-indicators in Table 1, it can be seen that the share of public transport in total passenger transport has constantly decreased in the time span under study, by 2017 it was more than 2% lower compared to 2015 levels. The share of renewable energy in transport decreased in 2016 but by 2017 its average had increased more than 5% above 2015 value. And the share of freight transport decreased between 2015 and 2017 staying 3.7% lower than 2015 levels.

Regarding the reverse sub-indicators, the average of road deaths for all countries has decreased more than 9% from 2015 to 2017. The average of GHG

Table 1. Mean and DC of the indicators data used in the construction of the CI.

Indicator	2015		2016		2017	
	Mean	DC	Mean	DC	Mean	DC
Public transport	18.175	0.241	18.011	0.238	17.768	0.246
Freight transport	27.979	0.731	26.982	0.728	26.936	0.724
Renewable energy	6.544	0.795	6.191	0.746	6.884	0.733
Road deaths	5.800	0.366	5.625	0.325	5.325	0.358
GHG emissions	208.670	0.771	211.493	0.714	213.696	0.696
New car emissions	120.946	0.078	118.757	0.066	119.168	0.064
Energy dependency	92.605	0.245	90.736	0.248	89.935	0.250

emissions for all countries has increased more than 2.4% during the time span studied. The mean of CO₂ emissions from new passengers cars has increased from 2016 to 2017 but still remained 1.5% below 2015 levels. And the average energy dependency of the EU countries decreased almost 3% between the years under analyse.

The highest data dispersion relative to the mean was observed in the share of renewable energy, which translates the difference among countries in available renewable energy. Another high DC value was obtained by the GHG emissions sub-indicator, reflecting the different policies of EU countries for reducing emissions. The share of freight transport also had a high DC, since some countries have geographical locations and environmental conditions that facilitate the utilization of rail and inland waterways. The DC for these three sub-indicators, however, have been constantly decreasing during the time span of the data, reflecting a tendency to increase the homogeneity among EU countries.

The lowest variability relative to the mean was observed for the CO₂ emissions from new passengers cars. This can be reflecting a higher homogeneity in the energy efficiency performance of vehicles engines among car manufacturers.

4.2 Performance assessment of the EU countries

The transport environmental performance for each country in a given year was computed by aggregating the seven chosen sub-indicators using the FKHM model, presented in Eq.(1).

The CI of the transport environmental performance was calculated using the data from the time span of three years, from 2015 to 2017 and it is assessed by comparison to the best practices observed during this time period. The results are summarized in Table 2. The countries are ranked based on their 2017 CI results from the highest to the lowest.

The average of the CI results in the three years analysed was around 0.591 and had only slight variations through the years. The average decreased by almost 3% in 2016 when compared to 2015, increased again in 2017 but still kept slightly below 2015 levels, by 1.17%. The standard deviation of the CI results was similar in the three year, showing that the results variability was kept the same during this period.

Table 2. Transport environmental performance results.

Country	2015	2016	2017
Denmark	0.972	0.937	1.000
Hungary	1.000	1.000	1.000
Netherlands	1.000	0.906	1.000
Sweden	0.878	0.960	1.000
Romania	1.000	0.977	0.948
Slovakia	0.886	0.927	0.895
Latvia	1.000	0.918	0.856
Austria	0.826	0.821	0.803
Czechia	0.761	0.773	0.800
Lithuania	0.790	0.763	0.784
Finland	0.842	0.620	0.759
Bulgaria	0.700	0.693	0.662
Poland	0.633	0.600	0.594
Belgium	0.548	0.570	0.583
France	0.540	0.522	0.542
Germany	0.531	0.550	0.538
Italy	0.539	0.550	0.525
Slovenia	0.488	0.416	0.494
Luxembourg	0.491	0.469	0.489
UK	0.420	0.410	0.416
Portugal	0.378	0.395	0.395
Spain	0.312	0.442	0.381
Croatia	0.463	0.348	0.341
Greece	0.189	0.162	0.216
Estonia	0.161	0.165	0.164
Ireland	0.141	0.125	0.131
Malta	0.139	0.126	0.130
Cyprus	0.131	0.120	0.120
Mean	0.599	0.581	0.592
St. Dev.	0.290	0.283	0.286

This assessment identifies nine efficient units: Denmark (in 2017), Latvia (in 2015), Hungary (in 2015, 2016 and 2017), Netherlands (in 2015 and 2017), Romania (in 2015) and Sweden (in 2017). From 2015 to 2017, half of the countries followed a small improvement and half of the country had a slight decrease in their overall performance. The highest improvement in the CI score between 2015 and 2017 were observed in Greece, Spain and Sweden, which increased in 2017 by 14%, 22% and 13% above 2015 levels, respectively.

The highest decrease during this time frame were observed for Croatia (26.4%) and Latvia (14.4%). The highest improvement in the time-span of one year was observed in Greece, that had a large decrease in its CI score between 2015 and 2016, but between 2016 and 2017 its CI value increased more than 33%. Estonia, Ireland, Cyprus and Malta were the most inefficient countries in this analysis

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with almost no improvement in the considered years. Besides Estonia, all these countries also had a decrease in their CI value in 2017 when compared to 2015.

This study also compares the forward and reverse sub-indicators of the benchmark countries, which obtained a CI score of 1, with the inefficient ones. The mean for each sub-indicator is calculated for both groups (benchmarks and inefficient countries). Figure 1 shows a comparison for each sub-indicator between the benchmark countries and the inefficient ones.

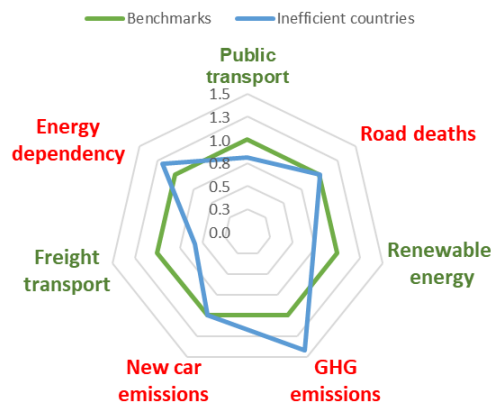


Fig. 1. Comparison between benchmarks and inefficient countries.

Analysing Figure 1, it is possible to notice the areas where the inefficient countries need improvement, for instance, by setting out policies and/or redefine output standards. Except for the number of road deaths and the new car emissions indicators, in which both groups had a very similar performance, the inefficient countries were always outperformed by the benchmarks. The inefficient countries have 80% of the share of public transport presented by the benchmarks and almost 75% of the renewable energy share presented by the benchmark group. In the freight transports sub-indicator, the inefficient countries have less than 60% of the value presented for the benchmarks. Considering the reverse sub-indicators, with regard to the GHG emissions, the inefficient countries had a value more than 40% higher than the benchmarks. The average of energy dependency sub-indicator of the inefficient countries was almost 20% higher than the average for the benchmarks.

Most of the work to improve transport sustainability should be done in reducing the GHG emissions from fossil fuel, improving the infrastructure and promote policies to increase the share of freight transport that uses rail and waterways and also increasing the share of transport energy from renewable sources. The public transport of the inefficient countries also needs improvements in its accessibility and quality to allow a larger share of passenger to benefit from it.

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There is still also margin to reduce the oil and petroleum dependency through changes in the transport energy consumption.

5 Conclusions

The assessment of the transport environmental performance was made through the aggregation of seven transport sub-indicators. The model used to obtain the CI values was derived from a variant BoD model with virtual proportional weights restrictions. Based on the results achieved, it is possible to conclude that, in general, the EU countries had almost no variation on their transport environmental performance and by 2017 were, on average, 1.17% lower than 2015 values. This result points out that EU countries should make efforts to enable them to develop and strengthen their ability towards sustainability.

The performance assessment identified that only nine units were efficient: Denmark (in 2017), Latvia (in 2015), Hungary (in 2015, 2016 and 2017), Netherlands (in 2015 and 2017), Romania (in 2015) and Sweden (in 2017). By using these units as benchmarks and comparing their performance in each sub-indicator with the remaining units (the inefficient ones), it was possible to identify the areas that need improvement. Most of the work to improve transport sustainability should be done by drastically reducing the GHG from fossil fuel, increasing the share of freight transport that uses rail and waterways and also the share of transport energy from renewable sources.

Future works should explore other models for treating anti-isotonic sub-indicators in order to allow results comparison among those different models. Furthermore, some other sub-indicators can be taken into account, to calculate the composite indicator for each country.

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