CHEMICAL ENGINEERING TRANSACTIONS
VOL. 107, 2023
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Petar S. Varbanov, Bohong Wang, Petro Kapustenko

ISBN 979-12-81206-07-6; **ISSN** 2283-9216
DOI: 10.3303/CET23107047

Road Safety and Sustainability: A Comparison of Country Rankings

Csaba Koren*, Ziyad N. Aldoski

Department of Transport Infrastructure and Water Resources Engineering, Széchenyi István University, 9026 Egyetem tér 1, Győr, Hungary
koren@sze.hu

Road traffic deaths are a crucial problem in the world. At the same time, sustainability is a global issue. Numerous publications are dealing with road safety and sustainability separately as a basis for country rankings, but if you are searching for “road safety and sustainability”, no relevant results are found. The research question of this paper is: How is the safety performance of countries with good sustainability ranks? Vice versa: are countries with lower sustainability ranks more dangerous in traffic? To answer these questions, international sustainability and safety ranking scales were compared using Spearman correlation coefficients. The key finding of the paper is that there is a strong correlation between sustainability and the safety ranking of countries. However, there are some exceptions, countries with significantly different sustainability and safety performances.

1. Introduction

Numerous countries have come to acknowledge the significance of prioritizing road safety and sustainability, leading them to implement standardized indicators for evaluating their efforts in these domains. These indicators serve as essential tools for assessing and monitoring progress, identifying areas that require improvement, and setting benchmarks aligned with global standards.
The UN's Sustainable Development Report (SDR) serves as an annual assessment of advancements made toward achieving the Sustainable Development Goals (SDGs). The most recent edition (United Nations, 2023) emphasizes the core principles of the SDGs, encompassing social inclusion, responsible production and consumption, international cooperation, and universal access to clean energy, which have gained even greater importance as critical tools to combat contemporary global issues.
This paper explores the relationship between rankings in sustainability and road safety. This relationship was not mentioned in previous papers, and it reveals the complexity of road safety.

2. Literature review

The chapter is structured into three subchapters: Road safety assessments, Sustainability assessments, and Sustainability rankings.

2.1 Road safety assessments

Road safety itself cannot be measured. What we observe is the opposite of safety, i.e., accidents. However, the registration of accidents is different from country to country. Property damage-only accidents in many countries are not registered at all, and accidents with slight injuries are seriously underreported. Despite the efforts of international organizations, even the definition of serious injuries is not uniform. Therefore, only the fatalities can serve as a basis for international comparison (Tešić et al., 2018).
To allow for differences in country sizes, two types of mortality indicators are used in the relevant literature: population-based (fatalities per inhabitant) and exposure-based (fatalities per vehicle or fatalities per car). A study by Cheng et al. (2018) examined the impact of data source estimates (World Health Organization versus Global Burden of Disease) and the type of mortality indicator (population-based versus exposure-based

Paper Received: 12 April 2023; Revised: 04 July 2023; Accepted: 27 October 2023
Please cite this article as: Koren C., Aldoski Z.N., 2023, Road Safety and Sustainability: A Comparison of Country Rankings, Chemical Engineering Transactions, 107, 277-282 DOI:10.3303/CET23107047

mortality) on road safety performance evaluation. They found a mixed picture. There were some consistencies and some differences in country ranking between the two data sources and the two indicators.
A more detailed study concentrating on spatial differences (Ziakopoulos, 2020) used different sizes of spatial units as the basis for spatial analyses and found that apart from information and data availability, spatial areas of each size have different advantages and disadvantages.
Many researchers indicate that road safety is a main concern in low-income countries (e.g., Heydari et al., 2019). Understanding safety mechanisms amidst increasing transport motorization is vital. Future research should improve data systems, address non-fatal injuries, estimate economic burdens, scale up programs, transfer knowledge, and enhance capacity development.
A recent study (Bao et al., 2022) examined seven safety performance indicators of 21 European countries for both 2008 and 2015. They identified two country groups based on the indicators. The results show that the members in the two country groups are almost identical to the countries east and west of the former Iron Curtain.

2.2 Sustainability assessments

Composite indicators offer a practical approach to managing the complexity of dealing with a large set of indicators. For this purpose, Luzzati and Gucciardi (2015) employed a method involving the combination of different normalization, aggregation rules, and weighting systems to compute numerous composite indicators. They then derived rankings based on the frequency distribution of each "competitor" according to these composites, using this method to rank EU countries in terms of sustainability.
In 2015, the UN adopted a plan of action for sustainable development until 2030, encompassing 17 Sustainable Development Goals (SDGs) with 169 sub-goals (targets) and approximately 250 indicators. The list and definitions of these indicators are regularly updated, with the latest version from 2023 (United Nations, 2023). The SDGs span various domains such as poverty alleviation, education, health, water, agriculture and nutrition, women empowerment, decent work, sustainable consumption and production, inequality, marine ecosystems, climate action, peace and justice, terrestrial ecosystems, and means of implementation. In this paper, there is no space to list these 17 goals and 169 sub-goals.
National development plans often incorporate the SDGs as a central component. Meyer and Hedden (2020) analyzed results from 2015 onwards and assessed the potential to reach target values on nine indicators related to six human development SDGs. They found that, with the current set of policy priorities, the world is projected to make only limited progress toward achieving these SDGs by 2030. The paper emphasizes the challenges in attaining certain SDG indicators, including access to safe sanitation, upper secondary school completion, and addressing underweight children. Additionally, they identified 28 vulnerable countries that are not expected to achieve any of the nine human development-related target values.
Another study by Lamichane et al. (2021) assessed the sustainable development performance of OECD countries toward the 2030 agenda using the 17 SDGs. They observed improvements in SDG1 (No Poverty), SDG7 (Affordable and Clean Energy), SDG11 (Sustainable Cities and Communities), SDG17 (Partnerships to Achieve the Goal), and the overall group mean of the 17 SDGs. Conversely, SDG4 (Quality Education) and SDG8 (Decent Work and Economic Growth) showed declines. The study found the highest performance in SDG8 (Decent Work and Economic Growth) with a score of 78.06 and the lowest performance in SDG17 (Partnerships to Achieve the Goal) with a score of 29.93. In the case of sustainability issues, it is critical to synthesize as many critical aspects as possible that could have an impact on the studied problem (Dorgo et al., 2018).

2.3 Sustainability rankings

The Sustainable Development Report (SDR) offers an annual evaluation of the progress made by the 193 UN Member States toward achieving the Sustainable Development Goals (SDGs) since their adoption in 2015. The most recent available edition at the time of this paper is the 2022 version (Sachs et al., 2022).
The report comprehensively analyzes countries' advancement in reaching the SDGs and identifies areas where progress falls short. Each country's overall SDG Index score and individual goal scores are expressed as percentages of optimal performance. The difference between a country's score and the maximum value of 100 represents the percentage points it needs to bridge to attain optimal SDG performance. The same set of indicators is uniformly used for all countries to calculate the SDG Index score and rankings.
While there may be significant variations in rankings, minor differences in aggregate SDG Index scores can result in small fluctuations in rankings. Therefore, differences of two or three places between countries' rankings should not be interpreted as being "significant." On the other hand, disparities of 10 places or more could indicate meaningful distinctions in terms of SDG performance between countries.
Although many interesting and relevant sources are available both about road safety performances and sustainability ranking of countries, no literature was found about the interaction of these two aspects.

3. Sustainability and road safety data for this research

The data used for this study was sourced from the Sustainable Development Report (Sachs et al., 2022). The SDG ranking and traffic deaths per 100,000 population were directly obtained from the report, while the road safety ranking was derived by the authors. For the road safety ranking, the countries were ranked based on the lowest ratio of traffic deaths, with rank 1 being the best performing in terms of road safety. Tables 1 and 2 present the first and last 10 countries in terms of SDG ranking along with their corresponding road safety data and ranking.

A clear trend emerges from the data, indicating that the top ten highest-ranking countries in terms of SDGs are all located in Europe, with seven of them securing road safety ranks within the top twenty. In contrast, the bottom ten countries in the SDG ranking predominantly belong to the African region, with their road safety statistics showing victims' rates nearly ten times higher than those observed in the leading countries.

This comparison highlights the significant disparities between regions concerning both sustainable development progress and road safety performance, emphasizing the pressing need for targeted efforts and interventions in regions facing greater challenges in these domains.

Table 1: The first 10 countries by their 2023 SDG rank and their road safety ranking

Country	2023 SDG index rank	Traffic deaths per 100,000 population	Road safety ranking
Finland	1	3.89	12
Sweden	2	3.14	7
Denmark	3	3.7	10
Germany	4	3.78	11
Austria	5	4.87	19
France	6	5.13	22
Norway	7	2.12	4
Czechia	8	5.95	29
Poland	9	9.38	52
Estonia	10	4.46	18

Table 2: The last 10 countries by their 2023 SDG rank and their road safety ranking

Country	2023 SDG index rank	Traffic deaths per 100,000 population	Road safety ranking
Liberia	157	38.9	163
Afghanistan	158	15.86	88
Congo, Dem. Rep.	159	34.86	159
Sudan	160	26.76	131
Niger	161	25.51	125
Somalia	162	27.4	135
Yemen, Rep.	163	29.36	141
Chad	164	32.43	154
Central African Republic	165	37.72	162
South Sudan	166	36.73	161

4. Method

The methodology employed in this study focuses on assessing the relationship between road safety and the Sustainable Development Goals (SDGs) using the Spearman rank correlation coefficient. This statistical measure evaluates the strength and direction of the monotonic association between the two variables. The Spearman method is preferred due to its robustness in handling non-linear and non-normally distributed data.

To calculate the Spearman rank correlation coefficient, each data point in both variables is assigned a rank based on its relative position when the data is sorted in ascending order. The correlation is then determined by calculating the correlation coefficient for these ranks.

Method for calculating the Spearman rank correlation:

1. For each variable, rank the data points separately in ascending order. The smallest value receives a rank of 1, the second smallest value a rank of 2, and so on. Assign the average rank to the tied data points if there are ties.
2. Subtract one variable's ranked values from the other variable's ranked values to obtain the differences in ranks for each data point.
3. Square each difference in ranks obtained in Step 2.
4. Calculate the Spearman Rank Correlation Coefficient using the formula Eq(1)

$$\rho = 1 - \frac{6 \cdot \sum d^2}{n \cdot (n^2 - 1)} \quad (1)$$

Where:

ρ = Spearman rank correlation coefficient
Σ(d^2) = Sum of the squared differences in ranks
n = Number of data points (pairs of observations)

To analyze the correlation, Statistical Package for the Social Sciences (SPSS) was used. The computed Spearman rank correlation coefficient of 0.788, as depicted in Table 3, indicates a strong and positive monotonic relationship between road safety and the SDGs. To enhance the accuracy of the analysis, the Modified Z-Score method was employed to detect potential outliers within the datasets, ensuring the reliability of the findings.

Table 3. Spearman rank correlation analysis

			SDG2023 Index	Traffic Deaths (per 100,000 population)
Spearman's rho	SDG2023	Correlation Coefficient	1.000	0.788**
		Sig. (2-tailed)	.	.000
		N	166	166
	Traffic Deaths (per 100,000 population)	Correlation Coefficient	0.788**	1.000
		Sig. (2-tailed)	.000	.
		N	166	166

**. Correlation is significant at the 0.01 level (2-tailed).

5. Results

Figure 1 depicts each country represented by a point, and the positions of these points are determined by the country's SDG and road safety rankings. Countries with similar SDG and road safety rankings are plotted close to the SDG rank = Road safety rank line. This alignment suggests a correlation between the countries' performances in terms of sustainable development and road safety.

Table 4: 10 countries with the highest difference in ranking (better in SDG than road safety

Country	2023 SDG Index Rank	Road safety ranking	Difference in ranking
Thailand	43	153	110
Dominican Republic	62	166	104
Vietnam	55	149	94
Chile	30	79	49
Namibia	109	158	49
Armenia	56	104	48
Venezuela, RB	117	164	47
Uruguay	32	78	46
Poland	9	52	43
Cabo Verde	89	132	43

Tables 4 and 5 present the 10 countries where the differences between the two rankings are the most significant. In other words, these countries exhibit notable disparities in their performances concerning SDGs and road safety. Such differences could highlight areas where certain countries excel in sustainable development but lag

in road safety or vice versa. Analyzing these countries with substantial discrepancies between their SDG and road safety rankings could offer valuable insights into potential challenges and opportunities for improvement in both domains. It may also provide a basis for further research and targeted interventions to address the underlying factors contributing to the differences in their performance.

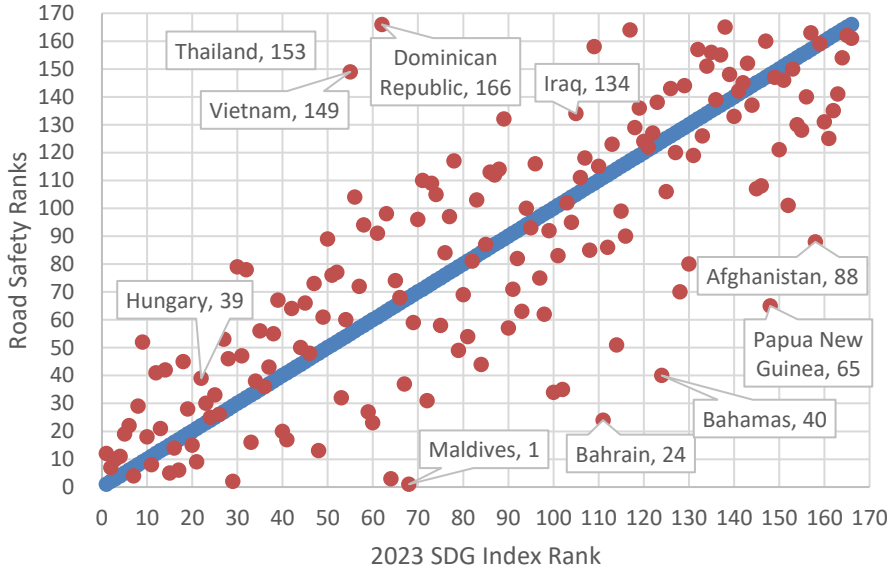

Figure 1: SDG index rank and road safety rank of countries.

Table 5: 10 countries with the highest difference in ranking (better in road safety than SDG)

Country	2023 SDG Index Rank	Road safety ranking	Difference in ranking
Bahrain	111	24	87
The Bahamas	124	40	84
Papua New Guinea	148	65	83
Afghanistan	158	88	70
Maldives	68	1	67
Brunei Darussalam	102	35	67
Qatar	100	34	66
Trinidad and Tobago	114	51	63
Singapore	64	3	61
Pakistan	128	70	58

6. Discussion

The points representing countries in Figure 1 show a relatively good alignment along the SDG rank = Road safety rank line, with a Spearman rank correlation coefficient of 0.788. While road safety is one of nearly 250 indicators in the Sustainable Development Goals evaluation, its impact on the overall SDG ranking should formally be marginal.

On the other hand, several studies, including Jamroz et al. (2019), have demonstrated that economic development plays a significant role in road safety. Factors such as the condition of vehicles, road infrastructure, and the availability of emergency services are closely related to a country's GDP per capita. Moreover, as motorization levels increase, social attitudes towards road safety change, and education levels become relevant in shaping attitudes related to safety measures like wearing helmets and seat belts and adhering to speed limits.

It has to be mentioned that road safety-related data always have uncertainties. A segment of the accidents is not reported to authorities. The share of underreporting depends on the administrative system of the country and on the severity of accidents. A large part of accidents with property damage or slight injuries are frequently

not included in the statistics. Therefore, even though fatalities are statistically low numbers, they are the only indicators usable for international comparison.
Examining Figure 1 as well as Tables 4 and 5 reveals points that deviate significantly from the SDG rank = Road safety rank line. Some countries, such as Thailand, the Dominican Republic, and Vietnam, have road safety rankings around 100 places poorer than their sustainability rankings. These countries must prioritize road safety efforts despite their relatively higher positions in sustainability rankings, as they have the potential to make improvements. On the other end, some countries have better road safety rankings than their SDG positions, but some have small populations living on islands, leading to potential statistical bias. However, for others, there is no such excuse, and they should focus on increasing their efforts in achieving the SDGs while also maintaining attention to road safety.

7. Conclusions

The main finding of this work is that road safety is closely correlated with sustainability. At first glance, it may seem surprising that the simple number of fatalities per population goes hand in hand with sustainability ranking, which comes as a synthesis of 17 different sustainable development indicators. The reason behind this close correlation is that road safety itself is influenced by several components of sustainability: e.g., the safety standards of cars and roads (engineering) are related to economic development, and the acceptance of traffic rules is related to social issues (education, enforcement).
The findings contribute to a deeper understanding of the relationship between road safety and sustainability and provide insights for policymakers, researchers, and stakeholders to develop effective strategies for improving road safety and achieving sustainable transportation systems globally.
Further studies employing time series data could reveal how the relationship between road safety and sustainability evolves over time. Additionally, conducting more detailed analyses by continents and incorporating additional variables may uncover further interesting relationships and dynamics in this context.

References

Bao Q., Zhai Z., Shen Y., 2022, Assessing Road Safety Development in European Countries: A Cross-Year Comparative Analysis of a Safety Performance Index. Appl. Sci., 12, 9813.
Cheng X., Wu Y., Ning P., Cheng P., Schwebel D.C., Hua G., 2018, Comparing road safety performance across countries: Do data source and type of mortality indicator matter? Accident Analysis and Prevention 121, 129–133.
Dorgo G., Honti G., Abonyi J., 2018, Automated analysis of the interactions between sustainable development goals extracted from models and texts of sustainability science. Chemical Engineering Transactions, 70, 781-786.
Heydari S., Hickford A., McIlroy R., Turner J., Bachani A.M., 2019, Road Safety in Low-Income Countries: State of Knowledge and Future Directions. Sustainability, 11, 6249.
Jamroz K., Budzynski M., Romanowska A., Zukowska J., Oskarbski J., Kustra W., 2019, Experiences and Challenges in Fatality Reduction on Polish Roads. Sustainability, 11, 959.
Lamichane S., Egilmez G., Gedik R., Bhutta M.K.S., Erenay B., 2021, Benchmarking OECD countries' sustainable development performance: A goal-specific principal component analysis approach. Journal of Cleaner Production, 287, 125040.
Luzzati T., Gucciardi G., 2015, A non-simplistic approach to composite indicators and rankings: an illustration by comparing the sustainability of the EU Countries. Ecological Economics, 113, 25–38.
Meyer J.D., Hedden, S., 2020, Are we on the right path to achieve the sustainable development goals? World Development, 127, 104749.
Sachs J., Lafortune G., Kroll C., Fuller G., Woelm F., 2022, From Crisis to Sustainable Development: the SDGs as Roadmap to 2030 and beyond. Sustainable Development Report 2022, Cambridge University Press, Cambridge, United Kingdom.
Tešić M., Hermans E., Lipovac K., Pešić D., 2018, Identifying the most significant indicators of the total road safety performance index. Accident Analysis and Prevention, 113, 263–278.
United Nations, 2023, Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. <https://unstats.un.org/sdgs/indicators/indicators-list/>, accessed 24.10.2023.
Ziakopoulos A., Yannis G., 2020, A review of spatial approaches in road safety. Accident Analysis and Prevention, 135, 105323.