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Fuzzy Logic Applied to Sustainable Development Goals and Human Trafficking

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Abstract: In 2015, the leaders of all the UN's Member States agreed to the 2030 Agenda for Sustainable Development. The 17 Sustainable Development Goals and their 169 associated targets address five areas of critical importance: people, planet, prosperity, peace, and partnership. The purpose of this paper is to take the metrics and data provided and transform them into a fuzzy logic setting. This allows for the analysis of the results in SDG Index and Dashboards Report 2019 by using the techniques of fuzzy logic. Many of these 17 Sustainable Development Goals are related to the terrible crime of human trafficking. We also examine these goals in a fuzzy logic setting.

Keywords: Sustainable Development Goals; human trafficking; fuzzy logic; Organization for Economic Cooperation and Development

1. Introduction

There have been strong papers written on the issues of sustainability, climate change, human trafficking, and modern slavery. One uses linguistics such as low (very), medium, and high (very) to measure a country's achievement of various goals and targets [1], another uses colors [2], and another uses numbers [3]. The purpose of this paper is to unify these papers and in fact place the study of these issues in a well established mathematical model. We use mathematics of uncertainty to accomplish this. The issues of sustainability, climate change, human trafficking, and modern slavery are prime candidates for the use of the mathematics of uncertainty due to the lack of accurate data available. After having placed these issues in a mathematical model, our main goal is to rank countries with respect to their achievement of the Sustainable Development Goals (SDGs).

All Member States of the United Nations adopted Agenda 2030 and the SDGs in 2015. The SDGs posit that States have a collective interest and responsibility to ensure that the most vulnerable people and populations are not left behind in economic, social, and environmental progress. The SDGs describe a universal agenda that applies to and must be implemented by all countries, both developed and developing [2]. It was stated in [2] that sound metrics and data are critical for turning the SDGs into practical tools for problem solving by (i) mobilizing governments, academia, civil society, and business, (ii) providing a report card to track progress and ensure accountability, and (iii) serving as a management tool for the transformation needed to achieve the SDGs by 2030. The purpose of this paper to take the metrics and data provided in [2] and transform them into a fuzzy logic setting. This allows for the analysis of the results in [2] by using the techniques of fuzzy logic [4,5].

Once the study of sustainability, climate change, and human trafficking has been placed in a mathematical setting, mathematics can be used to push forward the examination of these problems. For example, the amount flow of trafficking from one country to another has been given linguistically [6]. In [6], terms such as low (very), medium, and high (very) were given to describe the amount of flow. These terms cannot be combined to determine the over all flow into a country.

Say the flow from countries x, y, z into w is low, medium, and very high, respectively. These linguistic terms cannot be combined easily to obtain the overall flow. However, there are techniques in fuzzy logic to add these terms [2,7]. In Section 2, it is explained that an overall score was obtained for each target by multiplying the scores given in each of the three categories. Multiplication was used to emphasize that for a goal or target to score highly, it must meet all three criteria. Multiplication is an example of a t-norm in fuzzy logic. Hence, the use of multiplication opens the use of other t-norms [8]. In Section 3, it is explained that OECD countries are assigned colors in [1] as a ranking in their achievement of the SDGs. The rankings of individual SDGs were determined by averaging the two worst colors (finding the average of orange and red may be problematic to some). The operation average in fuzzy logic is a particular type of aggregation operator. Hence, once the results of [1] are placed in a fuzzy logic setting, the door is open to use other aggregation operators. In fuzzy logic, there are numerous fuzzy similarity measures that can be used to measure the similarity of two rankings. These methods can be compared to methods in statistics. The area of decision analysis mathematics of uncertainty is also useful in combining for example expert opinion concerning the importance of the SDGs. Dempster–Shafer theory was used in [8].

The recent papers [9–12] may also be of interest to readers. For example, the work in [10] discussed the difficulty of measuring and monitoring of human trafficking within the context of the 2030 Agenda and its SDGs. The paper shed light on measuring difficulties and recommendations on how to overcome them. It was stated in [10] that the current SDG indicators were inadequate for measuring human trafficking and need to be urgently improved. The paper proposed seven points of future action to create intersectional linkages and better data collection in order to obtain a fuller picture of human trafficking. A future research project combining the ideas of [10] and the mathematics of uncertainty might be of interest.

An outcome from the UN Conference on Sustainable Development (Rio + 20) in 2012 was international agreement to negotiate a new set of global Sustainable Development Goals (SDGs) to promote sustainable development after 2015 [13]. The report in [13] proposed a methodology for identifying which of the different goals and targets represent the biggest transformational challenges in any given implementation context. The Rio + 20 Outcome Document can be found in [14].

In [13], Stakeholder Forum created a methodology to enable relative scores to be assigned to each of the different targets and goals according to their difference significance in different contexts. The method uses assessors to assign their own independent scores of the significance of each of the proposed targets in the implementation context in question, according to three separate criteria. The three criteria proposed were applicability, implementability, and the transformational impact (both in the country concerned and for the world as a whole). The assessors' scores are then aggregated and averaged to give an overall score for each target and then combined to give an average score for each goal. The highest scores are given to those targets and goals that are both clearly applicable and implementable in the country in question and that represent the biggest transformational challenge. Conversely, lower scores are given to targets and goals that are less applicable or implementable in a particular country, for the reasons given in [3]. The methodology is described in more detail in Section 2.

In this paper, we focus on countries belonging to the Organization for Economic Cooperation and Development (OECD). The OECD is made up of 35 democracies with market economies that work with each other, as well as with more than 70 other member economies to promote economic growth, prosperity, and sustainable development. We assigned numbers from the closed interval $[0, 1]$ to the scores given a country in [2]. This places the analysis of sustainability in [2,3] in the area of fuzzy logic. The determination of the scores can then be determined in many different ways. For example, one can use any number of norms or aggregation operators. We used a particular norm and also the aggregation operator, average. These approaches are discussed in more detail in Section 2. This gave three measures of how well a country is meeting each of the 17 goals. These 17 scores for a country

were then averaged using a weighted average to determine a single number that measured how well a country was achieving the goals. The selection of the weights is discussed in Section 2.

The 17 SDGs are: G_1 no poverty, G_2: zero hunger, G_3: good health and well-being, G_4: quality education, G_5: gender equality, G_6: clean water and sanitation, G_7: affordable and clean energy, G_8: decent work and economic growth, G_9: industry, innovation and infrastructure, G_{10}: reduced inequalities, G_{11}: sustainable cities and communities, G_{12}: responsible consumption and production, G_{13}: climate action, G_{14}: life below water, G_{15}: life on land, G_{16}: peace, justice, and strong institutions, G_{17}: partnerships and goals. These SDGs were discussed in more detail in [2].

We found that Denmark, Finland, and Sweden rank the highest in achieving the sustainable development goals with respect to the average. For human trafficking, we found that Denmark, Slovenia, and Finland ranked the highest.

Our work in this paper is only part of a major study being undertaken by the authors. In another approach using the mathematics of uncertainty, we determined a different method for ranking the countries with respect to their achievement of the SDGs. We used a similarity measure to determine the similarity of the above two methods and the method of ranking in [2].

2. Weighted Average

In this section, we discuss the construction of the weighted average used to determine a single number that measures how well a country is doing in meeting the 17 SDGs. Note that G_{17} is not listed in the following equation. Goal 17 and the targets within the other goals that are specifically directed towards international cooperation and the development assistance responsibilities of developed countries were excluded from the analysis in [3].

The coefficients (or weights) in the following equation were determined as follows : (Table 1).

Table 1. Values from [15].

Country	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_{15}	G_{16}	G_{17}
Australia	0.6	0.2	0.8	0.6	0.4	0.6	0.2	0.4	0.4	0.4	0.6	0.2	0.2	0.4	0.4	0.6	0.4
Austria	0.8	0.4	0.6	0.4	0.4	0.6	0.6	0.6	0.4	0.6	0.6	0.2	0.2	0.5	0.6	0.8	0.2
Belgium	0.8	0.4	0.6	0.4	0.6	0.4	0.4	0.4	0.4	0.6	0.6	0.2	0.2	0.2	0.6	0.6	0.4
Canada	0.6	0.4	0.4	0.8	0.4	0.4	0.8	0.6	0.4	0.6	0.6	0.2	0.2	0.4	0.4	0.6	0.4
Chile	0.6	0.2	0.4	0.2	0.4	0.6	0.6	0.4	0.2	0.2	0.4	0.4	0.2	0.4	0.4	0.2	0.4
Czech Rep.	0.8	0.4	0.4	0.4	0.4	0.6	0.4	0.6	0.4	0.6	0.6	0.4	0.2	0.5	0.6	0.8	0.4
Denmark	0.8	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.4	0.2	0.4	0.2	0.6	0.8	0.6
Estonia	0.6	0.2	0.4	0.6	0.4	0.6	0.6	0.6	0.2	0.4	0.6	0.2	0.2	0.4	0.6	0.4	0.4
Finland	0.8	0.4	0.6	0.8	0.4	0.6	0.8	0.6	0.4	0.8	0.6	0.2	0.2	0.4	0.6	0.6	0.4
France	0.8	0.4	0.6	0.4	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.2	0.2	0.4	0.6	0.4	0.4
Germany	0.6	0.4	0.6	0.6	0.4	0.6	0.6	0.6	0.4	0.6	0.6	0.2	0.2	0.2	0.6	0.6	0.4
Greece	0.6	0.4	0.4	0.2	0.4	0.6	0.6	0.4	0.4	0.4	0.4	0.2	0.2	0.4	0.6	0.4	0.2
Hungary	0.6	0.4	0.4	0.2	0.4	0.4	0.4	0.6	0.2	0.6	0.6	0.4	0.2	0.5	0.8	0.4	0.4
Iceland	0.8	0.4	0.6	0.4	0.6	0.4	0.8	0.6	0.4	0.8	0.4	0.2	0.2	0.2	0.4	0.8	0.2
Ireland	0.8	0.4	0.8	0.6	0.4	0.4	0.4	0.4	0.4	0.6	0.6	0.2	0.2	0.4	0.6	0.6	0.2
Israel	0.4	0.2	0.8	0.2	0.4	0.4	0.4	0.6	0.6	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Italy	0.6	0.4	0.8	0.4	0.4	0.6	0.6	0.4	0.2	0.4	0.4	0.2	0.2	0.2	0.6	0.6	0.4
Japan	0.6	0.4	0.6	0.8	0.2	0.6	0.4	0.6	0.8	0.4	0.4	0.2	0.2	0.4	0.6	0.6	0.2
Korea Rep.	0.6	0.4	0.4	0.6	0.2	0.4	0.4	0.6	0.6	0.4	0.6	0.4	0.2	0.4	0.4	0.6	0.2
Latvia	0.4	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.2	0.2	0.6	0.2	0.4	0.2	0.6	0.4	0.2
Lithuania	0.4	0.2	0.4	0.4	0.4	0.4	0.4	0.6	0.2	0.2	0.6	0.4	0.2	0.4	0.6	0.4	0.4
Luxembourg	0.6	0.4	0.8	0.4	0.6	0.6	0.2	0.4	0.2	0.6	0.4	0.2	0.2	0.5	0.4	0.4	0.2
Mexico	0.4	0.2	0.4	0.2	0.4	0.4	0.2	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.2	0.2	0.4
Netherlands	0.8	0.2	0.6	0.6	0.4	0.6	0.4	0.6	0.6	0.6	0.6	0.2	0.4	0.2	0.6	0.4	0.2
New Zealand	0.6	0.2	0.6	0.6	0.6	0.6	0.8	0.6	0.4	0.4	-	0.4	0.2	0.4	0.4	0.4	0.2
Norway	0.8	0.2	0.8	0.4	0.8	0.6	0.8	0.4	0.4	0.8	0.6	0.2	0.2	0.6	0.4	0.4	0.6
Poland	0.6	0.2	0.6	0.6	0.4	0.6	0.4	0.6	0.2	0.4	0.4	0.2	0.2	0.2	0.8	0.4	0.2
Portugal	0.6	0.2	0.6	0.6	0.4	0.4	0.8	0.6	0.4	0.4	0.4	0.2	0.2	0.2	0.6	0.6	0.4
Slovak Rep.	0.8	0.4	0.6	0.2	0.4	0.6	0.4	0.4	0.2	0.6	0.6	0.4	0.2	0.5	0.6	0.4	0.4
Slovenia	0.8	0.2	0.6	0.6	0.4	0.4	0.8	0.6	0.4	0.6	0.6	0.2	0.2	0.2	0.6	0.6	0.4
Spain	0.6	0.2	0.6	0.6	0.4	0.6	0.6	0.4	0.2	0.4	0.4	0.4	0.2	0.4	0.6	0.6	0.4
Sweden	0.8	0.4	0.8	0.4	0.6	0.6	0.8	0.6	0.6	0.6	0.6	0.2	0.2	0.4	0.6	0.4	0.6

Table 1. *Cont.*

Country	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_{15}	G_{16}	G_{17}
Switzerland	0.8	0.4	0.6	0.4	0.4	0.6	0.8	0.4	0.4	0.4	0.6	0.2	0.4	0.5	0.4	0.4	0.4
Turkey	0.4	0.2	0.4	0.2	0.2	0.4	0.4	0.4	0.2	0.2	0.4	0.4	0.2	0.2	0.2	0.2	0.4
U.K.	0.6	0.4	0.6	0.6	0.4	0.6	0.4	0.6	0.6	0.4	0.6	0.2	0.2	0.4	0.4	0.6	0.2
United States	0.4	0.2	0.4	0.6	0.2	0.6	0.4	0.6	0.4	0.2	0.4	0.2	0.2	0.6	0.6	0.2	0.2

Table 1 on p. 6 of [3] contained the overall marks for the goals. The marks totaled 53.5. The individual goal marks were divided by 53.4 so that the new goal marks were between zero and one, and their total was one. The equation was thus placed in the area of the mathematics of uncertainty.

$$\begin{aligned} SDG \quad = \quad & 0.03G_1 + 0.04G_2 + 0.03G_3 + 0.05G_4 + 0.04G_5 + 0.05G_6 \\ & +0.12G_7 + 0.05G_8 + 0.04G_9 + 0.07G_{10} + 0.05G_{11} + 0.12G_{12} \\ & +0.13G_{13} + 0.08G_{14} + 0.05G_{15} + 0.05G_{16} \end{aligned}$$

The individual goal marks in Table 1, p. 6 of [3], were determined as follows: The individual category scores (determined by assessors) and the overall scores for each goal and target were presented in the tables in Annex 2 of [3]. These were obtained by averaging the collective scores from the assessors. The scores given were out of a maximum of two for individual category scores and a maximum of eight for overall scores.

Each target was assessed as to whether it was applicable, implementable, and transformative, p. 10 of [3]. Three independent assessors provided scores for each of the individual categories working on the methodology elaborated in [3]. An overall score was then obtained for each target by multiplying the scores given to each of the three categories. Multiplication was used to emphasize that for a goal or target to score highly, it must meet all three criteria.

3. SDG Values

In Figure 5, p. 24 of [2], OECD countries were assigned colors as a ranking in their achievement of $G1$ through $G17$. The colors assigned were green, yellow, orange, and red. A green rating on the SDG Dashboard denoted achievement and was assigned to a country on a given SDG only if all the indicators under the goal were rated green, yellow, orange, and red, indicating increasing distance from SDG achievement. The rankings of individual SDGs were determined by averaging the two worst ratings, e.g., green, green, yellow, red yields orange, the average of yellow and red. In order to place the analysis in a fuzzy logic setting, we assigned the numbers $0.8, 0.6, 0.4, 0.2$ to the colors green, yellow, orange, red, respectively

The purpose of the norm function used in the paper is merely to provide another way to interpret the data. Its explanation follows its definition.

Define $t : [0,1]^n \to [0,1]$ by for all $(a_1, ..., a_n) \in [0,1]^n$,

$$t(a_1, ..., a_n) = \begin{cases} \wedge\{a_1, ..., a_n\} & \text{if} \quad a_1, ..., a_n > \lambda, \\ \vee\{a_1, ..., a_n\} & \text{if} \quad a_1, ..., a_n < \lambda, \\ \lambda & \text{otherwise.} \end{cases}$$

We can interpret the norm function t in the following manner: if $a_1, ..., a_n > \lambda$, then the values are at least $\wedge\{a_1, ..., a_n\}$, and if $a_1, ..., a_n < \lambda$, then the values are at most $\vee\{a_1, ..., a_n\}$. In the following tables, we use the norm function t to determine the ratings. We let $\lambda = 0.5$. We applied this norm function to the ratings for each country on pp. 96–449, ref. [2] to obtain the following tables (Tables 2 and 3).

Table 2. Norm values.

Country	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_{15}	G_{16}	G_{17}
Australia	0.6	0.5	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Austria	0.8	0.5	0.5	0.5	0.5	0.6	06	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.8	0.5
Belgium	0.8	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Canada	0.6	0.5	0.5	0.8	0.5	0.5	0.8	0.6	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.6	0.5
Chile	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Czech Rep.	0.8	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.5	0.6	0.6	0.5	0.5	0.5	0.6	0.5	0.5
Denmark	0.8	0.5	0.6	0.5	0.6	0.6	0.6	0.6	0.5	0.8	0.5	0.5	0.5	0.5	0.5	0.8	0.5
Estonia	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.6	0.5	0.5	0.6	0.5	0.5	0.6	0.6	0.5	0.5
Finland	0.8	0.5	0.5	0.8	0.5	0.6	0.8	0.5	0.5	0.8	0.6	0.5	0.5	0.5	0.6	0.6	0.5
France	0.8	0.5	0.6	0.5	0.6	0.6	0.5	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Germany	0.6	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Greece	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.5	0.5	0.5	0.5	0.5
Hungary	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.8	0.5	0.5
Iceland	0.8	0.5	0.6	0.5	0.6	0.5	0.8	0.5	0.5	0.8	0.5	0.4	0.5	0.5	0.5	0.8	0.5
Ireland	0.8	0.5	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.5
Israel	0.5	0.5	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Italy	0.5	0.5	0.8	0.5	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5
Japan	0.5	0.5	0.6	0.8	0.5	0.6	0.5	0.6	0.8	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.5
Korea, Rep.	0.5	0.5	0.5	0.6	0.5	0.5	0.2	0.6	0.4	0.5	0.5	-	0.5	0.5	0.5	0.5	-
Latvia	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.6	0.5	0.5	0.5	0.6	0.5	0.5
Lithuania	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.2	0.5	0.5	0.5	0.5	0.6	0.5	0.5
Luxembourg	0.6	0.5	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Mexico	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Netherlands	0.8	0.5	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
New Zealand	0.6	0.5	0.6	0.6	0.5	0.5	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Norway	0.8	0.5	0.8	0.5	0.8	0.5	0.8	0.5	0.5	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Poland	0.6	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.5	0.5
Portugal	0.6	0.5	0.6	0.6	0.5	0.5	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.5
Slovak Rep.	0.8	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.6	0.5	0.5
Slovenia	0.8	0.5	0.5	0.6	0.5	0.5	0.8	0.6	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.5
Spain	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.5
Sweden	0.8	0.5	0.8	0.5	0.5	0.6	0.8	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.6
Switzerland	0.8	0.5	0.6	0.5	0.5	0.6	0.8	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Turkey	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.4	0.5	0.5	0.5
U.K.	0.6	0.5	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
United States	0.5	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.5	0.4	0.6	0.2	0.5	0.5	0.5	0.5	0.5

Table 3. Averages.

Country	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_{15}	G_{16}	G_{17}
Australia	0.733	0.475	0.800	0.686	0.600	0.733	0.500	0.633	0.660	0.400	0.600	0.560	0.320	0.600	0.440	0.620	0.550
Austria	0.800	0.650	0.776	0.550	0.500	0.743	0.750	0.667	0.720	0.667	0.667	0.333	0.400	-	0.640	0.800	0.500
Belgium	0.800	0.700	0.775	0.640	0.700	0.700	0.550	0.638	0.720	0.733	0.600	0.433	0.480	0.400	0.720	0.740	0.650
Canada	0.733	0.600	0.741	0.800	0.600	0.633	0.810	0.700	0.640	0.533	0.667	0.440	0.320	0.550	0.600	0.744	0.550
Chile	0.600	0.571	0.654	0.533	0.520	0.771	0.750	0.567	0.520	0.257	0.500	0.560	0.480	0.550	0.560	0.620	0.533
Czech Rep0.	0.800	0.575	0.729	0.543	0.560	0.743	0.600	0.767	0.620	0.667	0.650	0.467	0.520	-	0.760	0.720	0.500
Denmark	0.800	0.650	0.788	0.725	0.767	0.771	0.750	0.700	0.740	0.800	0.550	0.467	0.550	0.450	0.720	0.800	0.700
Estonia	0.600	0.550	0.694	0.778	0.567	0.743	0.650	0.767	0.640	0.400	0.700	0.500	0.560	0.750	0.760	0.700	0.500
Finland	0.800	0.575	0.765	0.800	0.667	0.771	0.800	0.667	0.720	0.800	0.700	0.400	0.400	0.600	0.760	0.780	0.600
France	0.800	0.650	0.765	0.625	0.667	0.743	0.650	0.600	0.760	0.667	0.600	0.400	0.400	0.600	0.680	0.700	0.600
Germany	0.733	0.650	0.776	0.629	0.600	0.743	0.650	0.733	0.720	0.600	0.700	0.400	0.320	0.350	0.720	0.700	0.600
Greece	0.600	0.600	0.725	0.578	0.533	0.714	0.650	0.440	0.556	0.400	0.500	0.200	0.440	0.550	0.680	0.680	0.450
Hungary	0.733	0.625	0.725	0.556	0.573	0.686	0.650	0.667	0.554	0.533	0.650	0.633	0.520	-	0.800	0.600	0.600
Iceland	0.800	0.567	0.775	0.650	0.650	0.714	0.800	0.720	0.740	0.800	0.600	0.300	0.500	0.400	0.450	0.800	0.500
Ireland	0.800	0.625	0.800	0.700	0.633	0.657	0.550	0.700	0.680	0.600	0.650	0.400	0.560	0.550	0.720	0.780	0.350
Israel	0.600	0.600	0.800	0.575	0.550	0.686	0.600	0.733	0.756	0.267	0.538	0.300	0.520	0.267	0.480	0.640	0.450
Italy	0.667	0.575	0.800	0.644	0.567	0.714	0.700	0.600	0.533	0.467	0.550	0.367	0.440	0.400	0.760	0.700	0.600
Japan	0.600	0.657	0.776	0.800	0.433	0.743	0.600	0.733	0.800	0.333	0.533	0.467	0.520	0.500	0.640	0.760	0.500
Korea, Rep	0.667	0.714	0.741	0.750	0.467	0.714	0.600	0.760	0.740	0.467	0.600	0.480	0.560	0.500	0.560	0.711	0.450
Latvia	0.600	0.550	0.635	0.711	0.500	0.657	0.700	0.733	0.500	0.267	0.650	0.433	0.600	0.350	0.760	0.580	0.450
Lithuania	0.600	0.550	0.647	0.657	0.600	0.600	0.650	0.733	0.511	0.200	0.650	0.467	0.450	0.600	0.760	0.620	0.550
Luxembourg	0.733	0.600	0.800	0.575	0.650	0.743	0.560	0.700	0.620	0.600	0.600	0.300	0.500	-	0.640	0.740	0.450
Mexico	0.467	0.543	0.662	0.533	0.567	0.514	0.500	0.533	0.444	0.200	0.550	0.567	0.520	0.600	0.480	0.480	0.500
Netherlands	0.800	0.625	0.788	0.686	0.650	0.771	0.550	0.700	0.760	0.733	0.650	0.333	0.600	0.400	0.722	0.740	0.450
New Zealand	0.733	0.571	0.775	0.714	0.700	0.714	0.800	0.767	0.700	0.400	0.667	0.480	0.520	0.550	0.480	0.740	0.500
Norway	0.800	0.550	0.800	0.700	0.800	0.724	0.800	0.667	0.740	0.800	0.650	0.300	0.450	0.400	0.800	0.700	0.450
Poland	0.733	0.550	0.706	0.711	0.567	0.629	0.550	0.700	0.560	0.467	0.550	0.500	0.520	0.400	0.800	0.700	0.450
Portugal	0.733	0.523	0.753	0.700	0.567	0.686	0.800	0.733	0.640	0.400	0.550	0.333	0.560	0.450	0.720	0.740	0.550
Slovak Rep0.	0.800	0.575	0.741	0.457	0.560	0.657	0.650	0.667	0.560	0.733	0.600	0.440	0.400	-	0.760	0.700	0.500
Slovenia	0.800	0.550	0.762	0.711	0.667	0.686	0.800	0.733	0.640	0.733	0.700	0.468	0.400	0.400	0.720	0.780	0.680

Table 3. *Cont.*

Country	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_{15}	G_{16}	G_{17}
Spain	0.600	0.450	0.775	0.733	0.600	0.743	0.750	0.633	0.560	0.400	0.600	0.367	0.520	0.500	0.640	0.720	0.620
Sweden	0.800	0.600	0.800	0.675	0.733	0.770	0.800	0.733	0.760	0.667	0.700	0.400	0.480	0.450	0.720	0.720	0.750
Switzerland	0.800	0.600	0.788	0.675	0.680	0.770	0.800	0.667	0.740	0.533	0.750	0.300	0.520	-	0.640	0.700	0.450
Turkey	0.600	0.571	0.647	0.525	0.333	0.600	0.535	0.567	0.489	0.267	0.533	0.467	0.520	0.250	0.520	0.520	0.500
U.K.	0.733	0.625	0.775	0.714	0.600	0.771	0.600	0.667	0.760	0.400	0.600	0.360	0.400	0.550	0.600	0.725	0.450
United States	0.600	0.625	0.741	0.657	0.567	0.743	0.600	0.700	0.700	0.267	0.600	0.200	0.280	0.600	0.600	0.639	0.600

To find the averages, we have to go country by country (pp. 81–465, [4]) for OECD countries and average the color ratings. For example, Australia G_1: (green + green + yellow)/3 = (0.8 + 0.8 + 0.6)/3 = 0.7333.

4. SDG Rankings

No country from any other region ranked higher overall in [2] than the high ranking OECD countries of our ranking given in Table 4.

Table 4. SDG rankings.

Country	SDG Table 1/Rank	SDG Table 2/Rank	SDG Table 3/Rank
Australia	0.376/29.5	0.515/26	0.54579/31
Austria	0.482/5	0.548/11	0.60226/14
Belgium	0.404/24	0.520/24	0.59762/18
Canada	0.468/7.5	0.569/7	0.59793/17
Chile	0.364/33	0.510/27.5	0.56120/28
Czech Rep.	0.468/7.5	0.536/13	0.61690/10
Denmark	0.506/2	0.574/5	0.65676/1
Estonia	0.414/22	0.528/18	0.63030/4
Finland	0.514/1	0.601/1	0.64933/2
France	0.452/11	0.532/16	0.60012/15
Germany	0.444/13	0.525/20	0.57292/25
Greece	0.390/26	0.464/35	0.51811/32
Hungary	0.424/19	0.523/22.5	0.62026/9
Iceland	0.466/9	0.576/4	0.60723/13
Ireland	0.412/23	0.535/14	0.60867/12
Israel	0.312/34	0.502/30	0.51649/33
Italy	0.398/25	0.531/17	0.55934/30
Japan	0.430/16	0.538/12	0.58628/21
Korea Rep.	0.420/20.5	0.410/36	0.59892/16
Latvia	0.386/27	0.508/29	0.56425/27
Lithuania	0.374/31	0.489/31	0.55939/29
Luxembourg	0.376/29.5	0.524/21	0.57705/23
Mexico	0.306/35	0.479/33	0.50817/35
Netherlands	0.442/14	0.534/15	0.60976/11
New Zealand	0.446/12	0.552/10	0.62138/8
Norway	0.494/3	0.587/2	0.62215/7
Poland	0.380/28	0.523/22.5	0.57304/24
Portugal	0.426/17.5	0.562/8	0.59299/19
Slovak Rep.	0.426/17.5	0.526/19	0.58716/20
Slovenia	0.456/10	0.572/6	0.62511/6
Spain	0.434/15	0.510/27.5	0.57874/22
Sweden	0.492/4	0.580/3	0.63671/3
Switzerland	0.470/6	0.558/9	0.62549/5
Turkey	0.290/36	0.485/32	0.48291/36
U.K.	0.420/20.5	0.516/25	0.56769/26
United States	0.366/32	0.472/34	0.51195/34

5. Human Trafficking

The purpose of this section is to present the rankings of the OECD countries with respect to human trafficking. The rankings using the method in this paper will be compared with other rankings in other works of our major project.

Out of the 17 SDGs, human trafficking is specifically mentioned in three targets under three goals: G_5 (gender equality), G_8 (decent work and economic growth), and G_{16} (peace, justice, and strong institutions). However, many other SDG targets and goals are relevant to address human trafficking. This issue is rooted in development issues at large including poverty, education, child labor, abuse, and exploitation, gender equality and discrimination, and migration and the effects of climate change [16]. Other SDGs mentioned in [16] that contribute to combating human trafficking are 5, 2, 8.7, 16.2.5.3, 210.7.4.1, 4.3, 4.4, 17.18, and 17.19 [16]. It was mentioned by Professor Rochelle Dalla, Editor-in-Chief of the Journal of Human Trafficking, that SDG 12 is also important in combating human trafficking since it is directly related to the promotion of fair trade production, advocacy, and market practices, in addition to consumer knowledge and choice [13]. Table 1 on p. 6 of [3] contained the overall marks for the goals. The marks pertaining to the SDGs under consideration for human trafficking totaled 28.6. The individual goal marks were divided by 28.6 so that the new goal marks were between zero and one, and their total was one.

The coefficients in the following equation were determined by dividing the entries in Table 5 by 28.6.

$$\begin{aligned} G &= 0.06G_1 + 0.09G_4 + 0.08G_5 + 0.09G_6 + 0.09G_8 \\ &\quad +0.13G_{10} + 0.09G_{11} + 0.22G_{12} + 0.09G_{16} + 0.06G_{17}. \end{aligned}$$

Table 5. The individual goal marks.

G_1	G_4	G_5	G_6	G_8	G_{10}	G_{11}	G_{12}	G_{16}	G_{17}	**Total**
1.8	2.5	2.2	2.5	2.7	3.6	2.6	6.3	2.7	1.7	28.6

The tables used to determine the following rankings in Table 6 are the appropriate sub-tables of Tables 1–3.

Table 6. Human trafficking rankings.

Country	**Color/Rank**	**Norm/Rank**	**Average/Rank**
Australia	0.440/22.5	0.502/27	0.5947/17
Austria	0.484/9	0.567/6.5	0.5864/20
Belgium	0.458/16	0.539/16	0.6322/6
Canada	0.484/9	0.560/8	0.6078/13
Chile	0.368/30	0.487/30	0.5354/31
Czech Rep.	0.522/2.5	0.558/9.5	0.6203/7
Denmark	0.550/1	0.610/2	0.6772/1
Estonia	0.440/22.5	0.527/19	0.6053/15
Finland	0.522/2.5	0.611/1	0.6640/3
France	0.476/12	0.548/12	0.6062/14
Germany	0.484/9	0.546/13	0.6094/12
Greece	0.356/32.5	0.434/35	0.4637/36
Hungary	0.456/17.5	0.515/23.5	0.6187/9
Iceland	0.490/5	0.570/4	0.6136/10
Ireland	0.448/20	0.549/11	0.5995/16

Table 6. *Cont.*

Country	Color/Rank	Norm/Rank	Average/Rank
Israel	0.300/36	0.487/30	0.4932/33
Italy	0.494/29	0.509/25	0.5510/28
Japan	0.452/19	0.541/14	0.5679/24
Korea Rep.	0.456/17.5	0.378/36	0.5888/19
Latvia	0.356/32.5	0.505/26	0.5372/30
Lithuania	0.410/27.5	0.461/32.5	0.5301/29
Luxembourg	0.416/25.5	0.519/22	0.5692/23
Mexico	0.302/35	0.461/32.5	0.4890/34
Netherlands	0.466/14.5	0.558/9.5	0.6588/4
New Zealand	0.488/6.5	0.524/20.5	0.6118/11
Norway	0.512/4	0.581/3	0.6187/8
Poland	0.410/27.5	0.515/23.5	0.5832/22
Portugal	0.422/24	0.533/18	0.5544/27
Slovak Rep.	0.468/13	0.540/15	0.5922/18
Slovenia	0.478/11	0.567/5.5	0.6653/2
Spain	0.466/14.5	0.496/28	0.5626/26
Sweden	0.488/ 6.5	0.564/7	0.6502/5
Switzerland	0.416/25.5	0.536/17	0.5853/21
Turkey	0.358/31	0.487/30	0.4771/35
United Kingdom	0.446/21	0.524/20.5	0.5631/25
United States	0.338/34	0.439/34	0.4966/32

The above ranking is the first of its kind. There are currently no other rankings with which to compare it. Research is underway to obtain other rankings that then can be compared by using fuzzy similarity measures.

6. Conclusions

We focused on countries belonging to the Organization for Economic Cooperation and Development (OECD). We assigned numbers from the closed interval $[0, 1]$ to the scores given a country in [2]. This placed the analysis of sustainability in [2,3] in the area of fuzzy logic. We used three measures of how well a country was meeting each of the 17 goals. We found that Denmark, Finland, and Sweden ranked the highest in achieving the sustainable development goals with respect to the average. For human trafficking, we found that Denmark, Slovenia, and Finland ranked the highest. Major research is underway to examine the other regions under consideration in [1]. The techniques being used from mathematics of uncertainty were discussed in the Introduction.

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