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Integrating LPI and EPI by using BWM method

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Abstract— *The increased challenges on countries for reaching sustainability necessitate them to evaluate logistical system through considering both economic efficiency and environmental impacts. This study proposes an approach to scale green logistics performance by merging two global indices: the Logistics Performance Index (LPI) and the Environmental Performance Index (EPI). The primary objective is to combine logistical and environmental factors by utilizing the Best-Worst Method (BWM), a multi-criteria decision-making approach, to establish relative weights for the combined criteria from both indices. The LPI focuses on logistics infrastructure and efficiency, while the EPI captures environmental sustainability, particularly in areas such as climate change mitigation. By combining both scoring systems and filtering countries in both indices, a unified index was constructed for 133 countries. Results showed that climate change mitigation (CCH) emerged as the most influential factor, followed by logistics infrastructure (I), indicating the growing concern on environmental issues in trade and supply chain development. The merged indicator provides a balanced framework to evaluate green logistics and gives insights into policymakers to create or improve sustainable trade systems. The methodology and results can be a foundation for future studies to develop more inclusive performance indices.*

Keywords— *Logistics Performance Index (LPI), Environmental Performance Index (EPI), Green logistics, Best-Worst Method (BWM), World bank indicators, multi-criteria decision-making (MCDM).*

I. Introduction

In a world driven by globalized economy, countries can't depend solely on themselves to prosper, they need to interact with other nations to use their products and they can use the country's product. This interaction is the core of trading and essentially trading is the backbone of the economy. Historically, products transported to other countries take months to reach, yet in the modern world there are faster means of transport. Having faster means of transport created bigger demand for products and the supplying country must manage this demand, hence the introduction of logistics. Logistics, in its most basic sense, involves overseeing the procurement, transportation, and stock management of materials that guarantee the highest profitability for the organization through cost-efficient order fulfillment [1]. Logistics' main goal is to reduce costs through revising every single element in the supply chain network, so logistics is to manage the supplies to meet the demand through the supply chain. The world bank as a global leading organization provides indices for countries to evaluate the countries performances in different sectors including economy, education, trade …etc, underneath the trade sector, there are multiple indicators to evaluate the supply chain performance of countries. Logistics are included as well in these indicators, one of the major and most used indicators is the logistics performance index (LPI). The world bank ensued more interest in the logistics sector after the COVID-19 outbreak and the huge disruption happened to the global supply chain networks [2], this has put greater importance for analyzing indicators such as the LPI. Transport is one of the major influences on logistics and LPI.

This expansion in trade and logistics affects the environment, mostly negatively. A bigger trade volume requires more shipments and more ports, subsequently the environment get affected. Environmental performance index (EPI) is a similar index to LPI, the index rates the country's performance based on three main factors to evaluate which countries are the best.

Merging the data from both indicators could have the potential to evaluate the country's green logistics performance. Using a multi-criteria decision-making technique to rate the criteria. Defining the criteria's importance is the main step which then other techniques can be used to create a merged indicator. The best-worst method is an MCDM method is used to differentiate between the criteria and set a new weight for the combined factors from EPI and LPI.

II. Research Objectives

This study aims toward merging the data between LPI and EPI and defining the importance of all the criteria between both indicators. The study is set to achieve the following:

1. Set a foundation to create a joined indicator between EPI and LPI
2. Defining the weights of criteria obtained from EPI and LPI

III. Problem Statement

The LPI index is a tool used to assess the country's performance in logistics. This tool focuses on transportation and economical aspects, adding a new perspective to this index could help in expanding the index and make it more comprehensive. Thus, merging this index with EPI index to create a bigger index focuses on logistics and the environment simultaneously. However, each one of these indicators has its own factors and those factors aren't related thus it would be difficult to set a numerical number for their importance with respect to the factors. Therefore, the need for an MCDM method to create balanced weights for all the factors.

IV. Literature Review

Since the introduction of LPI, there has been many studies on accepting the LPI as the assessing tool for the logistical performance of the country such as Turkey [3], Bulgaria [4] and Saudi Arabia [5]. One of the perspectives which LPI has been studied on was related to the global competitiveness index in which [6] concluded that improving certain components in the

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LPI index affects the competitiveness index of the country. [7] used the global competitiveness index with the LPI index, the study focused on the sub-components of the global competitiveness index and its possible effect on the LPI. Through constructing a regression model to determine the effects of components related to infrastructure on LPI, it was found that two major components (railroad infrastructure and port infrastructure) have the biggest impact. The study concluded with the recommendation that enhancing railroad and port infrastructures would improve the country's logistical performance and the whole trading sector. [8] studied LPI with competitiveness and prosperity. Using hierarchical regression to find the mediator relationship between LPI, GCI and GDP. The mediator effect of LPI on the relation between GCI and GDP was found to be statistically significant. This indicates that a nation's logistics capability contributes to the connection between its competitiveness and wealth. The study recommended that understanding the relationships among logistics performance, competitiveness, and prosperity can provide important insights for policymakers and businesses. [9] studied the relationship between LPI and corruption perception index (CPI) and foreign trade volume (FTV) of countries. In a similar method as [8] this study used hierarchical regression to measure the mediator effect. It was found that there is statistical significance between LPI, CPI and FTV, understanding these relationships provided important insights for policymakers and businesses aiming to enhance a country's trade competitiveness. [10] examined the factors of LPI and its empirical linkages with economic and environmental indices, the study was done to shed the light on the innovations which helped during the global lockdown due to COVID-19 in 2020. Those innovations averted a global supply chain fallout; however, it may have been at the expense of the environment. In the study, Empirical estimates were obtained using Fully Modified Ordinary Least Squares (FMOLS), Generalized Method of Moments (GMM), and Quantile Regression (QR) models. It was found that human development index, trade openness and urbanization are key factors on enhancing logistical performance, it was also found that LPI has a positive impact on carbon emissions; meaning that current supply chain is still producing high levels of carbons. [11] focused on studying developing countries, it was found out from the study that three main components in the LPI index (customs, infrastructure and logistics cost) have a great impact on the country's trading growth. [12] studied the possible association between green logistics performance and sustainability reporting using signaling theory. The study used the LPI as an indicator to measure the green logistics performance. The moderation analysis indicates that in weak corporate governance environments, the relationship between logistics performance and sustainability reporting is stronger. This indicates that sustainability reporting assists in addressing the void created by inadequate corporate governance.

The green practices are included in multiple phases within the logistical network, from product design, manufacturing, distribution and recycling procedures, yet it remains a hard task to fully integrate green policies into the logistical operation while keeping the same rate performance [13]. Countries and consumers have pressured logistical companies to impose practices for mitigating environmental impacts, however companies are trying to balance between imposing environmental practices and cost efficiency [14]. One of the earlier practices analyzed was freight services, especially trucks causing more pollution than its now, so some research embarked on studying the relationship between environmental impacts as result of logistical activities. [15] focused on the freight impact on the environment, the most impact came from heavy good vehicles which produces around 80 % of the freight pollution. So, the main goal of environmental logistics or sustainable logistics is to find balance between the three pillars of sustainability, environmental, social and economic pillars [16].

Similar to the LPI, there are indicators allocated for environmental performance or a composite index including environment with other economic factors. [17] gathered the most important environmental indices such as environmental performance index (EPI), Sustainability Competitiveness Index (SCI)… etc, in the aim to evaluate these indices for developing effective policy directions. Stronger nations with strong GDP and strong environmental laws tend to have the best score in most indices [18]. The involvement of technology and big data has been a turning point in how the environment is treated, with the need for measures for environmental performance, EPI can be a strong measurement to rate the country's performance [19]. [20] connected the logistical performance index with the environmental degradation. Using a regression model for 42 Asian countries, it was found that international shipments help reducing the CO2 emissions while Timeliness contributed the most in increasing the CO2 emissions. While [21] went for a different approach by combining the LPI score with environmental performance index, this merge of those index resulted in another green logistics performance index (GLPI). From their new index, they conclude that improving logistics has an impact on carbon emissions and greenhouse gases, yet countries went through improving their economy through trading and logistics at the expense of the environment. [22] used the DEA method to assess the EPI as an example of composite indicators. The study was based on pessimistic and optimistic DEA models. They concluded that the weights of such indicators are extremely important to identify specifically, and they showed that having flexibility in weights could overemphasize an underlying performance criteria making the country or the directory full focus on this criterion and ignore the others. [23]used (GLPI) to evaluate the green performance of EU countries to allow for comparison of changes over time to evaluate the progress or any drawbacks happened to a certain country.

V. Research Methodology

The LPI scores were presented on a 1-5 scale, meaning that the highest score is 5 and the lowest score possible is 1. Countries are also able to get decimal scores, not just the integers. On the other hand, the EPI scores use the 100-point system, each country has a score starting from 0 up to 100 including decimal values. Another point to consider while merging the data, there are some countries included in EPI while not included in LPI and vice versa. Therefore, to make a

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reasonable analysis the score system should be aligned and remove countries which have no data in either one of them.

Score out 5= (EPI factor score)/25+1

This equation was used to change each country's score to 5 points scale. This equation ensures that the score is converted to 1-5 points by dividing on 25 we get the decimal value of the score from 0-4 and then adding 1 to the score to make it from 1-5. Applying this to every single country creates a consistent dataset which includes EPI and LPI factors altogether.

For the BWM, the main theory of this method is based on pairwise comparisons. The difference lies in the reduced number of comparisons between PCM and BWM, in the BWM the preference scale is used to indicate the most important criterion compared to other criteria in a scale from 1 to 9. Ahead of doing the preference scale, it's important to select the most important criteria and the worst criteria as those two will be the base for comparison. After the preference scale, two sets of comparisons are presented, one is best to worst and the other is others to worst. Using those two sets, an optimization model can be created to minimize the maximum absolute differences between the weights and the preferences. The solution of the optimization model is the optimal weights for each criterion. Since this theory is highly subjective on the results of the preference scale, a consistency ratio index should be calculated to measure the consistency of the rating the best to others and others to worst sets.

The detailed step for the method is as follows:[24]

1. Identify a set of criteria $\{c_1, c_2 \dots c_n\}$
2. Select the most important criterion and the least important criterion
3. Determine the preference scale for best to others vector by rating the best criterion to all the other criteria in a scale from 1 to 9. Giving a preference of 1 means equally important, while 9 means the preference is absolutely more important.

$A_B = \{a_{B1}, a_{B2} \dots a_{Bn}\}$

Where a_{Bj} resembles the preference scale of criterion B over criterion j. It's also obvious that the preference scale of a_{BB} is 1.

4. Determine the preference scale for the others to worst vector by rating all the other criteria to the worst criterion in a scale from 1 to 9.

$$A_w = \{a_{1w}, a_{2w} \dots a_{nw}\}$$

Where a_{jw} resembles the preference scale of criterion j over criterion w. It's also obvious that the preference scale of a_{ww} is 1.

5. Calculate the optimal weights $\{w_1, w_2 \dots w_n\}$

The optimal weights resulted should aimed to minimize the maximum absolute difference between the best to others vector $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and the others to worst vector $\left|\frac{w_j}{w_w} - a_{jw}\right|$.

$$\min \max j \left\{\left|\frac{w_B}{w_j} - a_{Bj}\right|, \left|\frac{w_j}{w_w} - a_{jw}\right|\right\}$$

Subjected to:

$$\sum_j w_j = 1$$

$w_j \geq 0, for\ all\ j$ (non-negativity constraint)

This can be written in an easier way,

$$\min \zeta$$

Subjected to

$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \zeta, for\ all\ j$$

$$\left|\frac{w_j}{w_w} - a_{jw}\right| \leq \zeta, for\ all\ j$$

$$\sum_j w_j = 1$$

$w_j \geq 0, for\ all\ j$ (non-negativity constraint) (2)

Solving the simplified model for ζ as the objective function and w_j as decision variables, would result in obtaining the optimal weights for each criterion.

6. Calculate the consistency ratio CR

$$CR = \frac{\zeta}{consistency\ index\ (CI)}$$

Where $CR \in [0,1]$, if the value of CR is closer to zero then its more consistent while values closer to one is less consistent. Consistency index is a given value based on the number of alternatives.

TABLE 1: Consistency Index[25]

a_{Bw}	CI
1	0
2	0.44
3	1.00
4	1.63
5	2.30
6	3.00
7	3.73
8	4.47
9	5.26

VI. Results & Discussion

After screening countries in both indices and picking only the countries included in both datasets, the final count of the countries which the analysis will be based on is 133 countries, reduced down from 160 for LPI 2023 and 180 for EPI 2024. Table 2 shows a sample of the countries after converging the EPI data and merging them with the LPI scores. In LPI there are 6 criteria, customs (C), infrastructure (I), shipments (S), logistic services (LS), Tracing and tracking (TC) and Timelines (T). While for EPI, the three main criterions were considered, ecosystem vitality (ECO), environmental Health and Climate change mitigation (CCH).

TABLE 2: Sample of dataset after merging LPI and EPI for top 10 countries

Country	C	I	S	LS	TC	T	ECO	HLT	CCH
Singapore	4.2	4.6	4.0	4.4	4.3	4.4	3.2	3.6	2.6
Finland	4.0	4.2	4.1	4.2	4.3	4.2	3.7	4.4	3.9
Denmark	4.1	4.1	3.6	4.1	4.1	4.3	3.5	4.1	3.7
Germany	3.9	4.3	3.7	4.2	4.1	4.2	4.2	4.0	3.6
Netherlands	3.9	4.2	3.7	4.2	4.0	4.2	3.7	4.0	3.4
Switzerland	4.1	4.4	3.6	4.3	4.2	4.2	3.8	4.0	3.4
Austria	3.7	3.9	3.8	4.0	4.3	4.2	4.1	3.8	3.2
Belgium	3.9	4.1	3.8	4.2	4.2	4.0	3.8	3.8	3.4
Canada	4.0	4.3	3.6	4.2	4.1	4.1	3.4	4.1	2.9

The countries shown in the table represent the merger of EPI and LPI. Each country has a rate of 1-5 which makes it easier to analyze and compare in further analyses. When analyzing the performance of a country such as Singapore which is the best

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country in the world in LPI index, it shows that the have strong logistic capabilities but poor climate change mitigation actions. This means that if those countries reranked again Singapore would not be in the best position as in LPI. So, this merger has the potential to give insights into some aspects of the country's sustainability performance.

For the weight's calculation, Since the criteria aren't connected and it's made up of two sets of factors, it would be difficult to choose a single criterion over the other one. For instance, if choosing (CCH) as the most important criterion how can it be compared to (I), even experts would find it difficult to justify their ratings. Thus, weights have been divided into 50% for the LPI factors and 50% for the EPI factors, this division helps make the comparison relatable and justifiable. In LPI, the selected criteria were (I) and (TC) as the best and the worst respectively. Those two criteria have been chosen through literature [26] [27][28]

For the EPI, in this case there are three factors only and since the main focus on environment, climate change should be the most important criterion, as this factor withheld the most impactful sub-indices such as greenhouse gas emissions and carbon dioxide emissions. Carbon dioxide itself is responsible for 20% of thermal absorption, other greenhouse gases diversly effect on the increasing temperature on earth [29]. These effects of GHG qualify the climate change criteria to be the most important related to the environment performance of a country especially that these effects of greenhouse gases could be mitigated putting the responsibility on the hand on the country's government to reduce down these[30]. Then, environmental health was considered the second most important due to the fact that this factor has within it the effect of household solid fuel such as coal and biomass. This fuel is one of the reasons behind indoor pollution leading to 3.55 million deaths each year [31]. Environmental health was chosen over Ecosystem vitality due to ecosystem vitality encompasses factors that are naturally found within the country, their existence depends on the location and can't be humanly meddled with their existence. So, environmental health is second and least important amongst the three is ecosystem vitality. This was the input into the BWM solver which was created and developed by Jaafer Rezeai [32] to compare the best criteria with the others and compare others with the worst criteria. With the weights being obtained for both LPI and EPI criteria using the solver. These weights shall be divided by 2 to ensure that the summation of weights equals to 1. This means that the final weights result is as follows:

TABLE 3: Final Weights

Criteria	C	I	S	LS	TC	T	ECO	HLT	CCH
Weight	0.0789	0.2029	0.0338	0.0473	0.0188	0.1183	0.0833	0.1458	0.2708

Based on table 3, weights have been set for the merged criteria between the LPI and EPI factors. Weighs were carefully considered based on literature and importance to ensure that these numbers are the closest to reality. These numbers achieved can be used in other MCDM methods to rank countries and find which countries are the best in terms of LPI and EPI altogether. When looking at the results, it showed that the highest as specified (I) is the highest From LPI and (CCH) is highest from EPI, but CCH is highest overall. (CCH) is highest due to the fact that there are fewer factors thus the differences appear clearly, while for LPI more factors and best factor has to be compared with others thus the differences between the rest appeared to be small.

VII. Conclusion & Recommendation

This study aimed to develop the LPI indicator and make it more comprehensive through merging it with the EPI indicator. In seeking to get a better understanding of some aspects in the sustainability performance of countries. The study effectively highlights the method of merging and applying MCDM method to find the weights of the merged criteria. The aim of MCDM is to prepare a foundation to build upon it a reasonable comparison for the new merged indicator.

The study showed in a deep understanding of how the merged indicator started and the drive goal behind making the merger. While the weights were identified through using BWM method to evaluate the 9 factors for the new indicator. Due to lack of real connection between the EPI and LPI factors, both indicators' factors have given half of the weights. Consequently, it was found that the CCH is the highest factor in weight followed by (I), those two factors were already chosen to be best according to literature, other factors' weights were set through method in accordance with the best.

- *Recommendation*

A. Mixing indicators can have huge potential in reading countries overall performance
B. Making balance between economic and environmental aspects is the key to achieving sustainability.

- Future Work

New paths could be extracted from the study and following different approaches to create new indicators for better understanding of the world economy and environmental stance. Future studies have to think about utilizing:

A. Apply MCDM method to rank the countries based on the weights found in the study.
B. EPI has many sub-indices which can be considered each by itself to get more specified results

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