Multi Attribute Utility Theory (MAUT) as a Tool to Develop Index and Dashboard for Goal 2 of SDGs: A Hypothetical Case Study

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Abstract: There is a need to develop indexes for the UN's 17 Sustainable Development Goals (SDGs) in order to monitor progress, ensure accountability and implement policy for achieving them by 2030. This paper suggests a methodological approach for constructing indexes based on a hypothetical data set of the selected indicators for Goal 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture) for five hypothetical countries representing the developed and developing world. The MAUT technique of Web-HIPRE (Hierarchical Preferences), an Internet-based free software program, is used for aggregating the indicators' scores and weightings. This case study shows that MAUT has the capacity to generate indexes on a 0 to 1 scale. During aggregate score calculation, the utility functions were considered as being additive and linear. The proposed methodological approach is able to rank the indexes of Goal 2 based on multiple indicators. Along with showing index scores, MAUT is also able to show the contribution of each indicator to the overall performance of the index through bar colours, which provides an effective way to visualize the results. This visualization can be used to develop a dashboard for Goal 2. The proposed framework can handle heterogeneous criterion measurement levels, deals with incommensurability and allows a transparent, replicable, sound and quantitative evaluation of the indexes of Goal 2 in order to facilitate comparison among countries. This comparison can be helpful for monitoring Goal-related progress and implementing Goal-related policies across countries. This methodological framework has the flexibility to be adapted for a variety of purposes at different scales for all 17 SDGs.

Keywords: SDGs, MAUT, Indicators, Index, Dashboard, Assessment

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Introduction

The United Nations declared 17 Sustainable Development Goals and 169 ambitious development targets as part of a plan of action to benefit humanity, the planet and prosperity over the next 15 years[1]. While all countries and stakeholders need to take action to achieve these development targets, it is also important to evaluate the progress of these targets, which "supports learning, transparency, accountability and improvement"[2]. National, regional, global and thematic[3] levels of evaluation and monitoring are necessary to understand status, progress, weakness, accountability and policy interventions for SDGs. The 169 targets can be considered as indicators[4] and could be used for assessing progress and comparing the achievement of different targets at the four different levels. However, indexes (composite indicator) could be suitable for integrated evaluation and comparison[5][6]. Transparent indexes are useful for evaluating performance and ranking[7] of the targets and can be elements of monitoring progress towards the SDGs and developing a dashboard.

Some widely known indexes are the Human Development Index[8] (HDI), Environmental Sustainability Index[9] (ESI), Ecological Footprint[10] (EF), Gender Empowerment Measure (GEM) and Quality of Life Index (QLI). Indexes are constructed such that laypersons can easily interpret them to identify trends across many separate indicators. Detailed information is always available since indexes are built by an aggregation of indicators[11]. Robust indexes are very

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useful for policy makers due to their inclusiveness and ease of communication and understanding[12]. For example, the development of the HDI, ESI and EF indexes followed specific procedures. A typical index “” is built as follows[11]:

$$I = \sum_{i=1}^{n} w_i \, x_i$$

Where
x_i = normalized variable
w_i = weight attached to x_i
$\sum_{i=1}^{n} w_i$ = 1 and $0 \leq w_i \leq 1, i = 1,2,\ldots,n.$

Technically, indexes are mathematically combined multidimensional data[13] and represent the issues of a complex subject matter[14] . The OECD[11] suggested a series of steps (Appendix:1) that includes establishing a theoretical framework, selecting variables, imputing missing data, multivariate analysis, normalization, weighting and aggregating and finally robustness and sensitivity analysis[11]. However, if reliable, scientifically sound and transparently developed indicators are available, indexes can be developed without following all these steps by normalization and aggregation of Multi Attribute Utility Theory (MAUT) techniques. Keeping this simple process in view, a methodological framework is proposed in this paper for developing indexes to compare the targets of SGDs for five hypothetical countries representing two developed and three developing countries. MAUT is used along with hypothetical data from the indicators suggested in 2015 by SDSN for the first four targets of Goal 2 of the SDGs.

Method and Materials

Figure 1 illustrates the methodological flowchart of the paper. In step one the set of indicators are selected for Goal 2(End hunger, achieve food security and improved nutrition and promote sustainable agriculture) and targets from SDSN (2015). In step two hypothetical data are developed for the target and the hypothetical countries (Table 1). In step three by applying MAUT index are developed for each target. In step four the results of the MAUT analyses were transformed into a dashboard with index values.

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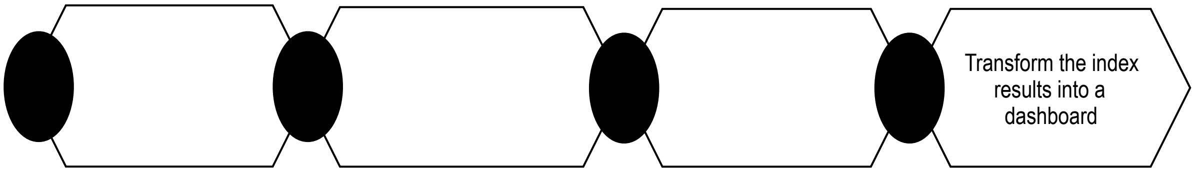

Figure 1: Four steps of MAUT-based index development

Table 1: Selected indicators of the first four target Goal 2 of SDGs and their hypothetical scores and weight for five hypothetical countries

Targets	Indicators	Abbreviation of the indicators	Weight	Indicators scores				
				Developing world			Developed world	
				A	B	C	D	E
Target 1: By 2030 end hunger and ensure access by all people, in particular the poor and people in vulnerable situations including infants, to safe, nutritious and sufficient food all year round	Proportion of population below minimum level of dietary energy consumption	DEC	Equal weight for the indicators are used	35	38	44	78	79
	Proportion of infants 6-23 months of age who receive a minimum acceptable diet	MCD		55	56	65	95	98
	Percentage of total daily energy intake from protein in adults	EPA		65	55	67	92	90
Target 2: By 2030 end all forms of malnutrition, including achieving by 2025 the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women, and older persons	Percentage of women of reproductive age (15-49) with anemia	RAA		39	40	41	80	89
	Prevalence of stunting and wasting in children under 5 years of age	WCU		30	32	50	89	93
	Percentage of population with shortfalls of: iron, zinc, iodine, vitamin A, folate, vitamin B12 and vitamin D	SFV		45	35	33	87	88
	Percentage children born with low birth weight	LBW		37	31	35	91	90
Target 3: By 2030 double the agricultural productivity and the incomes of small-scale food producers, particularly women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	Losses from natural disasters, by climate and non-climate-related events (in US$ and lives lost)	LND		25	28	20	95	92
	Crop yield gap (actual yield as % of attainable yield)	CYA		33	35	45	90	89
	Percentage of fish tonnage landed within Maximum Sustainable Yield (MSY)	FSY		20	20	18	90	90
	Cereal yield growth rate (%)	CYG		45	55	40	75	65
	Livestock yield gap (actual yield as % of attainable yield)	LYG		20	18	15	60	61
Target 4: By 2030 ensure sustainable	Nitrogen use efficiency in food systems 83.	NUE		12	25	21	70	69

food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters, and that progressively improve land and soil quality	Annual change in forest area and land under cultivation (modified MDG Indicator)	CFA	10	15	17	90	95
	Annual change in degraded or desertified arable land (% or ha)	DAL	10	15	10	88	75
	Public and private R&D expenditure on agriculture and rural development (% of GNI)	RDE	15	11	12	50	49

Source: Indicators are selected from SDSN (2015). Note: Indicator scores are all hypothetical. Equal weights are used for the indicators to avoid the effect of the weight on the index score.

MAUT is a branch of Multi-Criteria Decision Analysis (MCDA). MCDA is a structured approach that quantitatively evaluates alternatives in a decision-making process by considering both indicators and their weighting[15]. In MCDA, multiple indicators can be formally incorporated into an evaluation process[16]. The major steps of MCDA analysis are: (1) normalization and evaluation of the performance of each indicator (criterion); (2) determination of the weights representing the priorities for each indicator; and (3) aggregation (based on additive, multiplicative, or other distributional formalisms)[17]. In the MAUT method, the alternatives are evaluated with respect to each attribute and the attributes are weighted according to their relative importance[18]. According to Neste and Karjalainen[19]:

> If there is no interaction among alternatives, an alternative would have an overall value :
>
> where is the consequence of alternative in indicator ,
> is its value normalized to the 0–1 range and
> is the importance weight assigned to indicator .

The free online software program Web-HIPRE (Web-HIPRE is a web-version of the HIPRE 3+ software for decision analytic problem structuring, multi-criteria evaluation and prioritization.

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It can be found at http://hipre.aalto.fi/) is used to apply MAUT for index development. In Web-HIPRE, first of all a value tree (Figure 2a) was developed. The indicators' weights (considered equal for the purpose of this paper) were inserted in the software through direct priorities techniques and scores of the indicators were imported as "Valuefn." The "Import Valuefn" function proportionately normalized the indicator scores. These normalized scores were then used to develop "Composite Priorities" (index) using the software.

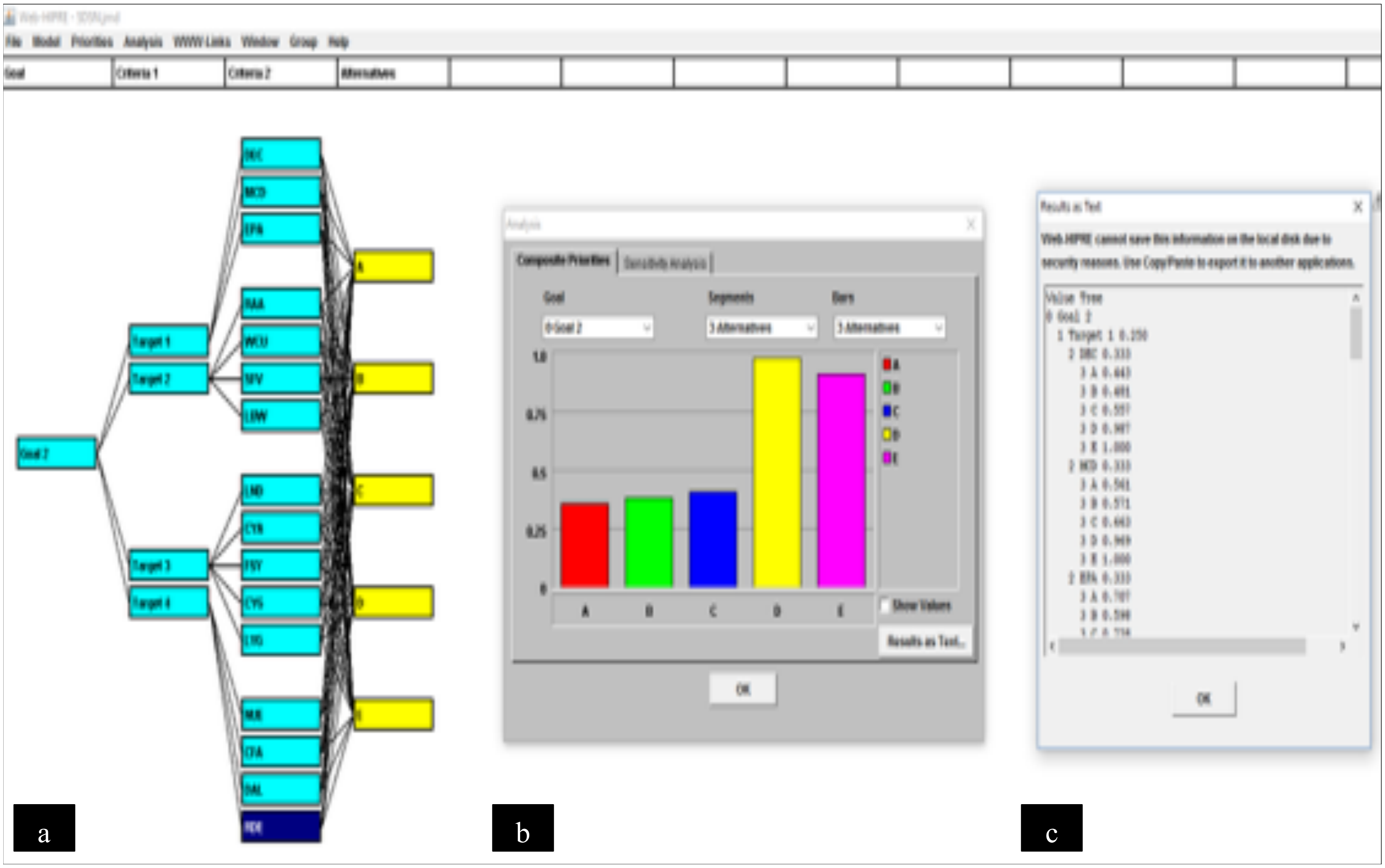


Figure 2: The general steps to develop index values and dashboard in Web-HIPRE: (a) Value Tree (Hierarchical structure), (b) Graphical representation of the overall score of the index and (c) Overall score of the index.

Result and Discussion

Applying MAUT with the help of web-HIPRE software in hypothetical scoring of the indicators in the hypothetical countries generates the index values and dashboard for Goal 2 (Table 2 and Figure 3), index values and dashboard for the targets of Goal 2 (Table 3 and Figure 4) and scores of the indicators and dashboard (Table 4 and Figure 5).

Table 2: Overall index score for Goal 2 for the hypothetical countries

Index	Countries				
	A	B	C	D	E
Goal 2	0.359	0.383	0.409	0.983	0.916

Figure 3: Presentation of the overall index scores for Goal 2 of the hypothetical countries

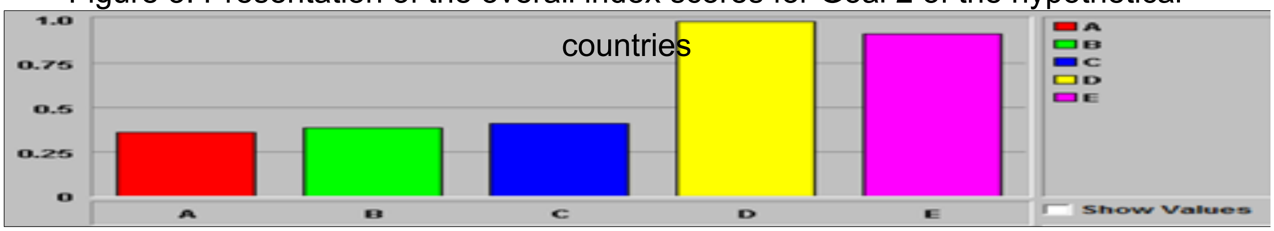


Table 3: Overall index scores of the targets of Goal 2 for the hypothetical countries in dashboard

Index	Countries				
	A	B	C	D	E
Target 1	0.143	0.138	0.162	0.246	0.248
Target 2	0.085	0.096	0.110	0.240	0.249
Target 3	0.089	0.097	0.084	0.249	0.241
Target 4	0.043	0.053	0.052	0.247	0.177
Overall	0.359	0.383	0.409	0.983	0.916

Figure 4: Presentation of the overall index scores for Goal 2 of the hypothetical countries in dashboard

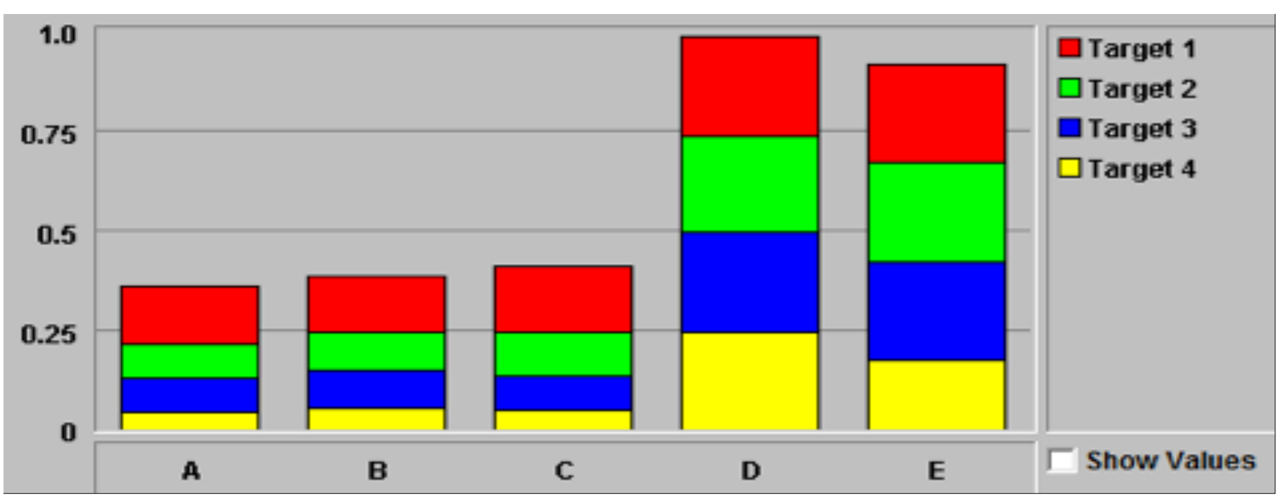
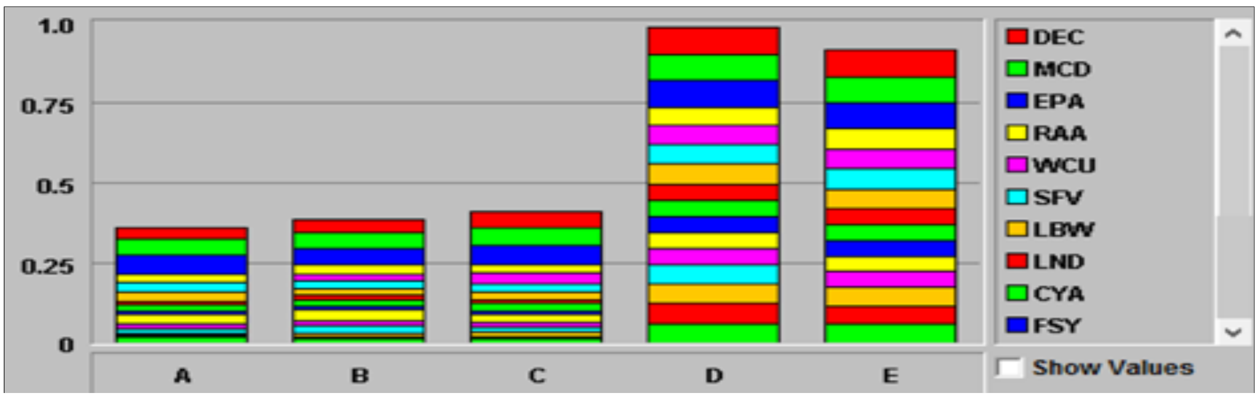


Table 4: Indicator scores for Goal 2 for the hypothetical countries

Countries	Indicators																Overall
	DEC	MCD	EPA	RAA	WCU	SFV	LBW	LND	CYA	FSY	CYG	LYG	NUE	CFA	DAL	RDE	
A	0.037	0.047	0.059	0.027	0.000	0.032	0.025	0.013	0.018	0.011	0.030	0.016	0.011	0.007	0.007	0.019	0.359
B	0.040	0.048	0.050	0.028	0.022	0.025	0.021	0.015	0.019	0.011	0.037	0.015	0.022	0.010	0.007	0.014	0.383
C	0.046	0.055	0.061	0.029	0.034	0.023	0.024	0.011	0.025	0.010	0.027	0.012	0.019	0.011	0.007	0.015	0.409
D	0.082	0.081	0.083	0.056	0.060	0.062	0.063	0.050	0.050	0.050	0.050	0.049	0.063	0.059	0.063	0.063	0.983
E	0.083	0.083	0.081	0.063	0.063	0.063	0.062	0.048	0.049	0.050	0.043	0.050	0.000	0.063	0.053	0.061	0.916

Figure 5: Presentation of the indicator scores for Goal 2 of the hypothetical countries in dashboard



Among the hypothetical countries, the overall score of the index for Goal 2 is highest in country "D" and lowest in "A". In this presentation of the index in the table and dashboard, higher scores should be interpreted as better performance related to Goal 2, the targets and the indicators in the hypothetical countries. This study tried to show the applicability of MAUT to generate index values and dashboards. MAUT analysis in Web-HIPRE can show the index value of Goal 2 and the index of the target and individual indicator scores in different ways at the same time. Showing the index scores and dashboard can be very useful to compare the performance on the goals, targets and indicators among the hypothetical countries. It can also be used as a baseline to compare with future performance related to the goals, targets and indicators, which can be very useful in crafting initiatives for improving performances in the hypothetical countries. This method generates an index score on a 0 to 1 scale (Figure 3, 4 & 5) where a score near 0 indicates bad performance and near 1 indicates good performance of the countries in terms of goals, targets and indicators.

The method proposed here to develop indexes and dashboards is capable of handling incommensurability of the indicators. The indicators that are selected in this study are measured in different units; nevertheless, this method can aggregate indicators by avoiding the unit and only considering indicators' scores. The issue of incommensurability is avoided through normalization of the indicators[20]. In this method, the score of the index depends solely on the performance of the indicators by the hypothetical countries and it is transparent and replicable. However, substantial technical and mathematical knowledge is required to generate index scores by using the proposed methods.

Conclusion

Using hypothetical scores of five hypothetical countries on the selected indicators and targets of Goal 2, a methodological approach is proposed to develop indexes for Goal 2 of the UN's SGDs. Developing indexes for different goals and targets of SDGs is very important for benchmarking the goals and targets, measuring and comparing performance among countries, and creating awareness for various stakeholders[21]. The methodology that is proposed here is easy to apply and can calculate the overall score considering all indicators. This method has the capacity to be an easily applicable methodology for studying performance related to the goals and targets of SDGs.

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Appendix: 1

Checklist for building a composite indicator

Steps	Description	Why it is needed
1st: Theoretical framework	Provides the basis for the selection and combination of variables into a meaningful composite indicator under a fitness-for-purpose principle (involvement of experts and stakeholders is envisaged at this step).	▪ To get a clear understanding and definition of the multidimensional phenomenon to be measured. ▪ To structure the various sub-groups of the phenomenon (if needed). ▪ To compile a list of selection criteria for the underlying variables, *e.g.*, input, output, process.
2nd: Data selection	Should be based on the analytical soundness, measurability, country coverage, and relevance of the indicators to the phenomenon being measured and relationship to each other. The use of proxy variables should be considered when data are scarce (involvement of experts and stakeholders is envisaged at this step).	▪ To check the quality of the available indicators. ▪ To discuss the strengths and weaknesses of each selected indicator. ▪ To create a summary table on data characteristics, e.g., availability (across country, time), source, type (hard, soft or input, output, process).
3rd: Imputation of missing data	Is needed in order to provide a complete dataset (*e.g.* by means of single or multiple imputation).	▪ To estimate missing values. ▪ To provide a measure of the reliability of each imputed value, so as to assess the impact of the imputation on the composite indicator results. ▪ To discuss the presence of outliers in the dataset.
4th: Multivariate analysis	Should be used to study the overall structure of the dataset, assess its suitability, and guide subsequent methodological choices (*e.g.*, weighting, aggregation).	▪ To check the underlying structure of the data along the two main dimensions, namely individual indicators and countries (by means of suitable multivariate methods, e.g., principal components analysis, cluster analysis). ▪ To identify groups of indicators or groups of countries that are statistically "similar" and provide an interpretation of the results. ▪ To compare the statistically determined structure of the data set to the theoretical framework and discuss possible differences.
5th:Normalisation	Should be carried out to render the variables comparable.	▪ To select suitable normalisation procedure(s) that respect both the theoretical framework and the data properties. ▪ To discuss the presence of outliers in the dataset as they may become unintended benchmarks. ▪ To make scale adjustments, if necessary. ▪ To transform highly skewed indicators, if necessary.

6th: Weighting and aggregation	Should be done along the lines of the underlying theoretical framework.	▪ To select appropriate weighting and aggregation procedure(s) that respect both the theoretical framework and the data properties. ▪ To discuss whether correlation issues among indicators should be accounted for. ▪ To discuss whether compensability among indicators should be allowed.
7th: Uncertainty and sensitivity analysis	Should be undertaken to assess the robustness of the composite indicator in terms of e.g., the mechanism for including or excluding an indicator, the normalisation scheme, the imputation of missing data, the choice of weights, the aggregation method.	▪ To consider a multi-modelling approach to build the composite indicator, and if available, alternative conceptual scenarios for the selection of the underlying indicators. ▪ To identify all possible sources of uncertainty in the development of the composite indicator and accompany the composite scores and ranks with uncertainty bounds. ▪ To conduct sensitivity analysis of the inference (assumptions) and determine what sources of uncertainty are more influential in the scores and/or ranks.
8th: Back to the data	Is needed to reveal the main drivers for an overall good or bad performance. Transparency is primordial to good analysis and policymaking.	▪ To profile country performance at the indicator level so as to reveal what is driving the composite indicator results. ▪ To check for correlation and causality (if possible). ▪ To identify if the composite indicator results are overly dominated by few indicators and to explain the relative importance of the sub-components of the composite indicator.
9th: Links to other indicators	Should be made to correlate the composite indicator (or its dimensions) with existing (simple or composite) indicators as well as to identify linkages through regressions.	▪ To correlate the composite indicator with other relevant measures, taking into consideration the results of sensitivity analysis. ▪ To develop data-driven narratives based on the results.
10th: Visualisation of the results	Should receive proper attention, given that the visualisation can influence (or help to enhance) interpretability	▪ To identify a coherent set of presentational tools for the targeted audience. ▪ To select the visualisation technique this communicates the most information. ▪ To present the composite indicator results in a clear and accurate manner.

Source: Adapted from OECD[11].

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