A Critical Review on the Applications of Optimization Techniques in the UN Sustainable Development Goals

Umar Muhammad Modibbo, Musa Hassan, Yashpal Singh Raghav and Mohammed Mijinyawa

May 20, 2021

A Critical Review on the Applications of Optimization Techniques in the UN Sustainable Development Goals

Umar Muhammad Modibbo[1]
Department of Statistics & Operations Research
Modibbo Adama University of Technology
PMB 2076, Yola, Nigeria
umarmodibbo@mautech.edu.ng

Yashpal Singh Raghav[2]
Department of Mathematics,
Faculty of Science,
Jazan University, KSA
yraghav@jazanu.edu.sa

Musa Hassan[3]
Department of Statistics
Adamawa State Polytechnic
Yola, Nigeria
alhass04@gmail.com

Mohammed Mijinyawa[4]
Department of Statistics & Operations Research
Modibbo Adama University of Technology
PMB 2076, Yola, Nigeria
m.mijinyawa@mautech.edu.ng

Abstract*—The United Nations agenda 2030 adopted sustainable development goals in 2015 with 17 targets and 231 unique indicators achievable in 2030. The ever-growing demand for member countries for these achievements resulted in the setting of individual aspirational goals. This article extensively discusses the optimization techniques applied in modelling and analyzing several member countries' vital economic indicators. The study reveals that goal programming (GP) and its variants mostly applied in this regard. Some variants identified include fuzzy GP, stochastic GP, polynomial GP, weighted GP, and GP with satisfaction function. Other multi-criteria optimization techniques also used in different concept. They include the analytic hierarchy process, the fuzzy-AHP, entropy method, the technique for order of preference by similarity to ideal solution (TOPSIS), the fuzzy-TOPSIS, the VIKOR method, the combined compromise solution method and data envelopment analysis. Most of the studies carried out in Africa, Asia, Europe and the UAEs. It shows that some targets are achievable while others are not. Several suggestions and conclusions made in respect of different countries studied to achieve the SDGs vision 2030.

***Index Terms*—Sustainable Development Goals, Optimization Techniques, Modelling, Aspiration Level, Economic Indicators, Government Policies**

I. INTRODUCTION

Sustaining future growth and development socially, environmentally and economically is challenging globally. The United Nations (UN) adopted an agenda 2030 in 2015 due to the failure of Millennium development goals (MDGs) known as the sustainable development goals (SDGs) agenda 2030. The exponential population growth coupled with the highly increasing demand for energy for production and consumption led to environmental degradation and pollution worldwide. The UN assembly, after extensive deliberation with member countries, came up with 17 sets of goals with over 200 indicators in September 2015 and targeted 2030 as the actualization year. These goals are enumerated and explained in [1]. They can be categorized into three major sectors: social, economic, and environmental factors [17]. To achieve these sets of goals, the government and stakeholders must formulate and implement sustainable and viable policies in each member country. For this purpose, there is a need for efficient energy consumption, economic improvement, and less emission to attain eco-friendly environments. Policies regarding the primary drivers such as economic development, power availability, employment opportunities and reducing greenhouse gases are imperative. However, these drivers might not be the same across the countries due to the uneven distribution of natural resources and technological advancement. One of the reasons for the diverse applications of the optimization techniques in addressing these issues by different researchers and policy-makers globally could be the uneven phenomena of resources and advancement technologically. Optimization techniques applied in this context are discussed in the next section.

II. OPTIMIZATION METHODS

This section discusses various multi-criteria decision-making (MCDM) optimization techniques in modelling and analyzing the SDGs agenda 2030 studied by several authors in different countries. The following section reviews those related to classical goal programming.

A. Classical Goal Programming

Most real-life decision-making problems involve multiple objectives; thus, a single solution is not possible to optimally satisfy all the goals or the objective since they could be conflicting. GP is identified as one of the multiple objective optimization techniques capable of addressing multi-criteria multi-objective problems. It is the model generalization of linear programming used for solving decision-making problems. The GP formulation appeared first in the literature in the early 60s [2]. Decision-makers (DMs) often set an aspiration of their targets with the hope of achieving them under certain conditions. Naturally, it is seldom to achieve the goals perfectly as required due to unforeseen circumstances; some goals can be over-achieved, and others can be under-achieved. The classical GP uses to minimize the unwanted deviations involved in the GP model function. A typical classical GP model is given as

$$Min\ Z = \sum_{i=1}^{p} \delta_i^+ + \delta_i^-$$

$$subject\ to:$$

$$\begin{cases} f_i(x) + \delta_i^- - \delta_i^+ = g_i, & i = 1,2,3,\dots,p \\ x \in h_s(x) \le 0, & s = 1,2,3,\dots,m \\ \delta_i^-, \delta_i^+ \ge 0, & i = 1,2,\dots,p \end{cases} \quad (1)$$

Here, $\delta_i^+\ and\ \delta_i^-$ are the positive (over-achievement) and negative deviations (under-achievement) concerning aspirational level gi. In (1), both the xis and the gis are precise and deterministic. Therefore, the need for over-achievement and under-achievement does not arise. In realistic situations, this modelling system is hard to apply, especially when some of the input parameters are stochastic and not precise. A more suitable model under a probabilistic environment is the Stochastic GP Model (SGPM). The model, according to [3], is written as:

B. Stochastic Goal Programming

$$Min\ Z = \sum_{i=1}^{p} w_i^+ \widetilde{\delta_i^+} + w_i^- \widetilde{\delta_i^-}$$

$$subject\ to:$$

$$\begin{cases} f_i(x) + \widetilde{\delta_i^-} - \widetilde{\delta_i^+} = \widetilde{g_i}, & i = 1,2,3,\dots,p \\ x \in h_s(x) \le 0, & s = 1,2,3,\dots,m \\ \widetilde{\delta_i^-},\ \widetilde{\delta_i^+} \ge 0, & i = 1,2,\dots,p \end{cases} \quad (2)$$

here $\tilde{g}_i$ are normally distributed with expectation μ_i and variance σ_i^2 i.e $N(\mu_i;\ \sigma_i^2)$. It is difficult to model under imprecise information. Transforming model (II-B) to deterministic due to uncertainty to take care of this problem, it was documented in [4] as follows:

C. Modified Stochastic Goal Programming

$$Min\ Z = \sum_{i=1}^{p} w_i^+ \widetilde{\delta_i^+}(\omega_j) + w_i^- \widetilde{\delta_i^-}(\omega_j)$$

$$subject\ to:$$

$$\begin{cases} f_i(x(\omega_j),\omega_j) + \widetilde{\delta_i^-} - \widetilde{\delta_i^+} = g_i(\omega_j), & i = 1,2,3,\dots,p \\ x \in h_s(x) \le 0, & s = 1,2,3,\dots,m \\ \widetilde{\delta_i^-}(\omega_j) \ge 0, & i = 1,2,\dots,p \end{cases} \quad (3)$$

where $\omega_{j's}$ are discrete events and $\sum_{j=1}^{s} p_j = 1$ the probabilities. Equation (3) is known as SGPM with scenario-based philosophy.

D. Lexicographic Goal Programming

In lexicographic GP, the objectives or goals are ranked in order of importance by the DM, this can be done by ordering the deviations (unwanted) into different levels of priority. Minimizing the higher priority level deviations infinitely is more important than any lower priority level deviations. The objectives are divided into different calsses of priority, and no two goals will be having equal priority. Ordinal ranking are assign to the goals and known as the pre-emptive factors. The priority relationships implies that multiplying goals by n, however large it could be, the lower level goal can not assumed the higher goal i.e $P_i > P_{i+1}$. Mathematically, the model can be stated as:

$$Min\ Z = \sum_{i=1}^{m} P_i \left(\delta_i^+ + \delta_i^-\right)$$

$$subject\ to:$$

$$\begin{cases} \sum_{j=1}^{n} a_{ij}x_j + \delta_i^- - \delta_i^+ - b_i, i = 1,2,3,...,m \\ \sum_{j=1}^{n} a_{ij}x_j \left(\le,=,\ge\right) b_i, \quad i = m+1, m+2,...,m+p \\ \delta_i^-, \delta_i^+, x_j \ge 0, \quad i = 1,2,...,m,\ j = 1,2,...,n \end{cases} \quad (4)$$

Where m is the number of goals, P the system constraints, k the priority levels and n the decision variables. P_i is the preemptive priority factors of the i^{th} goal.

E. Polynomial Goal Programming

Polynomial goal programming (PGP) is a GP variant applied in finance and portfolio management extensively in the literature. The model initially developed to analyze and determine the mean-variance-skewness of the DMs preferences of portfolio frontiers [7]. The PGP model is given as follows:

$$\begin{aligned} & Min\ Z = \delta_1^{p_1} + \delta_2^{p_2} \\ & \sum_{j=1}^{n} x_j E_j + \delta_1 = E^* \\ & \sum_{j=1}^{n} x_j \left(r_j - E_j\right)^3 + \delta_2 = S^* \\ & \sum_{j=1}^{n} \sum_{k=1}^{n} x_j x_k \sigma_{ij} = 1 \\ & \sum_{j=1}^{n} x_j = 1, \\ & x \in F \\ & \delta_1,\ \delta_2 \ge 0 \end{aligned} \quad (5)$$

where, δ_1 and δ_2 are deviations from the goals and p_1 and p_2 are parameters describing different preferences of portfolio combinations. $\boldsymbol{E}$ is the expected returns and $\boldsymbol{S}$ the skewness criteria. The differences between the corresponding goals and achievement levels of $\boldsymbol{E}$ and $\boldsymbol{S}$ explained by the first two constraints.

F. Weighted Goal Programming

In WGP, the deviations from the targeted objectives are assigned weights associated to each of the goal, where by the total weights must sum to a unity. Its simple model formulation is given as

$$Min\ Z = \sum_{i=1}^{p} w_i^+ \delta_i^+ + w_i^- \delta_i^-$$

$$\begin{cases} f_i\left(x\right) + \delta_i^- - \delta_i^+ = g_i, \quad i = 1,2,3,...,p \\ x \in F, \\ \delta_i^-, \delta_i^+ \ge 0, \quad i = 1,2,3,...,p \end{cases} \quad (6)$$

where $w_i^+;\ w_i^-$ are the deviational weights.

G. Fuzzy Goal Programming

Fuzzy GP is applied on the fuzzy set theory concept. Fuzzy sets deals with imprecise goals of a decision-maker. Some decisions happen under uncertainties and vagueness. The concept of imprecision in modelling real-life problems can be traced from the work of Zadeh [5]. Zimmermann [6] is first to proposed fuzzy programming appraoch in solving multiple objective problems. An FGP model is generally given as:

$$\begin{aligned} & Find\ X = \left(x_1, x_2, ..., x_n\right) \\ & such\ that \\ & F_k\left(X\right)\left(\succeq, \approx, \preceq\right) g_k, \quad k = 1,2,3,...,k \\ & AX \le b_i, \quad i = 1,2,3,...,m, \\ & X \ge 0, \end{aligned} \quad (7)$$

Here, the vector of goals is represented by g_k; that of resources by b_i; and that of the decision variables' coefficient by A. The symbol _ represent maximization type of $F_k(X)$; The symbols $\leq$ is for fuzzy minimization type and $\cong$ for fuzzy-equality type. F_k stands for the kth fuzzy objective and X stands for the decision variables vector in n-dimension.

The membership relation for fuzzy-minimization type is given as

$$\mu_k\left(F_k(X)\right) = \begin{cases} 1, & if\ F_k(X) \ge g_k, \\ \dfrac{U_k - F_k(X)}{g_k - L_k}, & if\ L_k \le F_k(X) \le g_k, \\ o, & if\ F_k(X) \le L_k, \end{cases} \quad (8)$$

The membership relation for fuzzy-max type is given as

$$\mu_k F_k^{\min}(x) = \begin{cases} 1, & if\ F_k(X) \geq g_{k,} \\ \dfrac{U_k - F_k(X)}{U_k - g_k}, & if\ g_k \leq F_k(X) \leq U_{k,} \\ o, & if\ F_k(X) \leq U_{k,} \end{cases} \quad (9)$$

The linear-membership function for the fuzzy-equality type is given by

$$\mu F_k(X) = \begin{cases} 0, & if\ F_k(X) \leq L_{k,} \\ \dfrac{F_k(X) - L_k}{g_k - L_k}, & if\ L_k \leq F_k(X) \leq g_{k,} \\ \dfrac{U_k - F_k(X)}{U_k - g_k}, & if\ g_k \leq F_k(X) \leq U_{k,} \\ o, & if\ F_k(X) \leq U_{k,} \end{cases} \quad (10)$$

where the upper limit is represented by Uk and the lower limit by L_k, and the aspiration levels by g_k for k^{th} goal as given by the DM.

H. Weighted Fuzzy Foal Programming

The weighted fuzzy goal programming (WFGP) is useful in comparing two or more objectives values by the DM. The ultimate goal is solving several conflicting objectives simultaneously considering the DM's priority. The WFGP model with k fuzzy-goals is given by

$$Maximize \sum_{k=1}^{k} \mu_k w_k$$

$$Subject\,to:$$

$$\mu F_k(X) = \begin{cases} \mu_k \leq \dfrac{F_k(x) - l_k}{g_k - l_k}, & if\ F_k(x) \geq g_k \\ \mu_k \leq \dfrac{U_k - F_x(x)}{U_k - g_k}, & if\ F_k(x) \leq g_{k,} \\ \mu_k \leq \dfrac{b_i + T * b_i - \sum_{i=1}^{m} a_{ij} x_j}{T * b_i}, & if \sum_{i=1}^{m} a_{ij} x_j \geq b_i \\ \mu_k \leq \dfrac{\sum_{i=1}^{m} a_{ij} x_j - b_i + T * b_i}{T * b_i}, & if \sum_{i=1}^{m} a_{ij} x_j \leq b_i \\ x_{ij} \geq 0, & j = 1, 2, 3, \ldots, n \\ \mu_k \geq 0, & \forall k. \end{cases} \quad (11)$$

here w_k is a relative weight assign to various objective, and $\sum_{k=1}^{K} w_k = 1$.

I. Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is one of the subjective structured techniques for ranking a multiple-goals decision making problem; it can be useful to rank sets of alternatives with DMs preferences among the alternatives, using a ratio scale numbered as $1, 2, \ldots, n$ points. It forms a pair-wise matrix of comparision. the Model is given thus:

$$N^{norm} = M_{ij},$$

$$M_{ij} = \frac{X_{ij}}{\sum_{j=1}^{n} X_{ij}}, \qquad \forall j = 1, 2, \ldots, n \qquad (12)$$

$$w_i = \frac{\sum_{j=1}^{n} M_{ij}}{n}, \qquad \forall i = 1, 2, \ldots, n \qquad (13)$$

Where N^{norm} is the normnalized matrix, w_i the weight of the entries and X_{ij} the element of the respective matrices.

J. Combined Compromise Solution Method

The combination of the weighted sum with exponential weighted product methods are referred to Combined Compromise Solution Method (CoCoSo). The method was initially integrated to solve MCDM problem [8]. The models are given below:

$$P_i = \sum_{j=1}^{n} s_{ij}^{wj}$$

$$Q_i = \sum_{j=1}^{n} s_{ij} w_j \qquad (14)$$

where P_i and Q_i are the sum of the power-weighted and weighted comparability of alternative i sequences, w_j is the j^{th} criteria weight, s_{ij} is the normalized ratings of alternative i in respect of criteria j, and it can be computed as follows:

$$x_{ij} = \begin{cases} \dfrac{q_{ij} \min_i q_{ij}}{\max_i q_{ij} - \min_i q_{ij}}, & for\,benefit\,criteria \\ \dfrac{\max_i q_{ij} - q_{ij}}{\max_i q_{ij} - \min_i q_{ij}}, & for\ \cos t\,criteria \end{cases} \qquad (15)$$

In Eqn. (15), q_{ij} is the rating of alternative i in respect of criteria j. The CoCoS uses relative performance score R_i for alternative ranking purposes and is given as

$$R_i = \frac{1}{3}\left(R_{ia} + R_{ib} + R_{ic}\right) + \left(R_{ia}.R_{ib}.R_{ic}\right)^{1/3}$$
$$with$$
$$R_{ia} = \frac{P_i + Q_i}{\sum_{i=1}^{m}\left(P_i + Q_i\right)},$$
$$R_{ib} = \frac{P_i}{\min_i P_i} + \frac{Q_i}{\min_i Q_i}$$
$$R_{ic} = \frac{\lambda Q_i + (1-\lambda)P_i}{\lambda \max_i Q_i + (1-\lambda)\max_i P_i}$$

The coefficient $\lambda \epsilon [0, 1]$ and usually set to 0.5.

K. Entropy Method

Entropy method is one of the techniques useful for determination of the criteria weights of an objective value just like AHP. It is simple model is given as

$$w_j = \frac{1 - y_j}{\sum_{j=i}^{n}\left(1 - y_j\right)}$$
$$y_j = \frac{1}{\ln(m)}\sum_{i=1}^{m} r_{ij}\ln(r_{ij}) \qquad (16)$$

Here, r_{ij} is the normalized ratings of alternative i relative to criteria j, n is number of criteria, and m number of objects to be evaluated.

III. APPLICATIONS OF THE TECHNIQUES IN SDGS

The above-discussed optimization models for MCDM has been used extensively by several authors in different countries since the announcement of SDGs agenda 2030 during the adoption in 2015 by the UN general assembly. For instance, in 2015, a classical GP described in Sec. (II) has been used to analyze the socio-economic of the United Arabs Emirates (UAE) with emphasis on workforce optimization. Goals related to the UAEs energy, environment and employment are models mathematically for the SDGs' sustainable achievements. A similar study conducted using stochastic, modified stochastic, polynomial, weighted, and lexicographic goal programming approaches in the UAEs [9]-[14].

In 2017 and 2018, nine of India's economy contributing sectors considered under the SDGs vision 2030 and a framework based on linear programming model formulated and solved using fuzzy goal programming concept [15], [16], [19]. The study extended to consider three broad economic sectors, viz the primary, secondary and tertiary and mathematical programming based on FGP and WFGP employed in the solution [18]. Recently, a multi-objective optimization modelling of the SDGs in the context of Nigeria have been studied [17]. The research uses FGP, WFGP and incorporated AHP in determining the goals weight. It further analyzed the SDGs achievement targets and suggested some viable recommendation for the policy-makers to implement.

Most recently, the CoCoSo and Shannon Entropy methods are used in assessing the SDGs achievement level of the European Union (EU) countries [20]. The study reveals Sweden as the best country relative to other EU countries in terms of SDGs implementation and outputs, and Romania appeared to be the last position. AHP has been used in ranking renewable energy alternatives in light of SDG 7 and weight assessment for SDGs indicators in Jordan [21]- [23]. TOPSIS and data envelopment analysis (DEA) used to generate performance efficiency of the SDGs indicators as well as the relative ranking of its weights [24]. The SDGs in the 28 EU countries studied and ranked using the TOPSIS and VIKOR methods [25].

IV. CONCLUSION

Achieving sustainable development goals remain the aspiration of all UN member countries. This article reviewed some well-known MCDM techniques applied in modelling and optimizing the SDGs of different nations. The reported studies conducted in Africa, Asia, UAEs and the EU. This study discovered that GP and its variants are the most used optimization techniques in SDGs, followed by AHP, TOPSIS and VIKOR methods and their extension under a fuzzy environment. Other methods include DEA, CoCoSo, Shannon entropy, and TPOSIS-VIKOR. This study is the first, to the best of the authors' knowledge, in reviewing only the optimization techniques applied in analyzing SDGs globally. As such, the uniqueness of the study is apparent.

REFERENCES

[1] United Nations: Department of Economics and Social Affairs. Sustainable Development. Accessed on 2021 Mar 28: at https://sdgs.un.org/goals.

[2] A. Charnes, W. Cooper. ”Chance constraints and normal deviates”. J. Amer stat. Ass.. 1962 Mar 1;57(297):134-48.

[3] B. Contini. ”A stochastic approach to goal programming”. Oper Res 1968; 16(3):576–586.

[4] B. Aouni, F. Ben Abdelaziz, D. La Torre. ”The stochastic goal programming model: theory and applications”. Journal of Mult-Crt Dec Anly. 2012 Sep;19(5-6):185-200.

[5] L. A. Zadeh. ”Fuzzy sets”. Infor. and contr, 1965, 8(3), 338-353.

[6] H.J. Zimmermann. ”Fuzzy programming and linear programming with several objective functions”. Fuzzy sets and sys.. 1978 Jan 1;1(1):45-55.

[7] T.Y. Lai, “Portfolio selection with skewness: A multi-objective approach. Review of Quantitative Finance and Accounting”, 1991, 1(3), pp. 293-305.

[8] M. Yazdani, P. Zarate, E.K. Zavadskas, Z. Turskis. ”A Combined Compromise Solution (CoCoSo) method for multi-criteria decisionmaking problems”. Manag. Decis. 2019 Oct 15: 57, 2501–2519.

[9] R. Jayaraman, D. La Torre, T. Malik, Y.E. Pearson. ”A polynomial goal programming model with application to energy consumption and emissions in United Arab Emirates.” In 2015 International Conference on Industrial Engineering and Operations Management (IEOM) 2015 Mar 3 (pp. 1-6). IEEE.

[10] R. Jayaraman, D. La Torre, T. Malik, Y.E. Pearson. ”Optimal work force allocation for energy, economic and environmental sustainability in the United Arab Emirates: A goal programming approach”. Engy proc. 2015 Aug 1;75:2999-3006.

[11] R. Jayaraman, C. Colapinto, D. La Torre, T. Malik. ”Multi-criteria model for sustainable development using goal programming applied to the United Arab Emirates”. Engy Pol. 2015 Dec 1;87:447-54.

[12] R. Jayaraman, D. Liuzzi, C. Colapinto, D. La Torre. ”A goal programming model with satisfaction function for long- run sustainability in the United Arab Emirates”. In 2015 IEEE international conference on industrial engineering and engineering management (IEEM) 2015 Dec 6 (pp. 249-253). IEEE.

[13] R. Jayaraman, C. Colapinto, D. Liuzzi, D. La Torre. ”Planning sustainable development through a scenario-based stochastic goal programming model”. Oprnl Res.. 2017 Oct;17(3):789-805.

[14] F. Guijarro, J.A. Poyatos. ”Designing a sustainable development goal index through a goal programming model: The Case of EU-28 Countries”. Sustai. 2018 Sep;10(9):3167.

[15] M. A. Nomani, I. Ali, A. F¨ugenschuh, A. Ahmed. ”A fuzzy goal programming approach to analyse sustainable development goals of India”. Appl Econ Lett.. 2017 Apr 16;24(7):443-7.

[16] S. Gupta, A. F¨ugenschuh, I. Ali. ”A multi- criteria goal programming model to analyze the sustainable goals of India”. Sustain. 2018 Mar;10(3):778.

[17] U. M. Modibbo, I. Ali, A. Ahmed. ”Multi-objective optimization modelling for analysing sustainable development goals of Nigeria: Agenda 2030”. Envron Dev Sustain 2020 Oct 6:1-35 https://doi.org/10.1007/s10668-020-01022-3.

[18] I. Ali, U.M. Modibbo, J. Chauhan, M. Meraj. ”An integrated multiobjective optimization modelling for sustainable development goals of India. Envron, Dev & Sustain. 2021 Mar;23(3):3811-31.

[19] S.M. Muneeb, M. Nomani, Z. Asim, A. Adhami. ”Assessing and optimizing decision-making policies of India with public employment growth as a key indicator toward sustainable development goals using multicriteria mathematical modeling”. J. of Pub. Aff.:e2635.

[20] D. Stanujkic, G. Popovic, EK. Zavadskas, D. Karabasevic, A. Binkyte-Veliene. ”Assessment of Progress towards Achieving Sustainable Development Goals of the “Agenda 2030” by Using the CoCoSo and the Shannon Entropy Methods: The Case of the EU Countries”. Susty.. 2020 Jan;12(14):5717.

[21] G. B¨uy¨uk¨ozkan, Y. Karabulut, E. Mukul. ”A novel renewable energy selection model for United Nations’ sustainable development goals”. Energy. 2018 Dec 15;165:290-302.

[22] R. Alawneh, F. Ghazali, H. Ali, AF. Sadullah. ”A Novel framework for integrating United Nations Sustainable Development Goals into sustainable non-residential building assessment and management in Jordan”. Sustainable Cities and Society. 2019 Aug 1; 49:101612.

[23] R. de Castro Vivas, A.M. Sant’Anna, K.P. Esquerre, F.G. Freires. ”Integrated method combining analytical and mathematical models for the evaluation and optimization of sustainable supply chains: A Brazilian case study”. Computers & Industrial Engineering. 2020 Jan 1;139:105670.

[24] I.H. Osman, F. Zablith. ”Re-evaluating electronic government development index to monitor the transformation toward achieving sustainable development goals”. J. of Bus Res.. 2020 Oct 23.

[25] P. Mateusz, M. Danuta, Ł. Małgorzata, B. Mariusz, N. Kesra. TOPSIS and VIKOR methods in study of sustainable development in the EU countries. Proc. Comp Sci. 2018 Jan 1;126:1683-92.