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A Multi-Criteria Model for Sustainable Development Goals Using Fuzzy Goal Programming-Application for Egypt

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Abstract:
This article proposes fuzzy goal programming model that combines optimal resource allocation with prospective goals for economic development, electricity consumption, employment, and greenhouse gas emission reduction in Egypt's primary economic sectors.
The presented model analyses the prospects for improvement, the effort required, and the implementation of sustainable development strategies. The model also offers valuable insights to decision makers for both strategic planning and investment allocations towards sustainable development. We validate the model by applying it to Egypt's important economic sectors to meet the country's 2030 sustainable development goals.

Keywords: Sustainable Development, Goal Programming, Multi Criteria Decision Making, Fuzzy Goal Programming, Membership function.

1 Introduction

Sustainable development (SD) is defined as development that meets current demands without jeopardizing future generations' ability to meet their own needs. The United Nations General Assembly in September 2015 formally adopted 17 Sustainable Development Goals (SDG)[1]. Planning for sustainable development requires integrating conflicting criteria on economics, energy, environment and social aspects. The main objective of the United Nations is to achieve these goals in every sector by 2030. Sustainable development practices help countries grow in ways that are adaptive to the challenges posed by climate change, which in turn help protect the natural resources important to our future generations [1].

With a population of approximately 104 million people, Egypt is the most populous Arab country. Its per capita gross domestic product (GDP) is estimated at $3,740. Egypt is a low-middle-income country, with poverty rates of 32.5%[2]. Between 1993 and 2019, Egypt's average unemployment rate was at 10.75 percent, with the highest rate of 13.40 percent

[1] https://www.un.org/sustainabledevelopment/
[2] https://www.capmas.gov.eg/

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in the third quarter of 2013, and the lowest rate of 7.50 percent in the second quarter of 2019.[345]
Energy consumption is deemed sustainable if it meets current demands without jeopardizing future generations' needs. Some neighboring countries' average per capita electrical energy consumption is ten times that of Egypt [2]. Electricity usage per capita is expected to peak in 2020. More than 750 million people do not have access to electricity, and over 2.6 billion people cook using harmful fuels like wood or coal.[6]

Reducing greenhouse gas emissions to levels consistent with the Paris Agreement will necessitate a system-wide transformation in energy production, distribution, storage, and consumption. The sustainable energy system is likely to see a shift towards using more electricity in sectors such as transportation and heating, energy conservation, and the use of hydrogen produced from low-emission energy sources. Resource planning problems often involve economic, environmental and social objectives that are in conflict with one another. There is an intimate connection between energy, environment, and sustainable development, as Dincer and Rosen [3] point out. Goal programming (GP) techniques have been used to apply multi-criteria decision models to a variety of energy planning, energy resource allocation, building energy management, transportation energy management, and energy project planning [4,5]. The importance of sustainable consumption and production in the SDGs was examined by Akenji et al [6], as well as how sustainable consumption and production objectives could be expressed efficiently in this evolving global policy framework. Han et al [7] proposed a multi-objective optimization model for determining viable technologies for producing electricity and treating CO_2 with the goal of maximizing predicted revenues while minimizing financial risk. San Cristóbal [8] looked at how GHG emission targets can be met and how they affect the mix of manufacturing activity in Spain, using a GP model to minimize GHG emissions, waste emissions, energy requirements, and maximize employment and output levels across important economic sectors. Flores et al. [9] proposed a mathematical programming methodology for energy investment planning.

In order to maximize the Net Present Value over time, the model incorporates renewable and non-renewable demands, new energy facility sources, and the present amount of fossil-fuel reserves. Gupta et al. [10] created a fuzzy goal programming model that allocates resources optimally by accomplishing future goals in terms of gross domestic product, electricity consumption (EC), and greenhouse gas emissions. Chang [11] used a goal programming approach to identify the key CO_2 generating industries in order to optimize production structure in order to meet China's emission reduction targets. Schult et al. [12] proposed mixed integer linear programming methods for solving large-scale input–output systems that represent an optimal allocation of global resources for a more sustainable global economy. Pal et al. [13] propose a linear GP approach for dealing with interval data uncertainty in thermal power generation and dispatch challenges. Balaman and Selim [14,15] use multiple fuzzy goal programming (FGP) methodologies to solve their model, which is a multi-objective optimization problem of biomass to energy supply chains in an uncertain environment. In the United Arab Emirates, Jayaraman et al. [16,17] created a mathematical model that incorporates optimal resource allocation to simultaneously achieve anticipated goals on economic development, energy consumption, workforce, and GHG emission reduction.

2 Methodology and Case Study

In this section, we presented a multi-criteria fuzzy goal programming model that combines optimal resource allocation with projected goals for economic development, EC, workforce, and Green House Gases emission reduction by 2030, as applied to Egypt's important economic sectors.

2.1 Multi-Criteria Fuzzy Goal Programming Formulation

Making decisions in the face of several, frequently contradictory and incommensurable factors is referred to as multi-criteria decision making (MCDM). Goal programming is a popular MCDM technique based on the distance function notion, in which the decision-maker (DM) seeks out the solution that reduces the absolute deviation between the objective's achievement level and its aspiration level. It was first used in the context of executive compensation by (Charnes et al, 1955) [18]. The phrase 'goal programming' was not in use at the time, and the paradigm was viewed as a linear programming adaption. (Charnes and Cooper, 1961) [19] provide a more formal framework of goal programming.

[3] https://www.worldbank.org/en/country/egypt/publication/economic-update-october-2019.
[4] https://web.archive.org/web/20200114010248/https://tradingeconomics.com/egypt/unemployment-rate?embed
[5] https://web.archive.org/web/20190619035125/https://www.ceicdata.com/en/indicator/egypt/unemployment-rate
[6] https://www.iisd.org/about-iisd/sustainable-development

The technique was further developed by (Ijiri, 1965) [20], and seminal textbooks by (Lee, 1972) [21] and (Ignizio, 1976) [22] popularized it as an operational research tool.

GP is a multi-objective optimization problem that balances a trade-off between conflicting purposes. It is an extension of linear programming that can handle multiple objectives. It's also used to undertake three different types of analysis:

- Determine the degree to which the goals may be met with the resources available.
- Determine the resources needed to achieve a specific set of goals.
- Providing the most satisfactory solution under a variety of resource constraints and goal priorities.

The GP model is a powerful and versatile decision-making technique that has been applied to a wide range of decision-making problems involving multiple objectives, including economics, accounting, engineering, agriculture, marketing, transportation, finance, and other types of competing situations.

2.2 Mathematical formula for goal programming:

As we mentioned, the purpose of GP is to reduce the gap between goal achievement and expectations., say $Z_i(x)$, $X = (x_1, x_2, ..., x_k)$, and these acceptable aspiration levels, $g_i(i = 1, 2, ..., K)$. Therefore, GP can be expressed as follows:

$$\text{Minimize} \sum_{i=1}^{k} |Z_i(x) - g_i| \tag{1}$$

$$\text{Subject to: } x \approx X = \{X \in \mathbb{R}^n;\ AX \leq b;\ x \geq 0\} \tag{2}$$

Where Z_i is linear function of the i^{th} goal and is the aspiration level of th goal.

$$Z_i(x) - g_i = d_i^+ - d_i^-; d_i^+, d_i^- \geq 0 \tag{3}$$

Here, is the total number of goals, is the right-hand side of the constraint coefficient, is the kth objective and is the aspiration level of the kth goal. Equation (1) can be formulated as follows:

$$\text{Minimize} \sum_{i=1}^{k} |d_i^+ - d_i^-|]$$

$$\text{Subject to: } Z_i(x) - d_i^+ + d_i^- - g_i = 0;\quad i = 1, 2, \ldots, k$$

$$x \in X = \{x \in \mathbb{R}^n; AX \leq b;\ x \geq 0\}$$

Where d_i^+ , $d_i^- \geq 0$ are, respectively under and over deviations of $i^t h$ goal.

Any optimization model that represents real-world situations includes a lot of parameters whose values are assigned through expert opinion, and in the traditional approach, they are required to specify an accurate value for the parameters. However, both the experts and the decision-maker often do not know the value of those criteria with precision. If exact values are suggested, they are merely statistical inferences based on previous data, and their stability is questionable, hence the problem's parameters are typically determined by the decision maker in an uncertain area. As a result, the knowledge of experts' opinions on the parameters is beneficial as fuzzy data that aids the decision maker in an open-ended area. Because the market is dynamic, determining the best decision criteria is tough; nevertheless, fuzzy linked data can assist in determining the best answer. This makes us resort to fuzzy numbers which deal with uncertain information [23,24]. Aspiration levels are considered exact, predictable, and well-known in GP formulations. However, the parameters in some decision-making (DM) scenarios can be hazy, imprecise, or unpredictable. In fact, there are many decision-making circumstances in which the DM lacks comprehensive information on some parameters, particularly the GP model's target values. (Narasimhan, 1980) [25] presented a FGP formulation based on the concept of membership functions to cope with such a circumstance. The interval [0, 1] is used to define these functions. When the ith goal is achieved and the decision multi criterion is completely satisfied, the membership function for that goal has a value of 1; otherwise, the membership function has a value between 0 and 1. Fuzzy goal programming is an extension of traditional goal programming that is used to handle decision issues involving many objectives in an uncertain environment. A general mathematical model of the fuzzy goal programming model can be stated as:

$$\begin{aligned} Z_i(X) &\geq g_i, \quad i = 1,\ 2,\ \ldots,\ K_0 \\ Z_i(X) &\leq g_i, \quad i = K_0 + 1,\ 2,\ \ldots,\ K_1 \\ Z_i(X) &\cong g_i, \quad i = K_1 + 1,\ 2,\ \ldots,\ K_2 \\ \text{Subject to: } x &\in X \quad = \{X \in \mathbb{R}^n;\ AX \leq b;\ x \geq 0\} \end{aligned}$$

where X is *a nn* dimensional decision vector. The symbol $\geq$ (the type of fuzzy-max) referring to that Z_i should be approximately greater than or equal to the aspiration level g_i signifies that the decision-maker is satisfied even if less than g_k up to a certain limit. The symbol $\leq$ (the type of fuzzy-min) referring to that $Z_i\ x$ should be approximately less than or equal to the aspiration level g_i up to a certain tolerance limit. The symbol $\approx$ (the type of fuzzy-equal) referring to that $Z_i(X)$ should be in the vicinity of the aspiration g_i signifies that the decision-maker is satisfied even if greater than (or less than) g_i up to a certain limit. For fuzzy-min, the membership function is defined as:

$$\mu Z_i(X) = \begin{cases} 1 & ; \quad if\ Z_i(x) \leq g_i \\ \dfrac{U_i - Z_i(x)}{U_i - g_i} & ; if\ g_i \leq Z_i(x) \leq U_i\,, \quad i = K_0+1,\ 2,\ \ldots K_1 \\ 0 & ; \quad if\ Z_i(x) \geq U_i \end{cases}$$

Where U_i is the upper tolerance limit.

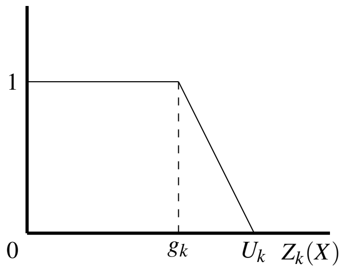

Fig. 1: Linear membership function $Z_i\ x\ \leq\ g_i$

For fuzzy-max, the membership function is defined as:

$$\mu(Z_i(X)) = \begin{cases} 1 & ; \quad if\ Z_i(x) \geq g_i \\ \dfrac{Z_i(x) - L_i}{g_i - L_i} & ; if\ L_i\ \leq\ Z_i(x) \leq\ g_i\,, i\ = 1,\ 2,\ \ldots\ K_0 \\ 0 & ; \quad if\ Z_i(x) \leq\ L_i \end{cases}$$

Where L_i is the lower tolerance limit for the kth fuzzy goal $Z_i\ X$.

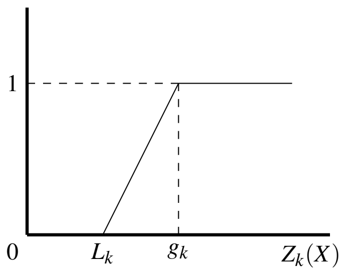

Fig. 2: Linear membership function $Z_i\ x\ \geq\ g_i$

In the case of the fuzzy goal of type $Z_i(X) \cong g_i$, i.e., fuzzy-equal, the membership function is defined as:

$$\mu(Z_i(X)) = \begin{cases} 0 & ; \quad if\ Z_i(x) \le L_i \\ \dfrac{Z_i(x)-L_i}{g_i-L_i} & ; if\ L_i \le Z_i(x) \le g_i \\ \dfrac{U_i-Z_i(x)}{U_i-g_i} & ; if\ g_i \le Z_i(x) \le U_i \\ 0 & ; \quad if\ Z_i(x) \ge U_i \end{cases} ,i = K_1+1,\ 2,\ \ldots\ K_2$$

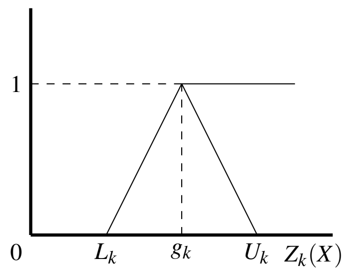

Fig. 3: Linear membership function $Z_i\ x \approx g_i$

A fuzzy constraint is a subset of X characterized by its membership function $\mu_A(x) : X \to 0,1$. The linear membership function for the fuzzy constraint is given by:

$$\mu_A(x) = \begin{cases} 1 & ; \quad if\ AX \ge b_i \\ \dfrac{(b_i+tol*b_i)-AX}{tol*b_i} & ; if\ b_i \le AX \le b_i+tol*b_i \\ 0 & ; \quad if\ b_i+tol*b_i \le AX \end{cases}$$

Here, tol is the tolerance interval. Using these definitions, the fuzzy goal programming model can be written as:

Find $x \approx X$
So as to Maximize λ
Subject to:

$$\lambda \le \frac{Z_i(x)-L_i}{g_i-L_i} \quad ;if\ Z_i(x) \ge g_i$$
$$\lambda \le \frac{U_i-Z_i(x)}{U_i-g_i} \quad ;if\ Z_i(x) \le g_i$$
$$\lambda \le \frac{(b_i+tol*b_i)-AX}{tol*b_i} \quad ;if\ b_i \le AX \le b_i+tol*b_i$$
$$x \in X = \{x \in \mathbb{R}^n; AX \le b;\ x \ge 0\}$$
$$\lambda \ge 0$$

2.3 Egypt's Sustainable Development: A Case Study

Egypt has the largest population density in the Arab world and one of the largest economies in it. While the economy was centralized and led by the state during the era (1956-1973), reforms in the nineties of the twentieth century aimed to reduce the state's role in the economy, and to adopt principles market-oriented economy, and Egypt's integration into the global economy. Between 2000 and 2010, per capita GDP grew from about $7,400 to $9,800, or about 3 percent annually, while the (Gini index) for Egypt, a measure of inequality, remained consistently low [26]. Egypt has succeeded in achieving most of the Millennium Development Goals, a set of eight global goals that ran from 2000 to 2015, and ranged from country requirements to halve extreme poverty to reduce the spread of HIV/AIDS and achieve universal primary education. According to the Millennium Development Goals (UNDESA, 2017a), Egypt reduced extreme poverty (population living on less than $25.1 a day) by more than 62 percent between 1990 and 2008, and has succeeded in meeting targets within the framework of the first goal of the Millennium Development Goals. By 2010, the net primary education enrollment rate in Egypt was 97 percent. The under-five mortality rate decreased by more than 74 percent between 1990 and 2013. The tuberculosis mortality rate decreased by more than 81 percent. Clean water and sanitation extended to more than 95 percent of the population. Population However, some targets remained unmet, particularly those related to Millennium Development Goal 3, "Promote gender equality and empower women". The ratio of girls to boys in primary education has converged, but has not reached the target of gender parity by 2013. During the same time frame, the share of women working in the non-agricultural sector decreased by 9 percent, declining to about 19 percent in 2013 [26]. Egypt's population is expected to grow by nearly 24 percent, rising from 93.8 million in 2015 to 122.6 million by 2030. With this growth, the country will remain somewhat youth. In 2030, 30 percent of the population will be under 15 years of age and more than 60 percent will be of working age (from 15 to 64). The Egyptian economy is expected to grow by 5 to 6 percent annually over the projected horizon, with a gross domestic product of $571 billion by 2030. GDP increased from $10,250 in 2015 to $14,270 by 2030, or roughly the level of Brazil in 2018. This growth is expected to reduce poverty and expand the middle class. In 2030, less than ten million people will live in poverty (according to define the population living below the current national poverty line in Egypt, which is equivalent to less than $3.40 per day in 2011 (compared to 2015, while the middle-class population (those living on between $10 and $50 a day) is expected to increase to more than double by 2030. Egypt may also face economic challenges such as the informal economy, unemployment, and low participation of women in the labor force. It is expected to decline Informal employment as a percentage of the non-agricultural labor force increased from 47 percent today to 36 percent by 2030. An additional 2.5 million people are expected to work in the informal sector. Women's participation in work, which today stands at about 20 percent, is not expected to grow significantly. Human development, in terms of the health and education of the population, is projected to improve steadily. Educational attainment, as measured by the average Egyptian's years of schooling, increases from 7.1 years in 2015 (6.5 for women and 7.8 for men) to 8.5 years in 2030 (8 for women and 9 for men). Thus, even while educational attainment increases across the board, female attainment continues to lag behind. Life expectancy increases from 71.3 years to 74 by 2030. And the under-5 mortality rate falls from 22 deaths per 1,000 live births in 2015 to 14.7 by 2030.7.

2.4 Data Collection and Model Formulation

In this paper, we considered employment as a decision variable, which is very important for sustainable development. The following goals related to gross domestic product, electricity consumption and greenhouse gas emissions are among the main goals for achieving the Sustainable Development Goals which are essential for the successful operation of the modern economy.

Gross Domestic Product (GDP)
Sector wise GDP are published by Ministry of Planning and Economic Development - National Accounts Data and IMF.[78] In some cases the most updated entry was unavailable, and we used the estimated annual percentage growth rate of GDP based on constant growth in local currency. Table (1) presents the sector wise per capita estimates of GDP with reference to the year 2019.
Electricity Consumption (EC)
The per capita estimates for electricity consumption across the sectors in Giga watt hour (Gwh) are summarized in Table (1). The sectorial data for electricity consumption was obtained from Ministry of Electricity and Renewable Energy with reference to the year 2019.[9]
Green House Gases Emissions (GHG)
GHG emission data was obtained from the United Nations Framework Convention on Climate Change (UNFCCC)[10], Climate Watch[11] and CAIT with reference to year the 2018.[12] Table (1) summarizes the sector specific per capita GHG emissions in Giga Grams of CO_2 equivalent. To estimate the value of greenhouse gas emissions in 2030, we used the conclusion shown in the paper presented by (Lamia Abdullah, 2020)[13] which states "to reduce total emissions by 20% by 2030" due to the absence of a formally measured target that can be relied upon in estimating the value of GHG in 2030.

7 https://mped.gov.eg/Analytics?id=61
8 https://www.imf.org/en/Home
9 http://www.moee.gov.eg/english_new/home.aspx
10 https://unfccc.int/sites/default/files/resource/BUR%20Egypt%20%20AR.pdf
11 https://www.climatewatchdata.org/countries/EGY
12 http://cait.wri.org/historical/Country%20GHG%20Emissions
13 https://journals.ekb.eg/article_73503.html

Number of Employees (NE)
The number of employees across the economic sectors were obtained from International Labour Organization[14], Central Agency for Public Mobilization and Statistics.[15] and UNDP. Table (1) presents the number of employees (in thousands) employed in each sector. The annual growth percentage of labor was used to project the data with reference to year 2019. We have used the following law to find the number of employees in 2030 because there is no specific value in any source.

$$\textbf{Number of employees} = \textbf{labor force} * (1 - \textbf{unemployment rate})$$

Table 1: Sectoral contribution of economic sectors to the identified goals.

Decision variable	Economic Sectors (in million)	GDP (in Gwh)	EC (MT CO_2e)	GHG Emissions	Number of Employment (in thousand)
X_1	Agriculture, forestry and fishing	669783.5	542.0	30.58	5542.5
X_2	Manufacturing	942408.0	5871.0	*	3431.3
X_3	Construction	371457.5	9873.0	**	3310.5
X_4	Transport, storage	277865.2	46.0	53.88	2397.1

Note: GHG Emissions in manufacturing (*) and construction (**) together is 41.12

Table (2) presents the projected goal values for the year 2030 with the corresponding growth rates for the four criteria. The GDP growth rates were estimated based on data from Egypt Vision 2030 17. Electricity consumption growth rates across the four sectors were also estimated from Energy Strategy 2035. The number of employees were estimated based on CAPMS and UNDP and similarly GHG emissions were estimated based on the research paper introduced by (Lamia Abdullah, 2020) and UNFCCC. Also; we used the following rule to find the value of compound annual growth rate formula.

$$\textbf{Compound annual growth rate} = \text{ending valuebeginning value}^{\frac{1}{numberofyears}} - 1$$

2.5 Model Formulation

In our model, we make use of a formulation as a multi-objective integer linear programming model to determine the optimum allocation of employees across different economic activities to maintain GDP growth, EC and GHG emissions. The objectives are formulated as follows:

[14] https://www.ilo.org/shinyapps/bulkexplorer20/?lang=en&segment=indicator&id=EMP_2EMP_SEX_ECO_NB_A
[15] https://www.capmas.gov.eg/Pages/Publications.aspx?page_id=5104&Year=23620

Table 2: Identified Goals for SDGs (2030)

Goals	Value	Goals by 2030	Compound Annual Growth Rate
GDP (in million EGP)	5526954.7	8132519.0	3.57%
Electricity consumption (in Gwh)	16332.0	27123.0	4.72%
GHG Emissions ($MTCO_2e$)	125.58	200.0	3.95%
Number of Employment (in thousand)	14681.4	36080.0	8.52%

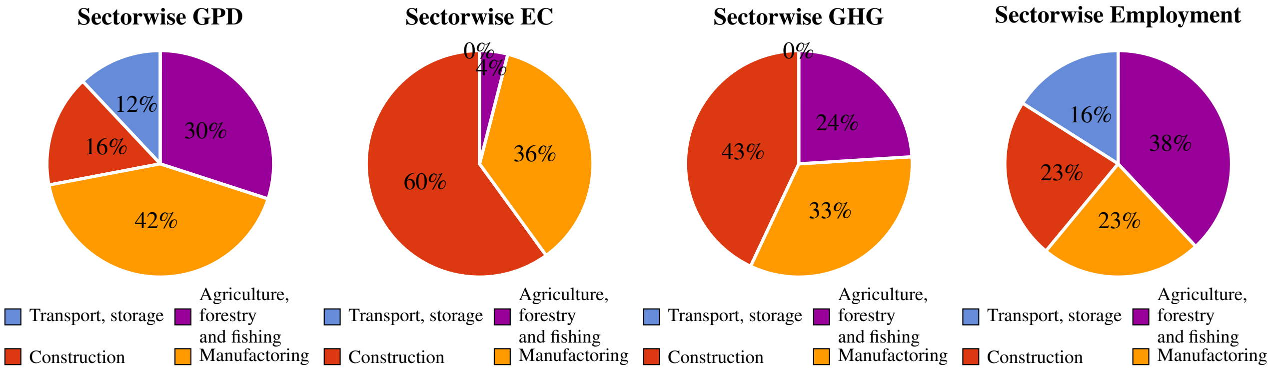

Fig. 4: Percentage contribution of the four chosen sectors

$$Z_1(X) = \sum_{j=1}^{4}(\frac{(GDP)_j}{e_j})x_j,$$
$$Z_2(X) = \sum_{j=1}^{4}(\frac{(EC)_j}{e_j})x_j,$$
$$Z_3(X) = \sum_{j=1}^{4}(\frac{(GHG)_j}{e_j})x_j,$$

Subject to:

$$\sum_{j=1}^{4} x_j \leq e_G$$
$$\sum_{j=1}^{4} (GDP)_j x_j \leq (GDP)_G$$
$$e_J \leq x_j \leq e_{GJ}, \forall\ j = 1,2,3,4$$

Here, the following symbols are used:

- •Objective function Z_1 optimizes the per-capita gross domestic product across the j_{th} economic sector.
- •Objective function Z_2 optimizes the per-capita gross electricity consumption across the j^{th} economic sector
- •Objective function Z_3 optimizes the per-capita greenhouse gas emissions across the j^{th} economic sector
- •x_j is the number of employees in the j^{th} contributing sectors.
- •e_j is the current employment in the j^{th} sector.
- •xe_G is the employment goal in the j^{th} sector.
- •GDP_j is the gross domestic product in the j^{th} sector.
- •EC_j is the electricity consumption in the j^{th} sector.
- •GHG_j is the GHG emissions in the j^{th} sector.

• GDP_j is the GDP goal for sustainable development.

The mathematical formulation for the model is as follows:

$$Z_1(X) = 120.8450158x_1 + 274.650424x_2 + 112.2058601x_3 + 115.9172333x_4 \geq 8150140.0$$
$$Z_2(X) = 0.09778981x_1 + 1.71101332x_2 + 2.98232865x_3 + 0.01918985x_4 \geq 39000.0$$
$$Z_3(X) = 5.5173658 * 10^3 x_1 + 6.099261325 * 10^3 x_2 + x_3 + 0.0224771599x_4 \geq 145.41$$

Subject to:

$$x_1 + x_2 + x_3 + x_4 \leq 36080.0$$
$$669783.5x_1 + 942408.0x_2 + 371457.5x_3 + 277865.2x_4 \leq 18954400.0$$

and the bounds:

$$x_1 \geq 5542.5, \quad x_2 \geq 3431.3$$
$$x_3 \geq 3431.3, \quad x_4 \geq 2397.1$$

The model formulated above cannot be solved directly. Therefore, the fuzzy goal programming approach must be used. Firstly; calculate the lower bound and upper tolerance limit of goals from the previous goal programming model.

Table 3: Lower & Upper tolerance limit of goals

	Lower bound	Upper bound
Z_1	2261514.0	8138649.0
Z_2	16332.0	80149.66
Z_3	125.5800	606.5598

Secondly; formulate the fuzzy goal programming approach using ($tol = 0.1$).

Max λ

Subject to:

$$
\begin{aligned}
&5888626.0\,\lambda \leq Z_1 - 22611514.0\\
&-11491.0\,\lambda \leq 8138649.0 - Z_1\\
&22668.0\,\lambda \leq Z_2 - 16332.0\\
&41149.66\,\lambda \leq 80149.66\,Z_2\\
&19.83\,\lambda \leq Z_3 - 125.5800\\
&461.1498\,\lambda \leq 606.5598\,Z_3\\
&3608.0\,\lambda \leq 39688.0 - (x_1 + x_2 + x_3 + x_4)\\
&1895440.0\,\lambda \leq 20849840.0 - (669783.5x_1 + 942408.0x_2 + 371457.5x_3 + 277865.2x_4)\\
&554.25\,\lambda \leq x_1 - 6096.75\\
&343.13\,\lambda \leq x_2 - 3774.43\\
&331.05\,\lambda \leq x_3 - 3641.55\\
&239.71\,\lambda \leq x_4 - 2636.81
\end{aligned}
$$

3 Results and Discussion

We apply the fuzzy goal programming approach presented in section 2 to the above model formulation. The numerical optimization software LINGO is used to solve the resulting optimization problem. Tables (4, 5) show the optimal compromise of objective values with optimal employment in several sectors.

Table 4: Optimal employment in different sectors.

Tol	λ	x_1	x_2	x_3	x_4
0.1	0.7897889	6534.491	19505.11	3903.010	2826.130
0.2	0.7675688	7501.850	18190.44	4480.807	3244.508
0.3	0.7458936	8445.485	16908.0	5044.434	3652.624
0.4	0.7247436	9366.257	15656.64	5594.405	4050.853
0.5	0.7040999	10264.99	14435.24	6131.211	4439.549
0.6	0.6839445	11142.46	13242.73	6655.319	4819.679
0.7	0.6642603	11999.41	12078.09	7167.174	5189.679
0.8	0.6450310	12836.57	10940.37	7667.200	5551.743
0.9	0.6262410	13654.60	9828.641	8155.804	5905.536
1.0	0.6057299	14442.26	8941.041	8626.269	6246.195

Table 5: Objective function values.

Tol	λ	Z_1	Z_2	Z_3
0.1	0.7897889	6912285.164	45706.80121	242.3487941
0.2	0.7675688	6781440.435	45283.19034	252.5956358
0.3	0.7458936	6653801.261	44869.94894	262.5910755
0.4	0.7247436	6529256.987	44466.73365	272.3444135
0.5	0.7040999	6407695.706	44073.17984	281.8643167
0.6	0.6839445	6289008.9	43688.93184	291.1589859
0.7	0.6642603	6173093.585	43140.23039	300.2362735
0.8	0.6450310	6059860.223	42947.05188	309.1038995
0.9	0.6262410	5949213.168	42588.88826	317.7689299
1.0	0.6057299	5892895.415	42556.77883	327.2275696

The goals related to projected economic growth, EC, and targeted GHG emission while preserving the total number of jobs by 2030 may not be achievable without additional efforts to diversify sources of electricity generation and investments in high-productivity sectors, according to the results of the presented model. Tables (4, 5) show the results. If the value of is between 0.79 and 0.60, we have achieved a 79 percent achievement level. However, in order to meet the aim perfectly by 2030, the value of must be one. As a result, the government should increase its efforts in each sector in order to meet the aim perfectly.

This model suggests that the achievement of the goal set for economic growth until the year 2030 will not be possible without any additional measures in every economic sector of the country.

3.1 Gross Domestic Product Growth

The above model suggests that the achievement of the goals set for GDP growth by year 2030 is not possible without some extraordinary efforts towards GDP growth. These efforts may include capital formation, and technological improvement. Working to expand the establishment of industrial zones in new cities, amending some regulations, laws regulating industrial activities, searching for procedures related to encouraging, integrating industrial activities for medium, and small enterprises into the formal economy. Such as activating granting incentives and exemptions for small, medium enterprises, and micro. Facilitating the provision of raw materials for industry, activating import control tools. A study of the localization of technical schools in major industrial complexes. Creating a sustainable knowledge-based economy is essential to help achieve the envisioned economic future.

3.2 Electricity Consumption

The model clearly demonstrates the necessity for extraordinary governmental steps to reduce electricity usage in order to meet the astronomically high demand. As a result, the model suggests that the objective of meeting energy demand by 2030 will not be met without extra measures to diversify electricity generation sources. Alternative and renewable energy sources are necessary to meet rising demand. This is in line with the current focus and efforts on increasing investments in clean and renewable energy sources to address growing energy issues. Furthermore, low power quality, frequent outages, and a lack of electricity place a significant burden on the fast-growing trade and industry. As a result, effective strategies to assist the state in producing electricity may be required.

3.3 GHG Emissions

The model also shows that lowering greenhouse gas emissions by 2030 without extra steps in each sector will be impossible. To meet the 2030 target for greenhouse gas emissions, rely on renewable energy sources, impose tight emission regulations, implement a national energy conservation program, and build smart cities. The model's policy-specific message is to focus on diversifying the energy portfolio by adding alternative energy sources, as well as a significant push to reduce domestic GHG emissions.

Finally; It can be said that it is difficult to achieve any of the three objectives to be achieved if and only if the number of employees in each sector of economic activity is optimal.

4 Conclusions

Making decisions is often complicated, involving value trade-offs and uncertainty. In this research, we provided a fuzzy goal programming model that combines optimal resource allocation with projected goals for economic development, electricity consumption, workforce, and GHG emission reduction by 2030, as applied to Egypt's important economic sectors. Rising energy consumption is always correlated with increased GDP, which contributes to increased GHG emissions. The model implies that Egypt's objective of GDP growth will not be met, and that further research and preparation is required. It also recommends that Egypt take some required measures in the direction of renewable technologies, such as solar and wind energy, which have enormous potential for achieving sustainability goals. This can also aid in meeting greenhouse gas emission targets, as well as meeting electricity consumption targets. The model also provides a quantitative and mathematical reason for additional investments in order to improve Egypt's energy portfolio composition. The model's study emphasizes the importance of continued research into alternative (green) energy sources. Implementing tactics in this approach will have a favorable influence on GDP. The model described here gives decision-makers relevant information and forecasts the Egyptian economy's future demands for growth. Recent breakthroughs in nuclear power plants, wind energy harvesting, concentrated solar energy, and smart city development attest to Egypt's leadership position in attaining sustainable development by 2030.

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Author Contributions

AE conceived the study, conducted the model run, analyzed the results, and wrote the manuscript. SB collected the data and contributed to the reading of the manuscript. AR contributed in model formulation, concept and design. ES supervised this study, contributed to the critical reading of the manuscript, and provided input for the final version. All authors read and approved the final manuscript.

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Availability of Data and Materials

All the data used during the research is announced on the Internet, as I announced the locations of this data within the search

Declarations

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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