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Mathematical modeling of sustainable development goals of India agenda 2030: a Neutrosophic programming approach

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Abstract
Since 2015, the United Nations sustainable development goals (SDGs) agenda 2030 has been designed with 17 goals, 169 targets, and 232 unique indicators to help address environmental, development, and sustainability issues globally. India, like other developing nations, desired to achieve its vision 2030 targets. Several authors studied India's SDGs with different approaches. However, none of the studies explores the concept of neutrosophic programming (NP). It is against this drawback; this study presents an optimization model for India's socio-economic and environmental goals based on the NP concept. The NP model is capable of handling indeterminacy in optimization-related problems for which other techniques do not. The formulated models simultaneously optimized the gross domestic product (GDP) growth, electricity consumption, and greenhouse gas (GHG) emissions. The solutions revealed that the degree of satisfaction for the goals related to GDP, electricity consumption, and GHG emissions could be achieved partially. Also, it suggested the required optimal number of employment for each economic sector to achieve India's vision 2030. The SDGs model was further solved with the goal programming (GP) technique and compared with the NP results to validate the proposed concept. It has been found that the proposed model gives a better compromise solution than the GP model. The study can help and guide policymakers in working toward vision 2030 attaintment. Other interested researchers can use the concept in other countries to help decision-makers understand managerial policy implications.

Keywords Sustainable Development Goals · Neutrosophic Programming · Electricity Consumption · Gross Domestic Products · Greenhouse Gas Emissions

1 Introduction

Sustainability concept initially coined in forestry, which means do not harvest what exceed the yield of the forests in a new growth (Kuhlman and Farrington 2010). It is said to be a "development that meet the present without compromising the ability of future generations

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to meet their needs" (Brundtland et al. 1987). Sustainability is a normativity phenomenon about the way humans should evaluate and make judgements toward the natural environment and how they are responsible for interacting with one another in the present time and guaranteeing the future unborne generation (Baumgärtner and Quaas 2010). Any society that is not capable of sustaining herself cannot be maintained in the long run, which invariably means it will cease to exist or function at some point in time (Heinberg and Lerch 2010). The term sustainability or "sustainable development" has a variety of concepts and definitions depending on the feasible phenomena it reflects. A search on Amazon.com for sustainability (August 25, 2019) yielded over 9,000 books with titles containing the word. Another search on Google Scholar revealed about 34,50,000 results, of scholarly journal articles with the word sustainability development in their titles.

Sustainable development emerged with the growing economies and need, and it tries to uphold the synergy between environment and development. Besides this, it promotes equity among generations. The SDGs attempted to address not only the genesis of poverty but also the global quest for development to provide a life of dignity to all. The Sustainable Development Goals are the actionable core of the new development agenda. The SDGs comprehensively comprises goals integrating economic, social, and environmental dimensions of development (Table 1)(Srikanth 2018). The adoption of the document titled "Transforming Our World: the 2030 Agenda for Sustainable Development" on 25th September of year 2015 marked the 70th General Assembly of the UN, where 17 "Sustainable Development Goals (SDGs)" and 169 targets came to fore. Officially SDGs came into effect from 1 January 2016 (on expiry of the MDGs), and carry forward the unfinished agendas of MDGs for continuity to reach the targets by the year 2030.

Many factors are significant to the failures of MDGs, among which is the uneven success of the goals recorded globally. Another issue was that developed countries were not ready to sacrifice. Overall constraints in the structural content, developmental processes, and lack of political will to enforce the implementation led to its failure in most member states. MDGs were formed in the year 2000, to develop a common agenda among countries and to make the quality of life better on the planet. One of its goals was to ensure environmental sustainability. The government faced severe challenges in attaining sustainability, though the targets not fully accomplished, the process of implementation left behind several important lessons on how the countries can address the problems as the SDGs roll out, serving as a vehicle to continue with what is not achieve by MDGs. SDGs are also regarded as development plan 2030. These are: "No poverty; Zero hunger; Good health and well-being; Quality education; Gender equality; Clean water and sanitation; affordable and clean energy; decent work and economic growth; Industry, innovation, and infrastructure; Reduced inequalities; Sustainable cities and communities; Responsible consumption and production; climate action; Life below the water; Life on land; Peace, justice and strong institutions; and Partnership for the goals". These goals are sub-divided into four categories, according to Sharma et al. (2018), and we present them in Table 1.

The 17 goals are interconnected and can be categorized into three major goals: (i) economic, (ii)social, and (iii)environmental. Therefore, this study considers these significant goals for India. There are nine contributing sectors economically which are considered in the modeling. The optimization model formulated is based on the NP concept discussed in Section 5. In policy implementations, the decision-making process tends to have three different outcomes in reality. One that is true and acceptable by the decision-maker(s), another one that is false and cannot be accepted, and the one between the two which the decision-maker(s) is/are satisfied and can accept. No researcher uses the neutrosophic concept in SDGs to the best of our knowledge, as evident from the litertaure review in Section 2. Most

Table 1 Categories of the Sustainable Development Goals of India source: Data on SDG Retrieved on 14 /08/2019 from http://www.indiaenvironmentportal.org.in/content/456489/the-sustainable-development-goals-report-2018/

S/N	Social Goals	Environmental Goals	Economic	Fostering Peace & Partnership Goals
1	**Goal 1:** No Poverty	**Goal 12:** Sustainable consumption & production	**Goal 7:** Affordable & clean energy	**Goal 16:** Peace, Justice & Strong institutions
2	**Goal 2:** Zero hunger		**Goal 8:** Decent work & economic growth	
3	**Goal 3:** Good health and well being	**Goal 13:** Climate action	**Goal 9:** Industry, Innovation and Infrastructure	**Goal 17:** Partnerships for the goals
4	**Goal 4:** Quality education	**Goal 14:** Life below water	**Goal 10**: Reduced inequalities	
5	**Goal 5:** Gender equality	**Goal 15:** Life on Land	**Goal 11:** Sustainable cities & communities	
6	**Goal 6:** Clean water and sanitation			

authors used traditional goal programming with its variants, which can only optimize the under and over achievement goals or the satisfaction level. In contrast, neutrosophic programming has three sets of results in respect of decision-makers aspirations as explained in Section 7.1. Therefore, it conveys more information regarding the solutions than the previous techniques. Hence, this justifies the novelty of the study.

2 Literature Review

This section review literature under subsection of SDGs, goal programming (GP), and neutrosophic concept as follows.

2.1 Sustainable Goals

Over a decade since the inceptions of global agendas, there exists huge research in the field of developmental issues across disciplines. The trend continues to give insight into the way decision-makers will realise the potentials of the policies that they make regarding a particular problem(s) at hand. A tripartite concept of social sustainability, viz: development, bridge, and maintenance sustainabilities are used by Vallance et al. (2011). The study explore the contradictions and complements between them in promoting sustainable development. A problem of E-waste management system for both developed and developing countries was extensively reviewed and assessed by Wath et al. (2010). Based on their review and discussion, they proposed a road map for E-waste management system to ensure an effective environmental sustainable developments goals for India. Choudhury et al. use the Geographic Information System (GIS) to strengthen the monitoring of SDGs indicators (Choudhury et al. 2018). The study uses India as a pilot case for strengthening spatial standards and maps the existing spatial and numerical datasets relevant to land-related SDGs indicators with a particular focus on the socioeconomic domain in India. According to the study, absence of GIS standards and clear guidance compromise various existing statistical data sources which can ultimately undermine the achievement of socio-economic targets of SDGs. A linear programming framework was used incorporating multi-criteria modeling approach for the analysis of SDGs in India by Gupta et al. (2018). Goal programming with satisfaction function has been used to analyzed SDGs (Ali et al. 2021). The concept of Fuzzy programming incorporating analytic hierarchy process in SDGs modeling and analysis has been recently studied (Modibbo et al. 2021; AlArjani et al. 2021). The concept of linear programming (LP) used to allocate resources that are competing and conflicting in nature (Muhammad et al. 2015). Sustainable Development Goals play paramount importance in addressing energy-related challenges. The gaps surrounding the interactions between energy targets and non-energy targets of SDGs are reviewed by McCollum et al. (2018). Their study found that positives interactions outweigh the negatives ones between the SDGs target. They suggested an urgent need for interdisciplinary research toward fresh perspective, scientific tools and new data development, among others. Also of relevance for policy-making, they called for a wider effort in promoting policy-coherence and assessments that are an integral part of addressing potential policies across sustainability domains, temporal, and geographic boundaries. Policy interventions have been specifically assessed to overcome the barriers and to enhance the deployment of renewable energy for the future in India (Kumar et al. 2010). The concept of "Triple Bottom Line (3BL) framework for sustainability", was employed to evaluate social, environmental, socio-economic implications in the contexts of natural resource management and green product development for strategic and operational decision-making (Murali 2015). Multiple Criteria Decision Making (MCDM) techniques application to sustainable renewable energy has been carryout and documented in Kumar et al. (2017). A stochastic goal programming with satisfaction function was developed to analyze sustainable development goals (Ali et al. 2021; Jayaraman et al. 2017). The study incorporates electricity consumption, economic growth, greenhouse gas emissions, and employment strength of the India and the United Arabs Emirate. The effect of power consumptions and carbon dioxide emission was studied using a polynomial goal programming model and documented in Jayaraman et al. (2015). Recently, a critical review on the application of optimization techniques in the UN SDGs has been conducted and documented; however, none of the reported works uses the NP concepts (Modibbo et al. 2021). Therefore, this research is novel and present a new concept in SDGs modeling and optimization, which serve as a footprint to other researchers.

A power sector of India was studied (Srikanth 2018) and specific recommendations proposed toward timely implementation and achievement of sustainable development goals 7 for the government of India. Renewable energy initiatives of India are reviewed by Chandel et al. (2016). In their study, they focused on climate change and various components of power generation as captured in the "National Action Plan on Climate Change(NAPCC)", and they highlighted the need for advanced and compelling technological inputs for the exploitation of renewable energy in the country. The progress of sustainable development goal 2 (zero hunger) of Indian states had examined and found to exist among the indicators of food security in agriculture to nutritions, disconnects, and linkages. The study suggested that a singular approach to food security policy is inappropriate to sustained this goal (Das et al. 2018). "Fuzzy goal programming approach" was used to analyze the SDGs of India, taking into consideration key improvement opportunities and efforts required to implement the sustainable developmental plans (Nomani et al. 2017). The multi-objective optimization problem of energy sustainability in smart cities was modeled and solved using genetic algorithms and documented in Chui et al. (2018). The study contributed to the energy utilization and sustainability debates in the public domain.

2.2 Goal Programming

Most real-life decision-making situations involve multiobjective; thus, a single solution cannot optimally satisfy all these multiple objectives because they could be conflicting in nature. GP is among the techniques for modeling and solving such optimization problems. It is capable of addressing multi-criteria multiobjective problems. It is the generalization of the linear programming model for solving decision-making problems. Charnes and Cooper initially proposed the GP formulation and appeared in the literature in the early 60s for the first time. Charnes and Cooper (1962). Decision-makers (DMs) often set targets goals and try to achieve them under certain conditions. Naturally, it is infrequent to achieve the goals ideally 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

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

Here, $\delta_i^+ + \delta_i^-$ are the positive (over-achievement) and negative deviations (under-achievement) with respect to aspirational level g_i. In (1), both the $x_i s$ and the $g_i s$ are precise and deterministic. The GP model (1) has many variants as extension. In realistic situations, this system of modeling is hard to apply especially when some of the input parameters are stochastic and not precise. One of the variants of GP which is more suitable model under probabilistic environment is the Stochastic GP Model (SGPM) proposed by Contini (1968).

2.3 Neutrosophic concept

Ye (2018) presented some basic operations of neutrosophic number and a neutrosophic function involving neutrosophic numbers and developed a neutrosophic linear programming method to handle neutrosophic number optimization problems. Abdel-Basset et al. (2019a) proposed a solution approach to solve "neutrosophic linear fractional programming" problem (NLFPP) in which the objective function, the resources utilization and the technological coefficients are in the form of "triangular neutrosophic numbers". They transformed the problem into an equivalent crisp "multi-objective linear fractional programming" problem (MOLFPP) and then converted it to a single objective LPP. Neutrosophic Linear Programming models were introduced by Abdel-Basset et al. (2019b) where the parameters represented a trapezoidal neutrosophic number, and they proposed a solution technique for the problem. Garg (2018) develop nonlinear programming model using the concept of "technique for order preference by similarity to ideal solution (TOPSIS)", to solve decision-making problems where interval neutrosophic numbers were incorporated in the criterion values and importance. Das and Roy (2015) developed an algorithm for solving the nonlinear multi-objective problem based on neutrosophic optimization and compared it with an intuitionistic fuzzy technique. Rizk-Allah et al. (2018) used a multi-objective model to construct a neutrosophic compromise programming model and obtained the best compromising solutions. Ahmad and Adhami (2019) formulated a multiobjective nonlinear transportation problem with fuzzy parameters under neutrosophic decision set, and investigated the degree of membership and non-membership for different objectives. The NP concept have been applied in many field such as production planning among others (Khan et al. 2021b). However, the NP concept has not been tested in studies related to SDGs; hence, the present study bridges the existing literature gap by applying the NP approach in the SDGs of India as a model illustration study. Therefore, this research contributed to the bank of literature. Also, the result proved to be better than the concepts already applied in this domain of study. Other interested researchers can replicate this study framework in several countries with slight modification; since the SDGs are global issues and not specific to India.

3 Overview Of India's 2030 Agenda

India is not an exceptional state among the committee of nations and hence part and parcel of the global developmental agenda 2030. This section viewed the success, failures, and way forward to actualising the dream of India in sustainable development mission 2030.

3.1 The Millenium Development Goals (MDGs)

During the year 2000, the UN General Assembly committed herself to eradicate extreme poverty through global partnership and set eight goals to achieve within fifteen years (2015) with sixty indicators and twenty-one targets. The declaration is known as "Millenium Development Goals (MDGs)". According to Kamepalli and Pattanayak (2015), it is one of the most resounding commitments ever in the history of nations globally. The goals are; "Eradicate extreme poverty and hunger; Achieve universal primary education; Promote gender equality and empower women; Reduce child mortality; Improve maternal health; Combat HIV/AIDS, malaria, and other diseases; ensure environmental sustainability, and Develop a global partnership for development" There is a significant variation in the achievement of these goals among member countries. India recorded a tremendous achievement on some targets and work-in-progress on the others before the scheme elapsed. According to Kamepalli and Pattanayak (2015), one of the two targets of goal one and goal six had achieved, respectively, that is "halving the percentage of population below the poverty line." and "the prevalence of HIV among pregnant women age 15-24 years" which decline from 0.89% in 2005 to 0.32% in 2013, while other targets of the goals felt short of the target at the end of the scheme. Also goal 2, 3, 4 and part of goal 6 were very close to the target before the end of the program, but goal eight and part of goal 7 were close to the targets as shown in Fig. 1.

3.2 India's Sustainable Development Goals

Over the years, India has focused its developmental projects to meet its sustainability targets for the vision 2030. It is alleviating poverty through guaranteeing economic growth, employment, energy consumption, food security, disaster resilience, and ecological protection as priorities. India like other countries also, confronted with emerging challenges of environmental degradation, increasing inequities and uneven distribution of natural resources among its states, and pronounced human underdevelopment indices evident by the government as well as her citizenries. The post-MDGs framework for Sustainable Development Agendas served as an opportunity for India to integrate efforts and renew mandates for meeting her national aspirations in line with the global declaration for the brighter future of the unborn generation. We are going to dissect the 17 goals in respect of India as follows:

Goal 1: "End poverty in all its ramifications everywhere"- This is the primary goal for the agenda which require actions on all the 16 other goals to achieve this goal.

Goal 2: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture"- There are numerous factors which require urgent attention to achieve this goal, these include but not limited to adequate production of food locally through enhancing mechanized agricultural farming, investing huge amount in irrigation, regeneration of wasteland, conservation of soil and water, rain-fed farming, and ability to import food that cannot be produced in local context.

MDGS	TARGETS	INDICATORS	STATUS
1 ERADICATE EXTREME POVERTY AND HUNGER	**Target 1:** Halve, between 1990 and 2015, the proportion of people whose income is less than one US dollar per day. **Target 2:** Halve, between 1990 and 2015, the proportion of people who suffer from hunger	1. The all India Poverty Head Count Ratio (PHCR) estimate was 47.8% in 1990. In 2011-2012, the PHCR at all India level is 21.9%. 2. It is estimated that in 1990, the proportion of underweight children below 3 years is 52% and expected to reduce to 33% by 2015.	Achieved Felt Short of Target
2 Achieve universal primary education	Target 3: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling.	3. The Net Enrolment Rate (NER) in Primary education (age 6-10 years)was estimated at 84.5% in 2005-2006(U-DISE) and the NER has increased to 88.08% in 2013-2014 (U-DISE).	Very close to the target
3 Promote gender equality and empower women	Target 4: Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015.	4. Gender Parity Index (GPI-Number of female to male) of Gross Enrolment Ratio (GER) as of 2013-2014 is 1.03 in Primary education, 1 in secondary Education and 0.89 in tertiary education. As per 2011 census, the ratio of female youth literacy rate to male is 0.91 at all India level and is likely to reach the level of 1.0 by 2015. It is projected that, the share of women in wage employment can at best reach a level of about 22.28% by 2015. Proportion of seats held by women in National parliament is only 12.24%	Very close to the target
4 Reduce child mortality	Target 5: Reduce by two-thirds, between 1990 and 2015, the under-five morality rate.	5. Under Five Mortality Ration (U5MR) was estimated at 125 deaths per 1000 live births in 1990. As per Sample Registration System 2013, the U5MR is 49 deaths per 1000 live births, and as per historical trend, it is likely to reach 48 deaths per 1000 live births.	Very close to the target
5 IMPROVE MATERNAL HEALTH	Target 6: Reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio.	6. In 1990, the estimated MMR was 437 per 1, 00,000 live births. As per the latest estimates, the MMR status at all India level is at 167 in 2011-2013. As per historical trend, MMR is likely to reach the level of 140 maternal deaths by 2015.	Felt Short of Target
6 COMBAT HIV/AIDS, MALARIA AND OTHER DISEASES	Target 7: Have halted, by 2015, and begun to reverse the spread of HIV/AIDS. Target 8: Have halted, by 2015, and begun to reverse the incidence of malaria and other major diseases	7. The prevalence of HIV among pregnant women age15-24 years is showing declining trend from 0.89\% in 2005 to 0.32% in 2012-2013. 8. Malaria has consistently come down from 2.12 per thousand in 2001 to 0.72 per thousand in 2013, but slightly increases to 0.88 in 2014(P). Tuberculosis prevalence per lakh population has reduced from 465 in 1990 to 211 in 2013. TB incident per lakh population has reduced from 216 in 1990 to 171 in 2013. TB mortality per lakh population has reduced from 38 in 1990 to 19 in 2013.	Achieved Very close to the target
7 Ensure environmental sustainability	**Target 9:** Integrate the principle of sustainable development into country policies and programmes and reverse the loss of environmental resources. **Target 10:** Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation. **Target 11:** By 2020, to have achieved a significant improvement in the lives of at least100 million slum dwellers.	9. As per 2013 assessment, the total forest cover of the country is 697898 sq km which is 21.23% of the country's geographical area. There is an increase of 5871 sq km forest cover during 2011-2013. The estimated CO_2 emission (Million tonnes) in 2013 is 1954.02. The CO_2 emission showed a percentage increase of 235.57% in 2014 over 1990. As per 2011 census, 67.3% household are using solid fuels (firewood, crop residue, cow dung cake, coke, etc) for cooking against 73.3% in 2011. The census further reveals that, 86.5% and 26.1\% households in both rural and urban areas are using solid fuels for cooking respectively. 10. During 2012, at all India level, 87.8% households had access to improved source of drinking water while 86.9\% households in rural and 90.1% households in urban areas had access to improved source of drinking water. The NSS 2012 revealed 43.4% households in all India level had no latrine facilities. At all India level, 2015 target is unlikely to be met; the percentage of household without sanitation facility is likely to be 47.31% vis-à-vis the target of 38.09%. 11. Cannot be measured statistically	Close to the target Felt short in target in sanitation Not Available
8 A GLOBAL PARTNERSHIP FOR DEVELOPMENT	**Target 18:** In cooperation with the private sector, make available the benefits of new Technologies, especially information and communications.	18. The overall tele-density in the country has shown tremendous progress and is at 76% as at 31st July 2014. The internet subscribers per 100 population accessing internet through wire line and wireless connection has increase from 16.15 in June 2013 to 20.83 in June 2014.	Close to the target

Fig. 1 India's MDGs Stattus at the End of 2015. Legend: Yellow colour = Very close to target, Green colour=Close to target, Red=Felt short of target, Light Blue colour=target achieved, dark Black colour=Target not achieved

To achieve agricultural and food production, food and nutrition security, will require transformation into nutrition security for the entire populations (Das et al. 2018), this call to the device for strategic techniques and approaches to improve the linkages between agriculture and nutrition in developing countries (McDermott et al. 2015). It will cost India USD 729 billion for achieving food security and the system of sustainable agricultural production from the year 2015 to 2024 (Bhamra et al. 2015).

Goal 3: "Ensure healthy lives and promote well-being for all at all ages"- This goal requires having access to quality and affordable healthcare system for all, and the health index value to reach at least 0.9. Sound healthcare systems will reduce the high rate of mortality, morbidity, and malnutrition across different age groups in the country (Das et al. 2018). The ratio of public to total expenditure on health is just 33% which is very low compared to sub-Saharan Africa with 45% against the world's average of 63% This translate to one per cent of total India's GDP. To achieve goal 3 and 0.9 health index, India will require $ 880 billion till the year 2030; hence, there is a need for India to increase on public healthcare expenditure. The higher a country spends on public health, the better it secures the health outcomes as evident in countries with high expenditure on public health (Bhamra et al. 2015; Dreze and Sen 2015).

Goal 4: "Ensure inclusive and equitable quality education, and promote lifelong learning opportunities for all"- Provisions such as "Right to Education Act", is playing a vital role in ensuring inclusive education in primary and secondary schools in India, but the early childhood development, pre-primary school, higher and tertiary education aspect, a lot need to be done to enhance this system incorporating vocational and technical schools for independent skills acquisitions. According to Bhamra et al. (2015), it will cost India USD555 billion to achieve this goal. Ninety per cent jobs in India required vocational training and are skill-based, only fifteen per cents have marketable skills, and 2.4 per cent has undergone formal skill training out of the existing workforce in India, respectively. The government has pledged to skill and train 500 million by the year 2022, also for India to become a leading manufacturing economy globally. It requires 291 million skilled workers by the year 2022. [20], Bhamra et al. (2015); Mehrotra et al. (2014).

Goal 5: "Achieve gender equality and empower all women and girls"- Achieving this goal means improving gender equality index as it exhibits a strong correlation between the Gender Gap and the national competitiveness of India. Presently, India has a similar gender index gap with some African and South-East Asian countries like Ghana, Uganda, Tanzania, Cambodia and Bangladesh, respectively. Equal educational opportunities and participation in the country's economy, political empowerment, access to health, among others are the indicators for this indices. Women need to be empowered in all endeavours of life as they constitute 48.20% of Indian population (Chandramouli and General 2011). India will require about USD1408 billion to achieve this goal (Bhamra et al. 2015).

Goal 6: "Ensure availability and sustainable management of water and sanitation for all"- Indian rivers and water bodies need to be well managed and sustained to guarantee the ecological flow. The problem of water pollution in river Ganga and the like also need to be addressed by revisiting, improving and enforcing the "Ganga River Basin Management Plan (2015)." These will ensure the water security for domestic, agricultural, and industrial applications such as irrigation. The achievement of this goal requires many resources, for instance, access to clean drinking water for all and sanitation of the Ganga pollution problem will cost India about USD 322 billion (Bhamra et al. 2015).

Goal 7: "Ensure access to affordable, reliable, sustainable, and modern energy for all"- The nation's access to reliable affordable and sustainable modern energy is the driving fule engine for sustainable development growth of any nation in the world (Oyedepo 2012). The importance of sustainable, reliable, and affordable modern energy cannot be overemphasized, and this is another critical sector that demands a holistic approach in achieving it. Stakeholders such as industries, decision-makers, and the general society regarded this goal as very challenging (Chui et al. 2018). Increasing greenhouse gas emission through fossil fuel increase leads to the issues of climate change (Chandel et al. 2016). India, being the fourth largest emitter of CO_2 in the world, need to regulate and reduce her emissions. Because of the rapid fossil fuels depletion, the power sector in India nearly contributes half of the carbon emission. The efficient utilization of renewable sources of energy will balance demand and supply in the energy sector and reduce the carbon emission in the country. For sustainable development, energy is of fundamental issue (Oyedepo 2014). The renewable sources of energy such as ocean; wind; geothermal; solar; fuel cell technology; and biomass energies can solve the problem of energy shortage in India if put into being used (Kuhlman and Farrington 2010). The renewable sources of energy such as ocean; wind; geothermal; solar; fuel cell technology; and biomass energies can solve the problem of energy shortage in India if put into being used (Kumar et al. 2010).

Goal 8: "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all"- Manufacturing and service sectors which are the major classes of MSMEs as contained in the MSMED act 2006, should be enhanced, and other related labour forces are empowered to be able to reap the sustainable growth of India's economy. More strategic employment opportunities should be generated to cater for the teeming youth in the country. According to the International Monetary

Fund, India would be the largest economy in the world after USA and China come 2050 with over 8% annual growth rate in GDP. According to Bhamra et al. (2015), India will require about USD 2,360 billion to finance the MSMEs, which will, in turn, contribute about 20-25 per cent to the country's gross domestic product. India pledges to improve its economic growth by $33-35$ per cent in the year 2030.

Goal 9: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation" - The need for developing infrastructures in any nation cannot be overemphasized. It play a vital role in promoting sustainable development. No country will be termed as developed without huge investiment in infrastructure. India has always consider infrastural development as its top most priority for inclusive economic growth. Sustainable Manufacturing Industries and operations are of paramount importance to goal 9 of Indian SDGs, socially, environmentally, and economically. Practices such as process design, eco-design, product recovery, cleaner production, lean practices, and green supply chain are necessary for the manufacturing firms to attain sustainability.

Goal 10: "Reduce inequality within and among countries"- This goal is not far different from many goals in the context of India. Inequalities exist in many sectors of the economy and have multiple faces that can be addressed simultaneously by addressing those sectors. For instance, there is inequality in the employment opportunities, the education sector, access to clean water, electricity, food, health status, and social security, among others. These imply that goal ten, with all other goals of the SDG, are interconnected.

Goal 11: "Make cities and human settlements inclusive, safe, resilient, and sustainable"- This area is very challenging, and it requires the government to develop the cities by building houses for all through proper planning which will take a long time, considering the population of the country with many leaving in slum areas. Over 30% of its population leaves in poverty, 4.9% are unemployed age 15 years and above, and about 1.77 million are homeless. There is a need for efficient transportation systems and urban development, enhancing the initial 500 cities (AMRUT) and 100 smart cities programmes and a host of others. It has been estimated to cost USD 2073.8 billion for the attainment of this goal (Bhamra et al. 2015).

Goal 12: "Ensure sustainable consumption and production patterns"- For India to achieve sustainable economic growth and development, the way goods are produced and consume should be checked. The ecological issues must be reduced, toxic waste disposal and pollutants have to be managed, the share of natural resources have to manage and utilise efficiently, recycling of waste should be encouraged, more efficient supply chain and production should be created, quality of life should be maximized, and waste is minimized.

Goal 13: "Take urgent action to combat climate change and its impacts"- The effect of climate change if not tackle well, will hamper the development of many sectors in the Indian economy. It is one of the central trending issues in the world. India is the fourth largest emitter in the world and pledged to reduce her CO_2 emission intensity drastically (by 20-25 per cent in 2020 and 33-35 per cent in 2030 of its GDP) as it contributes immensely to climate change. The eight national development mission of India as captured in "National Action Plan on Climate Change (NAPCC)", should be strengthened for effective action in combating climate change. According to the "Planning Commission of India", it will require about USD 270 billion to champion the implementation of the "National Action Plan for Climate Change (NAPCC) and State Action Plan for Climate Change (SAPCC)". This goal can be attained indirectly as it is linked to several goals above once they are achieved.

Goal 14: "Conserve and sustainably use the oceans, seas, and marine resources for sustainable development"- This goal will be sustained, having realized good infrastructure and industrialization (goal 9), sustainable consumption and production (goal 12), combating the impact of climate change (goal 13), sustainable use of ecosystems (goal 15), and promoting inclusive and peaceful society (goal 16). They are inter-related to each other; hence, a holistic approach will result in fruitful development in the entire country. This challenging goal requires a collective and collaborative action among all stakeholders at the state, national, and regional levels, with a view of ensuring healthy partnership to coordinate the policymaking and implementation (Unger et al. 2017).

Goal 15: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss." - The world is supporting the protection of terrestrial ecosystems and biodiversity by way of financial assistance. The loss of forest and degradation of land is on the increase, hunting and killing of wildlife and invasive species are other of the day. Extinction of species is one of the irreversible and fundamental human impacts on nature. India needs to diversify its strategy in protecting its ecosystems for the future generation of her population. For long-run sustainability of natural terrestrial and freshwater resources, it is of paramount importance to protect terrestrial sites, mountains, and freshwater biodiversity that are important to her healthy ecosystem. Human activities such as urbanization, expansion of farmland, desertification among others contribute primarily to land degradation, hence, must be check and curtail.

goal 16: "Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels " -There are many government policies for addressing most of these goals. The overall requirements are building reliable, inclusive, autonomous, viable, effective, accountable, and corruption-free institutions will go a long way in helping to achieve mission 2030 of India.

Goal 17: "Strengthen the means of implementation and revitalize the global partnership for sustainable development."- This goal ensures implementation of all other SDGs through financial assistance from the reliable and developed nations, technology transfer, support for capacity building, ability to monitor and track achievement throughout the period. India needs to improve its capacity in revenue generation and domestic taxation. Investment in technology will help the country to grasp the benefit of all economic sectors, thereby eradicating poverty which is one of the top priority of India. Also, leveraging on technologies will hamper productivity in agriculture, enhance healthcare status, control environmental degradation and give rise to sustainable development processes. India, like other developing nations, faced with food security, infrastructural development and a host of others. These are achievable through technological and financial assistance from developed countries and expansion of indigenous industries. Building capacities at all level through strengthening public institutions and government agencies will also help in such direction.

4 Mathematical Models for SDG-India

The mathematical models for SDG-India were initially proposed by Nomani et al. (2017) and extended by Gupta et al. (2018); Ali et al. (2021). They used the concept of Fuzzy Goal Programming (FGP) in which the former analyzed the goals related to India's environment, energy and sustainability for the year 2030 while the later incorporated a weighted FGP and obtained varying solutions set based on the priorities of the decision-makers. In both cases, numerical data were used to validate the models. The India's SDGs were modeled and integrated under three major sectors-viz: the primary; secondary; and tertiary using GP with satisfaction function and documented in Ali et al. (2021). This study proposes an SDGs model based on the Neutrosophic programming concept to analyze the SDGs of India. The country's economy comprises of three basic sectors viz: the primary; secondary, and tertiary. The primary sector is made up of the Agricultural activities; the secondary sector is made up of the manufacturing activities, while the tertiary sector is made up of the service activities. Generally, the basic sectors are subdivided into nine different economic contributing sub-sectors and are summarized in Table 3. Here, we consider three major future goals of India which are inter-connected with other goals, the current and the projected values for these goals are summarized in Table 2. These are the GDP growth, energy consumption and GHG emissions. Achieving the three goals will guarantee the achievement of the remaining goals for the year 2030. Equation 2 presents the SDG-India model related to the economic sectors based on the goal programming concept of Eq. (1).

$$Optimize\begin{cases} Z_1(X) = \sum_{1=1}^{9}\left[\frac{(GDP)_j}{e_j}\right]x_j, & related\ \ to\ \ gross-domestic-products \\ Z_2(X) = \sum_{1=1}^{9}\left[\frac{(EC)_j}{e_j}\right]x_j, & related\ \ to\ \ gross-elecricity-consumption \\ Z_3(X) = \sum_{1=1}^{9}\left[\frac{(GHG)_j}{e_j}\right]x_j, & related\ \ to\ \ greenhouse-gas-emissions \\ Subject\ \ to\ \ set\ \ of\ \ constraints: \sum_{j=1}^{9}x_j \le e_G, & constraint\ \ related\ \ to\ \ overall\ \ employment\ \ goal \\ \sum_{j=1}^{9}(GDP)_j x_j \le (GDP)_G, & constraint\ \ related\ \ to\ \ GDP \\ \sum_{j=1}^{9}(GVA)_j x_j \le (GVA)_G, & constraint\ \ related\ \ to\ \ GVA \\ e_j \le x_j \le e_{Gj}, \forall j = 1,2,\dots,9. & constraint\ \ related\ \ to\ \ sectoral\ \ manpower \end{cases} \tag{2}$$

5 Neutrosophic Programming

Neutrosophic set is a set which has a characteristic of truthfulness, indeterminacy and falsity as its subset or membership in a given proposition. Decision-making process usually has some elements of imprecision inherently, as such, the neutrosophic concept serves as a framework that measures the degree of truthhood, indeterminacy and falsehood existing in the process (Smarandache 1999). The set can be defined as follows:

Table 2 Identified goals of SDG during the year 2030 as projected source: UNFCCC (2015); Nomani et al. (2017); Gupta et al. (2018)

S/N	Goals	Current Value	Goals by the year 2030	Annual growth rate (%)
1	GDP in INR (Billion) 2014	98576.73	264251	10.50
2	Electricity consumption (GWh) 2013	871446.8	2525604	11.17
3	GHG emission (million tonnes) 2007	1904	5700	8.66
4	Number of employment (million) 2014	462.33	747.155	3.85

Let assume X to be a universal space and let $x \in X$. A neutrosophic set N_s belonging to the set X has three memberships with characteristics of truth μ_N^T(x), indeterminacy σ_N^I(x), and a falsity υ_N^F(x), and it are denoted by the relation :

$$N_s = < x, \ \ \mu_N^T(x), \ \ \sigma_N^I(x), \ \ \upsilon_N^F(x) > |x \in X \tag{3}$$

Where μ_N^T(x), σ_N^I(x), and υ_N^F(x) are standard or non-standard real sub sets belonging to]0^- ,1^+[, that is, $\mu_N^T(x) : X \rightarrow]0^-,1^+[$, σ_N^I (x): X →]0^-,1^+[, and υ_N^F (x):X →]0^-,1^+[. The sum of the memberships (μ_N^T(x), σ_N^I(x), and υ_N^F(x)) has no restriction, hence $0^- \leq$ sup (μ_N^T(x)) + sup (σ_N^I(x)) + sup (υ_N^F(x)) ≤ 3.

The proposed NP has the capacity of handling the existence of indeterminacy in an optimization related problem by way of optimizing the membership functions simultaneously. In other words, it maximizes the degree of satisfaction (truthhood), dissatisfaction (falsity) and minimizes the degree between truth-hood and falsehood (indeterminacy). The procedure begins by determining the individual minimum ("ideal solution"), and individual maximum ("anti-ideal solution") and then the degree of the three membership functions are constructed (Rizk-Allah et al. 2018).

The standard form of a multi-objective optimization model can be mathematically expressed as follows:

$$Maximize(Minimize) \quad F(x) = Z_1(x), Z_2(x), ..., Z_k(x)$$

subject to:

$$g(x) \leq 0, \qquad x \in X \tag{4}$$

Here, the upper and lower bounds for each objective function are denoted by U_k and L_k (k=1,2,..., K), respectively. The neutrosophic model has two distinct features, a case where the ultimate goal is all of the maximization types and the other is that of minimization category. These can be explained as follows:

Case 1: In reality, the goals of some policy-maker(s) could be to maximize the revenue, satisfaction, profit, resources and so on while having some boundaries or limits within which they must make such a decision. In such a scenario, the upper and lower values for the neutrosophic environment are computed as:

$$\begin{cases} U_k^T = U_k, \quad L_k^T = L_k, & For\ truth\ membership \\ U_k^I = U_k^T, \quad L_k^I = L_k^T + q_k(U_k^T - L_k^T), & For\ indeterminacy\ membership \\ U_k^F = L_k^T + q_k(U_k^T - L_k^T), \quad L_k^F = L_k^T, & For\ falsity\ membership \\ k = 1, 2, ..., K \end{cases} \tag{5}$$

where the variables q_k's are tolerance for falsity and indeterminacy membership functions, choosing by the decision-maker. The membership functions for the NP are constructed as follows:

$$\mu_k^T = \begin{cases} 0, & Z_k \leq L_k^T \\ \dfrac{Z_k - L_k^T}{U_k^T - L_k^T}, & L_k^T \leq Z_k \leq U_k^T \\ 1, & Z_k \geq U_k^T \end{cases} \tag{6}$$

$$\sigma_k^I = \begin{cases} 0, & Z_k \le L_k^I \\ \dfrac{Z_k - L_k^I}{U_k^I - L_k^I}, & L_k^I \le Z_k \le U_k^I \\ 1, & Z_k \ge U_k^I \end{cases} \tag{7}$$

$$\upsilon_k^F = \begin{cases} 0, & Z_k \le L_k^I \\ \dfrac{U_k^F - Z_k}{U_k^F - L_k^F}, & L_k^F \le Z_k \le U_k^F \\ 1, & Z_k \ge U_k^F \end{cases} \tag{8}$$

Maximize the Truth (μ_k^T) and Indeterminacy (σ_k^I) membership functions; and Minimize the falsity (υ_k^F) membership functions.

Case 2: A situation where the objective is to minimize certain quantities such as time, cost, waste, and the like, the upper and lower values for the neutrosophic environment can be computed as:

$$\begin{cases} U_k^T = U_k, \quad L_k^T = L_k, & \textit{For truth membership} \\ U_k^I = L_k^T + q_k(U_k^T - L_k^T), \quad L_k^I = L_k^T, & \textit{For indeterminacy membership} \\ U_k^F = U_k^T, \quad L_k^F = L_k^T + q_k'(U_k^T - L_k^T), & \textit{For falsity membership} \end{cases} \tag{9}$$

where the variables q_k' and q_k are tolerance for falsity and indeterminacy membership functions, choosing by the decision-maker. The membership functions for the NP are constructed as follows:

$$\mu_k^T = \begin{cases} 1, & Z_k \le L_k^T \\ \dfrac{U_k^T - Z_k}{U_k^T - L_k^T}, & L_k^T \le Z_k \le U_k^T \\ 0, & Z_k \ge U_k^T \end{cases} \tag{10}$$

$$\sigma_k^I = \begin{cases} 1, & Z_k \le L_k^I \\ \dfrac{U_k^I - Z_k}{U_k^I - L_k^I}, & L_k^I \le Z_k \le U_k^I \\ 0, & Z_k \ge U_k^I \end{cases} \tag{11}$$

$$\upsilon_k^F = \begin{cases} 0, & Z_k \le L_k^I \\ \dfrac{Z_k - L_k^F}{U_k^F - L_k^F}, & L_k^F \le Z_k \le U_k^F \\ 1, & Z_k \ge U_k^F \end{cases} \tag{12}$$

Maximize the Truth (μ_k^T) and Indeterminacy (σ_k^I) membership functions; and Minimize the falsity (υ_k^F) membership functions.

5.1 Additive Operator of Membership function

Using Eqs. (5) - (8) of membership function, the additive model is given below:

$$\begin{cases} Max \quad \sum_{k=1}^{K}\left(\mu_k+\sigma_k-\upsilon_k\right) \\ \mu_k=\frac{Z_k-L_k^T}{U_k^T-L_k^T}, \quad \sigma_k=\frac{Z_k-L_k^I}{U_k^I-L_k^I}, \quad \upsilon_k=\frac{U_k^F-Z_k}{U_k^F-L_k^F} \\ \mu_k\geq\mu_k^T, \sigma_k\geq\sigma_k^I, \quad \upsilon_k\geq\upsilon_k^F, \\ \mu_k\geq\sigma_k, \mu_k\geq\upsilon_k, \mu_k+\sigma_k+\upsilon_k\leq 3, \\ \mu_k,\sigma_k,\upsilon_k\in[0,1], k=1,2,...,K. \\ g(x)\leq 0, \\ x\in X \end{cases} \tag{13}$$

In view of Eq. (13), The equivalent SDG model defined in Eq. (2) can be written as follows:

$$\begin{cases} Max \quad \sum_{i=1}^{3}\left(\mu_i+\sigma_i-\upsilon_i\right) \\ \mu_1=\frac{Z_1-L_1^T}{U_1^T-L_1^T}, \quad \sigma_1=\frac{Z_1-L_1^I}{U_1^I-L_1^I}, \quad \upsilon_1=\frac{U_1^F-Z_1}{U_1^F-L_1^F} \\ \mu_2=\frac{Z_2-L_2^T}{U_2^T-L_2^T}, \quad \sigma_2=\frac{Z_2-L_2^I}{U_2^I-L_2^I}, \quad \upsilon_2=\frac{U_2^F-Z_2}{U_2^F-L_2^F} \\ \mu_3=\frac{U_3^T-Z_3}{U_3^T-L_3^T}, \quad \sigma_3=\frac{U_3^I-Z_3}{U_3^I-L_3^I}, \quad \upsilon_3=\frac{Z_3-L_3^F}{U_3^F-L_3^F} \\ \mu_i\geq\sigma_i, \quad \mu_i\geq\upsilon_i, \quad \mu_i+\sigma_i+\upsilon_i\leq 3, \\ \mu_i,\sigma_i,\upsilon_i\in[0,1], i=1,2,3. \\ \sum_{j=1}^{9}x_j\leq e_G, \\ \sum_{j=1}^{9}(GDP)_j x_j\leq(GDP)_G, \\ \sum_{j=1}^{9}(GVA)_j x_j\leq(GVA)_G, \\ e_j\leq x_j\leq e_{Gj}, \forall j=1,2,...,9. \end{cases} \tag{14}$$

5.2 Multiplicative operator of membership function

Using Eq. (9) - (12) of membership function, the multiplicative model is given as:

$$
\begin{cases}
Min \quad \sum_{k=1}^{K}\{(1-\mu_k)(1-\sigma_k)\upsilon_k\} \\
\mu_k = \frac{U_k^T - Z_k}{U_k^T - L_k^T}, \quad \sigma_k = \frac{U_k^I - Z_k}{U_k^I - L_k^I}, \quad \upsilon_k = \frac{Z_k - L_k^F}{U_k^F - L_k^F} \\
\mu_k \geq \mu_k^T, \sigma_k \geq \sigma_k^I, \quad \upsilon_k \geq \upsilon_k^F, \\
\mu_k \geq \sigma_k, \mu_k \geq \upsilon_k, \mu_k + \sigma_k + \upsilon_k \leq 3, \\
\mu_k, \sigma_k, \upsilon_k \in [0,1], k = 1, 2, ..., K. \\
g(x) \leq 0, \\
x \in X
\end{cases}
\tag{15}
$$

In light of Eq. (15), the equivalent SDG model defined in Eq. (2) can be stated as follows:

$$
\begin{cases}
Min \quad \sum_{i=1}^{3}\left\{(1-\mu_i)(1-\sigma_i)\upsilon_i\right\} \\
\mu_1 = \frac{Z_1 - L_1^T}{U_1^T - L_1^T}, \quad \sigma_1 = \frac{Z_1 - L_1^I}{U_1^I - L_1^I}, \quad \upsilon_1 = \frac{U_1^F - Z_1}{U_1^F - L_1^F} \\
\mu_2 = \frac{Z_2 - L_2^T}{U_2^T - L_2^T}, \quad \sigma_2 = \frac{Z_2 - L_2^I}{U_2^I - L_2^I}, \quad \upsilon_2 = \frac{U_2^F - Z_2}{U_2^F - L_2^F} \\
\mu_3 = \frac{U_3^T - Z_3}{U_3^T - L_3^T}, \quad \sigma_3 = \frac{U_3^I - Z_3}{U_3^I - L_3^I}, \quad \upsilon_3 = \frac{Z_3 - L_3^F}{U_3^F - L_3^F} \\
\mu_i \geq \sigma_i, \quad \mu_i \geq \upsilon_i, \quad \mu_i + \sigma_i + \upsilon_i \leq 3, \\
\mu_i, \sigma_i, \upsilon_i \in [0,1], i = 1, 2, 3. \\
\sum_{j=1}^{9} x_j \leq e_G, \\
\sum_{j=1}^{9} (GDP)_j x_j \leq (GDP)_G, \\
\sum_{j=1}^{9} (GVA)_j x_j \leq (GVA)_G, \\
e_j \leq x_j \leq e_{Gj}, \forall j = 1, 2, ..., 9.
\end{cases}
\tag{16}
$$

6 Case Study

India is a UN member state that worked hard to achieved the MDGs and still striving energetically to attain the 2030 SDGs agendas. As we reviewed in sections 3 and subsection 3.1 and 3.2, We choose India to demonstrate the proposed NP models for the agenda 2030. The formulated SDG model (Eq. (2)) is a mixture of two types of objectives; maximization and minimization, hence; we use our proposed NP model for each type of the objectives and optimize the truth, indeterminacy and the falsity membership functions. We used model 13 and 15 for the additive and multiplicative membership functions and constructed the SDG-NP models 14 and 16.

The current and projected values for GDP, electricity consumption, GHG emissions and number of employees for the year 2030 are presented in Table 2. While, the contribution rendered by the nine sectors of the economy in respect of GDP growth, electricity consumption,

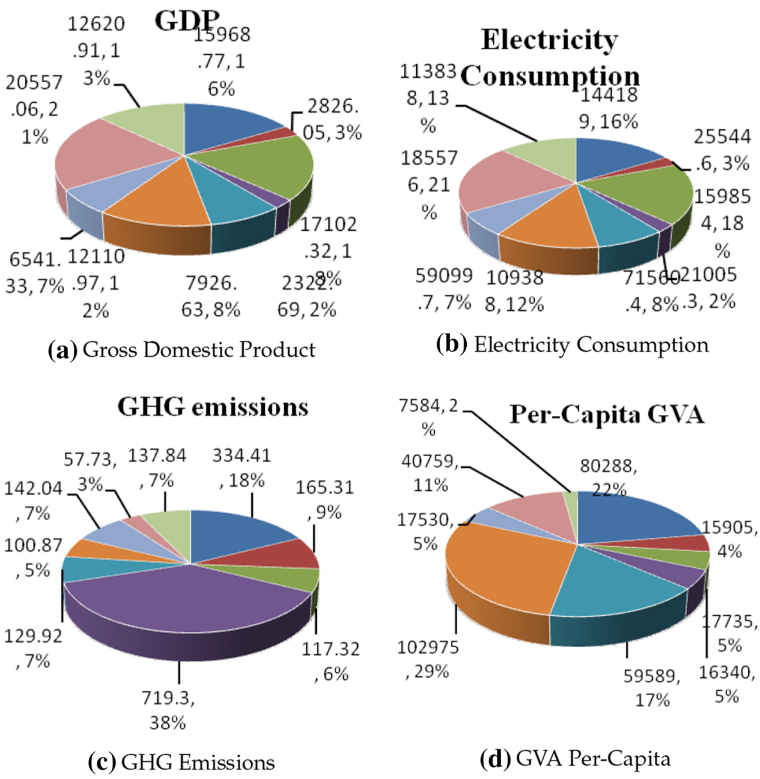


Fig. 2 GDP, EC, GHG, and GVA Per-Capita

GHG emissions, GVA per capita, and manpower are presented in Table 3. The information in Table 3 are pictorially represented in Figs. 2, respectively.

7 Results Analysis and Discussion

Equation (5) is used to calculate the lower and upper bounds for the first and second objective while Eqs. (6) - (8) are used for calculating their Truth, Indeterminacy, and falsity membership functions. Thus; we have:

$$\mu_1^T = \begin{cases} 0, & Z_1 \le 98576.73 \\ \dfrac{Z_1 - 98576.73}{264251 - 98576.73}, & 98576.73 \le Z_1 \le 264251 \\ 1, & Z_1 \ge 264251 \end{cases} \tag{17}$$

$$\sigma_1^I = \begin{cases} 0, & Z_1 \le 197981.29 \\ \dfrac{Z_1 - 197981.29}{264251 - 197981.29}, & 197981.29 \le Z_1 \le 264251 \\ 1, & Z_1 \ge 264251 \end{cases} \tag{18}$$

Table 3 The sectorial economic contribution of the identified goals

S/N	Economic Sector	GDP (in Billion INR)	EC (in GWh)	GHG emissions (in Million tones)	Per-capita GVA	NEMP (in '000)	MNEMP (in '000)
1	Agriculture, Forestry and Fishing	15,968.77	144,189	334.41	80,288	23,430	98,891
2	Mining & Quarrying	2826.05	25,544.6	165.31	15,905	18,770	79,222
3	Manufacturing	17,102.32	159,854	117.32	16,340	110,670	178,850
4	Electricity, Gas Steam & other utility service	2322.69	21,005.3	719.30	17,735	13,770	58,118
5	Construction	7926.63	71,560.4	129.92	59,589	14,580	61,537
6	Trade; repair; hotels and resturants	12,110.97	109,388	100.87	102,975	12,210	51,534
7	Transportation; Storage; communication and service related to broadcasting	6541.33	59,099.7	142.04	17,530	39,290	165,831
8	Financial, real estate and professional services	20,557.06	185,576	57.73	40,759	50,900	214,833
9	Community, social and personal services	12,620.91	113,838	137.84	7584	178,710	288,808

NEMP = Number of Employment, MNEMP = Maximum Number of Employment, EC = Electricity Consumption, GHG = GreenHouse Gases, GDP=Gross Domestic Product, GVA=Gross Value-Added

$$\upsilon_1^F = \begin{cases} 0, & Z_1 \le 98576.73 \\ \dfrac{247683.57 - Z_1}{247683.57 - 98576.73}, & 98576.73 \le Z_1 \le 247683.57 \\ 1, & Z_1 \ge 247683.57 \end{cases} \tag{19}$$

$$\mu_2^T = \begin{cases} 0, & Z_2 \le 871446.8 \\ \dfrac{Z_2 - 871446.8}{2525604 - 871446.8}, & 871446.8 \le Z_2 \le 2525604 \\ 1, & Z_2 \ge 2525604 \end{cases} \tag{20}$$

$$\sigma_2^I = \begin{cases} 0, & Z_2 \le 1698525.4 \\ \dfrac{Z_2 - 1698525.4}{2525604 - 1698525.4}, & 1698525.4 \le Z_2 \le 2525604 \\ 1, & Z_2 \ge 2525604 \end{cases} \tag{21}$$

$$\upsilon_2^F = \begin{cases} 0, & Z_2 \le 871446.8 \\ \dfrac{2194772.56 - Z_2}{2194772.56 - 871446.8}, & 871446.8 \le Z_2 \le 2194772.56 \\ 1, & Z_2 \ge 2194772.56 \end{cases} \tag{22}$$

Equation (9) is used to calculate the lower and upper bound for the third objective while Eqs. (10) - (12) are used for calculating their Truth, Indeterminacy, and falsity membership functions. Thus, we have:

$$\mu_3^T = \begin{cases} 1, & Z_3 \le 1904 \\ \dfrac{5700 - Z_3}{5700 - 1904}, & 1904 \le Z_3 \le 5700 \\ 0, & Z_3 \ge 5700 \end{cases} \tag{23}$$

$$\sigma_3^I = \begin{cases} 1, & Z_3 \le 1904 \\ \dfrac{4940.8 - Z_3}{4940.8 - 1904}, & 1904 \le Z_3 \le 4940.8 \\ 0, & Z_3 \ge 4940.8 \end{cases} \tag{24}$$

Table 4 Goal values obtained from NP Model

S/N	Goals in 2030	Additive Model	Multiplicative Model
1	GDP in INR (Billion)	245409.1	238980.6
2	Electricity consumption (GWh)	2194772	2134655
3	GHG emission (million tonnes)	3138.01	2975.165
4	Number of employment (million)	747155	747155

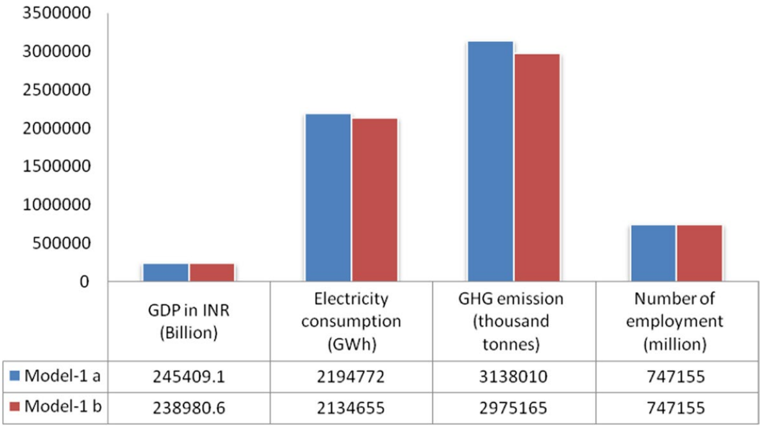


Fig. 3 Compromise values from Additive (Model-1 a) & Multiplicative (Model-1 b)

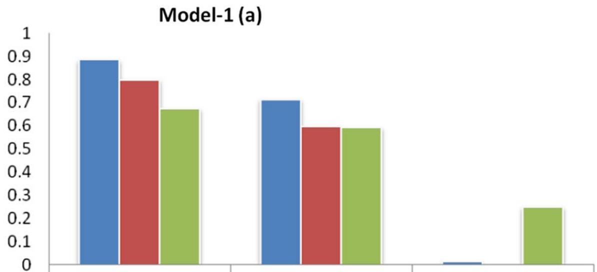
Table 5 Membership values obtained from NP Model

S/N	Membership	Objectives	Additive Model	Multiplicative Model
1	Truth (μ_i^T)	Z_1	0.8862713	0. 8474692
		Z_2	0.7999999	0.7636569
		Z_3	0.6749183	0.7178174
		Z_1	0.7156782	0.6186731
2	Indeterminacy (σ_i^I)	Z_2	0.5999998	0.5273138
		Z_3	0.5936479	0.6472718
		Z_1	0.01525413	0.05836749
2	Falsity (υ_i^F)	Z_2	0.0000001103265	0.04542886
		Z_3	0.2500908	0.2024251

$$\upsilon_3^F = \begin{cases} 0, & Z_3 \le 2283.6 \\ \dfrac{Z_3 - 2283.6}{5700 - 2283.6}, & 2283.6 \le Z_3 \le 5700 \\ 1, & Z_3 \ge 5700 \end{cases} \tag{25}$$

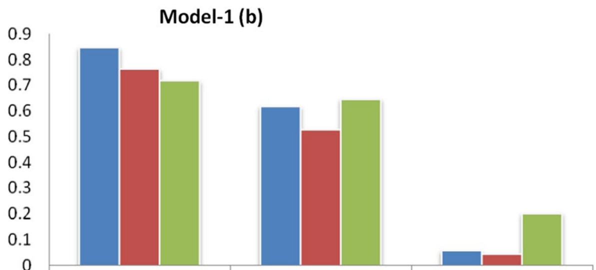
The lower and upper values of each sectoral employment are taken from Table 3.

The solutions obtained from the mathematical models (Eqs.(26) and (27)) are presented in Table 4, and pictorially in Fig. 3. The memberships of each objective are shown in Table 5. The results show that about 89 and 85 per cent of the GDP growth will be achieved based on the acceptability (Truth value) of NP additive and multiplicative models, respectively. While the electricity consumption goal will be attained by not less than 80 and 76 per cent, and the GHG emission goal will also be attained by 68 and 72 per cent, respectively, from additive and multiplicative models of the NP. Similarly, the indeterminacy of the three goals from both additive and multiplicative models is 72% and 61% for GDP growth, 60% and 53% for energy consumption and 59% and 65% for GHG emissions, respectively. Finally, the falsity aspect of attaining the goals is very negligent as shown by both additive and multiplicative models of the NP which can be observed from Table 5.



	Truth Membership	Indeterminacy Membership	Falsity Membership
GDP	0.8862713	0.7156782	0.01525413
Electricity consumption	0.7999999	0.5999998	1.10327E-07
GHG emission	0.6749183	0.5936479	0.2500908

Fig. 4 Membership values for Additive Model[Model-1(a)]



	Truth Membership	Indeterminacy Membership	Falsity Membership
GDP	0.8474692	0.6186731	0.05836749
Electricity consumption	0.7636569	0.5273138	0.04542886
GHG emission	0.7178174	0.6472718	0.2024251

Fig. 5 Membership values for Multiplicative Model[Model-1(b)]

Table 6 Employment in different sectors obtained from the NP model

S/N	Economic sectors	Additive Model	Multi-plicative Model
1	Agriculture, Forestry and Fishing	43665	31340
2	Mining & Quarrying	18770	18770
3	Manufacturing	125044	137371
4	Electricity, Gas Steam & other utility service	13770	13770
5	Construction	61537	61537
6	Trade; repair; hotels and resturants	51534	51534
7	Transportation; Storage; communication and service related to broadcasting	39290	39290
8	Financial, real estate and professional services	214833	214833
9	Community, social and personal services	178712	178710

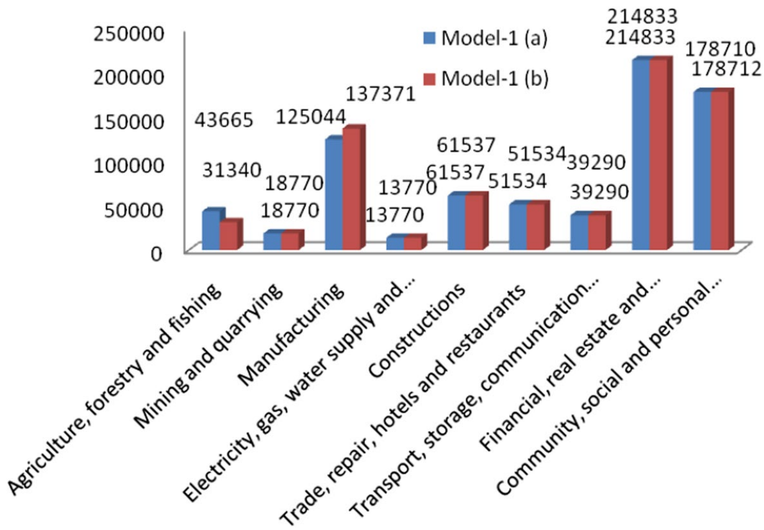


Fig. 6 Optimal employment for different sectors from Additive & Multiplicative Models [Model-1(a) & (b)]

The solutions of the NP model are pictorially represented in Figs. 4 and 5 accordingly. The proposed NP additive and multiplicative models further suggest the optimal number of employees required in each sector of the economy, to enable the government to achieve their goals as can be seen in Table 6 which are diagrammatically shown in Figs. 6, 7, and 8, respectively.

$$\begin{cases} Max \quad \sum_{i=1}^{3}\left(\mu_i + \sigma_i - \upsilon_i\right) \\ \mu_1 \geq \mu_1^T, \sigma_1 \geq \sigma_1^I, \upsilon_1 \geq \upsilon_1^F \\ \mu_2 \geq \mu_2^T, \sigma_2 \geq \sigma_2^I, \upsilon_2 \geq \upsilon_1^F \\ \mu_3 \geq \mu_3^T, \sigma_3 \geq \sigma_3^I, \upsilon_3 \geq \upsilon_1^F \\ \mu_i \geq \sigma_i, \quad \mu_i \geq \upsilon_i, \quad \mu_i + \sigma_i + \upsilon_i \leq 3, \\ \mu_i, \sigma_i, \upsilon_i \in [0,1], i = 1,2,3. \\ Z_1 = 0.681552283x_1 + 0.150562067x_2 + 0.159955905x_3 + 0.16867756x_4 + 0.543664609x_5 + \\ 0.991889435_x6 + 0.166488419x_7 + 0.403871513_x8 + 0.0706222931_x9 \\ Z_2 = 6.15403329x_1 + 1.36092701x_2 + 1.44442035x_3 + 1.52543936x_4 + 4.90812071x_5 + \\ 8.95888616x_6 + 1.50419191x_7 + 3.64589391x_8 + 0.636998489x_9 \\ Z_3 = 0.0142727273x_1 + 0.00880713905x_2 + 0.00106008855x_3 + 0.0522367466x_4 + \\ 0.00891083676x_5 + 0.00826126126x_6 + 0.00361516925x_7 + 0.00113418468x_8 + 0.000771305467x_9 \\ x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 \leq 747155, \\ 0.681552283x_1 + 0.150562067x_2 + 0.159955905x_3 + 0.16867756x_4 + 0.543664609x_5 + \\ 0.991889435_x6 + 0.166488419x_7 + 0.403871513_x8 + 0.0706222931_x9 \leq 264251, \\ 3.42671788x_1 + 0.847362813x_2 + 0.147646155x_3 + 1.28794481x_4 + 4.08703704x_5 + 8.43366093x_6 + \\ 0.446169509x_7 + 0.800766208x_8 + 0.0424374685x_9 \leq 1200000 \\ 23430 \leq x_1 \leq 98891, \quad 18770 \leq x_2 \leq 79222, \quad 110670 \leq x_3 \leq 178850, \\ 13770 \leq x_4 \leq 58118, \quad 14580 \leq x_5 \leq 61537, \quad 12210 \leq x_6 \leq 51534, \\ 39290 \leq x_7 \leq 165831, \quad 50900 \leq x_8 \leq 214833, \quad 178710 \leq x_9 \leq 288808 \end{cases} \tag{26}$$

$$\begin{cases} Min \quad \sum_{i=1}^{3}\left\{(1-\mu_i)(1-\sigma_i)\upsilon_i\right\} \\ \mu_1 \geq \mu_1^T, \sigma_1 \geq \sigma_1^I, \upsilon_1 \geq \upsilon_1^F \\ \mu_2 \geq \mu_2^T, \sigma_2 \geq \sigma_2^I, \upsilon_2 \geq \upsilon_1^F \\ \mu_3 \geq \mu_3^T, \sigma_3 \geq \sigma_3^I, \upsilon_3 \geq \upsilon_1^F \\ \mu_i \geq \sigma_i, \quad \mu_i \geq \upsilon_i, \quad \mu_i + \sigma_i + \upsilon_i \leq 3, \\ \mu_i, \sigma_i, \upsilon_i \in [0,1], i = 1,2,3. \\ Z_1 = 0.681552283x_1 + 0.150562067x_2 + 0.159955905x_3 + 0.16867756x_4 + 0.543664609x_5 + \\ 0.991889435_x6 + 0.166488419x_7 + 0.403871513_x8 + 0.0706222931_x9 \\ Z_2 = 6.15403329x_1 + 1.36092701x_2 + 1.44442035x_3 + 1.52543936x_4 + 4.90812071x_5 + \\ 8.95888616x_6 + 1.50419191x_7 + 3.64589391x_8 + 0.636998489x_9 \\ Z_3 = 0.0142727273x_1 + 0.00880713905x_2 + 0.00106008855x_3 + 0.0522367466x_4 + \\ 0.00891083676x_5 + 0.00826126126x_6 + 0.00361516925x_7 + 0.00113418468x_8 + 0.000771305467x_9 \\ x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 \leq 747155, \\ 0.681552283x_1 + 0.150562067x_2 + 0.159955905x_3 + 0.16867756x_4 + 0.543664609x_5 + \\ 0.991889435_x6 + 0.166488419x_7 + 0.403871513_x8 + 0.0706222931_x9 \leq 264251, \\ 3.42671788x_1 + 0.847362813x_2 + 0.147646155x_3 + 1.28794481x_4 + 4.08703704x_5 + 8.43366093x_6 + \\ 0.446169509x_7 + 0.800766208x_8 + 0.0424374685x_9 \leq 1200000 \\ 23430 \leq x_1 \leq 98891, \quad 18770 \leq x_2 \leq 79222, \quad 110670 \leq x_3 \leq 178850, \\ 13770 \leq x_4 \leq 58118, \quad 14580 \leq x_5 \leq 61537, \quad 12210 \leq x_6 \leq 51534, \\ 39290 \leq x_7 \leq 165831, \quad 50900 \leq x_8 \leq 214833, \quad 178710 \leq x_9 \leq 288808 \end{cases} \tag{27}$$

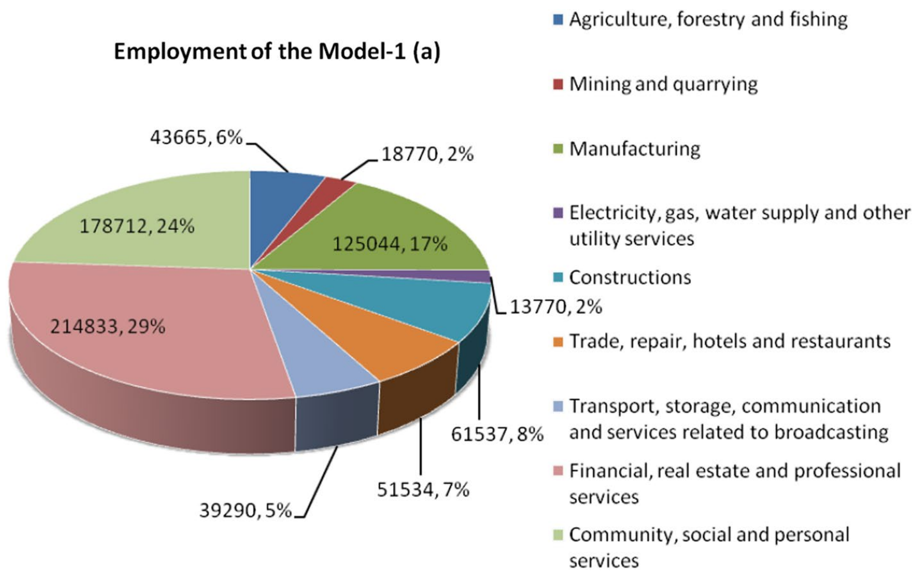


Fig. 7 Optimal employment for different sector obtained from Additive model(Model-1 (a))

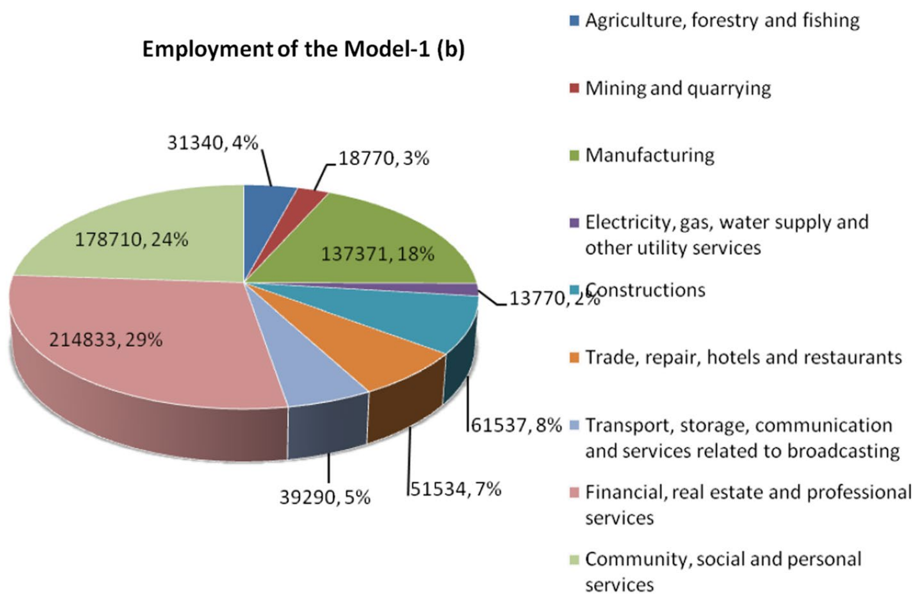
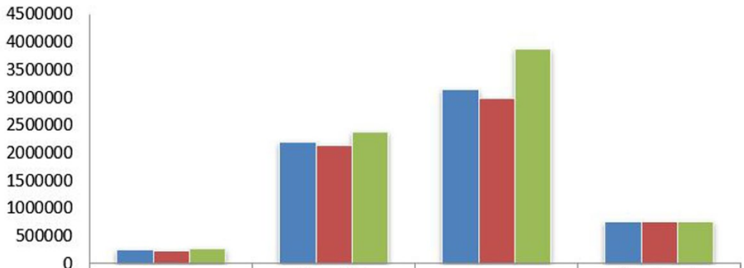


Fig. 8 Optimal employment for different sector obtained from Multiplicative Model (Model-1 (b))

7.1 Results comparision and model validation

In this section, two models are compared. The traditional GP and the proposed NP. It is found that the result from the GP model has slightly improved the two objectives- GDP



	GDP in INR (Billion)	Electricity consumption (GWh)	GHG emission (thousand tonnes)	Number of employment (million)
Model-1 a	245409.1	2194772	3138010	747155
Model-1 b	238980.6	2134655	2975165	747155
GP model	264251	2367354	3864665	747155

Fig. 9 Results comparision from NP Model-1 a & b and GP Model

and Electricity consumption goals while performed worst in GHG emission-related goals compared to the NP model (see Fig. 9). However, the decision-maker will want a result that gives the best possible compromise solutions for all objectives rather than a partial solution to some objectives. In this regards, the NP model is better than the GP model. Hence, the proposed NP model is validated and proved to be more suitable than the GP model when more objectives are involved. In multiobjective optimization, the best method is the one that provides an acceptable compromise solution to all objectives involved. Therefore, in this case, GHGs emission has an inferior solution using the GP model while the other two objectives have a superior solution. However, the results from the NP model (1 a & b) give a balance compromise solutions among the three objectives. Such a result from GP model is not acceptable by the decision-makers, because GHGs emission is a grave issue affecting the environment and ultimately affecting human lives. Policymakers will prefer the results from the NP model to that of the GP approach.

8 Conclusion

The primary purpose of this research work is to analyze the socioeconomic policies of India for the year 2030. An NP with additive and multiplicative operators of membership functions has been formulated to analyze the goals related to GDP growth, electricity consumption, and GHG emissions. The additive model revealed that 89% of GDP, 80% of electricity consumptions and 68% of GHG emissions would be achieved while the multiplicative model shows that 85% of GDP, 76% of electricity consumptions and 72% of GHG emissions would be achieved by the year 2030 under the current policy, respectively. The two models suggested the optimal number of employees required for each economic sector as well, but the degrees of goals achievement is not up to 100% evident from this study. This implies that the policy-makers can review and improve their policies toward these goals for realising the vision 2030 completely. Additionally, the formulated model of SDG India is solved with a GP model to compare the results with that of the NP models. The solution of GP models fails to balance the compromise solutions of all the objectives; however, the NP model does. Hence, it can be concluded that the NP approach is better in balancing all the compromise solution of a multiobjective optimization problem. The limitation of the present study is that it considers crisp data from the available government SDGs estimated targets and modeling the problem. It has not incorporated vagueness or imprecision in the information, most especially now with the covid-19 pandemic, the data may be revised and incorporate future uncertainty in subsequent research. Therefore, the present study can have potentials extensions to consider uncertainty in the parameters of the model.

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