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Evaluation of Nigeria's Sustainable Development Goals Agenda 2030 using mathematical programming

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ABSTRACT

It is impossible to overstate the importance of the Sustainable Development Goals (SDGs) to every society. Connecting economic, social, and environmental sustainability, the SDGs have 17 interconnected goals with 269 target indicators. To achieve the SDGs cost-effectively and efficiently, decision-makers (DM) and policymakers seek rigorous and robust decision-making tools like optimization modelling. This study considering the disruption of COVID-19 on the economic and sustainability issues globally, assessed the trend and progress associated with the SDGs target of Nigeria. The research utilized quantitative and qualitative data on critical factors such as Nigerian growth domestic product (GDP), power consumption by economic contributing sectors, employment, and greenhouse gas emissions, and considered in the modelling. The findings indicated areas where the authorities are performing well and where it needs to assert more effort strategically to address the country's economic challenges for socioeconomic growth and sustainability. The concept of the study can be replicated in other countries with some slight modification in the modeling and problem formulation. Future scope can explore the African vision 2040, using different concept.

1. Introduction

The SDGs as agreed by all UN member states working together to achieve them is the interest of everyone on earth. In practice, competing factors are always to be considered when making decision for optimal outcome. Management decision-making is one area where optimization approaches have matured, and new applications have been found in recent years. Disruptions and environmental unpredictability, such as the COVID-19 epidemic, have impacted Nigeria's

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progress towards various SDGs. Therefore, the government might be curious about which targets to focus on and which are unrealistic to achieve by 2030 based on the indicators. The potential for violence in the country has, without a doubt, slowed development in various economic spheres. The Nigerian government places a high priority on reducing hardship on the massive. Therefore, progressing towards the SDGs would be a huge step. However, compliance restrictions will be a significant barrier to meeting the SDGs. The attitudes of individuals, groups, and the public could be responsible for under-performance in several economic sectors, which must be investigated to guide the government on policy derivations. Other factors, such as uncertainties and limitations, and the economic factors must be considered for the nation's sustainability.

It is paramount to know whether the government's effort towards achieving the SDGs Agenda 2030 is attainable. As a result, evaluating the level of accomplishment of SDGs in Nigeria will help FGN make informed decisions in the annual budgetary provision towards achieving Vision 2030. Because of the uncertainty, the robustness of the method of this study will give managerial insight by presenting the sensitivity analysis of the result to help inform policymakers of the range within which solutions can address the issue at stake. The achievement of the SDGs agenda 2030 is a global issue; hence the benefit of this study cannot be over-emphasized. The study seeks to provide information for prompt action in the areas requiring a rapid response to actualize the country's dream. It will also serve as an aid to the government in the drafting and implementation of actionable policies and control strategies. Other researchers will use this study as a reference source for sustainability-related work. The non-governmental organizations interested in supporting humanitarian relief services may use the findings of this study for intervention purposes.

Every country globally has the same fundamental difficulties in sustainably achieving its development goals. Furthermore, these SDGs set by the UN member countries are targeted to be completed by 2030 by different nations [1]. However, several factors, such as disasters, pandemic outbreaks, insecurity, etc., could challenge achieving the SDGs targets [2]. Hence, there is a need to evaluate the level of these achievements to facilitate policy-making. A mathematical programming approach is well-suited to aiding policymakers in achieving their aspired goals in a context of uncertainty and competing objectives across social, economic, energy, and environmental domains [3, 4, 5]. The 17 SDGs generally revolve around social, economic, and environmental-related goals [6]. Dealing with multiple criteria for obtaining satisficing solutions, requires expert opinions and technical know-how of the researcher [7].

The principal aim of this research is to bring to the fore the modelling of conflicting goals, multiple criteria, and spatial indicators of SDGs' performance in assessing policy efforts towards achieving government agenda 2030 plans using mathematical optimization incorporating uncertainty. Also, these methods are complementary and gain more understanding and interpretation [8]. Agriculture being the subset of SDGs which is mainly the primary sector has been considered in a study by Modibbo [7]. Considering the unprecedented disruptions during the COVID-19 pandemic, which affected several sectors globally [3], this research proposes utilizing a multi-objective goal programming approach to examine Nigeria's sustainable development goals, Vision 2030. The specific objectives of the study are to identify and model the drivers of Nigerian SDGs using mathematical programming concepts, analyze the impact of constraints compliance to SDGs for national development and sustainability, evaluate the effect of the COVID-19 pandemic on the SDGs of Nigeria, quantify whether the target set by the federal government of Nigeria (FGN) by 2030 is achievable, and assess the level of achievement of the SDGs Vision 2030 in Nigeria. The research utilizes quantitative and qualitative data on critical factors such as Nigerian growth domestic product (GDP), power consumption by economic contributing sectors, employment, and greenhouse gas emissions, which were considered in the modelling. The data were sourced from published materials and official government documents through their respective sites; such as world information science, the SDGs website, and the world population prospects.

2. Literature Review

The Numerous scholars use various modelling methodologies in multiple nations with different decision variables to simulate sustainable development. For instance, in 2015, the socioeconomic analysis of the United Arab Emirates (UAE) focused on labour optimization was conducted using traditional goal programming (GP) [9]. Jayaraman et al. [10] have used a general-purpose model with a satisfaction function that considers the number of workers across various economic sectors and numerous sustainability objectives for GDP growth, energy use, and greenhouse gas (GHG) emissions. The model provides crucial inputs for formulating and applying strategies that are conducive to sustainable growth. To achieve the 2030 goals, they validate the model using statistics on critical economic sectors in the UAE. Jayaraman et al. [11] proposed another extension of GP techniques, known as weighted GP, to integrate the components of allocating scarce resources in achieving SDGs for UAEs. The SDGs' sustainable accomplishments are modelled after the UAE's energy, environmental, and job goals using stochastic goal programming Jayaraman *et al.* [6]. To verify the model, they used sectorial data on vital economic sectors for the UAEs acquired from various sources. To simultaneously satisfy future goals on economic growth, energy consumption, workforce, and greenhouse gas emission reduction applied to important economic sectors of the UAE, Jayaraman et al. [12] suggest a fuzzy goal programming model and extension of the GP. Nomani et al. [13] used the FGP approach to analyze India's 2030 environmental, energy, and sustainability objectives concerning the country's critical economic sectors. Several authors proposed the fuzzy logic to deal with complex problems related to sustainability [18, 19, 20, 21].

According to Gupta et al. [14], a multi-criterion modelling strategy utilizing the linear programming problem (LPP) paradigm is presented for concurrently optimizing these three sectors. Additionally, they created an FGP model that allows for the most efficient use of resources while reaching long-term targets for the GDP, EC, and GHG emissions. To achieve future objectives of GDP growth, EC, and GHG emissions, a weighted model of FGP was also given. This model allowed for the generation of varying solutions per the priorities set by the decision-maker. The concept of GP with a satisfaction function was used by Ali et al. [15] to propose a multi-objective optimization model that integrates economic growth, electricity consumption, greenhouse gas emissions, and the number of employees across the primary, secondary, and tertiary sectors of the Indian economy. For the sustainable development objectives of India Vision 2030, the model was validated using data from the three economic sectors. The findings gave a quantitative justification for attaining economic growth, electricity consumption, and optimal employment strength across the sectors. Modibbo et al. [4] proposed a multiple-objective optimization model that considers four scenarios based on an analytical hierarchy process (AHP) for Nigeria’s SDGs goals. Then, the model integrates FGP and WGP to analyze the achievement levels of the SDG targets. Alarjani *et al.* [1] proposed a new framework for SDG optimization in Saudi Arabia. They formulated FGP and WGP using the membership function, taking the weights from the AHP approach. Similarly, FGP have been applied in optimal mix of power generation for socio-economic sustainability. Recent research by Haq et al. [16] used neutrosophic programming in analyzing India’s SDGs. The model can manage ambiguity (indeterminacy), truthfulness, and falsehood in the decision-maker threshold. Several applications of optimization models in solving SDGs-related accomplishments have been studied and documented [4, 5].

Nigeria is the largest country in Africa, with a total land area of 923,768 square kilometers (356,667 square miles), of which 910,771 square kilometers (351,649 square miles) are land (98.6%). With a 2.60% yearly growth rate, the population is expected to reach above 200 million. The nation is currently rated seventh in the world and is expected to rise to the third-largest economy in Africa by 2050. The nation has the greatest population among African countries, with 46 million middle-class citizens. Following GDP rebasing, Nigeria has the largest market among African nations in terms of nominal GDP. By 2050, it was predicted to rank ninth globally in terms of GDP purchasing power parity (PPP).

The country is divided into six geopolitical zones: north-central; northeast; north-west; south-east; south-south; and southwest. Furthermore, the country is made up of 36 states and the Federal Capital Territory. According to Sambo [17], all states in Nigeria have natural resources to offer, ranging from agricultural plants to deep forests, rivers, lakes, and mountains located throughout the country. The geometric consequences of population expansion are linked to Nigeria's continued high demand for natural, human, capital, and material resources. According to the National Bureau of Statistics, GDP growth, as illustrated in Figure 1, represents the level at which nations are. This necessitates collaboration among social, economic, environmental, energy, and institutional systems to ensure the country's long-term development.

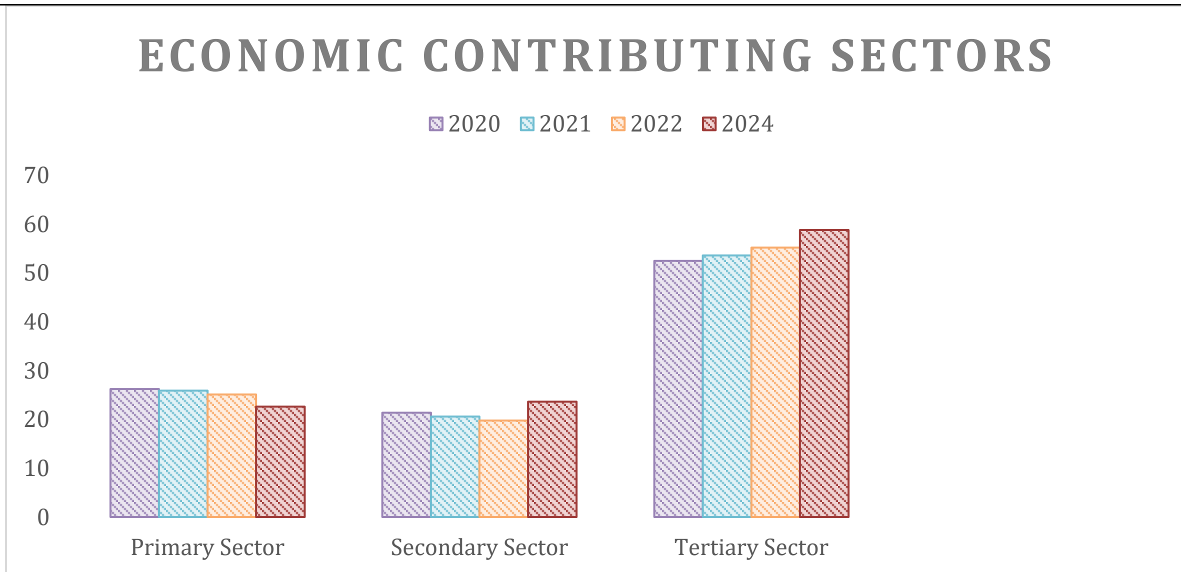

Figure 1: Nigerian Average GDP percentage growth from the last quarter of 2020-2024.

To achieve these sets of objectives, governments and other stakeholders must create and implement workable policies in each member country. Achieving eco-friendly surroundings requires reducing emissions, improving the economy, and using energy efficiently. Policies that address important issues such as job possibilities, power supply, economic growth, and greenhouse gas reduction are essential. However, due to the unequal distribution of natural resources and technological advancements, these characteristics may differ in each nation. One of the reasons why scholars and politicians around the world have used optimization techniques to solve these issues in a variety of ways may be the unequal distribution of resources and technical advancements. Figure 2 shows the population of the nation, its annual growth rate, and UN forecasts for the next 2100 years.

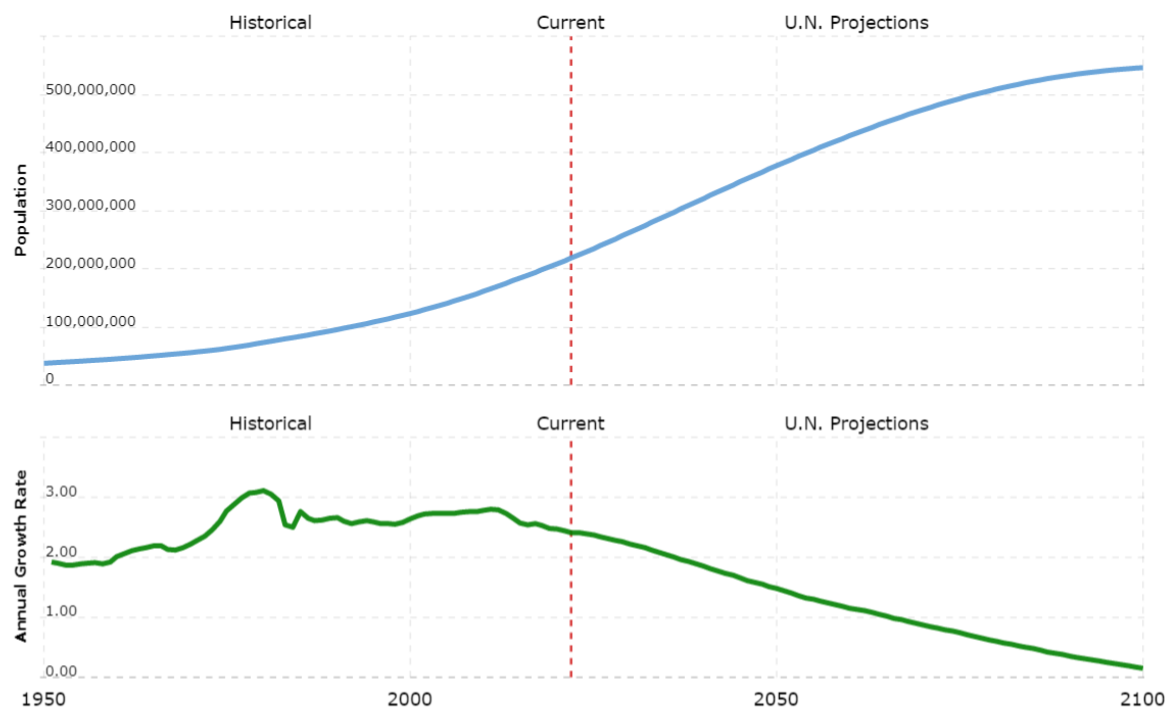

Figure 2: Nigerian Population and growth rate projections. Source: www.Worldometers.info

3. Methodology

The study will be conducted in stages. Initially, the contributing economic sectors will be identified and analyzed. The primary economic drivers and the three tiers of the SDGs: Viz- economic, social and environmental aspects will be captured. Hence, the problem under investigation will comprise more than one conflicting objective function—a mathematical programming approach best suits such multi-objective optimization problems (MOP). Mathematical programming or modelling is a formulation of a real-life situation into mathematical terms, each defined according to its usage in the model. The model is then solved and interpreted for decision-makers to use it. A typical MP problem is given in Eq. (1).

$$\begin{aligned} &\text{Max (or Min)}: \; Z = f(\underline{x}) \\ &\text{subject to;} \\ &a_i(\underline{x}) \leq (or = or \geq)\; b_i \\ &\underline{x} \geq 0 \end{aligned} \tag{1}$$

Where $\underline{x} = (x_1, x_2, x_3, \ldots, x_n)^T$ is a vector of $n-$components of unknown decision variables, $Z = f(\underline{x})$ is the set of objective functions and $a_i(\underline{x}),\ (i = 1,2,\ldots, I)$ constraints set with the resource limitation b_i. The restrictions $(\underline{x}) \geq 0$ are called non-negativity restrictions. Besides that, each constraint can only hold one of the symbols $\leq, =$ and $\geq$, depending on the nature of the objective functions $Z = f(\underline{x})$ and the constraints $a_i(\underline{x}),\ (i = 1,2,\ldots, I)$ and restrictions on the decision variables $\underline{x}$.

3.1 Data Presentation

Information related to the SDG targets by 2030 in Nigeria and that of employment, greenhouse gas emission and the electricity consumption have been source differently and presented in Tables 1-3. The forecast after the vision 2030 of SDGs are presented in Table 4 alongside the population ranking globally.

Table 1 Nigeria GDP (2019-2029)

YEAR	GDP (in billion USD)	GROWTH COMPARED TO PREVIOUS YEAR (In Percentage)
2019	474.5	2.21
2020	432.72	-0.79
2021	441.63	3.65
2022	476.47	3.25
2023	363.82	2.86
2024	199.72	2.86
2025	194.96	3.16
2026	224.78	2.99
2027	239.41	3.34
2028	260.96	3.34
2029	268.95	3.32

Source: www.statista.com (sourced from the IMF)

Table 2. Target Goals by the Year 2030

Economic Indicator	GDP (Million NAIRA)	ECC (in Billion kWh)	GHG (Mt CO_2 eq)	Number of Employment (Million)
Value	44,601,361.13	29,011.42	308.180	69,675,468.12
Goal by the year 2030	6,699,450,000	54,895.58122	453	99,675,468
Annual growth rate	7.1%	6.71%	2.6%	0.70%

Sources: NBS (2022), CBN 2021 bulletin, and Modibbo et al. (2021a).

Table 3. Current Values for the Three Economic Sectors

Economic Sectors	GDP (Million NAIRA)	ECC (in kWh)	GHG (in Mt CO_2)	Employment ('000)
Primary	14,395,264.42	5222.056	55,472.4	20,902,640
Secondary	8,792,476.85	12,184.80	129,435.6	13,935,094
Tertiary	21,413,619.86	11,604.60	123,272	34,837,734

Source: From the authors computation

Table 4: Nigeria Population Forecast after SDGs target from 2030 through 2050

Year	Population	Yearly % Change	Yearly Change	Migrants (net)	Median age	Fertility rate	Density (P/Km2)	Urban Pop %	Urban Population	Country's share of world population	World Population	Nigeria Global Rank
2030	262,380,970	2.01	4,970,638	24,085	19.3	3.82	288	59.6	156,299,881	3.06	8,569,124,911	6
2035	287,685,763	1.86	5,060,959	35,506	19.3	3.41	316	64.3	184,887,647	3.24	8,885,210,181	6
2040	312,710,416	1.68	5,004,931	41,202	21.7	3.10	343	69.1	216,083,536	3.41	9,177,190,203	5
2045	336,662,502	1.49	4,790,417	44,157	22.7	2.85	370	74.3	250,285,391	3.57	9,439,639,668	5
2050	359,185,556	1.30	4,504,611		23.9	2.66	394	79.9	287,130,349	3.72	9,664,378,587	5

Source: Worldometer (www.Worldometers.info) Elaboration of data by United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2024 Revision. (Medium-fertility variant).

The electrical consumption in Nigeria is highest in the residential sector, followed by the commercial and public services sectors, and finally the industrial sector. The industry that uses the most final energy is transportation. See Figure 3.

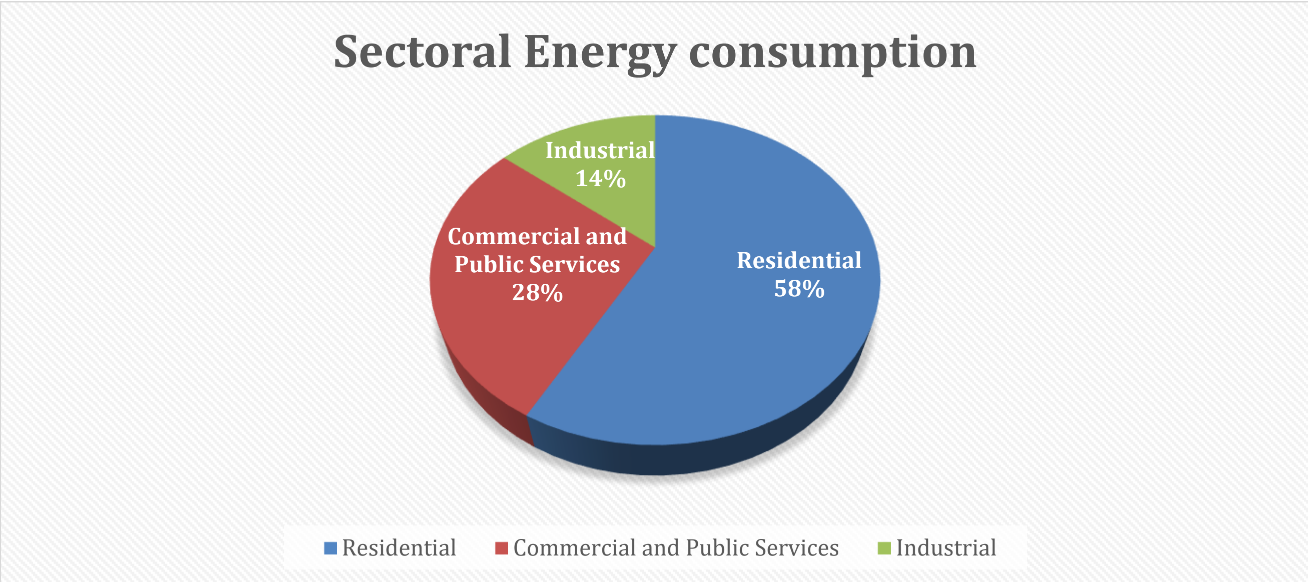

Figure 3. Energy consumption by sector. Source: Authors' computation from www.statista.com

The SDGs Model Formulation

Using the information in the Tables 1-3, we formulated the optimization model in light of Eq. (1). As follows:

$$Max.\ Z_1(X) = \sum_{i=1}^{3}[[(GDP)_i]]x_j \quad (2)$$

$$Min. Z_2(X) = \sum_{i=1}^{3}[(ECC)_j]x_j \quad (3)$$

$$Min. Z_3(X) = \sum_{i=1}^{3}[(GHG)_i]x_j \quad (4)$$

Subject to the set of constraints:

$$\sum_{i=1}^{3}\left[(\mathrm{GDP})_j\right]x_j \geq (\mathrm{GDP})_g \tag{5}$$

$$\sum_{i=1}^{3}\left[(\mathrm{ECC})_j\right]x_j \geq (\mathrm{ECC})_g \tag{6}$$

$$\sum_{i=1}^{3}\left[(\mathrm{GHG})_j\right]x_j \leq (\mathrm{GHG})_g \tag{7}$$

$$\sum_{i=1}^{3} x_j \leq (\mathrm{EMP})_g \tag{8}$$

$$E_j \leq x_j \leq E_g \; j = 1, 2, 3 \tag{9}$$

4. Result Analysis and Discussion

With Lingo version 16.0, the aforementioned models (2)– (9) were solved using the information in Tables 1 - 3, and the outcomes are shown in Table 5. The results indicated that there were significant positive deviations in D12, D22, and D32. The numbers can be interpreted as follows: by 2030, Nigeria will require a significant amount of energy and GDP in order to simultaneously meet all four requirements and reduce its GHG emissions. It suggests the addition of additional renewable energy sources, such as wind, nuclear, and solar, to fulfil Nigeria's growing energy needs. Only then will the nation achieve its Sustainable Goals Mission 2030.

Table 5 Lingo Solver Result version 16.0

Deviations / Variable	Value	Reduced Cost
D12	50142860000	0.000000
D22	65168930000	0.000000
D32	14200110000	0.000000
D11	0.000000	0.2000000
D21	0.000000	0.2000000
D31	0.000000	0.2000000
X1	209026.4	0.000000
X2	39350.9	0.000000
X3	348377.3	0.000000

5. Conclusion

It is crucial to use multi-criteria optimization modelling of sustainability goals while creating policies and tackling developmental challenges. In the context of Nigeria, economic policy, and the SDGs, this article uses a multi-criteria optimization model that takes into account employment, power consumption, greenhouse gas emissions, and economic growth by 2030. The model has provided mathematical support for modifications and changes in the energy industry, and the effects have been analysed. In the upcoming years, Nigeria will place a high priority on the development and application of renewable energy.

Author Contributions

All authors have participated in writing the paper, all of them have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data supporting the findings of this study are available in the paper.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper."

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