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Assessment of COVID-19 impact on sustainable development goals indicators in Egypt using fuzzy analytic hierarchy process

Mohamed Marzouk a,⁎, Nehal Elshaboury b, Shimaa Azab c, Alaa Megahed d, Mahmoud Metawie e

a Structural Engineering Department, Faculty of Engineering, Cairo University, Egypt
b Construction and Project Management Research Institute, Housing and Building National Research Center, Giza, Egypt
c Environmental Planning and Development Center, Institute of National Planning, (INP), Cairo, Egypt
d Integrated Engineering Design Management Department, Faculty of Engineering, Cairo University, Egypt
e Structural Engineering Department, Faculty of Engineering, Cairo University, Giza, Egypt

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ABSTRACT

COVID-19 significantly influences the Sustainable Development Goals (SDGs) in both developed and developing countries. Within the 2030 agenda, Egypt is likely to face enormous negative ramifications from the virus spread. As a result, efficient control of the adverse repercussions of this virus is critical to achieving this objective. This research assesses indicators of specific SDGs in reflecting COVID-19 impact by conducting several questionnaire surveys among experts in Egypt. The scope of this research is limited to addressing poverty alleviation (SDG1), hunger abatement (SDG2), healthcare promotion (SDG3), sustainable economic growth (SDG8), and climate change mitigation (SDG13). The indicators are prioritized using the relative importance index, weighted aggregated sum product assessment technique for order preference by similarity to an ideal solution, and fuzzy analytic hierarchy process. The rankings are finally aggregated using an approach based on the half-quadratic theory. The results reveal that the most significant indicators in reflecting the COVID-19 impact are the share of population living below the international poverty line, undernourishment prevalence, official health sector support, annual gross domestic product per capita growth rate, and number of disaster deaths for SDG1, SDG2, SDG3, SDG8, and SDG13, respectively. Recognizing and ranking the indicators could help decision-makers understand the behavior of SDG indicators in light of COVID-19. The research findings could assist policymakers in making informed decisions to reduce the pandemic effects and sustain achieving SDGs by 2030.

1. Introduction

In China, the first coronavirus disease 2019 (COVID-19) cases were reported in late 2019 [1]. On 11 March 2020, the World Health Organization (WHO) declared COVID-19 a global pandemic after the virus had spread to every country and territory on the planet [2]. COVID-19 confirmed cases had been 596,873,121, including deaths by 29 August 2022 [3]. Countries worldwide have taken various measures to control the virus spread, including lockdown, business and operation suspension, and travel restrictions [4]. This implies...
that the COVID-19 implications are not limited to the health sector and extend to the economic and social sectors [5].

The COVID-19 pandemic has decelerated global progress toward achieving the Sustainable Development Goals (SDGs) [5]. Specifically, all African countries were thought to be already falling behind in pursuing SDG targets, and this pandemic will jeopardize the accomplished progress [6]. In Egypt, the first confirmed infected and death cases were reported on 14 February 2020 and 20 March 2020, respectively. The Egyptian government has taken numerous countermeasures to mitigate the influence of the COVID-19 outbreak on human health. Examples of these strategies were practicing social distancing, imposing a curfew, allowing work/study from home, and delegating isolation sections in health facilities [7,8]. However, these policies were associated with a significant economic decline. Accordingly, COVID-19 has impeded the progress toward pursuing the SDGs in Egypt [9].

This research study aims to thoroughly evaluate COVID-19 impact on achieving the targets of specific SDGs in Egypt. COVID-19 negatively impacts public health and, consequently, all aspects of life, hindering the achievement of SDGs. This research aims to investigate the impact of COVID-19 on public health and the associated economic and environmental aspects. These aspects correspond to the first three goals in the world sustainable development agenda 2030: poverty alleviation (SDG1), hunger abatement (SDG2), and healthcare promotion (SDG3). The environmental and economic impacts of the epidemic are tightly linked to climate change mitigation (SDG13) and sustainable economic growth (SDG8) [10]. Questionnaire surveys were undertaken with key experts in the domain for scoring each indicator in the five assessed SDGs. Based on the gathered responses, the indicators were prioritized using Relative Importance Index (RII), Weighted aggregated sum product assessment-Technique for order preference by similarity to ideal solution (WT), and Fuzzy Analytic Hierarchy Process (FAHP) methods. The rankings were finally aggregated using an approach based on the half-quadratic theory. This research acts as a guide to help the government, stakeholders, and policymakers examine the pandemic’s implications on the SDG indicators and lessen their negative economic, social, and environmental repercussions. This information is beneficial for putting the 2030 Agenda for Sustainable Development into practice.

2. Literature review

The United Nations (UN) introduced SDGs on 25 September 2015. These goals shall be accomplished over fifteen years, beginning 1 January 2016 and ending 31 December 2030. The 2030 Agenda is a collection of 17 SDGs with 169 objectives designed to achieve a more sustainable, resilient, and prosperous world [11]. COVID-19 represents a major threat to achieving SDGs by 2030 [12]. Besides, it endangers the growth prospects of developing countries that lack the expertise or resources required to deal with the associated economic and social problems. This situation is considered a severe setback for the primary objectives of sustainable development, which are inclusion and no one being left behind [13]. Global unity and shared commitment must be critical in rebuilding momentum toward attaining the 2030 Agenda for Sustainable Development [14]. The UN has announced a strategy to “defeat the virus and establish a better world” to confront this pandemic. The plan asks for the world’s most powerful countries to establish decisive policy action and provide financial and technical assistance to the poorest and most vulnerable people [15]. Besides, the UN has started a fundraising campaign to gather USD 2 billion to combat COVID-19 [16].

Before COVID-19, the world was significantly off track to ending poverty (SDG1) by 2030, with forecasts indicating that 6% of the total population will still live in extreme poverty by 2030. A worldwide economic recession after the pandemic might force millions back into poverty and increase inequities [17]. The COVID-19 economic downturn will force 420–580 million people into poverty, resulting in the first increase in global poverty since 1990 [18]. There is no question that the poverty tsunami in developing countries is inextricably linked to other social problems such as illness, war, and inequality [19]. To eliminate hunger under SDG2, the proportion of the population impacted by food insecurity increased between 2014 and 2018 (i.e., before COVID-19). The situation has been worsened by the spillover effects of the COVID-19 crisis on supply chains, production, and household incomes [17].

Wang and Huang [20] conducted a bibliometrics analysis of the impact of COVID-19 on sustainability and SDGs. The results revealed COVID-19 pandemic had negative effects on 17 SDGs goals, whereas the pandemic may also bring opportunities to another 14 SDGs goals. The effects of the coronavirus are not limited to SDG1 (no poverty) and SDG2 (zero hunger). Like any other disease, this virus negatively infringes on health systems and threatens SDG3 (good health and well-being). This can be attributed to the fact that hospitals and other health facilities are overburdened in many countries.

Moreover, people might be hesitant to seek medical care for fear of becoming infected in these locations. The death rates might be significant because of the lack of equipment, infrastructure, and qualified personnel in underdeveloped healthcare systems [21]. Furthermore, vaccination programs for children have been discontinued in 70 countries, and health services for other diseases have been interrupted or neglected in many regions. Disruptions in health care services could reverse decades of progress, causing long-term downside consequences for public health [17]. Finally, pandemics could have a considerable psychological impact, exacerbated by socio-economic disparities and future uncertainty [22].

Some research studies focused on studying the impact of the coronavirus disease on SDG 3. For instance, Filho et al. [21] discussed the impact of the coronavirus epidemic on SDGs implementation worldwide. The findings reported the priority of COVID-19 for many health systems in developing countries. However, this might disrupt preventive initiatives for other diseases and overlook mental health problems. As a result, COVID-19 might endanger the process of implementing the SDGs. This research is important to track the SDGs implementation so that the attained progress is not jeopardized. Ekwebelem et al. [6] discussed the adverse consequences of the epidemic on the African countries to achieve the SDGs. The findings affirmed the importance of enhancing some SDGs in parallel with improving the healthcare systems to control the epidemic. Moreover, the African nations must devise policies that neither threaten the SDGs implementation nor imperil accomplished SDG objectives in response to the pandemic.

The coronavirus pandemic appears to have an unprecedented devastating impact on the global economy under SDG8 [23]. It unveils more powerful and long-lasting influences than those experienced during the global financial crisis of 2008–2009 [24]. This
can be attributed to supply chain disruption, business closure, unemployment, reduced trade and tourism, and travel restrictions in many countries [25]. Despite the government policy decisions and interventions deemed necessary to control the spread of the COVID-19 virus, they might hamper economic growth worldwide. It was estimated that the cost to the world economy would be about USD 1 trillion in 2020 [26]. However, this value might be underestimated due to the uncertainties about the pandemic’s length, spread, impact, and different policy responses. Safitri et al. [5] conducted a thorough literature review and semi-formal interviews with key stakeholders in Indonesia to provide a deep understanding of the COVID-19 implications on the SDGs and its fiscal stimulus package. According to the findings, the economic and social development pillars were the most influenced among the four pillars of sustainable development. It was perceived that fiscal stimulus could assist in maintaining SDG development, but there are some issues with its implementation. Finally, this research offered critical recommendations for the effective implementation of SDGs after the pandemic.

On the other side, the pandemic might become an unanticipated facilitator for achieving specific SDGs. For example, government expenditure during a recession could have a significant positive impact on the health sector [27]. Moreover, seeking green public procurement not only contributes to economic growth but also promotes environmental benefits [28]. At the same time, the beneficial influence of COVID-19 on the environment is widely acknowledged. The reductions in emissions result from halting travel and industrial activities as well as lessening the demand for fossil fuels [29]. Therefore, the current crisis can be perceived as an opportunity to accelerate the transition to a low-carbon future and mitigate climate change (SDG13) [30,31]. It could be therefore regarded as a good turning point in which resilience and stronger emergence are demonstrated. However, these benefits might be temporary; it is anticipated that the environmental deterioration will revert to previous levels once economic activities resume [21].

Several research studies addressed the COVID-19 impact on multiple SDGs within the 2030 Agenda for Sustainable Development. For example, Nundy et al. [32] investigated the global impact of the pandemic on the economic, energy, environment, transport, and human life sectors. These industries had been affected by the lockdown and social distancing strategies forced to curb the virus transmission. Most business operations ceased during the lockdown, significantly reducing energy consumption and improving the environment. Besides, the stagnant economy interrupted the human mindset and caused financial setbacks. The transportation sector attempted to recover from unsustainable losses without government assistance and friendly strategies.

Furthermore, priority shall be given to maintaining the quality of the indoor environment since many people have shifted to work remotely. The energy-efficient buildings also played an important role in reducing the building energy demand. The authors finally recommended collaborative assistance among all nations to meet the SDGs by 2030.

Ranjbari et al. [33] examined the COVID-19 effect on the triple sustainability pillars (i.e., economic, social, and environmental perspectives) and the SDGs. The study identified the current research gaps and proposed some research directions for sustainable development: 1) an action plan that modifies sustainability objectives and targets and creates a measurement mechanism based on the virus implications, 2) creative approaches for economic resilience, with a focus on SDGs 1 and 8, and 3) quantitative research expansion to harmonize the COVID-19-related sustainability research. In another study, Ranjbari et al. [34] mapped the SDG objectives and Iran’s implementation of the 2030 Agenda for Sustainable Development on a fuzzy action priority surface using a mixed-method methodology. This methodology comprised four primary phases: 1) listing the SDG targets influenced by COVID-19 using a modified Delphi method, 2) weighing the COVID-19 effects on the achievement of the SDG targets using the best-worst method, 3) weighing the impact of the SDGs targets on the implementation of sustainable development, and 4) determining the action priority scores of the SDG targets by developing a fuzzy inference system. As a result, the recovery Agenda for Sustainable Development included the following actions: cutting in half the proportion of the poor (SDG 1.2), development-oriented policies to support creativity and job creation (SDG 8.3), and stopping pandemics and other epidemics (SDG 3.3).

Shulla et al. [35] examined the impact of the COVID-19 outbreak on the interdependencies across SDGs based on focus group discussions. The research was limited to studying five SDGs, including health and wellness (SDG3), economic growth (SDG8), and climate action (SDG13). The findings indicated the interconnection between SDGs and COVID-19 outcomes. Ameli et al. [36] attempted to provide a policy response to achieve the SDGs while considering the long-term effects of COVID-19. The research proposed a qualitative analytical approach that consists of four steps: 1) identifying the causal-effect relationships among the independent SDGs in Iran using a fuzzy cognitive map, 2) examining possible pandemic implications on achieving the SDGs, 3) developing five strategies (i.e., sustainable food systems, green management, inclusive education, electrifying the labor market, and assisting energy-related projects), and 4) conducting scenarios for the five strategies based on the established links between the SDGs. The findings revealed that using any individual or combined strategy would lessen the COVID-19 impact on the SDGs in case of a medium pandemic activation level. In addition, employing a single strategy with a high activation level better achieved the SDGs than using a mix of strategies during low or medium pandemic activation levels.

The previous research studies have not tackled the following points inclusively: a) studying the COVID-19 implications and their impacts on achieving SDGs in Egypt, b) evaluating the SDGs at the indicator level, not the goal level, and c) considering and ranking the indicators based on their relative significance weights. To fill this gap, the major objective of this research is to examine the impact of the coronavirus pandemic on specific SDGs from the perspectives of different stakeholders in Egypt. This study provides policymakers with a decision-making tool for securing the resources and devoting the investments to the most influential indicators adversely affected by COVID-19. These recovery packages are essential for not only mitigating the pandemic’s short-term impacts but also promoting the achievement of SDGs and building a more resilient and sustainable community.

3. Impact of COVID-19 on SDGs in Egypt

Egypt is located on the African continent and has an area of around 1 million square kilometers. It is bounded to the north by the
Mediterranean Sea, to the south by Sudan, to the east by the Gaza Strip, Israel, and the Red Sea, and to the west by Libya. As illustrated in Fig. 1, Egypt is one of Africa’s COVID-19 hotspots; it ranks fourth after South Africa, Morocco, and Tunisia concerning the total infected cases [37]. Fig. 2 displays the COVID-19 spread in Egypt from 14 February 2020 until 28 August 2022. There had been 4719.34 cumulative infections per million persons on 28 August 2022 [38].

As of 29 August 2022, the total population in Egypt was estimated to be 106,488,227, while the population density was inferred to be 103 per square kilometer [39]. Overpopulation is a challenge that devours the rewards of accomplished growth and even imposes greater social and economic threats. As a result, the government attempts to control this problem and enhance demographic characteristics such as health, education, employment, and culture. This is integrated with optimizing human resource utilization through deploying a suite of training programs and capacity building [40]. The population structure of Egypt varies from that of Asian and European countries. Only 3.9% of Egyptians are over 65, whereas around 21% are between 18 and 29. COVID-19 has been reported to be more dangerous in the elderly and those suffering from chronic diseases. On the other hand, the Egyptian youth can serve as a defensive line to reduce the transmission of this disease [7].

The COVID-19 pandemic resulted in a funding gap of $2.5 trillion in 2020, which developing nations need to attain the SDGs by 2030 [41]. There was a $1 trillion difference in public spending on Coronavirus recovery measures compared to the expenditures in developed nations. Like all countries worldwide, COVID-19 has had extensive ramifications in Egypt regarding public health and economy. The virus has significantly influenced public health services across the country. As a result, it poses a serious challenge to policymakers and health care professionals [7]. The economic growth rates were supposed to reach 5.8% and 6% in fiscal years 2019/2020 and 2020/2021, respectively. As a result of the pandemic repercussions, the Gross Domestic Product (GDP) growth was contracted, reaching 3.6% FY2019/2020. Moreover, the human development index fell considerably in 2020 for the first time since it was developed in 1990 (Egypt Today staff, 2021). However, the Egyptian economy is expected to recover quickly after COVID-19, thanks to local development that makes the country less susceptible to global economic setbacks.

Egypt has demonstrated a strong commitment to achieving sustainable development by filling two Voluntary National Reviews in 2016 and 2018 and establishing a national sustainable development plan, Egypt Vision 2030. The third voluntary report is supposed to be released in later 2021. Furthermore, the Egyptian government has collaborated with the UN in launching the 2018–2022 United Nations Partnership Development Framework (UNPDF) [42]. The partnership is centered on boosting digital development and promoting resilient communities (Egypt Today staff, 2021).

In response to the COVID-19 pandemic, the Egyptian government initiated proactive policies to offset the negative impacts on different sectors. It delivered monetary aid and training programs to more than 6 million regular and irregular employees. Additionally, it provided liquidity and reduced financial burdens for the shipping, aviation, and tourism sectors and the small and medium enterprises. It also adopted incentive measures such as decreasing interest rates, granting financing packages, and deferring loans of some sectors and tax payments. The government launched the first phase of the national project for developing Egyptian villages, “A Decent Life”, in January 2019. The project reduced the coronavirus impact on 4.5 million citizens in 375 villages. It enhanced the

![Fig. 1. COVID-19 cumulative cases per million persons in African nations as of 28 August 2022 (Our World in Data, 2022).](image-url)
efficiency of 12,000 houses, increased access to basic services by 50%, and lowered the poverty rates in some villages by 14%. Following the first phase’s success, the initiative’s second phase was inaugurated in December 2020 to enhance the lives of 50 million citizens in all Egyptian villages (Egypt Today staff, 2021).

According to the 2020 UN sustainable development report, Egypt ranked 83rd in the world in terms of attaining SDGs, up from 92nd in 2019. Egypt has accomplished many social, economic, and environmental goals for 2030. These objectives are relevant to infrastructure, access to services, electricity, drinking water, sanitation, and travel and tourist competitiveness, being part of Egypt Vision 2030. This is achieved by improving education and health services and making the business climate more appealing to domestic and foreign investors [43]. For the fiscal year 2019/2020, numerous indicators had improved thanks to legislative and institutional changes, assisting in achieving overall stability and growth. FY2019/2020, the unemployment and average inflation rates had declined to around 8% and 5%, respectively. This was followed by a substantial drop in unemployment rates, reaching 7.2% in the second quarter of (FY2020/2021). Besides, the inflation rate declined to 4.9% in February 2021 (Egypt Today staff, 2021).

Fig. 2. COVID-19 spread in Egypt from 14 February 2020 until 28 August 2022.

Fig. 3. Research study flowchart.
4. Materials and methods

This section provides a clear and comprehensive description of the research framework, the data collection methods, and the methods used to analyze gathered data, as described in the next sub-sections.

4.1. Research design and methodology

The proposed flowchart for assessing the SDG indicators in reflecting COVID-19 impact in Egypt is shown in Fig. 3. The framework starts with reviewing the SDGs within the research scope and identifying the indicators for each assessed SDG. Several experts in the domain have been selected and contacted to gather their responses to assess the importance degree of the SDG indicators. Decision matrices are then formulated for each SDG based on the perceptions of different experts. Based on the gathered responses, three ranking techniques (i.e., RII, WT, and FAHP) are employed to provide initial rankings for the indicators. Various procedures are employed in different decision-making methods, resulting in distinct rankings. As a result, it is important to employ an ensemble approach in the final stage to provide an aggregated ranking for the indicators and prioritize their influence in reflecting the COVID-19 impact.

4.2. Data collection methods

Questionnaire surveys were undertaken with key experts to assess the COVID-19 impact on indicators of specific SDGs (i.e., SDGs 1, 2, 3, 8, and 13) in Egypt. Appendix A lists the symbol and description of the assessment indicators for each SDG. Nine, twelve, twenty-six, thirteen, and six indicators were assessed for each SDG, respectively. The questionnaire was divided into four sections: an informed consent form, respondent information, questions, and indicator descriptions. The respondents were asked to assign only one score that ranges from “1-lowest importance” to “9-highest importance” for each indicator in the five SDGs. These scores represent the weights of importance of the assessed indicators from the perspective of experts. Besides, they were encouraged to assign distinct scores to different indicators. The online delivery method using Google Forms was chosen to maintain social distancing and eliminate negative consequences. The main stakeholders were selected based on their roles and responsibilities in implementing SDGs in Egypt. As a result, representatives from Egyptian government agencies participated in these questionnaires, including four experts from the institute of national planning (INP), one expert from Cairo University, one expert from the ministry of local development, one expert from the ministry of housing, utilities, and urban communities, one expert from the ministry of environment, and two experts from the ministry for agriculture and land reclamation.

During May–June 2021, a total of 10, 8, 5, 9, and 7 questionnaire surveys were gathered for each SDG, respectively. These answers were then imported into Microsoft Excel for data analysis and visualization. Regarding the expertise of the involved participants, about 54%, 41%, and 5% of the respondents have more than 20 years, 15–20 years, and 10–15 years of experience, respectively, as depicted in Table 1. The influence of the COVID-19 epidemic on SDG implementation in Egypt was reported based on the responses acquired from the questionnaire surveys.

4.3. Ranking techniques of indicators

This section provides background on the four applied ranking techniques of indicators; relative importance index, WT, fuzzy analytic hierarchy process, and ensemble ranking techniques.

Table 1
List of experts interviewed to investigate the COVID-19 effects on public health and SDGs.

| Expert          | Title                                                                 | Years of experience |
|-----------------|-----------------------------------------------------------------------|---------------------|
| 1               | President of INP                                                      | more than 20 years  |
| 2               | Professor of Management                                               | more than 20 years  |
| 3               | Professor of Agricultural Economics, Cairo University                  | more than 20 years  |
| 4               | Director of Regional Development Center, INP                         | 15–20 years         |
| 5               | Professor of environmental accounting                                  | more than 20 years  |
| 6               | Professor of planning systems, INP                                    | more than 20 years  |
| 7               | Assistant professor of environmental planning, INP                    | 15–20 years         |
| 8               | Head of the Arab Environment and Sustainability Sector, Arab Health and Development Cooperation. | 15–20 years         |
| 9               | Assistant Professor of Agricultural Economics                         | 10–15 years         |
| 10              | Strategic planning expert                                             | 15–20 years         |
4.3.1. Relative importance index

The RII technique was developed by Ref. [44] to describe the relative significance of different alternatives, as per Eq. (1).

\[
RII = \sum w / (A \times N)
\]

(1)

Where; \( w \) is the weight of importance of different alternatives from the perspective of each respondent, \( A \) is the highest weight of importance (i.e., 9), and \( N \) is the total number of responses. It is worth mentioning that the most significant alternative is associated with the highest value of the index.

4.3.2. WT method

The WT method is a novel approach that combines Weighted Aggregated Sum Product ASsessment (WASPAS) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods [45]. This approach ranks the alternatives (i.e., indicators related to each SDG) using weights of importance of attributes (i.e., responses) and performance measurements of alternatives. In this research, the weights of importance of responses are measured using the Shannon entropy method [46]. More details about the computational procedures can be found in this research [47].

The first step involves computing the WASPAS index for each alternative, as per Eq. (2).

\[
\psi_i = \phi \sum_{k=1}^{K} (\varphi^{(k)}(A_i \times W_j) + (1 - \Gamma) \prod_{k=1}^{K} \varphi^{(k)}(A_i)^{W_j})
\]

(2)

Where; \( \psi \) is the WASPAS index of the \( i^{th} \) alternative, \( \phi \) is the weight of the \( j^{th} \) attribute, \( A_i \) refers to the \( i^{th} \) alternative, \( \varphi^{(k)}(A_i) \) is the performance measure for the \( i^{th} \) alternative from the \( k^{th} \) decision-maker perspective.

The second step comprises finding the positive and negative ideal alternatives, as per Eqs. (3) and (4).

\[
r^+ = \min(\psi_i)
\]

(3)

\[
r^- = \max(\psi_i)
\]

(4)

Where; \( r^+ \) and \( r^- \) are the positive and negative ideal alternatives, respectively.

The last step considers computing the closeness coefficient for each alternative, as per Eq. (5).

\[
C_i = \frac{|\psi_i - r^-|}{|\psi_i - r^+| + |\psi_i - r^-|}
\]

(5)

Where; \( C_i \) is the closeness coefficient for each alternative. It should be noted that a superior alternative is linked to a higher closeness coefficient value.

4.3.3. Fuzzy analytic hierarchy process

An improved FAHP is utilized to quickly collect and analyze responses from many experts. This method is based on a new questionnaire survey includes all factors in the first column and ratings in the other columns. It is beneficial for developing a consistent judgment matrix based on diverse responses on a complicated topic, including many factors.

The procedures for employing the triangular FAHP technique to rank the indicators for each SDG are summarized as follows [48, 49]: a) allocating different scores to each indicator, b) representing each score by an interval number ranging from 1 to 9, and summarizing the lowest and highest scores attributed to this indicator, c) establishing a judgment matrix by comparing two indicators in the same layer pairwise and computing each coefficient as a ratio of the two-interval values for the two indicators, d) replacing the previously specified ratio with a crisp value that meets the consistency criterion of the judgment matrix, and e) replacing the crisp value with a triangular fuzzy number and creating a judgment matrix. The linguistic variables and the corresponding triangular fuzzy numbers can be found in related research papers [50]. Finally, Chang extent analysis has been used in this research to compute the weights of importance of the indicators from fuzzy pairwise comparison matrices because of its popularity in FAHP algorithms [51].

4.3.4. Ensemble ranking

A novel method based on half-quadratic theory is used to calculate the ensemble ranking of decision-making techniques, as per Eqs. (6)-(8) [52].

\[
\alpha_m = \delta(\left\| R^m - R^* \right\|_2)
\]

(6)

Where; \( \alpha_m \) is the half-quadratic auxiliary variable, \( m \) is the number of decision-making techniques, \( R^m \) is the ranking of the \( m^{th} \) decision-making technique, and \( R^* \) is the final aggregated ranking.

\[
w_m = \frac{\alpha_m}{\sum_j \alpha_j}
\]

(7)

Where; \( w_m \) is the weight of the \( m^{th} \) decision-making technique.
\[ R^* = \sum_{m} w_m \times R_m \]  

Eq. (9) calculates the consensus index, which represents the degree of agreement among decision-making techniques on the final ranking.

\[ C(R^*) = \frac{1}{KM} \sum_{k=1}^{K} \sum_{m=1}^{M} \frac{f_\sigma(R^*_k - R^*_m)}{f_\sigma(0)} \]  

Where; \( C(R^*) \) is the consensus index of the final ranking, \( K \) is the number of alternatives, and \( f_\sigma \) is the probability density function of the Gaussian distribution with a standard deviation of \( \sigma \) and a mean of zero.

Finally, Eq. (10) is used to evaluate the trust level, which determines the degree to which the ensemble ranking may be certified.

\[ T(R^*) = \frac{1}{K} \sum_{k=1}^{K} \sum_{m=1}^{M} w_m \times \left( \frac{f_\sigma(R^*_k - R^*_m)}{f_\sigma(0)} \right) \]  

Where; \( T(R^*) \) is the trust level of the aggregated ranking.

5. Results and discussion

The computation procedures used in the RII, WT, and FAHP methods for the SDG1 indicators are implemented using MATLAB R2019a and Microsoft Excel. As for the RII, the numerator is calculated by considering the respondents’ frequency and weight assigned to each indicator. Fig. 4 illustrates the collected responses for the influence of the epidemic on the SDG1 indicators in Egypt from the perceptions of ten experts. A detailed description of the computation procedures used in the RII, WT, and FAHP methods for the SDG1 indicators is included in Appendix B. Similarly, the procedures are followed for SDG2, SDG3, SDG8, and SDG13 indicators. The rankings obtained from the RII, WT, and FAHP methods are finally aggregated using an approach based on the half-quadratic theory. The rankings obtained from the RII, WT, and FAHP methods, as well as the ensemble rankings for SDG1 indicators, are shown in Fig. 5. The ensemble ranking is determined by minimizing the Euclidean distance to each calculated ranking. The results indicate that the share of the population living below the international poverty line is the most influential indicator among SDG1 indicators in reflecting COVID-19 impact in Egypt. The final ranking has a consensus index of 0.85, indicating a high degree of agreement among the rankings. Besides, it is associated with a trust level of 0.96, implying that the final ranking could be accredited.

The indicators of the remaining SDGs are computed similarly. Fig. 6 illustrates the rankings of the other SDG indicators in reflecting COVID-19 impact using RII, WT, and FAHP methods. It is worth noting that the ensemble rankings for SDG2, SDG3, SDG8, and SDG13 obtain consensus indices of 0.97, 0.99, 0.98, and 0.85, respectively. This indicates the significant degree to which all decision-making techniques agree upon the final rankings. Meanwhile, the rankings are associated with trust levels of 0.97, 0.99, 0.98, and 0.95, respectively. This implies that the aggregated rankings for all the assessed SDGs are reliable and trusted.

It is found that the top-five most significant indicators in reflecting the COVID-19 impact on SDG1 are the share of population living below the international poverty line, the population having access to basic services, the population living below the national poverty line, proportion of government expenditure on vital services, and pro-poor public social spending. Besides, this virus has the greatest influence on the following SDG2 indicators; undernourishment, food insecurity, average income of food producers, malnutrition among children under the age of 5, and food price anomalies. According to Dhehibi’s Study [53]; the National Strategic Review of Food Security and Nutrition in Iraq is developed in accordance with the most important SDG2 indicators, which are malnutrition among children under the age of 5, undernourishment, food insecurity, average income of food producers, and food price anomalies in order to achieve no hunger by 2030. Moreover, COVID-19 has the most significant effects on some indicators related to SDG3, namely official health sector support, essential health services exposure, medical staff density, the fraction of health facilities with affordable and accessible medicines, and the portion of the population with high health-related expenditures. For SDG8, the most influential indicators in reflecting COVID-19 are reported as follows: annual GDP per capita growth rate, inflation rate, tourism share
in GDP, unemployment rate, and the fraction of informal non-agricultural employment. The results of Elnagar and Derbali’s study [54]; which revealed that Egypt’s tourism industry is one of the most significant foreign exchange providers, are consistent with those of this study. Finally, the following are the most important indicators relevant to SDG13: number of disaster deaths, level of disaster risk reduction adaptation strategy, annual greenhouse gas emissions, number of small island developing nations and least developed countries with nationally determined contributions, long-term strategies, national adaptation communications and plans, and public awareness about climate change and environmental concerns. This conclusion is consistent with Ramadan and Ramadan’s [55] study findings, which showed that the most variable that could express the environmental situation is greenhouse gas emissions produced from different activities.

6. Conclusion

The coronavirus pandemic has taken a heavy toll on the global economy, with social and environmental consequences arising as secondary concerns. COVID-19 curtails the progress in achieving some Sustainable Development Goals (SDGs), which represent some ways by which quality of life may be restored, and the myriad difficulties related to food and water shortage or bad health conditions could be addressed. Therefore, it is of utmost importance to continuously focus on the SDGs implementation so that the progress made so far is not compromised.

This research study adds to the body of knowledge by analyzing the COVID-19 impact on specific SDG indicators in Egypt. This research was limited to studying SDGs related to eradicating poverty (SDG1), reducing hunger (SDG2), promoting healthcare services (SDG3), sustaining economic growth (SDG8), and mitigating climate change (SDG13). Questionnaire surveys were performed with stakeholders in Egypt directly involved in implementing SDGs. Relative importance index (RII), Weighted aggregated sum product assessment-Technique for order preference by similarity to ideal solution (WT), and Fuzzy Analytic Hierarchy Process (FAHP) methods were used to prioritize the indicators. Using the modified FAHP as a multi-criteria decision-making technique helps assess the alternatives in a row instead of performing pairwise comparisons between every two alternatives. As such, while using the pairwise comparison approach, AHP cannot cope with the impression and subjectivity of the expert judgment. As a result, the FAHP approach has captured the ambiguity in expert judgment while analyzing the impact of COVID-19 on SDG indicators in Egypt. Finally, the rankings were combined using a method based on the half-quadratic theory. The results showed that the share of the population living below the international poverty line, undernourishment prevalence, official health sector support, annual gross domestic product per capita growth rate, and number of disaster deaths were the most influential indicators in reflecting the COVID-19 impact on SDG1, SDG2, SDG3, SDG8, and SDG13, respectively. The SDG ensemble rankings obtained consensus indices of 0.85, 0.97, 0.99, 0.98, and 0.85, respectively. This indicated a significant agreement on the final rankings by all decision-making techniques.

Meanwhile, the rankings were associated with trust levels of 0.96, 0.97, 0.99, 0.98, and 0.95, respectively. This reflected the high trust in the aggregated rankings for all the assessed SDGs. It is envisaged that this study would provide helpful insights for decision-makers to improve SDG implementation in the COVID-19 era.

It is worth mentioning that this research is limited to the reliance on questionnaire surveys with relevant stakeholders to gather the required data. The COVID-19 consequences might change until the pandemic is fully controlled and handled. Therefore, it is recommended to extend the scope of this research in the future by tracking the progress of SDGs before and after COVID-19 to identify development gaps and achieve SDGs on schedule. This research can be expanded in the future by using system analysis to envision several scenarios to achieve sustainable development goals in light of this outbreak or other epidemics.

Declaration of competing 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.
Data availability

Data will be made available on request.

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Appendix A. Symbols and descriptions of the indicators for each assessed SDG

| SDG | Indicator symbol | Indicator description |
|-----|-----------------|-----------------------|
| SDG1 | I1-1 | Share of population living below the international poverty line |
|   | I1-2 | Share of population living below the national poverty line |
|   | I1-3 | The ratio of population covered by social protection |
|   | I1-4 | The ratio of the population having access to basic services |
|   | I1-5 | Number of disaster-related deaths |
|   | I1-6 | The portion of government expenditure on vital services |
|   | I1-7 | Grants attributed to poverty reduction |
|   | I1-8 | Disaster-related direct economic loss as a percentage of global GDP |
|   | I1-9 | Budgeting specified for the poor people |
| SDG2 | I2-1 | Malnutrition prevalence |
|   | I2-2 | The population prevalence of food insecurity |
|   | I2-3 | Stunting prevalence in children under the age of five |
|   | I2-4 | Malnutrition prevalence in children under the age of five |
|   | I2-5 | Anemia prevalence in women aged 15–49 years |
|   | I2-6 | Production volume per labor unit |
|   | I2-7 | Small-scale food producers’ average income |
|   | I2-8 | The proportion of agricultural land dedicated to profitable and sustainable farming methods |
|   | I2-9 | Agriculture orientation index for government spending |
|   | I2-10 | Export incentives for agricultural products |
|   | I2-11 | Anomalies in food prices |
|   | I2-12 | Agriculture sector government aid |
| SDG3 | I3-1 | The ratio of maternal mortality |
|   | I3-2 | Rate of neonatal mortality |
|   | I3-3 | The mortality rate among children under the age of five |
|   | I3-4 | The number of people killed in traffic accidents |
|   | I3-5 | Number of people dying as a result of contaminated water |
|   | I3-6 | Coverage of healthcare services |
|   | I3-7 | Aid to the health sector from the government |
|   | I3-8 | The density of health workers |
|   | I3-9 | Percentage of births attended by competent health professionals |
|   | I3-10 | The number of new HIV infections per 1000 healthy people |
|   | I3-11 | Incidence of tuberculosis per 100,000 people |
|   | I3-12 | Malaria prevalence per 1000 people |
|   | I3-13 | Incidence of Hepatitis B per 100,000 people |
|   | I3-14 | The number of persons who require treatment for neglected tropical illnesses |
|   | I3-15 | Deaths caused by diabetes, cancer, cardiovascular disease, or chronic respiratory disease |
|   | I3-16 | Suicide death toll |
|   | I3-17 | Treatment approaches for drug use disorders |
|   | I3-18 | Hazardous alcohol abuse |
|   | I3-19 | The proportion of women of reproductive age (15–49) who get their family planning needs fulfilled using contemporary techniques |
|   | I3-20 | The rate of adolescent births |
|   | I3-21 | The proportion of the population with high household health expenses as a proportion of total household spending or income |
|   | I3-22 | Household and ambient air pollution causing a high death rate |
|   | I3-23 | Deaths caused by unintentional poisoning |
|   | I3-24 | The prevalence of current tobacco usage among people aged more than or equal to15 |
|   | I3-25 | The proportion of health facilities with a core set of relevant medications on a long-term basis |
|   | I3-26 | Capacity for international health standards and health emergency preparation |
| SDG8 | I8-1 | The growth rate of annual GDP per capita |
|   | I8-2 | Informal work as a percentage of non-agricultural employment |
|   | I8-3 | Index of the stock market |
|   | I8-4 | Consumption of domestic materials |
|   | I8-5 | The rate of unemployment |
|   | I8-6 | Percentage of youth that are not enrolled in schools |
|   | I8-7 | The proportion of children who work |
|   | I8-8 | Tourism contribution to GDP |

Fig. 6. Rankings of indicators in relation to COVID-19.
Appendix B. Computation procedures used in the RII, WT, and FAHP methods for the SDG1 indicators

Step 1. Define the collected responses for the influence of the epidemic on the SDG1 indicators in Egypt from the perceptions of ten experts as listed in Table B1.

Table B.1
Frequency of significance of the indicator in reflecting COVID-19 impact from the viewpoints of ten experts

| Indicators | Significance |
|------------|--------------|
|            | 1 2 3 4 5 6 7 8 9 |
| I1-1       | 3 2 3 2 |
| I1-2       | 1 1 1 3 4 |
| I1-3       | 1 1 2 3 3 |
| I1-4       | 2 3 1 3 3 |
| I1-5       | 1 2 1 2 1 |
| I1-6       | 1 1 1 3 2 |
| I1-7       | 1 3 2 3 1 |
| I1-8       | 1 1 1 2 1 |
| I1-9       | 1 1 1 4 3 |

Step 2. Calculate RII by considering the denominator constant for all the indicators (i.e., 90). The index is computed by multiplying the number of indicators (i.e., 9) by the number of collected responses (i.e., 10), and dividing the numerator by the denominator. Finally, the indicators are ranked in descending order of importance as per Table B.2.

Table B.2
Rankings and RII computations for the SDG1 indicators

| Indicators | Weights of importance RII Rank |
|------------|--------------------------------|
| I1-1       | 74 0.82 2 |
| I1-2       | 77 0.86 1 |
| I1-3       | 64 0.71 6 |
| I1-4       | 68 0.76 4 |
| I1-5       | 56 0.62 9 |
| I1-6       | 69 0.77 3 |
| I1-7       | 57 0.63 8 |
| I1-8       | 61 0.68 7 |
| I1-9       | 66 0.73 5 |

Step 3. Use the Shannon entropy technique to determine the weights of importance for the attributes as per Table B.3.

Table B.3
wt of importance of the SDG1 indicators using Shannon entropy

| Terms Attributes | Entropy value | Diversification degree | Weight of attribute |
|------------------|---------------|------------------------|---------------------|
| Response 1       | 0.99          | 0.01                   | 0.08                |
| Response 2       | 1.00          | 0.00                   | 0.02                |
| Response 3       | 1.00          | 0.00                   | 0.03                |
| Response 4       | 0.99          | 0.01                   | 0.09                |
| Response 5       | 0.92          | 0.08                   | 0.60                |

(continued on next page)
Step 4. Describe the quantitative results of the WT method as listed in Table B.4.

Table B.4
Rankings and WT computations for the SDG1 indicators

| Indicators | WASPAS index | Closeness coefficient | Rank |
|------------|--------------|-----------------------|------|
| I1-1       | 6.67         | 1.00                  | 1    |
| I1-2       | 5.57         | 0.74                  | 3    |
| I1-3       | 3.61         | 0.28                  | 6    |
| I1-4       | 5.65         | 0.76                  | 2    |
| I1-5       | 2.44         | 0.00                  | 9    |
| I1-6       | 4.54         | 0.50                  | 4    |
| I1-7       | 2.49         | 0.01                  | 8    |
| I1-8       | 2.60         | 0.04                  | 7    |
| I1-9       | 4.39         | 0.46                  | 5    |

Step 5. Derive the triangular FAHP judgment matrix for SDG1 indicators and construct the judgment matrices for the remaining SDGs as per Table B.5.

Table B.5
Triangular FAHP matrix for SDG1 indicators

| I1-1  | I1-2  | I1-3  | I1-4  | I1-5  | I1-6  | I1-7  | I1-8  | I1-9  |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| (1.0,1.0,1.0) | (1.0,2,0,3.0) | (2.0,3.0,4.0) | (1.0,1.0,2.0) | (4.0,5.0,6.0) | (1.0,2.0,3.0) | (4.0,5.0,6.0) | (4.0,5.0,6.0) | (1.0,2.0,3.0) |
| (0.3,0,5,1.0) | (1.0,1.0,1.0) | (2.0,3.0,4.0) | (1.0,1.0,2.0) | (4.0,5.0,6.0) | (1.0,2.0,3.0) | (4.0,5.0,6.0) | (4.0,5.0,6.0) | (1.0,2.0,3.0) |
| (0.3,0,3,0,5) | (0.3,0,3,0,5) | (1.0,1.0,1.0) | (1.0,1.0,2.0) | (3.0,4,0,5,0) | (1.0,1,0,2,0) | (3.0,4,0,5,0) | (3.0,4,0,5,0) | (1.0,2,0,3,0) |
| (0.5,1,0,1,0) | (0.5,1,0,1,0) | (0.5,1,0,1,0) | (1.0,1,0,1,0) | (4.0,5,0,6,0) | (1.0,2,0,3,0) | (4.0,5,0,6,0) | (4.0,5,0,6,0) | (1.0,2,0,3,0) |
| (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (1.0,1,0,1,0) | (1.0,2,0,3,0) | (4.0,5,0,6,0) | (4.0,5,0,6,0) | (1.0,2,0,3,0) |
| (0.3,0,5,1,0) | (0.3,0,5,1,0) | (0.5,1,0,1,0) | (0.3,0,5,1,0) | (0.3,0,5,1,0) | (1.0,1,0,1,0) | (4.0,5,0,6,0) | (4.0,5,0,6,0) | (1.0,2,0,3,0) |
| (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (1.0,1,0,1,0) | (3.0,4,0,5,0) | (1.0,1,0,2,0) |
| (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (0.2,0,2,0,3) | (1.0,1,0,1,0) | (1.0,1,0,2,0) |
| (0.3,0,5,1,0) | (0.3,0,5,1,0) | (0.3,0,5,1,0) | (0.3,0,5,1,0) | (0.3,0,5,1,0) | (0.3,0,5,1,0) | (0.3,0,5,1,0) | (0.3,0,5,1,0) | (1.0,1,0,1,0) |

Step 6. Derive the possibility degree and normalized weight vector of the indicators from the fuzzy judgment matrices as per Table B.6. Finally, the indicators are ranked based on their weights of importance.

Table B.6
Rankings and weight vectors for SDG1 indicators using FAHP

| Indicators | Weight | Rank |
|------------|--------|------|
| I1-1       | 0.215  | 1    |
| I1-2       | 0.205  | 2    |
| I1-3       | 0.146  | 4    |
| I1-4       | 0.191  | 3    |
| I1-5       | 0.119  | 6    |
| I1-6       | 0.124  | 5    |
| I1-7       | 0.000  | 7    |
| I1-8       | 0.000  | 7    |
| I1-9       | 0.000  | 7    |
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