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An IoT model for supporting global governmental lockdown scenarios: investigating comparative lockdown strategies and assessing generic perception of pandemic response

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ABSTRACT

We propose an integrated IoT model to blend IoT technologies, neutrosophic theory and AHP to handle uncertain conditions of real-life situations and aid decision-makers with systematic and optimum decisions. In our case study, four ranked scenarios are assigned the appropriate IoT technology generated to support the government and competent authorities in the pandemic outbreak to prevent growing risks. Our study is based on the decision-makers' judgments that need to be expanded with more experts in the various aspects of government and competent authorities. The integrated IoT model provides a balance between the restart of economic life and COVID-19 outbreaks.

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KEYWORDS
COVID-19; Internet of Things; healthcare; analytic hierarchy process; integrated IoT model

1. Introduction

The first case was detected in November 2019 in Wuhan, China, for Coronavirus Disease, so-called COVID-19, according to the World Health Organization (WHO 2020a). COVID-19 is devoted to an aborted epidemic to a pandemic as severe acute respiratory syndrome coronavirus (SARS-CoV) to be announced by WHO as SARS-CoV-2 (Aman et al. 2021). In March 2020, WHO classified COVID-19 as a pandemic. The coronavirus outbreaks have recorded 81,772,965 confirmed cases of COVID-19, including 1,784,245 deaths and 57,935,293 recovered that spread within 220 countries on 29 December 2020 (WHO 2020b). COVID-19 is very dangerous for patients with weak immune systems and elderly persons with chronic diseases (Tuli et al. 2020). COVID-19 can be transmitted via respiratory, aerosol, and contact transmission. The clinical presentation for symptoms includes fever, dry cough, fatigue, anorexia, shortness of breath, sputum production, smell loss, and taste loss (Huang et al. 2020). The degree of illness can be managed according to four main categories: 1) Mild cases: managed with symptomatic

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treatment; 2) Moderate cases: managed with pneumonia treatment; 3) Severe cases: managed with pneumonia treatment; and 4) Critical Cases: managed with acute respiratory distress syndrome (ARDS) (Clinical Management of Covid-19 2020). The treatment plan differs according to the state of the disease. A detailed review presented by Clinical Management of COVID-19 (2020), Guan et al. (2020), and Wu et al. (2020) have described the current status of COVID-19 for transmission, clinical presentation, laboratory diagnosis, diagnosis testing, radiology findings, and prevention.

COVID-19 has spread and affected humanity and the world rapidly, creating a state of panic among governments and competent authorities (Channa et al. 2021). Since the pandemic happened and was widespread, governments decided to prevent the COVID-19 outbreaks by applying strict lockdowns and taking basic precautionary measures (Zhang et al. 2020). Some countries have been worst afflicted by the pandemic (e.g. Spain, Italy, and France) (Ceylan 2020). Governments did not have a systematic protocol for such a dramatic pandemic outbreak. Therefore, strict lockdown procedures in China were regulated closely with hard mobility restrictions, annotation of public transportation, limitation in social interaction, revocation for any grouping for any distance, and lockdown of any public affairs (Ocampo and Yamagishi 2020). The strict regulations of strict lockdowns have positive and negative effects. The positive impact affects the environment and reduces pollution, while the negative impact affects the economy, power sector, socio-economic, and mental health (Aragona et al. 2020; Kanitkar 2020). The COVID-19 crisis is not only affecting public health but also directly affecting the global economy.

Although the economic downturn can be measured and scaled, socio-economic and mental health cannot be measured and have unpredicted consequences. The lockdown forces people to meet their fundamental needs in a restricted time and sometimes cannot even reach their needs (e.g. food, clothes, etc.) (Loopstra 2020) due to the shortage of resources or the application of the stay-at-home rule. In addition, the average income for citizens decreases or is nonexistent, leading to mental health problems, e.g. stress, anxiety, etc (Torales et al. 2020). On the other side, Egypt realised the emergence of deficiencies in the general health of the citizen, especially patients with chronic diseases. Therefore, the presidential initiative was launched to check chronic disease and women's health. The presidential initiative supported citizens who were affected by the lockdown. Statistical studies reveal that citizens did not spend their treatment medication, causing public health deterioration regardless of COVID-19. Therefore, governments should maintain citizens' public and mental health. Indeed, the lockdown regulation may be preventing the COVID-19 outbreaks. However, as we mentioned, it has many side effects, such as disability for all vital activities. Governments and competent authorities should maintain sustainability to prevent the loss of main milestones for countries, e.g. the global economy and healthcare. Therefore, the lockdown relaxation scenarios are proposed to solve the stated challenges by balancing precautionary measures to prevent countries from the second wave of the COVID-19 pandemic (Gualtieri et al. 2020). Our focus for the lockdown and social distance approach is to develop an integrated Internet of Things (IoT) model to allow real-time communications, monitoring, analysis of the situations, and better decision-making for individuals, government and policymakers relevant to this special issue.

The main contribution of this paper,

- We presented an integrated IoT model to aid governments and competent authorities in reaching optimum decisions considering the surrounding conditions and alternatives.
- The integrated IoT model adopts the neutrosophic theory to solve the problem of indeterminate cases and the ability to represent qualitative and descriptive data in numerical form to be appropriate for further analysis.
- The analysis of lockdown relaxation scenarios can be described numerically with a neutrosophic scale to model the uncertainty cases for each scenario and help decision-makers reach the optimum scenario by considering the environmental conditions of uncertainty.
- The integrated IoT model will involve innovative use of technological aspects to aid governments and competent authorities in finding alternatives for direct interaction and human intervention using IoT technologies.
- The model adopts two primary alternative support and smart IoT technologies to support the decisions taken by governments and competent authorities to restart the economy and get back to normal daily activities.

This paper is presented as follows: Section 2 presents details about the strict lockdown in some countries and the transition to possible lockdown relaxation scenarios and preventive measures. Section 3 illustrates the proposed integrated IoT model to aid decision-makers with systematic and optimum decision scenarios using neutrosophic sets, analytical hierarchy process (AHP), and IoT technologies. Section 4 mentions the results of the case study to show the applicability and availability of the proposed integrated IoT model. Section 5 illustrates the IoT Applications to manage the pandemic of COVID-19 outbreaks in the light of applying the relaxation lockdown strategies. Section 6 introduces IoT Applications to manage COVID-19 outbreaks. Section 7 presents the implications and managerial insights for the proposed integrated IoT model to restrict the spread of the COVID-19 pandemic. Finally, Section 8 summarises the conclusion for the entire paper by highlighting future works and future trends.

2. Literature review

2.1 Emerged scenarios for COVID-19 outbreaks

This section presents the analysis of basic outlines for the COVID-19 pandemic in some countries, e.g. Germany, Kuwait, and France. The paper presents a systematic analysis of the curve of infected cases from the beginning of the pandemic and how decisions of the governmental and competent authorities affect the curve of infected cases by COVID-19. In Germany, Munich, the first confirmed case was recorded on 27 January 2020 (ECDC 2020; WHO 2020a). Other multiple confirmed cases were detected on 25 and 26 February at Baden-Wurttemberg. The death case was recorded on 9 March 2020 (Desson et al. 2020). On 17–18 March, another infected region was detected for transportation purposes for people from Italy and China (Liu, Magal, and Webb 2021). Therefore, the German disease and epidemic control authorities attempted to apply regulations to prevent the COVID-19 outbreaks. The national pandemic plan from 13 March 2020 to apply the protection stage is as follows: lockdown schools and kindergartens, lockdown academic learning semesters, and prevent visits to nursing homes (Hetkamp et al. 2020). After that, there were stricter procedures with no physical contact for more than one person. Consequently, on 15 April, the government announced that Germany achieved 'fragile intermediate success' due to the commitment of German citizens to the lockdown regulations. Subsequently, a relaxed lockdown regulation would apply to the gradual synchronous federal system. Unfortunately, in October, an attack of the second wave of COVID-19 on Germany. The government applied a more relaxed lockdown regulation, a so-called partial lockdown, to permit the work of schools and kindergartens. On 22 November 2020, the RKI reported 918,269 confirmed cases 14,022 deaths, and approximately 603,800 recoveries. The partial lockdown has been imposed on Germany until the end of 2020 by applying a strictly precautionary measure.

The second country included in the research analysis that underwent strict lockdown is Kuwait. The first confirmed case was recorded in Kuwait on 23 February 2020 (Alkhamis et al. 2020). The government and competent authorities applied the lockdown on schools on 1 March 2020, workplaces on 11 March 2020, commercial air travel and borders on 14 March 2020, and a partial curfew on stay-at-home on 22 March 2020. On 10 May, Kuwait was placed under full curfew based on the Ministry of Health assessment until 31 May Since more than 12,000 cases, 100 deaths have been reported up to 15 May 2020 (Alkhamis et al. 2020). On 19 May 2020, the number of confirmed cases increased, with 1171 confirmed cases recorded. Although the confirmed case curve increases, the death rate curve is considered less than expected. The highest daily death rate in Kuwait was recorded at 11 deaths on 30 May 2020. On 31 May 2020, the government announced the gradual relaxation of the strict lockdown, the so-called 'The plan to return to normal life in Kuwait'. The plan is gradually applied in five phases, with each phase tentatively lasting three weeks. The decision to transition to the next phase depends on the success of synchronisation results of the confirmed cases and the death rate curve with the plan. Kuwait applied relaxation lockdown scenarios according to the competent authorities for regulations ratings.

The third country included in the paper analysis is France. The pandemic of COVID-19 started on 24 January 2020, and the first confirmed case was recorded in Europe and France in Bordeaux (Roche, Garchitorena, and Roiz 2020)). From 13th to 17 March 2020, lockdown regulations were announced by the government in the first three months, starting with forbidden gatherings, encouraging social distancing, and case isolation (Walker et al. 2020). On 18 March 2020, France was under full lockdown until 11 May 2020. On 10 October 2020, France recorded in 24 hours 26,896 cases, which led to the second national lockdown on 28 October 2020. Therefore, the relaxation of the regulation lockdown should be carefully analysed with the study for other alternatives to prevent the COVID-19 outbreaks.

2.2 *Internet of Things platform and infrastructure*

The study of relaxation of lockdown scenarios should be extended with some technological solutions. This study proposes the use of neutrosophic set theory can handle the uncertain, inconsistent, and incomplete situations that face decision-makers in governments and competent authorities. The evaluation of scenarios can be managed with the analytical hierarchy process (AHP) according to decision makers' judgements of descriptive perspectives. The study also adopts the IoT to transition any traditional equipment or human intervention to be replaced with more digitised and automatic procedures.

As the IoT is an emerging technology and novel engine of information and communication technology, researchers predicted that IoT would lead to many critical aspects in industry, healthcare, etc (Abdel-Basset et al. 2020; Abdel-Basset, Chang, and Nabeeh 2021). The ramifications of IoT in technical sectors can make an unheavenly difference in the pandemic outbreak. The IoT technologies integrated a smart control of real-world machine goods with control of things, e.g. networks, laptops, etc (Ng and Wakenshaw 2017). The study highlights the five main influential factors mentioned in (Abdel-Basset et al. 2020) as a guideline to be achieved in the proposed integrated IoT model. The main influential factors that can be adopted from IoT technologies to provoke a positive impact on the pandemic of COVID-19 are mentioned as follows: 1) Telepresence: the smart connection between things on the Internet virtually with the neglecting of human intervention or physical attendance; 2) Connectivity: Ensure the direct communication between things and people with the grantee of smooth communication and successful deliveries, 3) Intelligent: the use of IoT technologies to make things smarter to perform automatically, monitor, and maintain tasks, 4) Value: the tangible benefits that can impact on the healthcare services on the COVID-19 pandemic, 5) Security: timely and securely the right information provoked to government and competent authorities to handle and take important decisions to prevent the COVID-19 outbreaks.

The proposed integrated IoT model utilises IoT technologies with influential factors to substitute human intervention in the procedures suggested by governments and competent authorities to be unvital. Furthermore, the integrated IoT model adopts IoT technologies in vital sectors to take the burden of human intervention to scan and monitor the workflow and ensure the strict application of precautionary measures. The proposed model utilises the use of IoT technologies to ensure a positive and valuable outcome that impacts COVID-19 outbreaks. Well connected with 4 G/5 G technologies with encryption, our integrated IoT model allows fast and secure dissemination of information and allows citizens to get live updates and instant messages without much delay and latency. The IoT technologies directly impact relaxation lockdown scenarios due to the ability to capture real-time data for the infected people and areas (Allam and Jones 2020). The main processes of IoT technologies that can be the milestones of relaxing the strict lockdown strategies are mentioned as follows (Singh et al. 2020):

- Monitor and screen COVID-19 infections in remote locations.
- Virtual management to convening remote communications and meetings
- The effective analysis and control of generated data are based on IoT technologies.
- Keep follow-ups and maintain reports with updated status.

The main processes of IoT technologies are used to manage relaxed lockdown scenarios with the support of smart IoT technologies. The IoT technologies can reduce human suffering during the COVID-19 pandemic with virtual and remote connections between managers, employees, patients, medical staff, etc., managing the main issues. Apart from tracing and monitoring patients and suspicious cases, IoT technologies can be effective in emergency cases and resource scarcity. The sensors can detect the vitals of patients and non-patients to raise reports with emergent details to the medical healthcare team. Smart applications can be used to make benefits for IoT technologies during the pandemic of COVID-19 (Hanna, Evans, and Booth 2020; Roy et al. 2020; Wong and Bandello 2020)

The IoT technologies are used in various sectors, fully/partially operated or suspended during the COVID-19 pandemic. The IoT technologies offer aided technologies to support decision-makers in restoring economic and normal daily activities, such as infrared technologies, smartwatches, optical cameras, and internet protocol cameras (Kumar, Kumar, and Shah 2020). Infrared technology is utilised as a sensor to detect thermal energy and generate electronic signals. The infrared can be used to enhance daily life activities, especially remotely during the pandemic. The infrared thermometer can be used mainly to detect human body temperature, whether normal or high, to prevent outbreaks of COVID-19. The infrared sensors can be used to automatically manage daily routines (e.g. opening/closing doors, power switches, etc.). Smartwatches are used to record the main human vitals and connect with governmental applications to monitor the health status of their citizens. Smartwatches can be used to track COVID-19 patients' health developments and locations for the purpose of home quarantine to guarantee the prevention of COVID-19 outbreaks. Consequently, if COVID-19 patients' location changes, the system can request a nearby police station to move patients for check-ups. Optical cameras can be utilised during the pandemic to make face recognition to detect persons classified as confirmed COVID-19 cases (Abdel-Basset, Chang, and Nabeeh 2021). Moreover, internet protocol cameras can be used to perform effective remote meetings, virtual conferences and discussions successfully. Other advanced IoT technologies can be used to manage economic and normal daily life remotely. Such IoT platforms and services are crucial for countries under resources, as citizens can connect to the internet more easily. Similarly, Business-to-Business (B2B) services are encouraged to open up businesses thanks to the use of IoT technologies. Goods and products can be better facilitated to the customers. The speed and efficiency of delivery can be affected to some extent since the low availability of goods, products, supply chains and logistics in developing countries can take its toll. However, since IoT technologies can work effectively with 4 G and 5 G communications, they allow customers to track the status of their goods and services online and keep the supply chain and business opportunities available and sufficiently competitive.

3. The proposed integrated IoT model for relaxation lockdown scenarios

IoT technologies have scientifically received attention in the healthcare sector in different phases during the pandemic outbreak. Advanced IoT technologies can be used in diagnosis, treatment, and follow-up for COVID-19 cases. Advanced IoT technologies have a valuable contribution to the relaxation of lockdown scenarios to restart economic and daily life activities. The advanced IoT technologies include the Internet of Medical Things (IoMT), wearable technologies, drones, robots, and smartphone applications (Abdel-Basset, Chang, and Nabeeh 2021; Nasajpour et al. 2020). The IoMT is a contemporary means to interconnect medical devices with sensors and medical applications across networks (Singh et al. 2020). Wearable technologies refer to electronic devices that can be owned as accessories, e.g. Smart Thermometers, Smart Helmets, Easy Band, and IoT-q-Band (Nasajpour et al. 2020). Drone technology is a flying robot controlled by a software application for remote monitoring (Chamola et al. 2020). The autonomous robot has the ability to carry out specific tasks without the intervention of external agencies (Abdel-Basset, Chang, and Nabeeh 2021). The integrated IoT model would aid government and competent authorities decide on the priories of relaxed lockdown scenarios with the appropriately mentioned IoT technologies. Figure 1 shows the allocation of supportive IoT technologies to the integrated IoT model. Indeed, the allocation of technologies is flexible and can be changed according to the decision-makers' judgements of the current situation of pandemic outbreak.

According to Figure 1, smartwatches and IP cameras are assigned for IoT support and smart IoT. Infrared technology, optical cameras, and drone technology are assigned to IoT support technologies due to the physical attendance of people. Finally, the IoMT, wearable technology, robotics technology and smart applications are allocated to smart IoT technologies due to the virtual communication and absence of physical attendance, and they can support B2B business activities, such as providing more resilient services in supply chains, logistics and availability of food and products. The status and information of merchants, suppliers and customers can be kept up-to-date in real time.

Additionally, the proposed integrated IoT model illustrates the AHP as a technique of MCDM to achieve an efficient decision-making process. The AHP is a unique method that aids decision-makers in finding solutions for complex and confusing obstacles (Ahmed et al. 2023). As a result, the AHP method can successfully decompose complex problems into subproblems. The AHP prioritises the scaled ratio of the problem to be computed

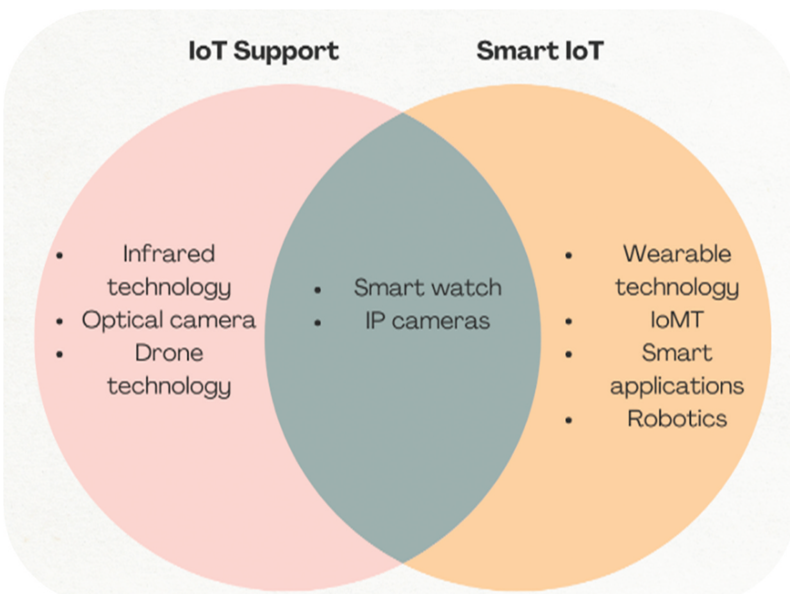

Figure 1. The allocation of IoT technologies during the COVID-19 pandemic.

using paired comparisons. The input of the AHP method includes actual measurements or subjective opinions (e.g. protocol description, preferences, weights, etc.). In contrast, the output of the AHP method provides the decision-maker with consistently scaled ratios to prioritise the inputs successfully. Indeed, the formulation of the problem of applying relaxation of the strict lockdown during the COVID-19 outbreak needs to be more critical and precise. Therefore, the model detects the need for the intervention of neutrosophic theory to help decision-makers reach optimum decisions in conditions of uncertainty, incomplete information, and inconsistency. The neutrosophic theory can handle the perspectives and descriptions of decision-makers according to numerical numbers (Abdelhafeez, Mohamed, and Khalil 2023).

In Figure 2, the integrated IoT model is presented with three main components: the neutrosophic theory, AHP, and IoT technologies. The neutrosophic theory modelled the description of the decision makers' judgements on a neutrosophic triangular scale. The AHP computes weights for the possible relaxation lockdown scenarios, checks for consistency, and generates final priorities for scenarios. According to the importance of scenarios, IoT technologies offer two solutions, either IoT support or smart IoT technologies. The 4 G/5 G connections ensure that IoT support and smart IoT technologies can deliver service requests and updates seamlessly and promptly. The integrated IoT model is affected by the current situation for COVID-19 outbreaks, the operation of the global economy, socio-economy, mental health, and uncertainty conditions. Finally, the model generates recommendations for decision-makers with ranked relaxation lockdown strategies. The integrated IoT model procedural steps are mentioned in detail as follows (Nabeeh et al. 2019):

***Step 1*. Determine the objective of your study.**

In this step, the lockdown relaxation scenarios are extracted from procedures applied to countries (Liu, Magal, and Webb 2021; Ocampo and Yamagishi 2020). The study mentioned a summary of the proposed relaxation scenarios in Table 1.

***Step 2*. Neutrosophic for the decision makers' judgements.**

As the relaxation lockdown scenarios are detected, the study focused on the judgements and perspectives of decision-makers. The integrated IoT model uses the triangular neutrosophic scale to present decision-makers' judgements (Nabeeh et al. 2019). The triangular neutrosophic scale is systematically derived from the Saaty scale to represent the true, indeterminate, and false cases successfully for each lockdown scenario, in addition to the degree of significance between scenarios from the perspectives of decision-makers. The triangular neutrosophic scale is mentioned in Table 2, which describes the neutrosophic triangular scale defined with the corresponding Saaty scale, code, the inverse of code, and description. For example, the neutrosophic scale of the ES code refers to being equally significant with the neutrosophic triangular scale $\langle\langle 6,7,8\rangle;0.09,0.10,0.10\rangle$, while the inverse code of ES^{-1} refers to $^{1}/_{\langle\langle 6,7,8\rangle;0.09,0.10,0.10\rangle}$.

***Step 3*. Aggregation for Decision-Maker's judgement.**

Regarding more than one decision-maker in the study, the integrated IoT model aggregates the neutrosophic decision-makers' judgements to generate a generalised insight to be used to analyse the AHP method further, as mentioned in Equation (1).

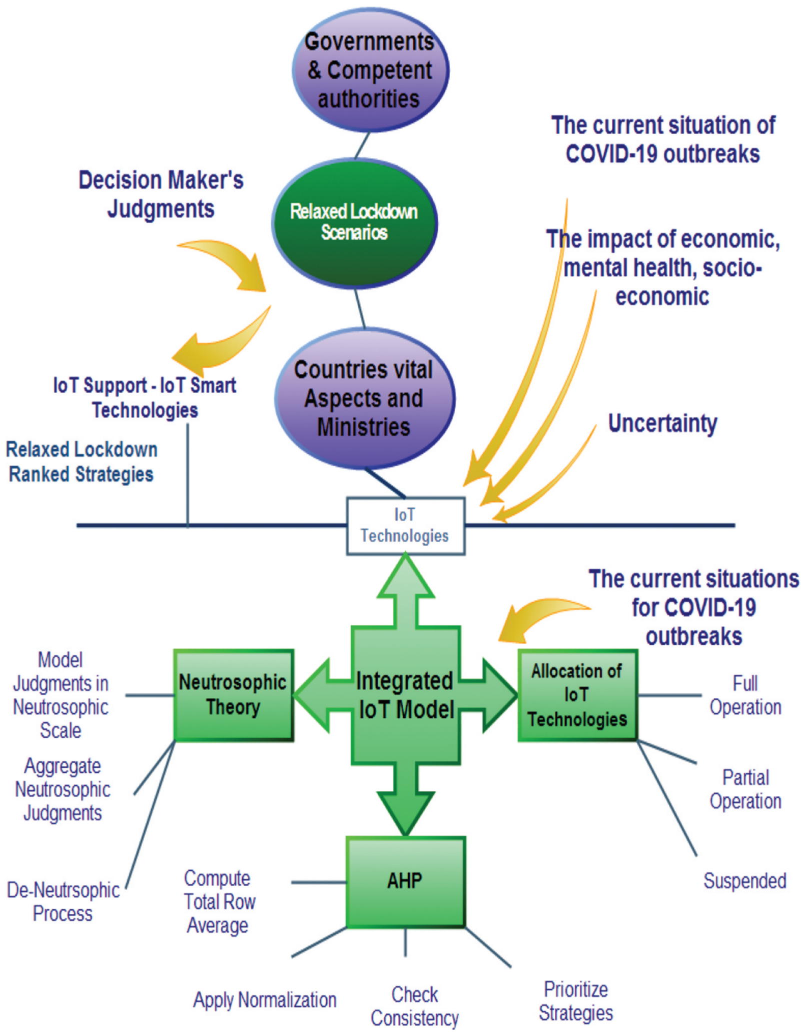

Figure 2. The integrated IoT model for relaxation lockdown strategies.

Table 1. The relaxation lockdown scenarios.

Code	Relaxation Lockdown Scenarios
R_1	Reduction in the overcrowding in public transportation.
R_2	Full capacity operation in the Ministry of Health.
R_3	Partial capacity in industrial sectors
R_4	Near to full capacity operation in the Ministry of Defense.
R_5	Partial to full capacity operation in the Ministry of Supply.
R_6	Partial operation of essential public and private construction projects
R_7	Partial curfew for elderly persons.
R_8	Partial operation of essential public and private construction projects
R_9	Minimise the strict applied to the concept 'Stay at Home'.
R_{10}	Limitation of the operations of restaurants, coffee shops, malls, and hotels.
R_{11}	Limitations the role of worship mosque and church.
R_{12}	Suspension in cinemas, kids' zones, and wedding halls
R_{13}	Enable remote and hybrid learning also for diplomatic missions and international organisations.

Table 2. The neutrosophic triangular scale with respect to the saaty scale.

Saaty Scale	Code	Description	Neutrosophic Triangular Scale	Code Inverse	Inverse Neutrosophic Triangular Scale
1	ES	Equally significant	$1 = ((1, 1, 1); 0.50, 0.50, 0.50)$	ES^{-1}	$1^{-1} = 1/1((1, 1, 1); 0.50, 0.50, 0.50)$
3	SL	Slightly significant	$3 = ((2, 3, 4); 0.30; 0.75; 0.70)$	SL^{-1}	$3^{-1} = 1/((2, 3, 4); 0.30; 0.75; 0.70)$
5	SS	Strongly significant	$5 = ((4, 5, 6); 0.80; 0.15; 0.20)$	SS^{-1}	$5^{-1} = 1/((4, 5, 6); 0.80; 0.15; 0.20)$
7	VSS	Very strongly significant	$7 = ((6, 7, 8); 0.90; 0.10; 0.10)$	VSS^{-1}	$7^{-1} = 1/((6, 7, 8); 0.90; 0.10; 0.10)$
9	AS	Absolutely significant	$9 = ((9, 9, 9); 1.00; 0.00; 0.00)$	AS^{-1}	$9^{-1} = 1/((9, 9, 9); 1.00; 0.00; 0.00)$
2	SCS-2	Sporadic values between two close scales	$2 = ((1, 2, 3); 0.40; 0.60; 0.65)$	$SCS\text{-}2^{-1}$	$2^{-1} = 1/((1, 2, 3); 0.40; 0.60; 0.65)$
4	SCS-4		$4 = ((3, 4, 5); 0.35; 0.60; 0.40)$	$SCS\text{-}4^{-1}$	$4^{-1} = 1/((3, 4, 5); 0.35; 0.60; 0.40)$
4					
6	SCS-6		$6 = ((5, 6, 7); 0.70; 0.25; 0.30)$	$SCS\text{-}6^{-1}$	$6^{-1} = 1/((5, 6, 7); 0.70; 0.25; 0.30)$
8	SCS-8		$8 = ((7, 8, 9); 0.85; 0.10; 0.15)$	$SCS\text{-}8^{-1}$	$8^{-1} = 1/((7, 8, 9); 0.85; 0.10; 0.15s)$

$$x_{ij} = \frac{\sum_{z=1}^{z} \left(a_{ij}{}^{z}\right)}{z} \tag{1}$$

***Step 4.* De-neutrosophic process**

The decision judgements are modelled in a complex neutrosophic triangular scale. Since the integrated IoT model deals with 15 relaxation lockdown scenarios, the study proposed to use the score function (Nabeeh, Abdel-Basset, and Soliman 2021). The score function is applied to transform the neutrosophic triangular scale into crisp values, as mentioned in Eq. (1). The resulting crisp values carry the description and judgements of the decision-makers' in a simple form for further computations.

$$s\left(r_{ij}\right) = \left|\left(l_{r_{ij}} \times m_{r_{ij}} \times u_{r_{ij}}\right)^{T_{r_{ij}} + I_{r_{ij}} + F_{r_{ij}}/9}\right| \tag{2}$$

Where l, m, u refer to the lower, median, and upper of the triangular neutrosophic scale, while T, I, F refer to truth-membership, indeterminacy, and falsity membership state, respectively, for the triangular neutrosophic number.

***Step 5.* AHP method, weights computations**

In this step, the AHP method is applied to calculate the expected weights for the generalised insights of the decision-makers on relaxation lockdown scenarios. The weights are calculated on two sub-steps row average and normalisation as follows (Mohamed, Abdel-Monem, and Tantawy 2023; Nabeeh, Abdel-Basset, and Soliman 2021):

Row average: Calculate the total row average using Equation (3).

$$w_i = \sum\nolimits_{j=1}^{n} \left(r_{ij}\right)/n; where i = 1, 2, 3, \ldots, m = 1, 2, 3, \ldots, n \tag{3}$$

Normalisation: Apply the normalisation using Equation (4).

$$w_i^z = w_i / \sum\nolimits_{i=1}^{z} w_i; where i = 1, 2, 3, \ldots, m. \tag{4}$$

Step 6. **Check the consistency ratio for the decision makers' judgements.**

The AHP method increases the efficiency of the resulting priorities for the relaxed lockdown scenarios using a consistency ratio (CR). CR applies systematic steps to ensure the correctness of the resulting weights. The CR should be less than or equal to 0.1 with respect to the comparison matrix. The details of the CR are clearly mentioned in (Nabeeh et al. 2019). If the CR is accepted, then the decision judgements are in a consistent state and the model will ensure the priorities for the relaxation lockdown scenarios. If the CR is not accepted, then the decision judgements are not inconsistent and need to be updated. Hence, the model computes the priorities in seconds until they reach an acceptable CR and consistent decision judgements.

Step 7. **Allocation of IoT technologies**

In this step, the integrated IoT model can recommend a substitution for a specific scenario in Table 1, according to the resulting priority with IoT technology according to the concepts of AHP. The vital scenario that is fully operated and affects economic, national security, and daily processes (e.g. ministries, army, and police) can be tracked, monitored, and screened with IoT technologies to ensure preventive measures and public health to prevent COVID-19 outbreaks. In comparison, non-vital scenarios that are suspended or partially operated (e.g. malls, cinemas, classrooms) can be substituted with IoT technologies to prevent physical human attendance or intervention.

Step 8. **Guidelines for decision-makers (government and competent authorities)**

The previous steps clearly show that a generalised weighted relaxed lockdown scenario is generated. The importance of each scenario is calculated to guide decision-makers in making the most proper decision. The model makes a professional extension to provide decision-makers with weighted aggregated alternatives. The model generated a weighted aggregated alternative that blends some relaxation lockdown scenarios. The model makes aggregates of the decision-making judgements on the model's aggregated relaxation lockdown scenarios.

4. A numerical case study

A numerical case study is illustrated to highlight the novelty of the proposed method and its applicability to real situations in the pandemic outbreak. They can be applied to any country of 220 infected countries by COVID-19. The case study presents the integrated IoT model step by step and provides novel decision alternatives with respect to complex criteria. Our proposal is suitable and helpful to any B2B activities and can provide instrumental guidance to the decision-making and predictability for getting sufficient goods and services to deliver them to customers on time. The descriptive steps for the proposed integrated IoT model are presented as follows:

Step 1. The study objective is determined and presented in Table 1. The table concluded the relaxed lockdown scenarios in 13 items. The 13 scenarios are derived from real-life situations that are applied in many countries worldwide.

Step 2. The study integrates more than one decision-maker, e.g. the Ministry of Health, Ministry of Interior, and Ministry of Planning and Human Development. The data are collected and modelled in the form of a neutrosophic triangular scale to show the degree of importance of the proposed scenarios – the decision judgements guide to generating integrated and optimised results in the pandemic outbreak.

Step 3. The study integrated the decision makers' judgements using Equation (1). The integrated decision makers' judgements are mentioned in Table 2. Table 3 represents the relationship between the criteria of relaxation lockdown scenarios. For simplicity, Table 3 values correspond to codes and code inverse codes mentioned in Table 2.

Step 4. The de-neutrosophic process is applied to convert the neutrosophic scale of descriptive decision judgements format, as input for the integrated IoT model, into the crisp format. The model applied the score function in Equation (2) to generate crisp values that are simple and readable for researchers and further computations, as mentioned in Table 4. Table 5 represents the conversion of the neutrosophic aggregated decision matrix into crisp values.

Step 5. The weights for the proposed relaxation lockdown scenarios are calculated according to two substages, total row average Equation (3) and (4). The weights for the 13 lockdown scenarios are mentioned in Table 6.

Step 6. After applying the steps of the CR for decision-makers' judgements, the result of the CR equals 0.02059 (considering detailed calculations of consistency index = 0.03212 and random consistency index = 1.56). Therefore, the CR is less than 0.1 and achieves the consistency of decision-maker judgements.

Step 7. The previous step assured the consistency of decision-maker judgements. Therefore, the priorities of relaxed lockdown scenarios are mentioned as follows: $R_2 \rightarrow R_1 \rightarrow R_3 \rightarrow R_4 \rightarrow R_5 \rightarrow R_6 \rightarrow R_7 \rightarrow R_8 \rightarrow R_9 \rightarrow R_{10} \rightarrow R_{11} \rightarrow R_{13} \rightarrow R_{12.}$ Indeed, another intelligent solution must be applied to prevent COVID-19 outbreaks, as presented in Table 7.

The integrated IoT model suggests using IoT technologies to help decision-makers and citizens achieve vital services remotely and prevent the infection of COVID-19. According to decision judgements, the model generates two decision alternatives:

(1) **IoT Support**: According to the priorities of relaxation lockdown scenarios, there are vital aspects that have a direct impact on the country's economy, health, supply chains, national security, etc. The high-priority scenarios need to be in a full operation state or at least partially operational. Hence, government and competent authorities need to be supplemented with IoT technologies to make continuous screening and monitoring to prevent COVID-19 outbreaks.

(2) **Smart IoT**: The relaxation lockdown scenarios with low priorities with respect to decision makers' judgements can be fully replaced with smart IoT technologies. Such sensors and screens can take the burden from humans to trace all vital processes (e.g. distance learning).

Figure 3 shows a descriptive vision for the relaxed lockdown scenarios assigned to IoT support or IoT or smart IoT technologies according to the weights and priorities generated with the proposed model. The descriptive vision considered the risk

Table 3. The neutrosophic aggregated decision judgements.

Scenarios	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}	R_{13}
R_1	ES	SL	SS	VSS	SL	SCS-2	SCS-4	SL	SS	VSS	SCS-2	SS	SL
R_2	SL^{-1}	ES	SL	SS	VSS	SL	SS	VSS	SCS-4	SL	SL	SS	VSS
R_3	SS^{-1}	SS^{-1}	ES	SCS-4	SS	SS	VSS	SL	SS	VSS	SL	VSS	SCS-4
R_4	VSS^{-1}	SS^{-1}	$SCS\text{-}4^{-1}$	ES	SL	SCS-4	SL	VSS	SL	VSS	SS	VSS	SCS-2
R_5	SL-1	VSS^{-1}	SS^{-1}	SL-1	ES	VSS	VSS	SCS-4	SL	SS	SCS-2	SS	SL
R_6	$SCS\text{-}2^{-1}$	SL-1	SS^{-1}	$SCS\text{-}4^{-1}$	VSS^{-1}	ES	VSS	SL	SCS-4	SCS-2	SL	SS	VSS
R_7	$SCS\text{-}4^{-1}$	SS^{-1}	VSS^{-1}	SL^{-1}	VSS^{-1}	VSS^{-1}	ES	SL	SL	SS	SCS-2	SL	SS
R_8	SL^{-1}	VSS^{-1}	SL^{-1}	VSS^{-1}	$SCS\text{-}4^{-1}$	SL^{-1}	SL-1	ES	SL	SL	SCS-2	VSS	SL
R_9	SS^{-1}	$SCS\text{-}4^{-1}$	SS^{-1}	SL-1	SL^{-1}	$SCS\text{-}4^{-1}$	SL^{-1}	SL-1	ES	SL	SS	SS	SCS-2
R_{10}	VSS^{-1}	SL^{-1}	VSS^{-1}	VSS^{-1}	SS^{-1}	$SCS\text{-}2^{-1}$	SS^{-1}	SL-1	SL^{-1}	ES	SL	SL	SL
R_{11}	$SCS\text{-}2^{-1}$	SL^{-1}	SL^{-1}	SS^{-1}	$SCS\text{-}2^{-1}$	SL-1	$SCS\text{-}2^{-1}$	$SCS\text{-}2^{-1}$	SS^{-1}	SL^{-1}	ES	SL	SS
R_{12}	SS^{-1}	SS^{-1}	VSS^{-1}	VSS^{-1}	SS^{-1}	SS^{-1}	SL-1	VSS^{-1}	SS^{-1}	SL-1	SL^{-1}	ES	SCS-2
R_{13}	SL^{-1}	VSS^{-1}	$SCS\text{-}4^{-1}$	$SCS\text{-}2^{-1}$	SL-1	VSS^{-1}	SS^{-1}	SL-1	$SCS\text{-}2^{-1}$	SL-1	SS^{-1}	$SCS\text{-}2^{-1}$	ES

Table 4. The generation of crisp values for the triangular neutrosophic scale.

Code	Crisp Value	Code Inverse	Crisp Value
ES	1	ES^{-1}	1
SL	1.850	SL^{-1}	0.539
SS	1.843	SS^{-1}	0.542
VSS	2.030	VSS^{-1}	0.491
AS	2.080	AS^{-1}	0.480
SCS-2	1.388	$SCS\text{-}2^{-1}$	0.720
SCS-4	1.848	$SCS\text{-}4^{-1}$	0.541
SCS-6	2.101	$SCS\text{-}6^{-1}$	0.475
SCS-8	2.139	$SCS\text{-}8^{-1}$	0.467

Table 5. The crisp format for the decision-makers' judgements.

Scenarios	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}	R_{13}
R_1	1	1.850	1.843	2.035	1.850	0.720	1.848	1.850	1.843	2.035	0.720	1.843	1.850
R_2	0.539	1	1.850	1.843	2.035	1.850	1.843	2.035	1.848	1.850	1.850	1.843	2.035
R_3	0.539	0.542	1	1.848	1.843	1.843	2.035	1.850	1.843	2.035	1.850	2.030	1.848
R_4	0.491	0.542	0.541	1	1.850	1.848	1.850	2.035	1.850	2.035	1.843	2.030	0.720
R_5	0.539	0.491	0.542	0.539	1	2.035	2.035	1.848	1.850	1.843	0.720	1.843	1.850
R_6	0.720	0.539	0.542	0.541	0.491	1	2.030	1.850	1.848	0.720	1.850	1.843	2.035
R_7	0.541	0.542	0.491	0.539	0.491	0.491	1	1.850	1.850	1.843	0.720	1.850	1.843
R_8	0.539	0.491	0.539	0.491	0.541	0.539	0.539	1	1.850	1.850	0.720	2.035	1.850
R_9	0.542	0.541	0.542	0.539	0.539	0.541	0.539	0.539	1	1.850	1.843	1.843	0.720
R_{10}	0.491	0.539	0.491	0.491	0.542	0.720	0.542	0.539	0.539	1	1.850	1.850	1.850
R_{11}	0.720	0.539	0.539	0.542	0.720	0.539	0.720	0.720	0.542	0.539	1	1.850	1.843
R_{12}	0.542	0.542	0.491	0.491	0.542	0.542	0.539	0.491	0.542	0.539	0.539	1	0.720
R_{13}	0.539	0.491	0.541	0.720	0.539	0.491	0.542	0.539	0.720	0.539	0.542	0.720	1

Table 6. The weights for relaxation lockdown scenarios.

Scenarios	Weights
R_1	0.114
R_2	0.120
R_3	0.113
R_4	0.099
R_5	0.091
R_6	0.085
R_7	0.075
R_8	0.069
R_9	0.062
R_{10}	0.061
R_{11}	0.058
R_{12}	0.040
R_{13}	0.042

degree to be classified as high risk, moderate-high risk, moderate risk, moderate-low, and low risk. The relaxed lockdown scenarios are allocated to risk classifications to help decision-makers make the appropriate decisions.

***Step 8*. Guidelines for decision-makers (government and competent authorities)**

Finally, the integrated IoT model generates the ranking of possible scenarios for relaxation lockdown scenarios based on the priority between scenarios. In addition, detecting the use of IoT technologies, whether to support or use smart IoT methods, is

Table 7. The IoT replacements with respect to IoT technologies alternatives.

Priorities of scenarios	IoT Support	IoT Replacement
R_1	✓	
R_2	✓	
R_3	✓	
R_4	✓	
R_5	✓	
R_6	✓	
R_7		✓
R_8	✓	
R_9	✓	
R_{10}		✓
R_{11}		✓
R_{12}		✓
R_{13}		✓

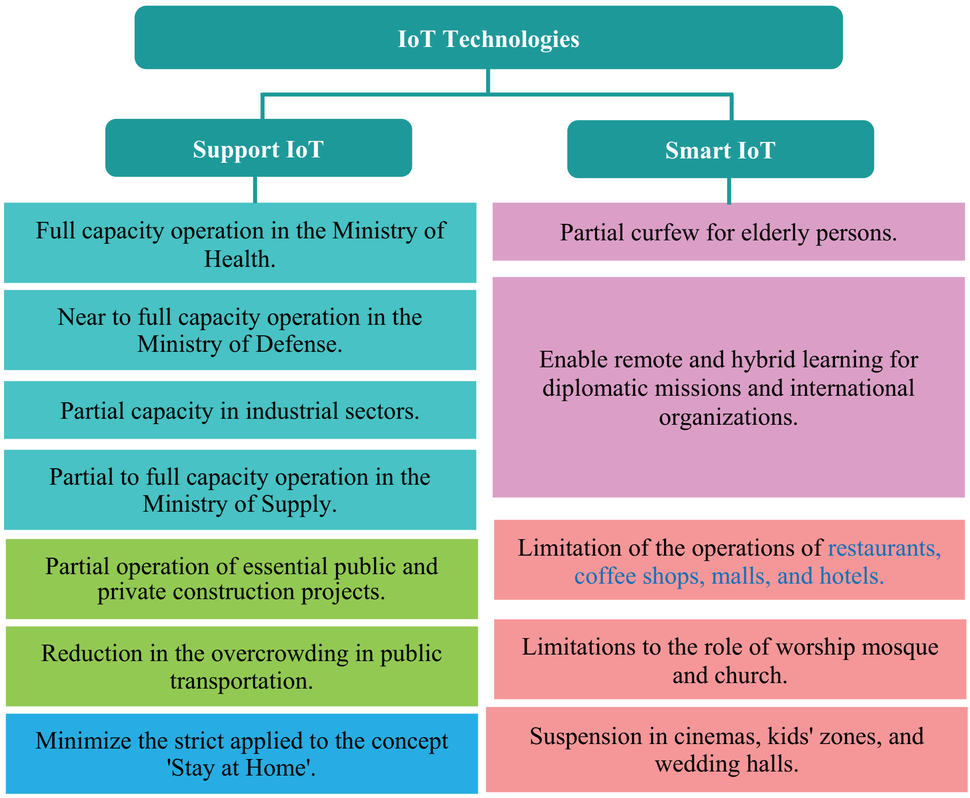

Figure 3. The relaxed lockdown scenarios and relation using IoT technologies.

presented in Table 8. Results in Table 4 generate four possible ranking strategies using permutes to the scenarios with similar weights to aid decision-makers with various procedures to prevent the spread of the pandemic outbreak. Besides, to detect the appropriate use for IoT, whether support or smart IoT technologies.

5. Discussion

The proposed integrated IoT model showed four final scenarios for the relaxation of lockdown scenarios, as shown in Figure 4. The four ranked scenarios are based on 13 scenarios, as described in Table 8. Figure 4 and Table 8 show that R_2 is the best alternative in the four ranking scenarios. In $ranking_1$, R_{13} is recommended to be worst alternative, and R_{12} is recommended to be worst alternative in $ranking_2$, $ranking_3$, and $ranking_4$. The model applied neutrosophic theory to model decision judgements in the conditions of uncertainty, inconsistency, and incomplete information- moreover, the novelty and uniqueness of the problem definition for the COVID-19 pandemic. According to decision-makers' judgements, the AHP method is a suitable technique for making priorities and ranking for the proposed scenarios. The model is empowered with IoT capabilities to aid humanity in preventing COVID-19 outbreaks. The model decided to guarantee systematic alternatives for the operation of the vital counties' aspects for operation/partial operation of the main vital activities to restart the economy.

5.1 Barriers to IoT technologies

Indeed, the applications of IoT technologies have many challenges and barriers. In this section, the study detects the main barrier that directly impacts the particle applied for the relaxed lockdown scenarios. The main obstacles from the literature (Dash et al. 2019; Min 2010; Suresh, Hemamala, and Ashok 2018) are mentioned and modelled in Figure 5. The barriers are consequential, and the high demand infrastructures are needed to make full/partial operation for main ministries and aspects in countries that adopt IoT technologies.

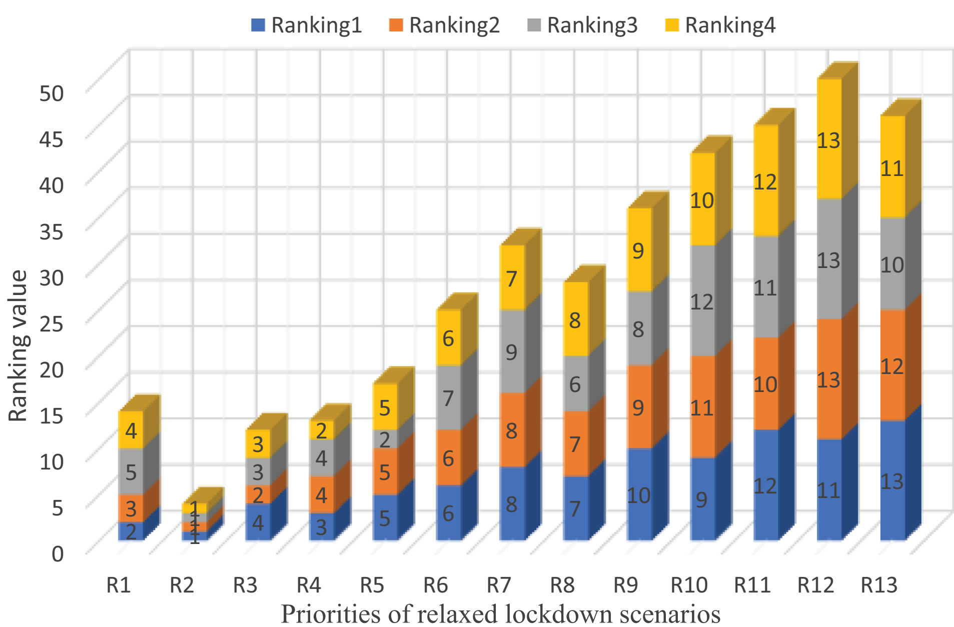

Figure 4. Modeling for the ranking of relaxation lockdown scenarios.

Table 8. Ranking of relaxed lockdown scenarios with respect to IoT technologies.

Scenarios	$Ranking_1$	$Ranking_2$	$Ranking_3$	$Ranking_4$	IoT Support	Smart IoT
R_1	2	3	5	4	*	
R_2	1	1	1	1	*	
R_3	4	2	3	3	*	
R_4	3	4	4	2	*	
R_5	5	5	2	5	*	
R_6	6	6	7	6	*	
R_7	8	8	9	7		*
R_8	7	7	6	8	*	
R_9	10	9	8	9	*	
R_{10}	9	11	12	10		*
R_{11}	12	10	11	12		*
R_{12}	11	13	13	13		*
R_{13}	13	12	10	11		*

Hence, powerful storage with efficient security techniques is required. In addition, decision-makers must have updated technical knowledge to manage critical situations during the COVID-19 pandemic. The details of the barriers are mentioned as follows:

- **Infrastructure:**

Infrastructure is a complex problem, especially in developing countries. To apply the IoT technologies to support replacing the operation of vital countries' sectors smartly, it needs a powerful IT infrastructure, e.g. networks, computers, sensors, etc. In addition to the need for high-speed networks and new business models.

- **Storage:**

There is a need for powerful storage capabilities to adapt to the huge amounts of data generated from relaxed lockdown scenarios, e.g. cloud computing.

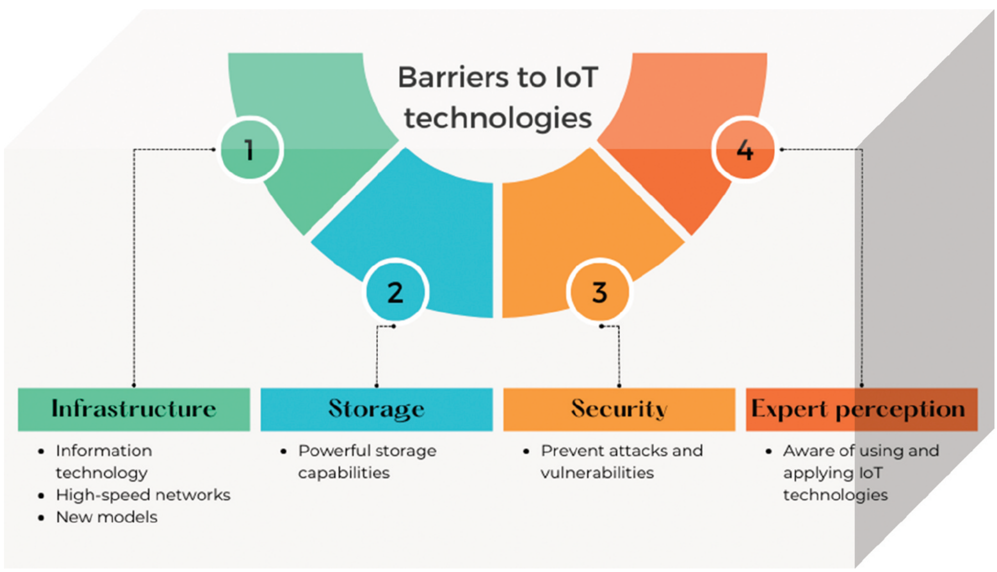

Figure 5. The barriers to IoT technologies.

- **Security:**

The vital data and procedures must not be exposed to any attacks or vulnerabilities to ensure the use of IoT technologies in applying lockdown scenarios.

- **Experts Perception:**

Experts and decision-makers must be aware of the use and application of IoT technologies, in addition to being aware of the benefits and challenges of IoT technologies to manage the governmental plan to prevent COVID-19 outbreaks optimally.

5.2 Analysis of barriers to integrated IoT model

In this section, the barriers and challenges affecting the operation of integrated IoT are judged and described by decision-makers in the Ministry of Health and Interior Affairs and the Ministry of Planning and Development. The analysis recommends the appropriate ranking of lockdown scenarios with respect to barriers. Indeed, the degree of barrier changed from one country to another according to the availability of resources and infrastructure. The integrated IoT model performs the following steps to recommend the most appropriate rank according to the barriers in Figure 5:

Step 1. Collect the decision makers' judgements to detect the most appropriate ranking scenario with respect to the expected barriers.

Step 2. Model the judgements in the triangular neutrosophic scale mentioned in Table 2 to manage and detect indeterminate situations in numerical form.

Step 3. Generate a generalised point of view using Equation (1), as mentioned in Table 9.

Step 4. Optimise a comprehensive and more readable format using Equation (2) and Table 4 to transform the neutrosophic scale to the crisp format mentioned in Table 10.

Step 5. Apply the AHP method using Equations (3) and (4) to generate weights for ranking scenarios, as mentioned in Table 11 and modelled in Figure 6.

Step 6. Recommend the most appropriate relaxed lockdown scenario according to the suggested barriers. Hence, in the light of Figure 6, the most effective scenarios are ranked in importance as follows: $\boldsymbol{Ranking_1 \rightarrow Ranking_2 \rightarrow Ranking_3 \rightarrow Ranking_4}$.

6. IoT applications to manage COVID-19 outbreaks

The IoT has a huge number of interconnected things to generate a smart system to manage the healthcare system. IoT technologies can track and monitor disease evolution. The data can be captured automatically without direct human intervention. The data

Table 9. General perspectives for the decision-makers on ranking scenarios with respect to barriers.

Scenarios	$Ranking_1$	$Ranking_2$	$Ranking_3$	$Ranking_4$
$Ranking_1$	ES	SL	SS	VSS
$Ranking_2$	SL^{-1}	ES	SL	SCS-4
$Ranking_3$	SS^{-1}	SL^{-1}	ES	SCS-4
$Ranking_4$	VSS^{-1}	$SCS\text{-}4^{-1}$	$SCS\text{-}4^{-1}$	ES

Table 10. Comprehensive perspectives for the decision-makers on ranking scenarios with respect to barriers.

Scenarios	$Ranking_1$	$Ranking_2$	$Ranking_3$	$Ranking_4$
$Ranking_1$	1	1.850	1.843	2.035
$Ranking_2$	0.539	1	1.850	1.843
$Ranking_3$	0.542	0.539	1	1.848
$Ranking_4$	0.491	0.542	0.5411	1

Table 11. The weight perspectives for the decision-makers on ranking scenarios with respect to barriers.

Scenarios	$Ranking_1$	$Ranking_2$	$Ranking_3$	$Ranking_4$
Weights	0.364	0.283	0.213	0.139
Ranking	1	2	3	4

generated can be used in the decision-making process to prevent COVID-19 outbreaks (Gupta and Misra 2020; Wong and Bandello 2020; Yang et al. 2020). The applications can manage human suffering needs during the pandemic outbreak. Table 12 represents the main IoT applications used as aided tools for supporting the two alternative integrated IoT models of IoT support or smart IoT technologies (Singh et al. 2020).

7. Managerial insights

The proposed integrated IoT aids governments and competent authorities of the countries infected with any pandemic to strike a balance between public health and

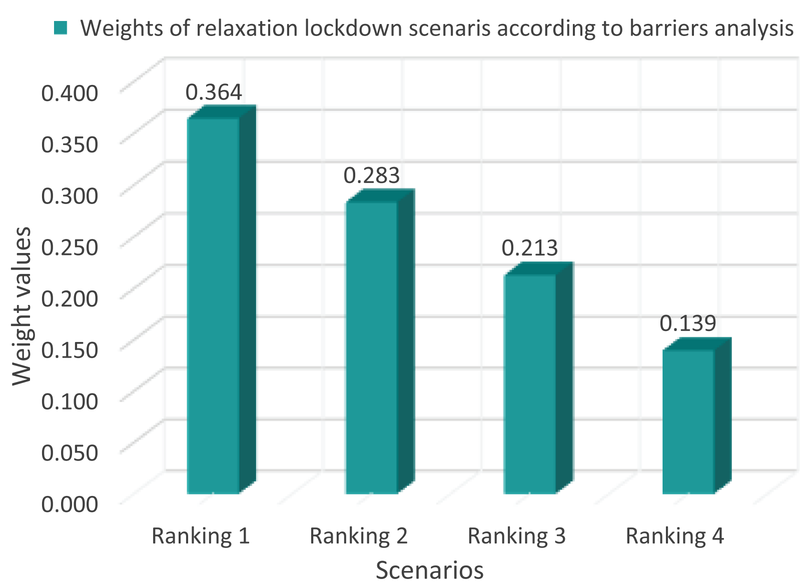

Figure 6. The weights of rankings scenarios with respect to barrier scenarios.

economic refresh. The various ranked scenarios can provide decision-makers with generalised insights to prevent pandemic outbreaks with some relaxation of strict lockdown procedures. The relaxation lockdown scenarios focused on the prevention of pandemic outbreaks by returning to some of the vital procedures to get back to normal life. The integrated IoT model tried to ensure the return of the economic life cycle. The relaxation lockdown scenarios attained the goal of making full or partial operation of living requirements. The 4G/5G in our integrated IoT model can ensure fast information updates for citizens and reliable delivery of decision support for decision-makers.

Decision-makers take on the burden of very complex and confusing obstacles due to the novelty of any pandemic outbreaks. The decision-makers do not have any previous systematic or similar situations to guide the process of decision-making to prevent pandemic outbreaks. The proposed integrated IoT model adopted the use of neutrosophic theory with AHP to help decision-makers reach the most appropriate decision solutions. The neutrosophic theory is used in deciding cases of uncertainty, inconsistency, and incomplete information. Due to the neutrosophic capabilities to model decision-maker judgements in descriptive expression and probably represent indeterminate cases. The AHP method is used to adjust the weighting to the complex relaxation lockdown scenarios and achieve the proper priorities recommended to the decision-makers in pandemic outbreaks.

The use of IoT technologies is the key factor in managerial insights that directly impact the prevention of pandemic outbreaks. The integrated IoT model used IoT technologies to generate two possible technologies for decision-makers to use: support or smart IoT technologies. The IoT support provides the full or partial vital country sectors that cannot be suspended by screening, tracking, and monitoring. While the smart IoT happens, it provides a fully automatic replacement for sectors in nonessential countries that can be remotely managed. Finally, the proposed integrated IoT model is a general, practical, and fixable approach to real-world environmental conditions, in addition to the ease of implementation in any country infected with any pandemic.

Table 12. IoT applications aided the integrated IoT model.

Applications	The aided role in the proposed integrated IoT Model
1. Smart connected healthcare system.	The smart healthcare system can have an impact on the performance of relaxed lockdown scenarios. Since the patients can be remotely tracked and monitored by medical staff, the data can be easily accessed, and the patients can be remotely treated. The smart connected healthcare system can professionally manage the scarcity of resources and emergent cases.
2. Remote consultation	The consultation service is offered anywhere, any place, at any time by specialists to provide the appropriate service remotely.
3. Track COVID-19 Cases	The remote connections with confirmed COVID-19 can ensure safety in giving medical services to patients, aiming to provide patients’ location in the case of quarantine. Tracking COVID-19 cases can resolve emergent cases by sending emergent requests to medical staff and competent authorities for immediate intervention.
4. Forecasting the spread of COVID-19	The use of statistical methods on the IoT technologies generated data to track the predictions of `COVID-19 outbreaks, the infected areas, and the predicted infected areas. The forecasting application is an emerging issue to ensure the validity of relaxed lockdown scenarios.

8. Conclusion and future trends

Due to the endless severity of the COVID-19 pandemic outbreaks and the absence of an effective vaccine or specified medicine drug, the governments did not have enough experience or systematic procedures to manage the COVID-19 pandemic to maintain the stability of the economy. When the governments apply strict lockdown scenarios to manage the severity of the rapid spread of COVID-19, the strict lockdown could negatively impact many sectors (e.g. the economy, mental health, etc.). Consequently, the governments realised the necessity of the return of partial/ full operation for the affected sectors. Therefore, the study proposed an integrated IoT model that aids decision-makers in generating the most proper relaxation lockdown scenarios considering the uncertain, inconsistent, and incomplete information. In the integrated IoT model, a neutrosophic theory with the AHP method is integrated to provide weighted relaxation lockdown scenarios with respect to decision-makers' judgements. IoT technologies can also aid decision-makers in relaxing lockdown scenarios, such that the full/partial operation sector is provided with IoT support technologies to track and monitor emergencies. As a result, the suspended operation sectors could be provided with smart IoT technologies. A case study was developed to show the applicability and availability of the proposed model to any infected country with COVID-19. The case study showed four ranked scenarios assigning the appropriate IoT technologies to support the government and competent authorities for COVID-19 outbreaks. The model can overcome the main barriers and challenges of IoT technologies with the integrated IoT model by generating a final recommendation with the appropriate relaxed lockdown scenario. Our proposed IoT model can support more reliable B2B platforms in critical times, such as providing status updates, communications and supply chain flow for goods and services, ensuring merchants, suppliers, and customers achieve win-win situations.

However, it is important to acknowledge that this study does have certain limitations. The presence of a small group of experts creates an opportunity for future research that can accommodate a wide range of stakeholders, as well as decision-makers and policymakers. Subsequent investigations could potentially employ a similar methodological framework to substantiate the credibility of the outcomes derived from this study. Furthermore, the proposed methodology exhibits flexibility in accommodating the addition or removal of new protocols within the existing set of guideline protocols. Subsequent research endeavours may focus on examining the sensitivity and implications associated with alterations in the quantity and nature of protocols implemented to adapt to the dynamic nature of the ongoing pandemic effectively. Furthermore, it is recommended that the utilisation of alternative fuzzy AHP extensions, such as hesitant fuzzy sets, type-2 fuzzy sets, and spherical fuzzy sets, be investigated and compared in relation to the outcomes of this study. Moreover, the future trends include using other aided disruptive technologies such as big data, AI, Blockchain, IoMT, Industry 4.0, drone technology, and robotics to assist decision-makers in applied relaxation lockdown scenarios with limited human intervention to prevent COVID-19 outbreaks. Additionally, the integrated IoT model can offer analysis and optimisation of other MCDMs, e.g. TOPSIS and DEMATEL. The use of predictive analysis can forecast the relaxation lockdown scenarios and their effects on COVID-19 outbreaks. Finally, the decision-making tools and disruptive technologies from this research work can be applied to other epidemiological situations.

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Ethical approval

This article does not contain any studies with human participants or animals performed by any authors.

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