MDPI

Review

Crisis Management Art from the Risks to the Control: A Review of Methods and Directions

Mohammed Abdalla [1], Louai Alarabi [2,*] and Abdeltawab Hendawi [3]

1 Faculty of Computers and Artificial Intelligence, Beni-Suef University, Giza 8655, Egypt; mohammed.a.youssif@fcis.bsu.edu.eg
2 Department of Computer Science, Umm Al-Qura University, Makkah 24236, Saudi Arabia
3 Department of Computer Science and Statistics, University of Rhode Island, Kingston, RI 02881, USA; hendawi@uri.edu
* Correspondence: lmarabi@uqu.edu.sa

Abstract: A crisis is an exceptional event that causes damage and negative impacts on organizations. For this reason, crisis management is considered as a significant action needed to follow crisis causes and consequences for preventing or avoiding these exceptional events from occurring again. Studies have devoted their efforts to proposing methods, techniques, and approaches in the crisis management direction. As a result, it is critical to provide a consolidated study that has an integrated view of proposed crisis management methods, crisis impacts, and effective response strategies. For this purpose, this paper first highlights the proposed techniques used in crisis management and presents the main objective behind each technique. Second, the risks and impacts resulting from a crisis are highlighted. Finally, crisis response strategies are discussed. The major contribution of this study is it can guide researchers to define research gaps or new directions in crisis management and choose the proper techniques that cope with their research problems or help them discover new research problems.

Keywords: crisis management; crisis risks and impacts; risk factors; crisis response strategies

1. Introduction

During the 1990s, the reported damages resulting from natural disaster crises led to economic losses averaging an estimated 66 billion US dollars yearly. In 1995, the reported damages resulting from the Kobe earthquake recorded losses of around 178 billion US dollars which is equivalent to 0.7 percent of global Gross Domestic Production (GDP). On the other hand, pandemics can limit the growth of economic rates, for example, COVID-19 led to a drop in the external private finance inflows of developing economies by 700 billion US dollars in 2020 compared to 2019 levels, exceeding the immediate impact of the 2008 Global Financial Crisis by 60 percent [1,2].

The crisis, in general, presents critical threats and challenges to different sectors in organizations, governments, and countries. Therefore, crisis management and emergency response systems are musts. First, the crisis symptoms and situations need to be evaluated and analyzed based on vast information provided about the crisis. Then, various effective communication and response plans need to be produced in a timely manner [3].

Mainly, the objective behind any crisis management system or contingency management system is enabling decision-makers to take proper decisions that help organizations and countries to recover from the crisis and get back to their normal functionalities before the crisis happened. This paper provides an integrated overview of different crisis management applications and presents the main idea behind each of them. Additionally, this paper surveys different crisis response strategies and implications resulting from different crisis types. Besides, this paper summarizes the risk factors which can lead to an increase in implications that result from the crisis. The main objective of this paper is to provide

researchers with integrated perceptions about crisis management's current problems and applications.

Contributions. The major contributions of this paper are the following:

- We summarize the existing studies in the area of crisis management.
- We compare existing systems that manage a crisis against different factors.
- We list future directions to highlight the open problems in the crisis management area.
- This paper represents a start point for researchers who are new in the crisis management area to provide them an up to date report and also guide them to solve some of the existing problems.

The rest of this paper after this introduction is organized as follows. Section 2 discusses and reviews different approaches, techniques, and methods in crisis management. Section 3 presents the different impacts and risks that result from the crisis. Section 4 explores the different response strategies during various crisis stages. Section 5 explores the risk factors which represent implications that result from the crisis. Section 6 investigates the research directions and open research areas in crisis management. Section 7 concludes the paper.

2. Literature Review

This section explores the previous attempts that manage and handle the crises. Crises can be classified into different types such as pandemic diseases, natural disasters, terrorist attacks, and so on. Crisis management systems or contingency management systems are designed and developed to avoid emergencies, and to plan how to deal with crises when they occur to mitigate their disastrous consequences [4,5].

A crisis is an unexpected event that causes damage to organizations and has a negative impact on an organization's reputation [6]. In [7]; the authors describe the planning for a crisis as "the action of eliminating risk and uncertainty to enable decision-makers to achieve more control on crises". To deal with crises, authors in [8] define crises as isolated events that can be examined via three things: (1) Causes, (2) consequences, and (3) caution and coping. First, the causes of crises can be described as failures that triggered the crisis immediately and the antecedent conditions which make the failures occur. Second, the consequences of the crises are the impacts caused by the crises, consequences include immediate and long-term impacts. Finally, caution and coping with crises; crises caution can be described as the actions taken to prevent or reduce the potential impact of the crisis; crises caution can be described as the measures considered to respond to a crisis that has already occurred. According to [7], a crisis passes by four different phases: (1) prodromal crisis phase, (2) acute crisis phase, (3) chronic crisis phase, and (4) crisis resolution phase. The prodromal crisis phase is the first stage, where the initial symptoms of the crisis begin to appear. The acute crisis phase is the second phase, where the crisis starts causing damage; the crisis response in this phase is based on the extent of the preparedness of the organization, and how to respond efficiently. The chronic crisis phase is the third phase, it is also called the "clean-up" phase of the crisis, where the organization attempts to recover from the crisis, define its vulnerabilities and record the lessons learned from the successes and failures of its response. The crisis resolution phase is the final phase, where the organization returns to normality and continues its full functionality. To conclude, effective crisis planning aims at early determining of the warning signals from the crisis.

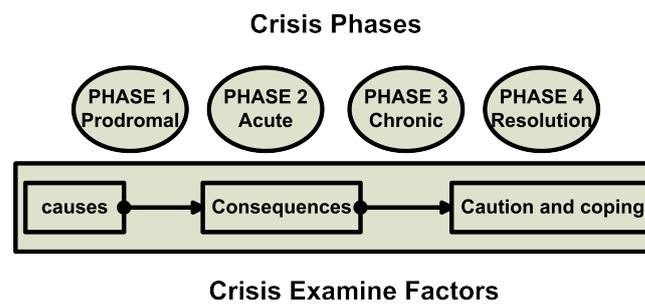Figure 1 presents the crisis phases and their examination factors.

Crisis Phases

Crisis Examine Factors

Figure 1. Crisis Phases.

In [9], the authors describe EXSGACM, which stands for Expert System for Gas Crisis Management. EXSGACM aims to assist managers in performing gas crisis analysis. In these types of crises, a management operator faces great pressure due to huge volumes of information that change dynamically, need to be processed quickly and where taking a quick and perfect decision is critical. For this purpose, EXSGACM is designed as a cost-effective expert decision support tool in these types of crises and enables decision-makers to alleviate the potential danger.

In [10], the authors propose a web-based console system named WIPER, which aims to assist managers in making proper actions during emergencies and detecting all possible risks. Mainly, WIPER depends on grounded real-time data from cell phone network providers. To respond to emergencies, WIPER introduces three useful types of information: (1) near-real-time information about the location of cell phone users in an area, (2) possible anomalies, such as roving crowds, and traffic jams, and (3) mitigation strategies, such as possible evacuation routes. Finally, WIPER enables decision-makers to evaluate and consider proper actions.

In [11], the authors propose a flexible service-oriented architecture, which aims to plan and support decision-makers in environmental crisis management.

In [5,12], the authors propose a contingency management system based on the agent intelligent infrastructure. First, the system starts by collecting information from heterogeneous databases, then the system begins in the monitoring of contingency situations in an open agent environment.

In [13], authors present a system named epiDMS which aims to manage the analysis of large epidemic simulation ensembles. Furthermore, epiDMS enables a lot of processing on a large volume of epidemic simulation ensembles to generate and visualize the observation progression of an epidemic and then address the challenges. Finally, epiDMS covers the lack of decision-making during healthcare emergencies by enabling critical economic and health services with significant impact.

In [14], the authors propose a system named GLEaMviz, which aims to simulate the outbreak of emerging human-to-human infectious diseases on a global scale. Mainly, GLEaMviz is composed of three key modules: (1) the client application module, (2) the proxy middle-ware module, and (3) the simulation engine module. The agility of GLEaMviz lies in allowing the end-user to define the disease compartmental model and configure the simulation scenario. Additionally, it allows the user to configure different parameters such as compartment-specific features, transition values, and environmental effects. Finally, the result produced is a dynamic map and a corresponding set of charts that quantitatively describe the Geo-temporal evolution of the disease.

In [15], the authors investigate the design of a model to manage a stochastic epidemic on a global scale. Furthermore, this investigation considers the data of airline travel flow between urban areas. Additionally, the investigation makes a sensitivity analysis of different and distinct levels of infectiousness of the epidemic and initial outbreak conditions; as a result, the investigation concludes the temporal and spatial evolution of the pandemic. Finally, decision-makers receive heuristic information to respond in these situations of emergency.

In [16], the authors design a framework to respond to organizational crises. The output from this framework is a narrative analysis that identifies the weaknesses in the chain's crisis response and presents good proposals to overcome them.

In [17], the authors design a novel system to control the aircraft fault contingency. For this purpose, this system aims to achieve an on-board health state assessment on real-time and automated contingency management efficiently.

The validity of information is significant during crisis responses. So, information is critical to crisis response because when the crisis conditions change, information must be changed accordingly. Additionally, when the information becomes outdated due to any change in crisis conditions, bad decisions and outcomes will be considered. In [18], the authors design four types of crisis response information networks. Mainly, authors classified these networks based on two dimensions: (1) information flow intensity, and (2) network density. In general, the four types of crisis response information networks include: (1) Information Star, (2) Information Pyramid, (3) Information Forest, and (4) Information Black-out. Finally, guidelines are concluded for managers to deploy convenient information networks during crisis response.

Motivated by the need for schools to respond to different crisis situations, authors in [19] present a framework to facilitate crisis response activities by providing a common set of concepts, principles, terminology, and organizational processes. As a result, this framework coordinates the communication between multiple agencies following a crisis and facilitates the lack of information flow.

In [20], the authors present a system named IDAPS, which stands for Intelligent Distributed Autonomous Power System. IDAPS aims to manage customer-owned distributed energy resources efficiently; these resources can be shared in an autonomous grid during both normal and outage operations. Authors expect that IDAPS will make significant contributions during emergency conditions, and will create a new market for electricity transactions among customers.

In [21,22], authors propose a framework that provides the communication and information needs of first responders, and also supports the decision making needs of command and control personnel. Moreover, this framework focuses on the value of insights and information consolidated from different communities. Consequently, the framework proposes how command and control personnel can be brought to bear on crisis decision making.

In [23], the authors describe a system that controls a team of vehicles. This system includes three major ingredients: (1) a plan dependency identifier, (2) a contingency monitor, and (3) an alert formulator. First, the plan dependency identifier starts to analyze a mission plan and identify mission constraints of the mission plan. Second, the contingency monitor continuously reviews the execution of the mission plan for violations of the mission constraints. Finally, the alert formulator determines whether a part of the mission plan is threatened by a violation of one of the mission constraints.

To conclude, this section discusses various approaches and methods proposed for managing different types of crises; these types include environmental crises and pandemic crises.

3. Risks and Impacts

This section explores the impacts caused by various types of crises.

In [24], the authors surveyed the impacts of terrorist activities, and crises occurred due to incidents and casualties resulting from these activities. Empirically, authors highlighted and measured the damage resulting from terrorist activities from different aspects of economic and social sides. As a case study, the authors take into account the attacks on the World Trade Towers in New York on 11 September 2001, and the bombings of three railway stations in Madrid on 11 March 2004. Overall, the authors conclude that terrorist activities have dangerous impacts on these various aspects : (1) Tourism, (2) foreign and internal investments, (3)stock markets, and (4) foreign trade.

Foot-and-mouth disease is an infectious disease that represents a great danger to animals and people. In [25], the authors highlight the damage that happened due to the outbreak of this disease in 2001 in the UK. Authors summarized the damage impacts as follows: (1) loss on labor market, and foreign exchange market, (2) loss in tourism sectors, as hotels, catering and pubs are locked down, and (3) loss in agriculture sectors, as milk and meat products are not produced due to outbreak of diseases. These losses have a direct impact on the overall economy of the UK; authors highlight that over the period 1995–2000, before the outbreak of the disease, the average economy annual growth rates were 5.4% and 1.7% and, after the outbreak of the disease, the growth rates for 2001 were 1.9% and −14.5%.

In [26,27], authors analyzed the impact of swine flue spread on UK tourism and highlighted how this virus caused a crises in the UK economy. The authors studied the period between 2008 Q1 and 2009 Q1 which represents the outbreak period of the virus. The authors mentioned that the UK lost around 4.7 million visitors in this period, which represents 14.3% of overall visitor arrivals, and describes how this is an impact of an economic crisis.

Natural disasters include hurricanes, earthquakes, and floods, these disasters cause serious damage to society. Authors in [28,29] highlight the long term impacts that result from natural disasters, how these impacts affect the health and education sectors, and how this affects the current stock of human capital resources. In [30], the authors analyzed the impact of natural disasters on long-term investments. In [31,32], the authors describe short-term damages resulting from natural disasters that can disrupt economic activities in the present and future. These short-term damages include loss of capital and loss of labor. In general, loss of capital can be something like damage to factories and houses, while the loss of human capital is something like people's deaths and human disabilities. Loss in labor and capital can reduce the output in several sectors like the agricultural, industrial and educational sectors, which results in minimizing the total production output. In [33], the authors present a study that summarizes the impacts of natural disasters on various economic sectors, the authors describe disaster types and their severity on the economy.

In [34–36], authors conclude the effects of pandemics outbreak on economic growth and present long-term and short-term shocks on economic growth. Additionally, the authors describe the impact of pandemic outbreaks on changing individuals' behavior such as the fear induced by going to their workplaces, which affects production output.

In [37,38], the authors discuss Spanish flu, which started in 1918. Spanish flu caused 20 million to 100 million deaths, and this led to a significant decrease in the gross domestic product in the following countries: Australia (3%), Canada (15%), UK (17%), US (11%).

In [38,39], the authors discuss Asian flu, which started at 1957, Asian flu caused 0.7 million to 1.5 million deaths, and this led to a significant decrease in the gross domestic product in the following countries: Canada, Japan, the UK, and the US by 3%.

In [40,41], the authors discuss the SARS pandemic, which started at 2003; SARS caused 744 deaths, and this led to a significant decrease in gross domestic product in the following countries: China ($4 billion), Canada ($3–$6 billion), and Singapore ($5 billion).

In [42,43], the authors discuss Swine flu, which started at 2009; Swine flu caused 151,700–575,500 deaths, and this led to a decrease in gross domestic product in the Republic of Korea ($1 billion).

To conclude, any type of crisis directly causes economic growth decline. Figure 2 highlights and concludes crisis impacts.

Figure 2. Crisis Impacts.

4. Crisis Response Strategies

This section explores the different response strategies used during various crisis stages.

In [44,45], the authors classify the impacts of crisis response strategies into various types such as: (1) no response, (2) base response, (3) reputation repair, and (4) both base response and reputation repair. In [6], authors highlighted a theory named situational crisis communication theory (SCCT); based on it, they suggest a framework that provides a deep insight to select a proper crisis response strategy. Authors categorize the crisis response strategies into two major stages including: (1) base responses, this stage also is named "initial crisis responses", which includes instructing information (what event occurred, the impact of the crisis on people, and decisions required) and adjusting information (what is the current actions executed to avoid the crisis occurring again); and (2) reputation repair strategies; in stage strategies are used to prevent any bad reputation. In [44], authors propose a framework that inspects the effective crisis response strategies, this framework is constructed based on SCCT notions. Empirically, authors tested this framework, and results shows that base responses reduce the negative outcomes for an organization.

In [46], the authors defined a crisis timing strategy named "stealing thunder", which means that an organization breaks the news about its own crisis before the crisis is publicly known. In [47], authors study the impact of crisis discovery time and how it is significant in affecting organizational reputation after crisis occurrence. Authors confirms that the self-discovery of a crisis enables the decision maker to take proper decisions by using crisis response strategies. Finally, the authors concluded the timing significance to highlight the crisis information in addition to the means of crisis response strategy content.

In [48], the authors examine the impacts of crisis response strategies on distributing responsibilities during the organization's crisis and relationship quality results; then the correlation between the relationship quality result indicators is highlighted. The findings of this study conclude that the existence of the crisis itself has a negative impact on relationship quality.

5. Risk Factors

This section explores risk factors, which are the factors that lead to an increase in implications resulting from the crisis.

Natural disasters can lead to an increase in risk factors for the outbreak of infectious diseases through affecting bad water and sanitation stations that existed before, for example, cholera outbreaks after flood disasters. Additionally, many severe gastroenteritis cases resulting from cholera outbreak were confirmed after Hurricanes Allison [49] and Katrina [50].

Floods assist the spread of leptospirosis in human society. Floods encourage the proliferation of rodents; these rodents generate leptospirosis through water and soil containing contaminated urine from infected rodents. There are several cases reported in developing countries that confirmed the outbreak of disease after floods. Investigations reported confirmed cases in 2000 affected by leptospirosis in India [51] and Thailand [52] after flood disasters.

Viral hepatitis A and E occurs in areas where no water safe for human uses is available. In 2005, more than 1500 infected cases occurred after an earthquake happened in Pakistan. The report highlighted that the infected cases were among persons in areas with no safe water [53].

Authors in [34] discussed the spread of diseases as a high risk factor; authors discussed that the crowded residential compounds can be considered as foci for disease transmission and assist in diseases outbreak.

In [54], authors identify six risk factors for the spread of an epidemic: (1) consumption of bushmeat, (2) poor health infrastructure, (3) worldwide air travel, (4) global trade and markets, (5) trend of urbanization, and (6) environmental factors.

Due to the spread of the COVID-19 pandemic, governments strongly warned persons at high-risk and those most vulnerable to infection to avoid crowded places and take social distance measurements [55,56]. According to [57,58], in the united kingdom, up to 25% of the population are classified as high-risk people, including persons over 70 years old and persons that fall under particular health conditions like cancer, cardiovascular disease, and respiratory problems. As a result, strict restrictions are considered from governments like reducing the movement in crowded places and streets. Authors in [59,60] identified obesity and smoking as risk factors that can increase the risk. In [61], the authors report that men are at higher risk than women; they justify this by the fact that men have comorbidities and higher smoking rates.

In [62], the authors introduce a retrospective analysis of COVID-19 pandemic patients. The analysis is performed based on two factors: body mass index (BMI) and age. Results show that persons aged less than 60 years and with BMI between 30 and 34 are considered critical cases and need specific care.

In [63], authors classified patients of the COVID-19 pandemic as high-risk in several categories:

- Patients had comorbidity, with hypertension being the most common.
- Patients had diabetes
- Patients had coronary heart disease

The number of patients studied was around 191—135 from Jinyintan Hospital and 56 from Wuhan Pulmonary Hospital.

In [64], authors identify older age people suffering from hypertension as a high risk of death. Additionally, male patients with heart injury and hyperglycemia. The authors mentioned that the potential development of COVID-19 for these types of patients is rapid.

Authors in [65] concluded that the risk of death related to COVID-19 increased in persons over 50 years old or persons with heart, lung, liver, and kidney disease. Additionally, the authors confirm the risk of death in men is higher than in women.

6. Research Directions

This section discusses future work and open research directions in the crisis management area.

Future research directions include: (1) pandemic real-time management; there is a need for a system that is able to monitor, control and manage real-time updates about pandemic spread speed, number of affected people with their regions, and world-wide latest updates about serum and vaccines; (2) a real-time monitoring tool for crisis impacts on economic rates; there is a need for a system that communicates updates for decision makers about negative impacts on the economic growth rates during a crisis in a timely fashion; (3) macro level crisis response management; there is a need for a system that integrates different sectors of organizations during a crisis to be communicated in an efficient way and detect if there is any lack in any sector, the objective of this type of system is to make control and command personnel perform immediate corrective action in a timely fashion; (4) remote-working management approaches during a pandemic; there is a need for remote working approaches, techniques and methods that allow different types of jobs to be automated or controlled by workers from remote places; this will help in reducing the spread of a pandemic; and (5) simulation-based scenarios for crisis impacts; there is a need for a system that is able to integrate different scenarios based on simulations between different units communicated to permit the decision maker to take preventive actions in a timely manner.

6.1. Pandemic Real-Time Management

A solution that manages pandemic dynamic updates that happen every moment is a must. The main idea of this solution is enabling decision-makers to monitor carefully the evolution of a pandemic across country or organization or specific entity and allow them to consider proper actions that mitigate or prevent all possible risks. The key features of this system: (1) integration with all health sectors and collect all data, (2) identify and track the lack of medical staff in each unit, (3) identify and track the lack or need for tools and drugs mandatory for patients, (4) Identify infectious areas and alert people to avoid these places, and (5) guide people with safety instructions to avoid infections. The result from this system will be live reports sent to several actors every period within the day regularly. These reports include: (1) reports sent to control and command personnel; these reports contain number of infected persons, number of deaths, infectious areas, lack of medical resources in hospitals, number of recovered persons and need from other sectors like police officers or other government sectors; (2) reports sent to normal persons to avoid infectious areas and provide them with safety guidelines. These reports will help decision-makers form an integrated view about the pandemic as a whole and allow them to take effective preventive actions.

Figure 3 illustrates a Pandemic real-time management solution. The data is provided from health sectors and other sectors; then the data is processed in real-time to generate live reports that decision-makers use for review, monitor, and control.
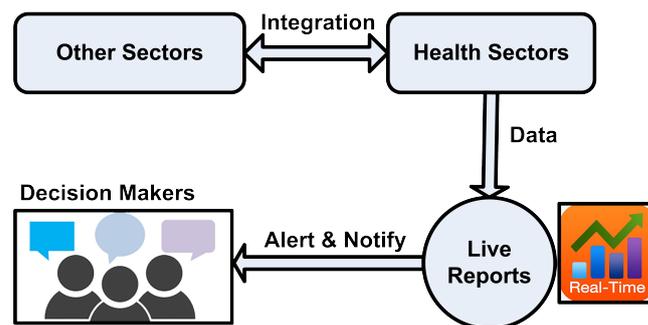

Figure 3. Pandemic real-time management solution.

6.2. Real-Time Economic Growth Rate Monitoring

There is a need for a solution that continuously monitors the updates that occur on the economic growth rates and gross domestic product regularly during the crisis. The key features of this solution include the following: (1) identify the workforce affected by the crisis, (2) identify the loss in capital, (3) introduce real-time narrative cost analysis of damages, (4) identify various sectors in governments, countries, and organizations impacted by the crisis, (5) determine the losses or downgrade that occurred on products, and (6) alarm top management before falling into any financial crisis. The results of this solution are live reports that mainly depend on involving economists and businessmen to inject their inputs and solutions. Consequently, decision-makers will decide how to avoid failing in any financial losses.

Figure 4 presents a real-time economic growth rates monitoring solution. First, different data and information are collected and sent to economists in organizations to study and investigate the financial current situation. After that, based on economists' detailed study, they propose different solutions and introduce them to decision-makers. Finally, decision-makers decide how to avoid any financial crisis that may happen, how to improve the financial current situation, and how to recover from any losses occurred.
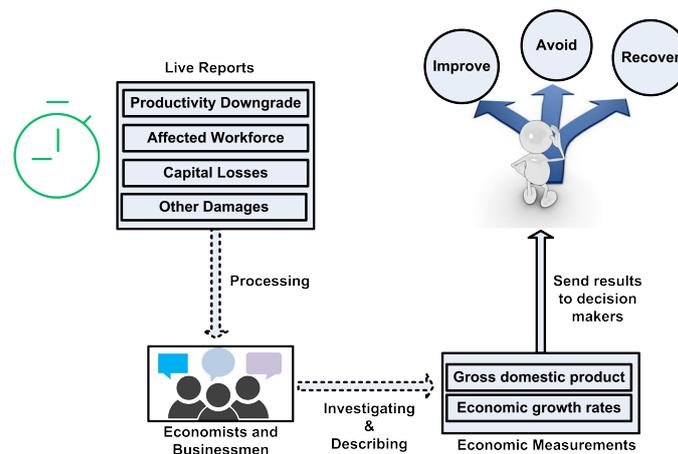
Figure 4. Real-time economic rates monitoring solution.

6.3. Real-Time Macro Crisis Response Solution

There is a need for a macro [66] solution that integrates different units and responds on time during a crisis to rescue affected cases and reduce losses. This solution also must have the ability to monitor and identify lacks in each integrated unit. First, the system will be invoked by alarms from the places impacted by the crisis. Next, the system will identify which units are proper for dealing with the current situation of the crises. Then, the system responds to first responders for intervention to deal with the crisis. For example, responders can be civil defense, paramedics, police officers, pilots with rescue aircraft, and so on. Additionally, If the system responds with all requirements and observes any shortage in supporting the crisis, system administrators must alarm specialized authorities to assist and provide units that satisfy the shortage.

Figure 5 illustrates the main idea of the real-time macro crisis response solution. The solution is invoked by actors who are affected by the damage of the crisis. Then, all units are integrated to effectively delegate to correct responders to make immediate corrective actions. If the responders notice any lack or shortage in resources they notify administrators to rectify the shortage by communicating with specialized authorities.
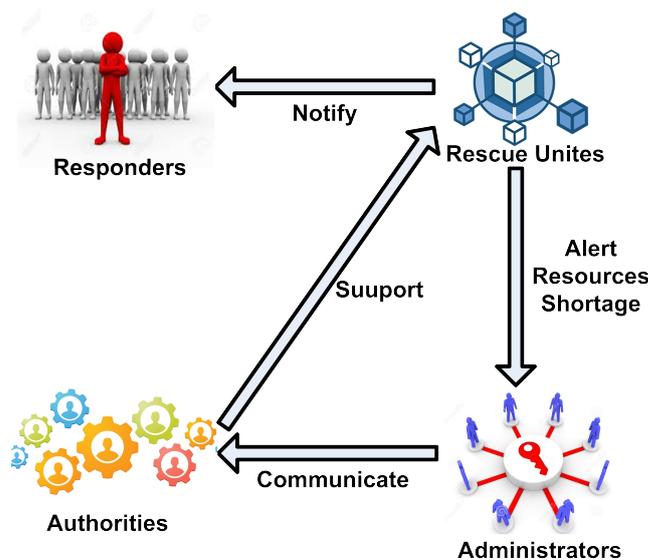

Figure 5. Real-time macro crisis response solution.

6.4. Smart Remote Working Approaches

There is a need for different solutions that enable workers to perform and control their jobs remotely during pandemic outbreaks without any need to go to workplaces or deal

with many people to reduce the spread of the pandemic. These solutions must contain different procedures that automate different activities performed in jobs, involve artificial intelligence tools and techniques that permit workers to learn how to operate the machines and how to do specific tasks, and different communication methods that permit workers from different sections to contact others easily, for example, a smart solution that can enable factory workers to power on, run, and power off factory machines from their homes.

6.5. Simulation-Based Solutions for Crisis Scenarios

There is a need for a solution that simulates several crisis scenarios that help decision-makers to make decisions that reduce the crisis impacts when a crisis happens. First, the system will define different cases that can happen during a crisis, these cases are defined by end-users using different input data. Second, the solution describes and presents how to deal with the evolving levels of the crisis. Finally, the result from the system is a map that contains crisis cases and proposed solutions with different plans and the corrective or preventive actions needed. This solution will help decision-makers to make an adaptive analysis of the crisis and to take their decisions in the right way that is suitable for all different crisis stages.

Figure 6 illustrates the main idea of this solution. First, the simulation of different crisis cases is defined. Next, managers or decision-makers plan and put forward all possible proposed solutions suitable for these cases. After that, they check and review the crisis scenario and its sequences to define if anything is missing or check any weak points. Finally, decision-makers adopt this simulation so that it is ready for execution.
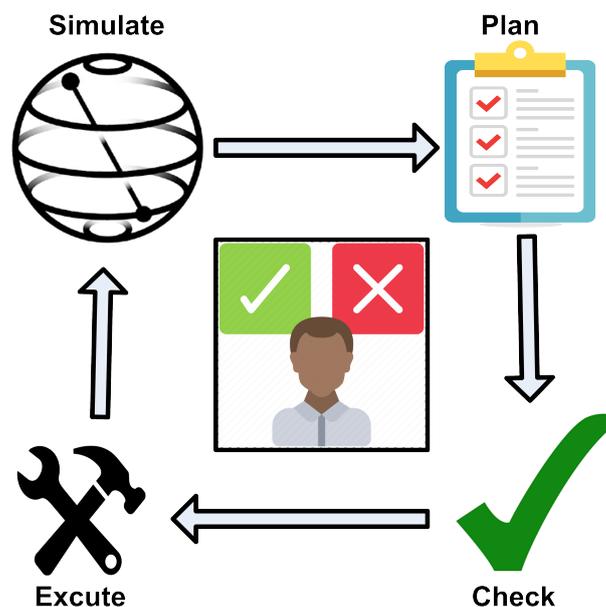

Figure 6. Simulation-based solutions.

7. Conclusions

In summary, the main objective of this study is to investigate and discuss the risks and impacts resulting from a crisis and propose robust solutions that can manage and control the crisis. Overall, this work starts by presenting the state of the art of all existing solutions that manage a crisis. Next, the impacts caused by various types of crisis are explored. In addition, the risks generated from these impacts are described as well as how the risks can directly or indirectly cause declines in economic growth rate. After that, the crisis response strategies are defined across various crisis phases in order to reduce or prevent all possible risks. Finally, this work proposes different solutions as future directions which will help decision-makers to take proper actions when a crisis happens and help organizations return to normality and continue with full functionality.

Conflicts of Interest: All the authors declare no conflict of interest.

References

1. Baxter, P.J. Catastrophes-Natural and Man-Made Disasters. In *Conflict and Catastrophe Medicine*; Ryan, J., Mahoney, P.F., Eds.; Springer: London, UK, 2002; pp. 27–48.
2. World Trade Organization (WTO). Trade Set to Plunge as COVID-19 Pandemic Upends Global Economy. Available online:https://www.wto.org/english/news_e/pres20_e/pr855_e.htm (accessed on 29 December 2020).
3. Kettebekov, N.K.E.S.S.; Sharma, R. Multimodal human-computer interaction for crisis management systems. In Proceedings of Sixth IEEE Workshop on Applications of Computer Vision, Orlando, FL, USA, 4 December 2002; pp. 203–207.
4. Linlejohn, R. *Crisis Management: A Team Approach*; American Management Associations: New York, NY, USA, 1983.
5. Kitano, H.; Tadokoro, S. RoboCup Rescue: A Grand Challenge for Multiagent and Intelligent Systems. *AI Mag.* **2001**, *22*, 39–52.
6. Youngblood, S. Ongoing Crisis Communication: Planning, Managing, and Responding, (Coombs, WT) and Handbook of Risk and Crisis Communication (Heath, RL and O'Hair, HD, Eds.)[Book reviews]. *IEEE Trans. Prof. Commun.* **2010**, *53*, 174–178. [CrossRef]
7. Fink, S. *Crisis Management: Planning for the Inevitable*; American Management Association: New York, NY, USA, 1986.
8. Shrivastava, P. Crisis theory/practice: Towards a sustainable future. *Ind. Environ. Crisis Q.* **1993**, *7*, 23–42. [CrossRef]
9. Tsang, E.; Ngai, E. EXSGACM: an expert system for gas crisis management. *Expert Syst. Appl.* **1996**, *10*, 75–90. [CrossRef]
10. Schoenharl, T.; Madey, G.; Szabó, G.; Barabási, A.L. WIPER: A Multi-Agent System for Emergency Response. Avaliable online: http://idl.iscram.org/files/schoenharl/2006/921_Schoenharl_etal2006.pdf (accessed on 29 December 2020).
11. Vescoukis, V.C.; Doulamis, N.D.; Karagiorgou, S. A service oriented architecture for decision support systems in environmental crisis management. *Future Gener. Comput. Syst.* **2012**, *28*, 593–604. [CrossRef]
12. Sheremetov, L.; Contreras, M.; Valencia, C. Intelligent multi-agent support for the contingency management system. *Expert Syst. Appl.* **2004**, *26*, 57–71. [CrossRef]
13. Liu, S.; Poccia, S.; Candan, K.S.; Chowell, G.; Sapino, M.L. epiDMS: data management and analytics for decision-making from epidemic spread simulation ensembles. *J. Infect. Dis.* **2016**, *214*, S427–S432. [CrossRef]
14. Van den Broeck, W.; Gioannini, C.; Gonçalves, B.; Quaggiotto, M.; Colizza, V.; Vespignani, A. The GLEaMviz computational tool, a publicly available software to explore realistic epidemic spreading scenarios at the global scale. *BMC Infect. Dis.* **2011**, *11*, 1–14.
15. Colizza, V.; Barrat, A.; Barthelemy, M.; Valleron, A.J.; Vespignani, A. Modeling the worldwide spread of pandemic influenza: baseline case and containment interventions. *PLoS Med.* **2007**, *4*, e13. [CrossRef]
16. Paraskevas, A. Crisis management or crisis response system?: A complexity science approach to organizational crises. *Manag. Decis.* **2006**, *44*, 892–907. [CrossRef]
17. Roemer, M.; Tang, L.; Bharadwaj, S.; Belcastro, C. An integrated aircraft health assessment and fault contingency management system for aircraft. In proceedings of the AIAA Guidance, Navigation and Control Conference and Exhibit, Honolulu, HI, USA, 18–21 August 2008; p. 6505. [CrossRef]
18. Pan, S.L.; Pan, G.; Leidner, D. Crisis response information networks. *J. Assoc. Inf. Syst.* **2012**, *13*, 31. [CrossRef]
19. Nickerson, A.B.; Brock, S.E.; Reeves, M.A. School crisis teams within an incident command system. *Calif. Sch. Psychol.* **2006**, *11*, 63–72. [CrossRef]
20. Rahman, S.; Pipattanasomporn, M.; Teklu, Y. Intelligent distributed autonomous power systems (IDAPS). In Proceedings of the 2007 IEEE Power Engineering Society General Meeting, Tampa, FL, USA, 24–28 June 2007; pp. 1–8.
21. Turoff, M.; Chumer, M.; de Walle, B.V.; Yao, X. The design of a dynamic emergency response management information system (DERMIS). *J. Inf. Technol. Theory Appl.* **2004**, *5*, 3.
22. Hendawi, M.M.S.M.P.M.Y.A.W.T.A.; Stankovic, J.A. Data Sets, Modeling, and Decision Making in Smart Cities: A Survey. *ACM Trans. Cyber-Phys. Syst.* **2019**, *4*, 1–28.
23. Franke, J.L.; Jameson, S.M.; Paradis, R.D.; Szczerba, R.J. Hierarchical contingency management system for mission planners, 2011. US Patent 8,078,319, 16 Febuary 2005.
24. Frey, B.S.; Luechinger, S.; Stutzer, A. Calculating tragedy: Assessing the costs of terrorism. *J. Econ. Surv.* **2007**, *21*, 1–24. [CrossRef]
25. Blake, A.; Sinclair, M.T.; Sugiyarto, G. Quantifying the impact of foot and mouth disease on tourism and the UK economy. *Tour. Econ.* **2003**, *9*, 449–465. [CrossRef]
26. Page, S.; Song, H.; Wu, D.C. Assessing the impacts of the global economic crisis and swine flu on inbound tourism demand in the United Kingdom. *J. Travel Res.* **2012**, *51*, 142–153. [CrossRef]

27. Alcabes, P. Swine flu spans the great divide. *New Sci.* **2009**, *202*, 18. [CrossRef]
28. Fuente, J.B.A.D.; Santos, I. Do Natural Disasters Affect Human Capital? An Assessment Based on Existing Empirical Evidence. Available online: http://gpss.vizzuality.com/assets/resources/do_natural_disasters_affect_human_capital.pdf (accessed on 30 December 2020).
29. Berlemann, M.; Wenzel, D. Long-Term Growth Effects of Natural Disasters—Empirical Evidence for Droughts. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2701762 (accessed on 30 December 2020).
30. Keen, M.; Mani, M.; Freeman, P.K. Dealing with Increased Risk of Natural Disasters: Challenges and Options. *IMF Work. Pap.* **2003**, 1–38. [CrossRef]
31. Hochrainer, S. *Assessing the Macroeconomic Impacts of Natural Disasters: Are There Any?*; The World Bank: Washington, DC, USA, 2009.
32. Okuyama, Y. Economics of natural disasters: A critical review. *Resear. Paper* **2003**, *12*, 20–22.
33. Panwar, V.; Sen, S. Economic impact of natural disasters: An empirical re-examination. *Margin: J. Appl. Econ. Res.* **2019**, *13*, 109–139. [CrossRef]
34. Madhav, N.; Oppenheim, B.; Gallivan, M.; Mulembakani, P.; Rubin, E.; Wolfe, N. Chapter 17: Pandemics: Risks, Impacts, and Mitigation. In *Disease Control Priorities: Improving Health and Reducing Poverty*, 3rd ed.; Jamison, D.T., Gelband, H., Horton, S., Eds.; The International Bank for Reconstruction and Development/The World Bank: Washington, DC, USA, 2017.
35. Goniewicz, K.; Misztal-Okońska, P.; Pawłowski, W.; Burkle, F.M.; Czerski, R.; Hertelendy, A.J.; Goniewicz, M. Evacuation from Healthcare Facilities in Poland: Legal Preparedness and Preparation. *Res. Public Health* **2020**, *17*, 1779. [CrossRef] [PubMed]
36. Bradt, F.M.B.D.A.; Ryan, B.J. Global Public Health Database Support to Population-Based Management of Pandemics and Global Public Health Crises, Part I: The Concept. *Prehospital Disaster Med.* **2020**, 1–10.. [CrossRef]
37. Johnson, N.P.A.S.; Mueller, J. Updating the Accounts: Global Mortality of the 1918–1920 'Spanish' Influenza Pandemic. *Bull. Hist. Med.* **2002**, *76*, 105–115. [CrossRef] [PubMed]
38. McKibbin, W.J.; Sidorenko, A.A. *Global Macroeconomic Consequences of Pandemic Influenza*; Centre for Applied Macroeconomic Analysis: Acton, ACT, Australia, 2006.
39. Viboud, C.; Simonsen, L.; Fuentes, R.; Flores, J.; Miller, M.A.; Chowell, G. Global Mortality Impact of the 1957–1959 Influenza Pandemic. *J. Infect. Dis* **2016**, *213*, 738–745. [CrossRef]
40. Wang, M.D.; Jolly, A.M. Changing Virulence of the SARS Virus: The Epidemiological Evidence. *Bull. World Health Organ.* **2004**, *82*, 547–548.
41. Keogh-Brown, M.R.; Smith, R.D. The Economic Impact of SARS: How Does the Reality Match the Predictions? *Health Policy* **2008**, *88*, 110–120. [CrossRef]
42. Dawood, F.S.; Iuliano, A.D.; Reed, C.; Meltzer, M.I.; Shay, D.K.; Cheng, P.-Y.; Bandaranayake, D.; Breiman, R.F.; Brooks, W.A.; Buchy, P.; et al. Estimated Global Mortality Associated with the First 12 Months of 2009 Pandemic Influenza A H1N1 Virus Circulation: A Modelling Study. *Lancet Infect. Dis.* **2012**, *12*, 687–695. [CrossRef]
43. Kim, Y.W.; Yoon, S.K.; Oh, I.H. The Economic Burden of the 2009 Pandemic H1N1 Influenza in Korea. *Scand. J. Infect. Dis.* **2012**, 390–396.. [CrossRef]
44. Park, H. Exploring effective crisis response strategies. *Public Relations Rev.* **2017**, *43*, 190–192. [CrossRef]
45. Macpherson, R.I.S.; Burkle, F.M.Jr. Humanitarian Aid Workers: The Forgotten First Responders. *Prehosp. Disaster Med.* **2020**, 1–4. [CrossRef] [PubMed]
46. Arpan, L.M.; Roskos-Ewoldsen, D.R. Stealing thunder: Analysis of the effects of proactive disclosure of crisis information. *Public Relat. Rev.* **2005**, *31*, 425–433. [CrossRef]
47. Claeys, A.S.; Cauberghe, V. Crisis response and crisis timing strategies, two sides of the same coin. *Public Relat. Rev.* **2012**, *38*, 83–88. [CrossRef]
48. Ki, E.-J.; Brown, K.A. The Effects of Crisis Response Strategies on Relationship Quality Outcomes. *Int. J. Bus. Commun.* **2013**, *50*, 403–420. [CrossRef]
49. Waring, S.C., Reynolds, K.M.; D'Souza, G.; Arafat, R.R. Rapid assessment of household needs in the Houston area after tropical storm Allison. *Disaster Manag. Response* **2002**, *2002*, 3–9.
50. Centers for Disease Control and Prevention (CDC). Norovirus outbreak among evacuees from Hurricane Katrina—Houston, Texas, September 2005. *MMWR Morb. Mortal. Wkly Rep.* **2005**, *54*, 1016–1018.
51. Karande, S. An observational study to detect leptospirosis in Mumbai, India, 2000. *Arch. Dis. Child.* **2003**, *88*, 1070–1075. [CrossRef]
52. World Health Organization. Flooding and Communicable Diseases Fact Sheet. Risk Assessment and Preventive Measures. Available online: www.who.int/hac/techguidance/ems/flood_cds/en/ (accessed on 30 December 2020).
53. Yang, H.Y.; Hsu, P.Y.; Pan, M.J.; Wu, M.S.; Lee, C.H.; Yu, C.C.; Hung, C.C.; Yang, C.W. clinical distinction and evaluation of Leptospirosis in Taiwan – a case control study. *J. Nephrol.* **2005**, *18*, 45–53.
54. World Health Organization. *Factors that Contributed to Undetected Spread of the Ebola Virus and Impeded Rapid Containment*; WHO: Geneva, Switzerland, 2015. Available online: https://www.who.int/csr/disease/ebola/one-year-report/factors/en/ (accessed on 30 December 2020)
55. Jordan, R.E.; Adab, P.; Cheng, K.K. Covid-19: Risk Factors for Severe Disease and Death. *BMJ (Clin. Res.)* **2020**, *368*, m1198. [CrossRef]

56. Public Health England. Guidance on Social Distancing for Everyone in the UK. Available online: https://www.gov.uk/government/publications/covid-19-guidance-on-social-distancing-and-for-vulnerable-people/guidance-on-social-distancing-for-everyone-in-the-uk-and-protecting-older-people-and-vulnerable-adults (accessed on 30 December 2020).

57. Public Health England. Seasonal Influenza Vaccine Uptake in GP Patients: Winter Season 2018 to 2019. Available online: https://www.gov.uk\/government\/statistics\/seasonal-flu-vaccine-uptake-ingp-patients-winter-2018-to-201 (accessed on 30 December 2020).

58. Gov.uk. New Rules on Staying at Home and Away from Others. Available online: https://assets.publishing.service.gov.uk (accessed on 30 December 2020).

59. Huang, R.; Zhu, L.; Xue, L.; Liu, L.; Yan, X.; Wang, J.; Zhang, B.; Xu, T.; Ji, F.; Zhao, Y.; et al. Clinical Findings of Patients with Coronavirus Disease 2019 in Jiangsu Province, China: A Retrospective, Multi-Center Study. *PLoS. Negl. Trop. Dis.* **2020**, *14*, e0008280. [CrossRef]

60. Wang, D.; Hu, B.; Hu, C.; Zhu, F.; Liu, X.; Zhang, J.; Wang, B.; Xiang, H.; Cheng, Z.; Xiong, Y.; et al. Clinical characteristics of 138 hospitalized patients with 2019 Novel Coronavirus–Infected pneumonia in Wuhan, China. *JAMA* **2020**, *323*, 1061–1069. [CrossRef] [PubMed]

61. Livingston, E.; Bucher, K. Coronavirus Disease 2019 (COVID-19) in Italy. *JAMA* **2020**, *323*, 1335. [CrossRef] [PubMed]

62. Lighter, J.; Phillips, M.; Hochman, S.; Sterling, S.; Johnson, D.; Francois, F.; Stachel, A. Obesity in patients younger than 60 years is a risk factor for Covid-19 hospital admission. *Clin. Infect. Dis.* **2020**, *71*, 896–897. [CrossRef] [PubMed]

63. Zhou, F.; Yu, T.; Du, R.; Fan, G.; Liu, Y.; Liu, Z.; Xiang, J.; Wang, Y.; Song, B.; Gu, X.; et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet* **2020**, *395*, 1054–1062. [CrossRef]

64. Li, X.; Xu, S.; Yu, M.; Wang, K.; Tao, Y.; Zhou, Y.; Shi, J.; Zhou, M.; Wu, B.; Yang, Z.; et al. Risk Factors for Severity and Mortality in Adult COVID-19 Inpatients in Wuhan. *J. Allergy Clin. Immunol.* **2020**, *146*, 110–118. [CrossRef] [PubMed]

65. BMJ. Underlying illness risk factors for severe COVID-19 or death, ScienceDaily. 2020. Available online: https://www.sciencedaily.com/releases/2020/06/200601101308.htm (accessed on 30 December 2020).

66. Hendawi, A.M.; Khalefa, M.; Liu, H.; Ali, M.; Stankovic, J.A. A Vision for Micro and Macro Location Aware Services. In Proceedings of the 24th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems, Burlingame, CA, USA, 31 October–3 November 2016; pp. 1–4.