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Sustaining Organizational Operations during an Outbreak: Problems, Needs, and Opportunities for Information Systems

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ABSTRACT
Regulatory measures during an outbreak keep many organizations from operating as usual, requiring new practices and policies. Since society has become highly dependent on effective and efficient information systems (IS), understanding how outbreaks may impact IS is critical. By looking at existing literature, problems associated with sustaining reliable IS services, as well as changing needs for IS caused by the new circumstances are explored, and new opportunities for IS after the outbreak are discussed.

KEYWORDS
COVID-19; information systems; information technology; outbreak; epidemic; pandemic

Introduction

Catastrophic outbreaks, like the COVID-19 pandemic, extensively effect social interactions and thereby also substantially impact the economy. Fundamentally, catastrophic outbreaks, as other wide-reaching disasters, pose extreme disruptions in the regular functioning of social and economic systems (Perry, 2018). Cautionary and preventive measures by authorities may place severe restrictions on what people can do and how they can interact with their fellow citizens. Private and public sector organizations, including businesses and government agencies, may be unable to continue function as usual, requiring new processes and policies, and in extreme circumstances, these organizations may be forced to partially or fully suspend operations. On the whole, catastrophic outbreaks may cause many people to get seriously sick or lose their lives, but even more so, they may create economic conditions that severely affect people's livelihoods, as businesses shut down and individuals lose their jobs and possibly their life savings.

Contemporary society increasingly relies on sustained and dependable information technology (IT) and information systems (IS) in almost all aspects of life, in conducting business operations, offering education, providing healthcare, and other essential public services, as well as for communication and facilitating much of social interactions. Thus, it is of critical importance to understand how wide-reaching disasters, such as epidemics, pandemics, or other major outbreaks, may impact the effective and efficient supply, management, and utilization of IS.

In addition to overall economic distress, catastrophic outbreaks may create significant problems for the delivery of IS services, as managers and technicians in charge of sustaining the systems may be hindered by the restrictions and safety measures put in place to protect the populace and to bring the outbreak under control. Furthermore, the managers and technicians themselves may be victims of the catastrophic outbreak and not be able to carry out their normal duties.

The disruptions of usual business and societal practices caused by an outbreak may also bring about additional needs for IS services not currently provided, as customary modes of operation are impeded by newly imposed safety measures. Public and private organizations are very much dependent on modern technology to carry out their daily operations as well as for their tactical and strategic decision-making processes. Systems may need to be adapted, modified, or reengineered to respond to the added needs caused by the organizational changes and individual expectations during an outbreak. Additionally, the special circumstances caused by the catastrophic outbreak may also provide opportunities for new business activities and thus for improving or expanding IS services.

To some extent, problems, needs, and opportunities regarding IS in times of emergencies have been studied previously and reported on in the literature, and it seems that the lessons learned from past experiences should help in handling the current COVID-19 pandemic, a catastrophic outbreak. Unfortunately though, catastrophic outbreaks still catch authorities, public

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organizations, businesses, and citizens mostly unprepared. Based on existing literature dealing with IS during catastrophic outbreaks of various natures, the authors explore the problems associated with providing reliable IS services under such difficult conditions, as well as the extra needs for IS due to these special circumstances, and the opportunities for new IS services due to changes in customary operations. Our motivation is to provide a foundation for IS decision makers dealing with outbreaks to better equip them for managing the challenging situations.

Figure 1 summarizes the potential impact of the societal environment during a catastrophic outbreak on organizational IS. This environment is shaped by several external factors, including: regulations and restrictions imposed by central and local authorities; social distancing and isolation rules; high risk of infection; social trust and privacy protection concerns; supply chain interruptions, including in delivery of IT services; volatility in costs and prices for products and services; potentially diminished availability of highly qualified IT staff due to isolation and hospitalization; and the enhanced and special requirements for IT services to deal with new and modified operational processes.

The rest of this paper is structured as follows. After briefly defining the terminology used in the paper, we explore the impact on IT and IS due to catastrophic outbreaks based on existing literature, including problems with sustaining operation of existing systems, meeting changes in needs and system requirements due to the outbreak, and opportunities for improving or extending IS services in the aftermath of the catastrophic outbreak. We conclude the paper with final observations and suggestions for further investigations.

Terminology

An outbreak is understood as an unexpected upsurge of an illness, which may be localized or may affect a large population across a wide geographic area. An outbreak can be an epidemic, usually implying the rapid spread of an infectious disease. An epidemic that extends across a large region is frequently called a pandemic. Examples of pandemics are the Black Death of 14th century Europe, the 1918 Spanish flu outbreak, and most recently COVID-19.

Typically, a pandemic is associated with large numbers of serious illnesses and deaths, overwhelming the customary health-care system. Black Death by some estimates decreased Europe's population at the time from 75 million to 20 million (Getz, 1991). The 1918 Spanish flu outbreak killed 20–40 million people worldwide (Ioannidis, 2020) or even 50 million by some accounts (Morse, 2009).

Currently, there is no agreement on a precise definition of a pandemic or how to determine when it starts and when it ends (Morens et al., 2009). Ordinarily, for an outbreak to be called a pandemic, it must be an infectious disease that affects a large proportion of the population of a region, a "disease extensively epidemic" (Shope, 1958). As noted by Morens et al. (2009), the one common denominator for all past outbreaks that were designated as pandemics is widespread geographic

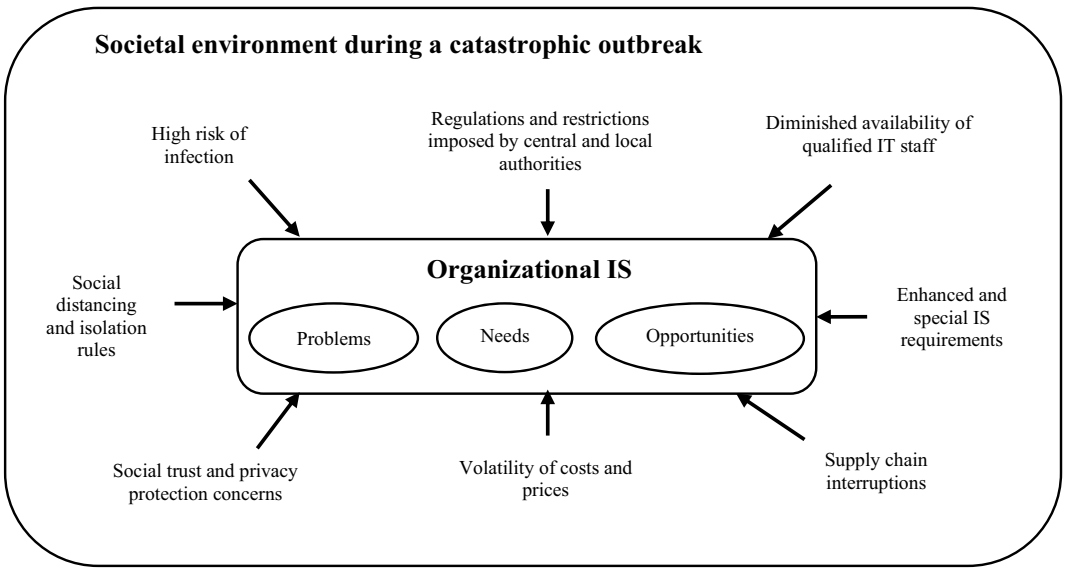

Figure 1. Societal impact on organizational IS during an outbreak.

extension. Additional common features have been disease movement and high attack rates, whereas other criteria sometimes applied, such as minimum population immunity, novelty, infectiousness, contagiousness, and severity are somewhat inconsistent. Perhaps the most controversial criterion often applied is severity (Morens et al., 2009; Shope, 1958). Many health-related international organizations no longer use any measure of severity to define a pandemic. For example, until May 2009, the World Health Organization (WHO) defined pandemics as outbreaks generating "enormous numbers of deaths and illness" but after May 2009, WHO dropped this phrase describing severity (Cohen & Carter, 2010).

This ambiguity about when exactly a catastrophic outbreak constitutes a pandemic and the lack of set policies about when authorities may declare a pandemic and impose special rules and restrictions makes the business environment in an outbreak rather unpredictable. Overall, a catastrophic outbreak causes great direct and indirect damage to a population's physical and mental health and wellbeing while at the same time bringing about enormous economic damage to organizations, regions, and countries.

The terms information technology (IT) and information and communications technology (ICT) are often used interchangeably, and refer to any technology that is used to electronically store, retrieve, transform, or transmit information or data in digital form. This includes computers, smart phones, digital television, computer networks, the Internet, etc. Information systems (IS) are systems that make use of IT and are designed for specific tasks or purposes, such as communication, payroll management, sales and marketing, etc. IS typically include five components: computer hardware, computer software, telecommunications, databases, and human resources and procedures (Gregersen, 2020).

IS must be properly maintained in order to keep operating effectively. IT professionals, part of the human resources component, are in charge of fixing bugs in IS and updating the systems to meet changing requirements. IS managers are in charge of assuring the appropriate availability and usage of the systems, by making timely and opportune decisions. During a catastrophic outbreak, the human resources component of IS is potentially the most vulnerable component, as people may be exposed to disease and become unavailable.

Problems with keeping existing information systems running

Sustaining the continued and effective operation of critical IS during the outbreak is of utmost importance. The working environment shaped by a catastrophic outbreak and the measures taken to control the outbreak typically lead to lower revenues and higher operational expenses for most organizations. Operations may be impacted by absenteeism of essential employees due to contracting or fear of contracting the disease, or due to company or government-imposed restrictions. Work restrictions and other regulations may change frequently and sometimes unpredictably.

Many organizations leverage the Internet and IT and integrate online tools as well as social media and online communication platforms into their business operations, and Mitchell (2007) maintains that IT is critical to business continuity during a catastrophic outbreak. Business continuity plans must take this into account, and the cornerstone to any continuity plan is effective communication and the ability to quickly receive and distribute information for decision-makers. When employees are unable or fearful to work in a physical location, remote working and access may be one remedy, requiring an appropriate IT infrastructure. Personnel shortages may affect not only the operational staff, but also upper-level decision-makers. Predefining task orders and procedures that normally require multiple layers of approval can be one option to alleviate the problem. For those employees for who tele-working is not an option, reducing workplace risks by implementing social distancing rules, mandating personal protective equipment, and carrying out frequent cleaning of the environment mitigate the risk of disease transmission, but also increase operational costs.

Enterprise Resource Planning (ERP) systems provide a suitable platform to allow for quick access to collected data and facilitate knowledge sharing (Salloum et al., 2018), and thus may also be beneficial during a catastrophic outbreak to manage and sustain business and public services operations. Via virtual private networks (VPN), employees can use these and other organizational IS to continue providing services remotely.

Yan et al. (2020) also state that a robust IT-infrastructure is extremely important to the delivery of IT-enabled health-care services during an outbreak. Thus, the consensus seems to be that providing the appropriate IT infrastructure to enable efficient communication, remote working, remote business operations, and remote services, together with appropriate policies and contingency plans are the most important ingredients for sustained IT and business operations.

Adjusted needs for IS services

Adapting quickly to the changed priorities created by the outbreak is critical to providing the services most

needed during these new circumstances. Tasks and functions that are considered important during normal times, may diminish in significance due to the needs of controlling the outbreak and providing new or modified services to substitute for social or economic activities that are no longer feasible. Most of the literature we found that deals with IT or IS during an outbreak report on the special needs during the crisis and responses to these new demands (Braa et al., 2007).

Recognizing a crisis early is crucial in managing catastrophic outbreaks. Ahmed et al. (2019) share lessons learned in concept development of an electronic disease early warning system as a tool for disease surveillance for early warning and response during a humanitarian crisis. The authors point out that successful implementation of this early warning system is possible through high-level determination, commitment, trust building, strong collaboration, and working relationships between government and the health sector.

Enhanced communication and rapid training can become particularly important during a catastrophic outbreak (Turoff, 2002). Bukhari and Bukhari (2020) point out the increased significance of hi-tech communication networks in the COVID-19 outbreak. Marr (2020) predicts increased interfaces and interactions without physical contact in a post COVID-19 world.

Rapid training of health professionals and managing patient data are other enhanced needs in an outbreak. Yan et al. (2020) state that during a pandemic, medical preparation should emphasize procedural training, as doctors or nurses following inappropriate medical procedures can increase the infection rate. In their study, Yan et al. found that because of the rushed schedule of the medical professionals who were responding to the COVID-19 outbreak in Wuhan, IT-enabled training, such as flipped classrooms was particularly suitable. In flipped classroom training, the hospitals posted online training videos to a platform like WeChat and then used the in-classroom format for practice training. The authors also found that artificial intelligence technologies can be used for online self-assessment systems, robots can be used in guiding patients and delivering medicines within the hospital, and QR bar codes can be used for collecting patient and visitor information.

Often during a catastrophic outbreak, people that are suspected of having been exposed are quarantined to prevent further spread of the disease. Yasir et al. (2020) state that during quarantine, because people have more free time to participate in social media, it increases their desire for online presence. People like to be involved and share their own experiences. Also, e-government and e-publishing may play an increased role, as people look on-line for basic information, protection measures, and development of the outbreak. However, when not explained well, some information broadcast via e-publishing may be misinterpreted, creating confusion and distrust in authorities.

Other authors also commend e-government during a catastrophic outbreak. Devadoss and Pan (2004) describe how in Singapore during the 2003 SARS pandemic the government mobilized its e-government platform for managing the crisis. The Defense Science and Technology Agency of the Singaporean government developed a system in two weeks to manage data and coordinate multiple agencies in their crisis responses. The authors argue that emergency management needs a sound infrastructure for effective information sharing, and e-government may provide such an infrastructure. The use of an emergency management system as part of e-government during an outbreak is widely described by other authors as well (Devadoss & Pan, 2004; Jaeger et al., 2007).

Kummitha (2020) discusses the role of smart technologies in controlling the virus transmission during COVID-19. Internet-of-Things (IoT) technologies have so penetrated Chinese cities that for example, passengers on public transport may be charged based on facial recognition, avoiding physical contact. Also, as another example, smart devices connected to utilities such as trashcans can automatically collect data alerting authorities when they reach capacity, avoiding much person-to-person interaction and opportunities for virus transmission. Facial recognition technology, mobile phone location-tracking, and space-based systems can be employed to monitor the movement of citizens, tracking possible virus spread. In many countries though, privacy laws and widespread public concerns may hamper some of these applications.

Apps for voluntary sharing of data to track COVID-19 symptoms, such as "COVID symptom tracker" (https://COVID.joinzoe.com/us) or "Trace Together" (https://www.tracetogether.gov.sg/) are discussed by O'Leary (2020). These apps allow monitoring individuals who are suspected of having the disease as well as people that they have been in contact with, thus letting exposed people be notified so they will self-quarantine. O'Leary also suggests that these apps can help carry out organizational responsibilities, as organizations may need to track the health of their workers to ensure the safety of all stakeholders and potentially avoid lawsuits. However, he also points out the privacy concerns and the risk of these data being misused during the outbreak as well as after the outbreak is passed.

Several authors point out the importance of patient monitoring in an outbreak. An interesting case of IS adaptations to manage clinically healthy COVID-19

patients in South Korea is reported by Bae et al. (2020). The system includes a dashboard created for the medical staff to monitor the vital signs and symptoms of all patients. A mobile app allows patients to consult with the medical staff, respond to questions, and enter self-measured vital signs, the results being uploaded to the hospital IS in real time. Interoperability between medical institutions is enabled via Cloud-based image sharing.

Binns et al. (2010), after studying the operational experience of public health units during the 2009 H1N1 influenza outbreak (swine flu pandemic) in New South Wales, found that a web-based multi-user access database for case management, as well as effective network communication, are essential. Devadoss & Pan, (2004) also mention the importance of creating a reference database to manage the 2004 SARS pandemic. However, they also point out the problems associated with data security and privacy. The use of collected data by different government agencies required tiered data access with different levels of authority.

Several researchers state that the COVID-19 pandemic has forced physicians and many health-care institutions to offer medical services using telehealth tools, to limit physical exposure to the patients (Hong et al., 2020; Parisien et al., 2020). Helou et al. (2020) observe the increased openness and willingness to adopt telehealth services by physicians, though skepticism, especially concerning efficiency, safety, and the adequacy of existing regulations remain.

COVID-19 has resulted in many schools and colleges to switch to online teaching. Online education has been around for some time, but this outbreak has forced even teachers without previous experience and without much preparation and tools to switch to this mode of instruction. O'Leary (2020) points out some of the problems with online education. Ali (2020) explores the necessity for online learning in the pandemic. IT requirements include dependable laptop computers and reliable Internet access for students, as well as appropriate online education software platforms.

Summarizing some of our findings, the identified needs for enhanced IS during a catastrophic outbreak are depicted in Figure 2.

Opportunities for IS in the aftermath of an outbreak

The break in customary operations due to the catastrophic outbreak may also provide opportunities to improve or extend IS services. By and large, the catastrophic outbreak ends when most special restrictions and regulations are lifted and the authorities declare that the spread of the disease is under control. New IS may be developed to deal with problems observed during the outbreak. These new systems may or may not become operational immediately, but they may help prevent or control future outbreaks. In addition, some new systems may help to capitalize on opportunities resulting from the changed organizational landscape. Most of the literature we found though, describes specific decision support and modeling tools that may help with earlier detection and with better management of future outbreaks.

Zafar et al. (2014) for example, report on a dengue information management system (DIMS) that was developed following a dengue epidemic in Pakistan in

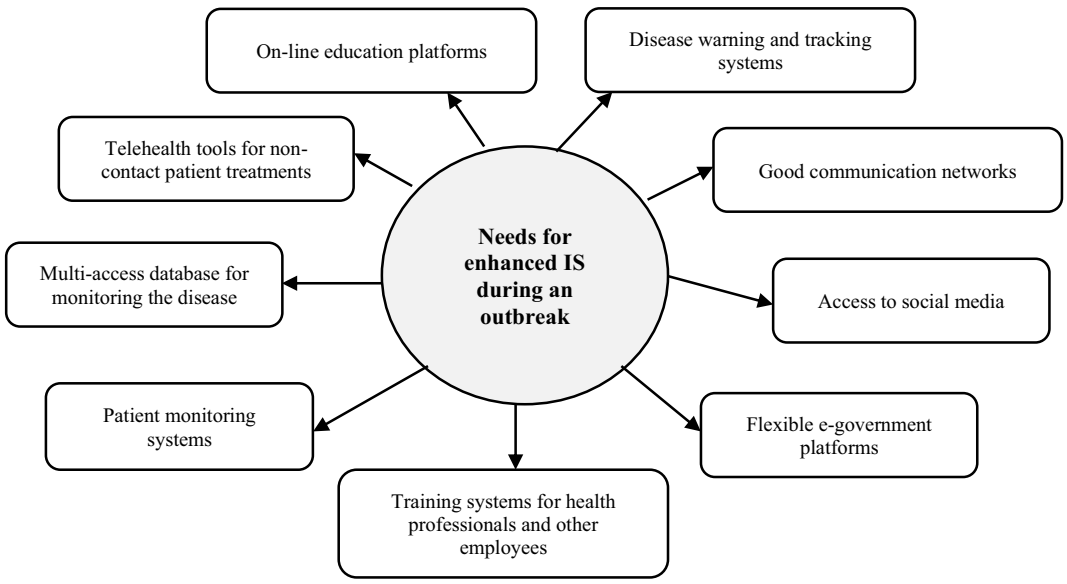

Figure 2. Needs for enhanced IS services during an outbreak.

2010 affecting over 350,000 people. Features of this system include: an electronic complaint routing sub-system to handle complaints coming in from the Helpline in real-time, a vector surveillance sub-system for tracking and reporting larvaciding activities, and a disease reporting sub-system to manage the clinical and lab diagnosis records of dengue affected patients. Use of DIMS has resulted in zero reported further deaths attributed to dengue in the one and one-half years following the system becoming available in 2012.

Referring to the 2009 H1N1 influenza outbreak, Araz et al. (2012) point out that pandemics can have profound social, legal, and economic consequences. They state that the pandemic experience has also made it apparent that the public needs to be better prepared to deal with this kind of situation, and that public health preparedness exercises are necessary. To this end, the authors report on a simulation model and tabletop exercise developed at Arizona State University that facilitates decision-making interactions around emergency response scenarios. Practicing emergency decisions may lead to better and more explicable policy implementations in the future.

Referring to the 2002 SARS pandemic, Aleman et al. (2011) point to the need for robust models predicting how and where a disease may spread, in order to determine suitable mitigation strategies. They propose an agent-based simulation model that views individuals as unique and assumes non-homogenous transmission correlated to demographic information. Results of the model are entered into a geographic information system to create a map for the predicted disease spread.

Final observations and suggestions for further investigation

Declaring and managing a catastrophic outbreak is a complex issue and the role of IS is vital. In this treatise, we explored the problems, needs, and opportunities for IS during and in the aftermath of a catastrophic outbreak. We reviewed the available literature in this regard and found that most of the literature deals with responding to the enhanced needs for new or modified IS. Relatively little has been published dealing specifically with ensuring the sustained operation of existing systems. This may indicate that the problems encountered are not sufficiently severe to merit study, or it may mean that uncovering and exploring this information is more difficult.

In addition, there is little focus on IT professionals, who as mentioned earlier, may themselves be victims of a catastrophic outbreak and unable to carry out their normal duties. Furthermore, responsibilities of IT professionals during an outbreak may require more effort and result in increased stress, as more stringent rules related to their work environment are put in force. It is not clear which capabilities, skills, and competencies are most critical for IT professionals in a catastrophic outbreak so as to preserve their effectiveness and positive attitudes toward their responsibilities. To this point, earlier studies indicated that a higher level of business competency may lead to higher job satisfaction and generally positive attitude (Kowal & Roztocki, 2015). Other personal characteristics, however, may be important during a catastrophic outbreak.

Also, there seems to not be much published research on new systems and technology developed in response to new business opportunities as a result of the break in customary procedures and the changed organizational landscape. Most articles we found dealing with new developments in the aftermath of a pandemic or epidemic deal with modeling and decision-making tools for preparation of future catastrophic outbreaks.

Many specific issues related to e-government that may also be of concern in a catastrophic outbreak were not elaborated on in the studies that we reviewed, including for example, e-voting. Krimmer et al. (2020) initiate a debate concerning safeguarding democracy during pandemics. When an election is held during a pandemic or epidemic, alternative ways to voting may need to be developed, avoiding voters to stand unprotected in crowded spaces waiting to cast their ballots in person and be in fear of getting infected. Three voting scenarios: traditional with added protection, voting by mail, and internet voting (e-voting) are briefly outlined by Krimmer et al. (2020). Though e-voting during an outbreak may be a necessity, once instituted, e-voting may become the norm for future elections (as in Estonia, where it is already included as a viable voting channel in all elections). In this regard, control mechanisms are necessary to prevent possible election manipulations. Also related to e-government, we did not find much discussion on providing opportunities for active involvement of citizens in the decision-making process concerning the management of catastrophic outbreaks. To this extent, e-democracy (Nastase et al., 2007) could provide a viable platform.

As observed by O'Leary (2020), buying patterns during outbreaks change. Many people are spending less on average, as their income may be reduced or they fear income loss for the near future. Thus, as suggested by O'Leary (2020), future research may examine how IS can be used to accommodate changes in buying behaviors. This research stream is particularly interesting, as the economic consequences of a catastrophic outbreak such

as the COVID-19 pandemic may last much longer than the actual outbreak.

Other topics that we did not find much coverage on include on-line teaching, that many educators find themselves to be involved in during a catastrophic outbreak, such as the COVID-19 pandemic, even if not always well prepared; virtual conferences, of immediate concern to academics that are used to large in-person conventions where they can meet with colleagues and discuss current scientific research; and on-line buying and food ordering, which is becoming increasingly popular.

There is also the danger of people becoming overly Internet dependent and comfortable with online activities, which may be to the detriment of the resumption of normal, non-virtual, activities, once the catastrophic outbreak passes. This may have profound consequences for some organizations, such as universities and other educational institutions. It is quite possible that many students who get accustomed to online learning will never return to physical classrooms. However, there are also still segments of the populace that do not have access to the Internet, by choice or by circumstance, thus increased dependency on the Internet by parts of the population may deepen the digital divide, which may be a topic for further research as well.

In addition to all the issues mentioned in the above discussion, another research opportunity is data security and privacy matters during an outbreak. As several authors (Devadoss & Pan, 2004) mentioned, during an outbreak data integration is often hasty, and security and privacy may be compromised.

To conclude, our hope is that this treatise, besides providing some foundation for IS decision makers dealing with future outbreaks to better equip them for managing the challenging situations, will also inspire other researchers to further explore the issues unveiled in our findings.

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