Technology and Information Management Supporting Resilience in Healthcare and Rescue Systems

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Abstract Health care and rescue system resilience is the multifactoral sum of technology, humans, information, processes, and management. The coronavirus (COVID-19) pandemic has been a catalyst for transformation globally and tested the resilience of health care and rescue systems in many ways. The relevant use of technology has been acknowledged as one important element in developing resilience, but there are still very few empirical studies that have studied the role of technology in supporting system-level resilience. This chapter examines how information system solutions have advanced system resilience during the COVID-19 crisis through a literature review and empirical case study of the Finnish health care and rescue sector. According to the results of this study, the use of different technology solutions and digital services in health care and rescue has increased during the pandemic, as the crisis has accelerated the development of an information system (IS) for data sharing as well as experiments on AI and robotics. However, in developing IS solutions, several challenges arise that are specific to the health care and rescue sector that need to be taken into account: strict legislation, the privacy of health data, and the fact that implementation of a digital service cannot compromise patient care.

Keywords Healthcare system · Rescue system · Resilience · Technology · Information management · COVID-19

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Introduction

Healthcare systems are one of the most critical systems in societies (European Observatory on Health Systems and Policies, 2020) constituting a solid foundation for daily life. In a crisis, situations are solved with ad hoc solutions causing complex networks of a human- technology mixture (Bakos, 2020). There may be signals of a sudden crisis, but the preparedness and resilience to shocks of health systems vary (European Observatory on Health Systems and Policies, 2020; Thomas & Rutter, 2008). Resilience can be seen as the ability of an individual, system, or organization to survive crises or shocks (Huey & Palaganas, 2020; Tariverdi et al., 2019) and actions to prepare for, adapt and respond to, and recover from stressful conditions or disruptive events, e.g., a natural disaster, pandemic, cyberattacks, economic crisis, conflicts, mass migration, or terrorist attacks (Linkov et al., 2013; Crowe et al., 2014; Ceferino et al., 2018; Landeg et al., 2019; Lo Sardo et al., 2019; Zhao et al., 2019; Hundal et al., 2020). A resilient organization needs the ability to prioritize and identify problems and respond proactively to crises, resilience concerns systems/leadership, organization culture, training and simulation, cross-domain communication, and a cooperative approach. The focus of this chapter is organization-level resilience. Health care and resilience are considered from diverse approaches, e.g., systems that support health infrastructure resilience (Atallah et al., 2018). Healthcare resilience is affected by both the interdependencies of hospital departments and services and by critical lifelines and infrastructure, such as transportation, supply chains, power and water networks, and internal and external communications systems (Cimellaro et al., 2018; Tariverdi et al., 2019; Zhao et al., 2019). However, in the context of health care, the resilience debate has been focusing more on the individual level and human factors, leaving room for studies that focus on system and organization level resilience, especially from the aspect of technology in supporting resilience.

The chapter construes a more comprehensive picture of resilience, and the crucial triangle of technology, adoption, and information management (IM). In the best-case scenario, technology solutions and information communication technology can support healthcare and rescue personnel in their daily work, enable supply chain management, ensure healthcare financing with efficient processes, and produce transparent processes for governance and service delivery (Otto et al., 2015) to advance healthcare system resilience.

The theoretical framework of the chapter leans on Ristvej and Zagorecki's classification of an information system (IS) in crisis management (CM), namely, early warning systems, geographical information systems, *training applications*, *decision support systems*, and *document and data sharing tools*. An IS has four specific functions: data collection, data storage, data processing and analysis, or data transfer and distribution (Ristvej & Zagorecki, 2011). While the focus here is on crisis management and technology, crisis management is considered through the lens of

IM, and ISs are considered to support certain functions in the organization (e.g., human resources compared with patient flows, patient appointment systems) or technology applications in the healthcare/hospital and rescue context (pilot projects, e.g., patient monitoring or pandemic infection tracking). This chapter examines this subject through a literature review and a qualitative empirical study focused on the Finnish healthcare (hospital context) and rescue services during the COVID-19 crisis; we seek answers to the questions of how IS solutions have advanced system resilience during the COVID-19 crisis and how these solutions have affected the operations of the healthcare and rescue agencies. The three following classification elements are considered in the empirical part of this chapter: training applications for personnel, decision support systems in pandemic operations, and document and data sharing tools between the actors.

Information systems and different applications in health care and rescue are not only a technical development but also a mindset, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology (Eysenbach, 2001). Thus, we are especially interested in identifying the role of IS in applications and tools in healthcare system resilience during the COVID-19 crisis, and we are also interested in taking a broader view of the phenomenon as a complex mixture of human operators, hardware, and software, where information management plays a crucial role, as stated by Bakos (2020).

The chapter continues with a brief introduction to resilience, technology, and information technology (IT). After reviewing the literature, the chapter describes data as a resource potential, the challenges of data utilization, and barriers to data and information exchange between institutions. After the theoretical approach, examples of digital technology solutions and innovations are introduced, and empirical insights are provided of technology support in a healthcare and rescue system case from Finland during the COVID-19 crisis. The chapter ends with a discussion and conclusion section that calls for interaction and cooperation between human technology and regional, national, and global data sources and practice models.

Resilience, Technology, and Information Management in a Healthcare and Rescue System

Resilience can be seen as the ability of an individual, system, or organization to survive crises or shocks (Huey & Palaganas, 2020; Tariverdi et al., 2019). The resilient organization also needs the ability to prioritize and identify problems and respond proactively to crises (Cimellaro et al., 2018; Falegnami et al., 2018). The resilience of systems can be influenced by leadership (Mansour et al., 2012; Deutsch et al., 2016), organization culture (Huey & Palaganas, 2020), training and simulation (Cimellaro et al., 2018; Huey & Palaganas, 2020; Hundal et al., 2020), procedures, and cross-domain communication and cooperation (Linkov et al., 2013; Cimellaro et al., 2018).

Health and resilience are considered from diverse approaches, e.g., systems that support health infrastructure resilience (Atallah et al., 2018). The resilience of the healthcare system can be seen, in other words how quickly and at what capacity health care can produce and provide healthcare services to the entire community in the event of a shock. Disruptive events in healthcare systems often lead to an unexpected increase in the number of patients or reduction in the number of healthcare providers (Lo Sardo et al., 2019). Both the interdependencies of hospital departments and services and critical lifelines and infrastructures affect healthcare resilience (such as transportation, supply chains, power and water networks, and internal and external communications systems) (Cimellaro et al., 2018; Tariverdi et al., 2019; Zhao et al., 2019). The resilience of healthcare systems can be measured and defined by economic losses during the crisis, casualties, recovery time, patient waiting time, bed capacity, and quality of service and care (Cimellaro et al., 2018; Crowe et al., 2014; Low et al., 2017; Tariverdi et al., 2019; Hundal et al., 2020).

Considering the practical infrastructure level, transportation, power and water networks, internal and external communication systems in organizations, and crucial supplies like oxygen, blood, medical equipment, and medication supplies are subject to technological reliability (Cimellaro et al., 2018; Tariverdi et al., 2019; Zhao et al., 2019). All these functions produce fragmented data. Technology platforms are one way to unify outspread data and information. At best, platforms can integrate and offer real-time data, enabling operational flexibility and response, and supporting decision-making in changing situations (Vecchi et al., 2002; Cimellaro et al., 2018).

Data per se is not valuable but has to be transformed into understandable information that brings some value to the recipient. It is said that "healthcare is undergoing a data revolution" (Panesar, 2019) and data is a crucial resource, as highlighted by the COVID-19 pandemic in the healthcare sector, for example. Increasingly, real-time data analysis to create predictive modeling during the crisis supports the mitigation of risks (Mensah et al., 2015; Lo Sardo et al., 2019; Hundal et al., 2020). Despite data being a potential resource, the challenges of data utilization culminate in unintegrated information systems or non-syncretized data, formulating barriers for data and information exchange between institutions (Liapis et al., 2015). Challenges in healthcare informatics were identified (e.g., Guah, 2004) nearly 20 years ago, yet the same stumbling blocks still exist. Besides technology solutions, technology absorptive capacity and the management of information and knowledge are needed as well (Bose, 2003; Raymond et al., 2017). Table 1 describes some operational guidelines for crisis management in healthcare and rescue organizations and the role of information management.

Table 1 Operational guidelines for CM in healthcare and rescue organizations (Wang & Wu, 2021)

Precrisis phase	Crisis phase	Postcrisis phase
Keep alert to detect potential threats Prepare CM plans Plan pandemic prevention routes Check inventory of reserve medical supplies Launch awareness campaigns	Identify competency/knowledge requirements Assemble CM team Define specific responsibilities Convene response consensus meetings Reduce the risk of exposure to contagion Contain nosocomial infections Protect the safety of healthcare workers Strict separation among zones of risk Patient risk stratification	Review and correct action planning Gradually resume activities Institutionalize and internalize lessons learned from the crisis

Deploying Digital Technology and Innovations in Practice in a Crisis

National and global collaboration and communication as well as open innovation (OI) practices between different organizations are needed to succeed in a crisis situation (e.g., government, education, and research institutions) (Patrucco et al., 2022). Innovations need *a place* to happen, and cooperative innovation processing with several actors can produce quick solutions in a shock or disaster situation. Digital innovations are almost never made in isolation but need a cooperation group or innovation ecosystem around them (e.g., Iyawa et al., 2016). Different innovation clusters like FabLabs (fabrication laboratory, often digital) have played a crucial role in problem-solving COVID-19 initiatives, e.g., using 3D printing for equipment production (Abbassi et al., 2021). However, in the public sector, innovation management is not an easy task, although many innovations are designed for the public sector, mostly by private sector actors. The structures of public organizations are still very bureaucratic and hierarchical. The information flows between organization levels may be slow, and understanding of the innovation and the knowledge problem behind it is lacking. In other words, the value of the innovation is not identified or recognized (Jalonen, 2013).

Regarding innovation and technology solutions, an evaluation process is needed to optimize the utilization of new technology in the organization. One example for evaluation is the activity checklist made by Kaptellin et al. back in 1990 that considers human and technology in addition to environment issues: *means and ends*, i.e., what the technology is for and how it helps humans to operate; *social and physical aspects of the environment* which integrates technology with them; *learning*, *cognition*, *and articulation*, i.e., internal or external activities that support technology utilization; and *development*, which frames the comprehensive development and transformation view (Kaptellin et al., 1999).

New research and analyzing methods for the healthcare and rescue research have been developed to understand epidemiology, for example, or to produce different scenarios such as environmental risks. To mention a few, next-generation sequencing technology (NGS) is not only intended for the analysis of samples or monitoring diseases, but it also affects the personnel's operational practices by creating easy-to-use automated workflows (Iyawa et al., 2016). Stratuscent (2021) has helped to build resilience during COVID-19 with its technical solution for scent detection, NOZE, a digitized sense of smell that can be integrated with several products. Another solution for air sensoring is Konikore (Koniku, 2021). These solutions can be used for monitoring the risk level of the airborne virus or for identifying some diseases or some safety-threatening issues (e.g., in travel or logistics) (Koniku, 2021; Stratuscent, 2021). High technology is fabulous, but let's keep our feet on the ground at the health and rescue operational level.

Operating clinical services in remote mode made a rapid leap at the beginning of the COVID-19 pandemic, globally enabling new health IT, on the one hand with organized trials and pilots, and on the other hand with new established practices with new IT in operations as well as knowledge sharing. Regardless of the name of the digital source (e.g., e-health, health apps, health platforms, or telemedicine), the functions around the solution are more relevant: individual level monitoring and data collection for healthcare or rescue staff, provision of health services to customers, remote communication and evaluation or monitoring the situation between customer and personnel, or wider data and information documentation platforms for information sharing at local, national, or global level (e.g., Iyawa et al., 2016).

At the very beginning of the COVID-19 situation, the Sheba Medical Center in Israel used InTouch Telepresence robots and the Hospital District of Helsinki, and Uusimaa (HUS) in Finland used the Murffi robot to communicate with and monitor patients remotely, allowing better communication between staff and patient to provide care with minimal physical contact and minimized virus infection. The robots were controlled from another room by doctors, nurses, and pharmacists (Wetzler, 2020; Kahri, 2021; Oborn et al., 2021). Cardmedic digital flashcards have been used in the UK for patient communication by phone, tablet, or computer, allowing the sharing of vital information and questions with the patient (Orlikowski & Scott, 2021). Remote monitoring and examination tools for COVID-19 include TytoCare to listen to the patient's heart and lungs as well as examining the throat and ears, and EarlySense to measure continuous heart rate and respiration rate through a sensor placed under the mattress of the bed. Both TytoCare and EarlySense sensors can be taken home by the patient, which saves hospital bed capacity (Wetzler, 2020).

During the COVID-19 pandemic, digital innovations have created new ways to support care work around the world. For example, the challenges of communicating with patients while using personal protective equipment (PPE) and staff's fear of contamination have contributed to the use of digital technologies in hospitals.

In Finland alone, there are over 50 Finnish start-ups or growth companies with innovative health and health technology solutions to tackle among other things the pandemic in healthcare and other healthcare service challenges, e.g., diagnostics and test manufacturing, remote operations, or platforms (HealthCapitalHelsinki, 2021). There are multiple ISs and huge amounts of different data that could be used and analyzed by healthcare and rescue actors. The challenge is how interoperable the ISs are and how to deliver real-time knowledge, for example, to support decision-making in crisis situations.

Support and Benefits of IT When Operating During a Crisis: Empirical Insights from Finland

In an acute crisis situation, the role of information management has been critical. At the beginning of the COVID-19 pandemic, several challenges occurred related to information management, not only at national and local levels but also at international level. The biggest city area (Greater Helsinki) as well as other smaller regions in Finland had challenges to see the comprehensive operational picture; however, after half a year, the structure of knowledge acquisition for the operational picture had improved, becoming more systematic, faster, and established in daily practices. The challenging issue is the huge amount of data, how to identify the relevant data in a crisis situation (e.g., KPMG, 2021).

Massive improvements were made very soon in gathering the data and in sharing timely status data at national level. Thus, the pandemic crisis has improved data acquisition and sharing practices tremendously in a short time window. The pandemic shock forced information management teams to develop operational picture systems rapidly, e.g., to control the inventory situation, treatment equipment, number of hospital beds, and human resources. Even though the analysis and reports have advanced during the pandemic, the information systems do not currently eliminate the manual work of analysis and reporting in Finnish institutions. Although the pandemic was an unknown, data was at the core of all decisions and public recommendations that led to actions. Only the future will show what kind of disaster information management model will be formulated from the current and functional operation models in Finland.

In Finland, the COVID-19 e-system for national symptom testing was organized by the biggest university hospital, HUS, to ensure clear and sufficient capacity for the testing system. In the first phase, a symptomatic individual made an electronic symptom assessment so as to avoid physical contact, and the application guided the person to the next steps, e.g., testing. However, at municipality level, the information systems occasionally crashed when reserving a test, inflicting congestion in the service. Citizens had a big role in utilizing digital services, simultaneously reducing the workload of the healthcare professionals at the beginning of the pandemic. In the Finnish online service, *Omaolo*, nearly 330,000 symptom checks were made during 60 days by citizens, which can be considered a great figure considering that Finland only has 5.53 million habitants. Similarly, the UK healthcare system has put into operation a digital online symptom checker (NHS 111 online) (Chambers et al., 2019); Singapore has the COVID-19 Symptom Checker (Singapore, 2021), and Japan the Stop COVID-19 Symptom Checker (Tokyo Government, 2021). However, symptom checkers have received criticism on both the reliability of the identification of the patients' symptoms and forwarding to medical care (Mansab et al., 2021), since in a crisis situation the reliability of the digital solution must be at the highest level.

In order to achieve a deeper understanding of the role of IS in crisis management in Finland during the COVID-19 pandemic, we carried out an empirical case study in one of the healthcare and rescue system districts in Finland. The Pirkanmaa Hospital District is a joint municipal authority owned by 23 municipalities. Tampere University Hospital (TAYS) is the hospital that provides services to hospital districts serving nearly 1 million inhabitants in the catchment area (TAYS, 2021a). We gathered the data through a series of facilitated workshops in which over 100 healthcare and rescue professionals participated during autumn 2021. The empirical data gathering focused on the themes of IS solutions and practices, as well as IS development targets in organizations. Questions were addressed as to what kind of IS works in a crisis, which practices are functional in coordination and cooperation, what kind of data and information production supports decision-making, and how geographical information can be integrated into regional information. All workshop participants were encouraged to have open dialogue instead of being guided by the selected theoretical framework. Some of the identified results are described below.

The use of different e-health services in health care has increased during the pandemic. The other example from TAYS is *OmaTays*, established in 2017, a digital service between customers or patients and TAYS. OmaTays is a service to manage functions from patient booking of an appointment or doctor's appointments to laboratory requests, offering an easy way to reschedule, ask questions, or attend a remote consultation. In May 2020, there were 45,000 application users, while by spring 2021, this number had grown to 100,000 users. The exhilarating speed of adoption can partly be explained by the COVID-19 pandemic. A new service in the OmaTays application was released in spring 2020, i.e., a COVID-19 tracking enquiry for those that were exposed to the COVID-19 virus and for people who tested positive for COVID-19. Over 50,000 coronavirus enquiries were filled in by citizens during the first year after the pandemic became active in the Tampere restriction area (Pasanen, 2021).

TAYS has also developed the TAYS TABU application to assist, for example, COVID-19 situation analysis at TAYS. TABU is a reporting visualization tool that allows staff, through one user interface, to read and analyze multiple data from various data collection databases. Further, it offers various user groups different reports to help them in their daily routines, supporting decision-making and developing operations (TAYS, 2021b).

TAYS aims to be the most digital university hospital in Finland in the future. They have been actively developing and implementing digitalization widely in their organization. In a case study where the participants represented the municipalities of Pirkanmaa Hospital District, especially healthcare personnel involved with human resources, it became evident that the comprehensive knowledge and information management process, i.e., data collection, data storage, data processing and data analysis, or data transfer and distribution needed restructuring from strategic goal setting to implementation. The process should be shared with common understanding by the personnel, described in detail, and process and operating models should be adopted and be accepted by all the users. In the case organizations, the present data is gathered and to some extent analyzed. However, the purpose of data collection is unclear to the personnel and thus can lead to neglect or unintended mistakes, for example, in data collection.

However, information technology is only a tool. In the case study, technology challenges often appeared because of the personnel's lack of competence to utilize the information systems. On the other hand, the remote services were implemented quickly; technological interaction between health professionals and customers became the new normal and was learnt through practice. For example, the shift to remote working and social distancing during COVID-19 improved and helped the adoption of different kinds of digital services by both the professionals and customers, such as remote doctor's appointments or the tracking enquiry system. By the middle of the pandemic, the responsiveness to rapidly changing situations and, for instance, action proposals, had improved, and learning by doing had consolidated routines in healthcare operations (KPMG, 2021).

Overall, ICT applications enable improvements in healthcare availability and in the quality and efficiency of services. Such tools and solutions include electronic patient databases, health network pages, personal wearable and portable communication systems, and various e-health services. These tools and solutions can be used as an aid in the prevention, diagnosis, and treatment of diseases and to support the delivery of high-quality, cost-effective, and customer-oriented services. In a crisis, a comprehensive operation picture of the crisis is valuable, and technology applications can support the decision-making processes and priorities of the operation chain. The other benefit is benchmarking and utilizing data sources from other regions nationally and globally.

Conclusions

The COVID-19 pandemic is a public health crisis where decision-makers are under pressure to respond quickly and to prove their capability to meet public health needs (El-Jardali et al., 2020). Various preparedness plans and models for crisis management have been made and anticipated by Finnish municipalities, hospital districts, and individual hospitals, as well as other authorities. As Dwight D. Eisenhower once said, "In preparing for battle I have always found that plans are useless, but planning is indispensable" (Eisenhower, 2021). As Maritsa and Kalemis point out, "many of the current healthcare systems and organizations are ruled over hierarchical conceptualizations governed by order and rules, thereby agonize to achieve immediate respond [sic] to the complex system pressures" (Maritsa & Kalemis, 2020). However, the crisis management and decision-making processes of healthcare systems and organizations have to respond to these pressures and have now been dynamically developed in the midst of a pandemic in terms of these processes, models, and new services.

The aim of the chapter was to analyze how IS solutions have advanced system resilience during the COVID-19 crisis and how these solutions have affected the operations of the agencies involved. The literature revealed that resilience can be defined as the ability of a system or organization to absorb and recover from shocks such as natural disasters, conflicts, or pandemics (Cimellaro et al., 2018; Hundal et al., 2020). Critical infrastructure, cooperation, cross-domain communication, organizational culture, and training affect healthcare resilience (Linkov et al., 2013; Cimellaro et al., 2018; Tariverdi et al., 2019; Huey & Palaganas, 2020). Information management involves knowledge sharing, data validation, and dissemination whose efficiency affects the outcome of the crisis. The efficiency of knowledge sharing and management is influenced by communication templates and models, situation awareness, and organizational culture (Bakos, 2020; Maritsa & Kalemis, 2020). It is important to notice the impact and importance of digital technologies during a crisis, in addition to resilience and knowledge management. Digital technologies, such as telemedicine and e-health, enable organizations to respond to the crisis (Gkeredakis et al., 2021), and during COVID-19, a number of digital innovations have been made in health care to promote remote communication, monitoring, and examination. Innovation, collaboration, and e-health solutions are the key components of recovery in times of crisis (Wetzler, 2020). During a crisis like COVID-19, organizations cooperate with stakeholders and across boundaries to produce new ways of creating knowledge, data sharing, and innovation (Gkeredakis et al., 2021).

It seems that complicated and interdisciplinary cooperation is needed when reforming an information system. Pioneers that have boldly developed technological solutions are already ahead of others in adapting their operations in the crisis. The cases of the robots presented here have reduced the demand for patient rooms, minimizing the risk of infection and consumption of protective equipment. The functions of the operation are guided by the analysis of the infection situation regionally, nationally, and globally. The health professionals have learned to identify the most relevant data from the huge amount of data and information they receive (KPMG, 2021), and, as practice has shown in the COVID-19 situation, learning has taken place "by doing," using technology solutions rather than training applications. Multidisciplinary cooperation is essential to create a real-time and comprehensive operation picture and to optimize the available human and economic resources. For instance, when robots are accepted as a partner and personnel have learned to utilize them in crisis operations, based on these results, robots provoke positive emotions among both personnel and patients.

However, sometimes a coincidence affects how to work in a crisis. One example comes from the case where a surgical hospital was modified into a COVID-19 hospital and the existing robot solution on the market, the Elisa Telecommunications and HUS Murffi robot, was piloted in the medical nursing of COVID-19 patients. A wider standpoint in technology utilization is needed. Now, new concepts of existing technology solutions and application utilization in other sectors are needed. For example, several robotic solutions exist in manufacturing operations that could be converted for health care and rescue operations. A coincidence may also happen via contact networks. Knowledge sharing between network contacts is an efficient way of learning, both for technology utilization and best operation practices. It is important to obtain integrated geo-information and regional information as well as integrated ISs to design an operational crisis information management system.

Resilience and the capability to react to shocks in health care or rescue and in the wider national context are worth ensuring and organizing. For example, not an easy thought, foreign investments in innovations or companies may consider how resilient operations in a certain region or country are (e.g., Le, 2021). In addition to lockdowns in society because of pandemics, a low level of investment, employability, or, on the other hand, a lack of employees (e.g., in health care) due to the crisis will affect the economy, leading to economic shock (Buchetti et al., 2021; Thomson et al., 2021).

According to the systematic literature review specified in the case of COVID-19, the use of different technology solutions and digital services in health care and rescue has increased during the pandemic. The crisis has accelerated the development of digital applications and data sharing as well as experiments on artificial intelligence (AI) and robotics in health care and rescue. IS applications, for instance, enable improvements in the availability of health care and in the quality and efficiency of services. However, in developing IS solutions, several challenges specific to the healthcare sector and rescue need to be taken into account: strict legislation, the privacy of health data, and the implementation of a digital service cannot compromise patient care. Patrucco et al. (2022) confirm that, even though there is an increased use of innovation policies promoting open innovation during the crisis, there is little evidence of consistency between the policy strategy used pre-COVID and during the crisis for each country. However, there is an increased use of four types of innovation policy instruments, i.e., those entailing formal consultation with stakeholders and experts, fellowships and postgraduate loans and scholarships, networking and collaborative platforms, and dedicated support for research infrastructure.

Although this chapter describes some experiences of healthcare resilience, the examples are only taken from a narrow group of countries, and there are many more excellent examples of technical solutions on the market and in the operational environment. Healthcare resilience and e-health solutions or robotics in health care merit deeper examination. Multi-professional cooperation is needed in research and innovation for preparing for the future and to solve challenges (Oborn et al., 2021); for example, the established virtual labs and Innovation Centers for Social and Health Care are brilliant spaces for developing new innovations and healthcare practices in preparation for a crisis. The purpose of these innovation cooperation platforms is to promote collaboration and innovations between start-ups, the healthcare industry and research partners, clinicians, and academia (Wetzler, 2020;

Oborn et al., 2021; Sote Virtual Lab, 2021). Further, besides technology solutions, the softer side, namely, human-technology interaction, the capability to utilize technology, and engagement of the personnel, is worthy of consideration.

Management models are not the only areas that have to prove their capability, logistics, material arrangements, and other infrastructure also matter, including how these elements and processes need to function in crisis events (Gkeredakis et al., 2021). Usually, disaster protocols are planned based on readiness, response, and recovery (Farazmand, 2009; Maritsa & Kalemis, 2020). When making an aftermath analysis of this pandemic crisis, these models will require thorough iterations.

References

Abbassi, W., Harmel, A., Belkahla, W., & Rejeb, H. B. (2021). Maker movement contribution to fighting COVID- 19 pandemic. *R & D Management*, 13. https://doi.org/10.1111/radm.12503

Atallah, D. G., Djalali, A., Fredricks, K., Arlington, L., Bussio, M., & Nelson, B. D. (2018). Developing equitable primary health care in conflict-affected settings: Expert perspectives from the frontlines. *Qualitative Health Research, 28*(1), 98–111.

Bakos, L. (2020). Knowledge management issues during organizational crisis: How human-machine communication helps. In A. Wensley & M. Evans (Eds.), *Proceedings of the 17th international conference on intellectual capital, knowledge management & organisational learning ICICKM*.

Bose, R. (2003). Knowledge management-enabled health care management systems: Capabilities, infrastructure, and decision-support. *Expert Systems with Applications, 24*(1), 59–71.

Buchetti, B., Parbonetti, A., & Pugliese, A. (2021). Covid-19, corporate survival and public policy: The role of accounting information and regulation in the wake of a systemic crisis. *Journal of Accounting and Public Policy.*https://doi.org/10.1016/j.jaccpubpol.2021.106919

Ceferino, L., Kiremidjian, A., & Deierlein, G. (2018). Probabilistic model for regional multiseverity casualty estimation due to building damage following an earthquake. *Asce-Asme Journal of Risk and Uncertainty in Engineering Systems Part A-Civil Engineering, 4*(3), 16.

Chambers, D., Cantrell, A., Johnson, M., Preston, L., Baxter, S. K., Booth, A., & Turner, J. (2019). Digital and online symptom checkers and health assessment/triage services for urgent health problems: Systematic review. *BMJ Open, 9*, e027743. https://doi.org/10.1136/bmjopen-2018-027743

Cimellaro, G. P., Malavisi, M., & Mahin, S. (2018). Factor analysis to evaluate hospital resilience. *Asce-Asme Journal of Risk and Uncertainty in Engineering Systems Part A-Civil Engineering, 4*(1), 7.

Crowe, S., Vasilakis, C., Skeen, A., Storr, P., Grove, P., Gallivan, S., & Utley, M. (2014). Examining the feasibility of using a modelling tool to assess resilience across a health-care system and assist with decisions concerning service reconfiguration. *Journal of the Operational Research Society, 65*, 1522–1532.

Deutsch, E. S., Dong, Y., Halamek, L. P., Rosen, M. A., Taekman, J. M., & Rice, J. (2016). Leveraging health care simulation technology for human factors research: Closing the gap between lab and bedside. *Human Factors, 58*(7), 1082–1095.

Eisenhower, D. D. Quotes. (n.d.). Available at BrainyQuote.com. Retrieved 10.6.2021.

El-Jardali, F., Bou-Karroum, L., & Fadlallah, R. (2020). Amplifying the role of knowledge translation platforms in the COVID-19 pandemic response. *Health Research Policy and Systems, 18*(1), 58. https://doi.org/10.1186/s12961-020-00576-y

European Observatory on Health Systems and Policies, Thomas, S., Sagan, A., Larkin, J., Cylus, J., et al. (2020). *Strengthening health systems resilience: Key concepts and strategies*. World Health Organization. Regional Office for Europe.

Eysenbach, G. (2001). What is e-health? *Journal of Medical Internet Research, 3*(2), E20.

Falegnami, A., Bilotta, F., Pugliese, F., Costantino, F., Di Gravio, G., Tronci, M., & Patriarca, R. A. (2018). A multicountry comparative survey about organizational resilience in anaesthesia. *Journal of Evaluation in Clinical Practice, 24*(6), 1347–1357.

Farazmand, A. (2009). Hurricane, Katrina, the crisis of leadership, and Chaos management: Time for trying the surprise. *Public Organization Review, 9*, 399–412.

Gkeredakis, M., Lifshitz-Assaf, H., & Barrett, M. (2021). Crisis as opportunity, disruption and exposure: Exploring emergent responses to crisis through digital technology. *Information and Organization, 31*(1), 12.

Guah, M. (2004). *Today's health care demands knowledge management strategy.* 26th international conference on information technology interfaces, 1, pp. 461–467.

HealthCapitalHelsinki. (2021). *Finnish companies with innovative health tech solutions to COVID-19 – Health Capital Helsinki*. Available Finnish companies with innovative health tech solutions to COVID-19 – Health Capital Helsinki. Retrieved 12.1.2022.

Huey, C., & Palaganas, J. (2020). What are the factors affecting resilience in health professionals? *A synthesis of systematic reviews, Medical Teacher, 42*(5), 550–560. https://doi.org/10.1080/0142159X.2020.1714020

Hundal, G. S., Thiyagarajan, S., Alduraibi, M., Laux, C. M., Furterer, S. L., Cudney, E. A., & Antony, J. (2020). Lean Six Sigma as an organizational resilience mechanism in health care during the era of COVID-19. *International Journal of Lean Six Sigma, 12*(4), 762–783.

Iyawa, G. E., Herselman, M., & Botha, A. (2016). Digital health innovation ecosystems: From systematic literature review to conceptual framework. *Procedia Computer Science, 100*, 244–252.

Jalonen, H. (2013). The knowledge-innovation nexus in the welfare service ecosystem. *International Journal of Knowledge-Based Development, 4*(1), 34–49.

Kahri, P. (2021). Case: murffi-videorobotticovid-19 hoitotyössä. HUS. presentation.

Kaptellin, V., Nardi, B., & Macaulay, D. (1999). The activity checklist: A tool for representing the "space" of context. *Interactions, 6*(4), 27–39. https://doi.org/10.1145/306412.306431

Koniku. (2021). Konikore. Available at https://koniku.com/. Retrieved 10.12.2021.

KPMG. (2021). *Jatkoselvitys koronakriisiin liittyvien toimenpiteiden toteutuksesta.*. Available at https://www.hel.fi/static/helsinki/korona/jatkoselvitys-koronakriisin-toteutuksesta-raportti-08062021.pdf. Retrieved 8.12.2021.

Landeg, O., Whitman, G., Walker-Springett, K., Butler, C., Bone, A., & Kovats, S. (2019). Coastal flooding and frontline health care services: Challenges for flood risk resilience in the English health care system. *Journal of Health Services Research & Policy, 24*(4), 219–228.

Le, N. P. (2021). *The impacts of COVID-19 pandemic on Foreign Direct Investment: The case of Southeast Asian Nations.* Academia letters. Available at Academia.edu | Search | The impacts of COVID-19 pandemic on Foreign Direct Investment: The case of Southeast Asian Nations. Retrieved 16.12.2021.

Liapis, A., Kostaridis, A. I., Ramfos, A., Hall, I., Gaetano, A. D., Koutras, N., Dobrinkova, N., Leventakis, G., Olunczek, A., Seynaeve, G., & Boustras, G. (2015). A position paper on improving preparedness and response of health services in major crises. *ISCRAM-med.*

Linkov, I., Eisenberg, D. A., Plourde, K., Seager, T. P., Allen, J., & Kott, A. (2013). Resilience metrics for cyber systems. *Environments Systems and Decisions, 33*, 471–476.

Lo Sardo, D. R., Thurner, S., Sorger, J., Duftschmid, G., Endel, G., & Klimek, P. (2019). Quantification of the resilience of primary care networks by stress testing the health care system. *Proceedings of the National Academy of Sciences of the United States of America, 116*, 201904826.

Low, S. P., Gao, S., & Wong, G. Q. E. (2017). Resilience of hospital facilities in Singapore's healthcare industry: A pilot study. *International Journal of Disaster Resilience in the Built Environment, 8*(5), 537–554.

Mansab, F., Bhatti, S., & Goyal, D. (2021). Performance of national COVID-19 'symptom checkers': A comparative case simulation study. *BMJ Health Care Inform, 28*, e100187. https://doi.org/10.1136/bmjhci-2020-100187

Mansour, M., James, V., & Edgley, A. (2012). Investigating the safety of medication administration in adult critical care settings. *Nursing in Critical Care, 17*(4), 189–197.

Maritsa, E. & Kalemis, K. (2020). *Leadership readiness in crisis context: Health preservation through shared knowledge.* 17th international conference on intellectual capital, knowledge management & organisational learning ICICKM 2020.

Mensah, P., Merkuryev, Y., & Longo, F. (2015). Using ICT in developing a resilient supply chain strategy. *Procedia Computer Science, 43*, 101–108.

Oborn, E., Pilosof, N., Hinings, B., & Zimlichman, E. (2021). Institutional logics and innovation in times of crisis: Telemedicine as digital 'PPE'. *Information and Organization, 31*(1), 8.

Orlikowski, W., & Scott, S. (2021). Liminal innovation in practice: Understanding the reconfiguration of digital work in crisis. *Information and Organization, 31*(1), 6.

Otto, K., Shekar, M., Herbst, C. & Mohammed, R. (2015). *Information and communication technologies for health systems strengthening: Opportunities, criteria for success, and innovation for Africa and beyond*. Health, Nutrition, and Population Discussion Paper; World Bank, Washington, DC. © World Bank.

Panesar, A. (2019). *Machine learning and AI for healthcare: Big Data for improved health outcomes*. Apress L. P, Print.

Pasanen, P. (2021). *Sähköinen asiointi kasvanut vauhdilla - OmaTaysilla jo 100 000 käyttäjää.* Available at https://www.tays.fi/fi-I/Sairaanhoitopiiri/Digitalisaatio/Sahkoinen_asiointi_kasvanut_vauhdilla__O(122999). Retrieved 13.12.2021.

Patrucco, A. S., Trabucchi, D., Frattini, F. & Lynch, J. (2022). The impact of Covid-19 on innovation policies promoting Open Innovation. *R & D Management, 52*(2), 273–293. https://doi.org/10.1111/radm.12495

Raymond, L., Pare, G., & Maillet, E. (2017). IT-based clinical knowledge management in primary health care: A conceptual framework. *Knowledge and Process Management, 24*(4), 247–256.

Ristvej, J., & Zagorecki, A. (2011). Information systems for crisis management – Current applications and future directions. *Communications, 2*, 59–63.

Singapore COVID-19 Symptom Checker (2021). Available at https://sgcovidcheck.gov.sg. Retrieved 13.12.2021.

Sote Virtual Lab. (2021). *Virtual lab for social and health care – about*. Available at About | Virtual Lab for Social and Health Care | Tampere Universities (tuni.fi). Retrieved 10.12.2021.

Stratuscent. (2021). *Bringing the sense of smell to devices everywhere*. Available at https://www.stratuscent.com/. Retrieved 10.12.2021.

Tariverdi, M., Fotouhi, H., Moryadee, S., & Miller-Hooks, E. (2019). Health care system disaster-resilience optimization given its reliance on interdependent critical lifelines. *Journal of Infrastructure Systems, 25*(1), 16.

TAYS. (2021a). *Pirkanmaa Hospital District*. Available at https://www.tays.fi/en-US/Hospital_District. Retrieved 11.12.2021.

TAYS. (2021b). *TABU*. Available at Digitalisaatio uudistaa toimintaa ja joustavoittaa asiointia | Tampereen yliopistollinen sairaala (tays.fi). Retrieved 11.12.2021.

Thomas, P., & Rutter, P. M. (2008). A computer literacy skills profile of pharmacists residing in two counties of England. *Health Information & Libraries Journal, 25*(4), 288–294.

Thomson, S., Garcia-Ramirez, J., Akkazieva, B., Habicht, T., Cylus, J., & Evetovits, T. (2021). How resilient is health financing policy in Europe to economic shocks? Evidence from the first year of the COVID-19 pandemic and the 2008 global financial crisis. *Health Policy*. https://doi.org/10.1016/j.healthpol.2021.11.002

Tokyo Government COVID-19 task force website. (2021). *How to get help if you suspect having COVID-19.* Available at https://stopcovid19.metro.tokyo.lg.jp/en/flow/. Retrieved 13.12.2021.

Vecchi, V., Cusumano, N., & Boyer, E. J. (2002). Medical supply acquisition in Italy and the United States in the era of COVID-19: The case for strategic procurement and public-private partnerships. *American Review of Public Administration, 50*(6–7), 642–649.

Wang, W.-T., & Wu, S.-Y. (2021). Knowledge management based on information technology in response to COVID-19 crisis. *Knowledge Management Research & Practice, 19*(4), 468–474. https://doi.org/10.1080/14778238.2020.1860665

Wetzler, D. (2020). *ARC battles Covid-19 with technology, The Sheba Medical Center at Tel Hashomer*. Available at Webinar #4: ARC Battles COVID-19 With Technology - Canadian Friends of Sheba Medical Center (shebacanada.org) Retrieved 13.4.2020.

Zhao, X. L., Miers, I., Green, M., & Mitrani-Reiser, J. (2019). Modeling the cybersecurity of hospitals in natural and man-made hazards. *Sustainable and Resilient Infrastructure, 4*(1), 36–49.