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Nobody Said IT Was Easy - Managing Government-Initiated Information Systems in Addressing and Preparing for Health Crises

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NOBODY SAID IT WAS EASY - MANAGING GOVERNMENT-INITIATED INFORMATION SYSTEMS IN ADDRESSING AND PREPARING FOR HEALTH CRISES

Research Paper

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Abstract

COVID-19 served to teach governments many painful lessons about their pitfalls and challenges in managing public health crises. Although both practitioners and academics have been aware that crisis information systems (CIS) constitute a valuable tool for crisis prevention and management, their implementation to counteract COVID-19 lagged by months. To analyze this crisis management mismatch, in this paper, we examine and identify the structural challenges and shortcomings of government-initiated crisis management through CIS. This paper analyzes two CIS projects tackling the COVID-19 crisis, funded by the German government. Drawing on a complexity-lens and the NASSS-framework, key shortcomings are identified. We derive propositions for future CIS projects to enable crisis preparedness. Our outcomes suggest that adopting a complexity perspective in planning, initiating, and developing governmental CIS provides a promising avenue for achieving successful crisis management. We contribute to literature by highlighting the suitability of the complexity-lens in health crises.

Keywords: Crisis Information Systems, Crisis Management, Pandemic Preparedness, Complex Systems.

1 Introduction

Public health crises such as the COVID-19 pandemic have blindsided plenty of governments and exposed that current crisis management and response preparation show major lacks (Ruiu, 2020; Kapucu and Moynihan, 2021). The pandemic demonstrated, in particular, that the current government-based management of health crises does only partially involve the factors of dynamic adaptation, rapid handling, and flexible resource allocation (Janssen and van der Voort, 2020). While corporate-related crises do indeed pose a major threat to companies and potential impact on customers (Coombs, 2007), health crises exhibit yet another issue: they concern everyone's health and thus have a boundary-spanning impact (Rai, 2020). In fact, they can cause harm in numerous ways, e.g., tangible through influences on the economic performance (Verschuur et al., 2021), as well as intangible through impacts on the physical (Bertsimas et al., 2020) or mental health (Pfefferbaum and North, 2020) of the affected individuals. Hence, with respect to pandemics such as COVID-19, health crises involve

important critical decisions about people's live and deaths. Accordingly, it is important to provide management tools that includes responses to address imminent public health crisis. In this context, due to the ever-increasing availability of digital information, leveraging crisis information systems (CIS) has been identified as a promising tool to manage, respond, and counteract those public health crises (Pan et al., 2012; Thomas et al., 2020).

COVID-19 in particular demonstrated that location data and the associated surveillance of citizens with the help of mobile apps have become successful means of tackling the ongoing crisis (Trang et al., 2020). However, as the pandemic progressed, a potential mismanagement emerged that prompted several questions: the crisis of COVID-19 began in 2019 (New York Times, 2021), a government-based app was released 7 month later (Reelfs et al., 2020), leading to a 1-year delay before contact-tracing gained any real traction among the population (Grill et al., 2021; Simon and Rieder, 2021; Statista, 2021). A period which has led to a surge in disease cases and deaths (AJMC, 2021; MHB, 2021). Considering the criticality of the management failure of such crises (Pearson and Clair, 1998), the reasons why a response, supported by government-initiated crisis information systems, was established only at such a late stage should be investigated.

In this context, we further identify that establishing pandemic preparedness through CIS has already been an important component incorporated by various projects recently (Braa et al., 2007; Kruk, 2008). Pan et al. (2005) and Devadoss and Pan (2004) reported that in response to the SARS virus, the Singaporean government had already implemented country-wide contact tracing through CIS in 2003. Although this knowledge was available and was widely acknowledged by researchers to be necessary to prepare for a health crisis of this nature (Van de Walle and Turoff, 2006; Yang and Hsieh, 2013), it appears that the actual governmental crisis preparation and management through CIS has not been adequately implemented in practice, if at all. Particularly considering the increasingly rapid and dynamic responses of organizational crisis practices (Bharosa and Janssen, 2010; Pavlou and Sawy, 2010), which view crisis management through IS as an important management domain (Nan and Lu, 2014), we argue that government-based CIS are subject to distinct structural patterns. These structures, in turn, pose potential adverse impact factors for various individuals in the context of health crises. Against this background, we pose the following research questions:

RQ1: *What are the shortcomings related to the management of government-initiated crisis information systems addressing public health crisis preparedness?*

RQ2: *Through which propositions can the identified shortcomings be addressed?*

To investigate these research questions, we analyze two government-initiated CIS aiming for pandemic preparedness via case study research. Viewing through the lens of a stakeholder-centric crisis response management, we employ the non-adoption, abandonment, scale-up, spread, and sustainability framework (NASSS) to analyze both cases. We identify that CIS to address and prepare for health crises must be conceptualized in a complex manner. Conversely, however, we uncover that the project view of the establishment of these CIS fails to acknowledge this complexity. We find key shortcomings involving the mismanagement of the overall initiation and handling of CIS in the context of health crises. Based on these findings, this paper derives propositions (PP) that inform future projects of health-related CIS by considering their complexity and enable pandemic crisis preparedness through sustainable operations and longevity.

2 Conceptual Background

2.1 The Complex Nature of Crisis Information Systems Management

Public health crises are confronting governments, people, institutions, and societies with new situations, fields for actions, and wide-ranging challenges (Pan et al., 2005). In particular, poor or lack of preparation and response can result in causing larger damage than initially incurred by the crisis (NyBlom, 2003; Junglas and Ives, 2007). Thus, managing and preparing for crises is of utmost necessity to overcome a crisis and avoiding as much impact as possible (Pearson and Mitroff, 1993;

Coombs, 2007). Due to this, a growing part of the literature deals with the question how a most appropriate and effective crisis response can be conceptualized (Bundy et al., 2017; Thapa et al., 2017). In this context, public health crises in particular assume a central role due to their multifaceted influences (Pan et al., 2005; Ruiu, 2020). In contrast to organizational crises, not only peripheral stakeholders are affected (Coombs and Holladay, 2008), but rather passive individuals without any direct link to the origins and emergence of the crisis (Pan et al., 2005). Managing them and preparing an appropriate response, therefore, is subject to crisis-specific traits that require consideration in their conceptualization (Yang and Hsieh, 2013).

Crises are events that arise abruptly with their specific development being unpredictable (Coombs, 2007), turning them into an overall event that is difficult to anticipate (Yang and Hsieh, 2013). In contrast to permanent threats, such as enduring health risks in the form of diseases, crises are subject to fluctuating permanence, not causing continuous damage, but rather triggering peaks of damage at certain points in time (Housel et al., 1986; Liu Zhi, 2009). In the context of CIS, we thus find a need for *sustained system availability*. Systems should not only exist for a limited period, but instead remain in a state of readiness and continuous use to immediately react to a crisis.

Moreover, crises are hardly isolated events, but affect a multiplicity of people and individuals, requiring crisis management as a society's task to go beyond single institutions (Coombs, 2007; Pan et al., 2012). Accordingly, overcoming a crisis is a joint task for societies (Thomas et al., 2020). CIS for addressing these crises should therefore in particular not represent separate developments that act independently, but rather demonstrate *continuous intersection with existing systems*. Developing a landscape of systems rather than many decentralized, disconnected systems is of utmost relevance.

Given that crises are transversal and rather diffuse events (Liu Zhi, 2009), it is necessary to ensure that current information about the crisis, the crisis event, and possible appropriate responses can be distributed and updated in a time-critical manner (Majchrzak et al., 2007; Castillo, 2016). This is further emphasized by the short half-life that such information possesses in times of crisis (Hale, 1997; Sigala, 2011). Especially in large-scale crises, such as public health crises like COVID-19, it is necessary that this knowledge management is maintained and available in a punctual manner (Housel et al., 1986; Van de Walle and Turoff, 2006). The informative crisis response network, which regulates the flow of information between different agencies (Pan et al., 2012), must therefore support the exchange of knowledge not only between agencies but also between individuals in the event of a health crisis. Thus, CIS need to meet the requirement to *provide up-to-date information* and be consistently maintained and serviced.

Crises, as already indicated, constitute challenges of various dimensions owing to their nature and characteristics (Pan et al., 2005). Therefore, the management of such events "in terms of socio-technical systems consisting of people, tasks and technologies and their interrelationships" (Thomas et al., 2020, p. 386) appears to be paramount. CIS for the management of such a crisis should therefore not only be integrated on a large-scale technical level, but also *integrated in the general society*. Awareness of relevant individuals of such systems and the associated tasks must consequently be addressed in crisis management and preparation.

Reviewing the literature on crises, especially public health crises, we conclude that the management of CIS concerning crisis response must satisfy four key requirements. These include long-term technical availability, permanent interconnection with existing and newly developed systems, continuous provision of up-to-date information, and ongoing integration with vital institutions and agencies.

2.2 Reviewing Government-initiated Crisis Information Systems

When conceptualizing government-initiated CIS, a range of challenges is present. Contemporary literature provides examples of actual system implementation in such projects, but best practices for doing so are limited (Boddy et al., 2009; Lynch et al., 2018). This applies in particular for analyzing and gaining insights into the interdependence of project factors (Bu et al., 2020). It also remains unclear, what the influence of financial and non-financial government contributions to the success and sustainability of such projects are (Homedes, 2001).

We note that these already existing challenges are amplified by the current COVID-19 crisis and consequently newly launched health projects (Koch and Schermuly, 2021), e.g., CIS. In the context of the pandemic, a wide range of actors such as governments, and research institutions started to research and kickstart surveillance projects, equipped with substantial resources, both tangible like funding and intangible such as political influence (Koch and Schermuly, 2021). In turn, manifold individual health projects (services and products) are initiated to improve health management for patients and service providers (Grehling and Maier, 2021). Yet, their impact and success are often questionable (Agarwal et al., 2010). Additionally, in the context of COVID-19, many of such health projects are planned with an expiring date: the end of the pandemic. Considering the literature on government-initiated projects, we recognize a vast intersection with popular causes of project failures when considering these characteristics (Akwei et al., 2020). Therefore, we argue that the development of strategies for sustainable crisis response and management and resulting learnings to overcome these failures would pave the way for true pandemic preparedness in the future (WHO, 2021).

Moreover, in the development, implementation, and evaluation of health-related information systems the consideration and analysis of stakeholders plays a key role (Eze et al., 2016; Lee and Sheikh, 2016; Nilsen et al., 2020). Many evaluation methods for these systems often consider only a limited number of stakeholder views and values, like financial evaluation methods, although all stakeholders can play a critical role in the success of health projects (Mei et al., 2013; Eslami Andargoli et al., 2017). Freeman's (1984) work on stakeholder theory as a strategic management approach is often seen as a starting point for the stakeholder idea by researchers in a business, ethics and society context (Dunham et al., 2006). Freeman defined stakeholders as “any group or individual who can affect or is affected by the achievement of a corporation’s objectives” (Freeman, 1984, p. 46). Lee and Sheikh (2016, p. 53) further view stakeholders in direct context to healthcare as “those involved directly and indirectly in the production and use of health IT at every level”. This definition will also be used as the working definition for the rest of this article, assuming that indirect production and use of CIS also includes a wide variety of stakeholders, like the government or individual citizens. Thus, to comprehensively analyze government-initiated CIS and understand the requirements of a successful long-term strategy of such, it is beneficial to adapt a stakeholder-based lens to cope with the multidisciplinary nature of these projects. When evaluating CIS, we must incorporate all relevant stakeholders, the technical infrastructure used, and all context-dependent elements as well as their interactions (Eslami Andargoli et al., 2017).

This body of literature supports our research endeavor in two aspects: First, we highlight that while the current structure of crisis-response projects is endorsed by governments, long-term sustainability appears to be a challenging goal to achieve. We demonstrate that a consideration of all relevant stakeholders is necessary to analyze why and to what extent problems of long-term sustainment exist.

2.3 A Conceptual Lens on Crisis Information Systems Success

The success of information systems in healthcare, i.e., CIS, is often criticized. However, the track record of technology programs, particularly projects that require major changes in organizations or across the healthcare system (e.g., platforms), is poor (van Limburg et al., 2011). The basis of this problem is non-acceptance among users, discontinuation by individuals, and difficulties in scaling up and disseminating the technology (van Limburg et al., 2011).

In the context of healthcare projects, the study by Greenhalgh et al. (2017) builds upon an extensive review and empirical case studies to summarize factors that bring health technologies beyond adaptation. The seven dimensions of the resulting non-adoption, abandonment, scale-up, spread, and sustainability (NASSS) framework provide a holistic view that incorporates health information system-specific factors which are identified by other researchers and hence provides a suitable lens for this research. Furthermore, to map the multi-layered and dynamic facets of projects and technologies implemented in the healthcare sector, they adopt the lens of complexity theory. Greenhalgh's NASSS provides the framework users with guiding questions on the individual dimensions (see Figure 1), which are to be answered during the analysis of the cases. The individual dimensions refer to both the

technical and the socio-economic environment. Based on the guiding questions the influence of the respective dimension on the overall project is classified into either simple, complicated, or complex (Greenhalgh et al., 2017, 2018). This classification, in turn, can be leveraged to determine whether the perceived simplicity, complicatedness, or complexity of a project corresponds to the factual circumstances. In analyzing a total of ten practical cases, Greenhalgh and colleagues were able to conclude that most health-related technology projects consider complex issues to be simple or complicated (Greenhalgh et al., 2017). Thus, leading to a project mismanagement that might cause adoption and sustainability issues. In the context of CIS for crisis prevention and response, we therefore argue that the NASSS framework is particularly useful for identifying potential discrepancies between project management and actual CIS development.

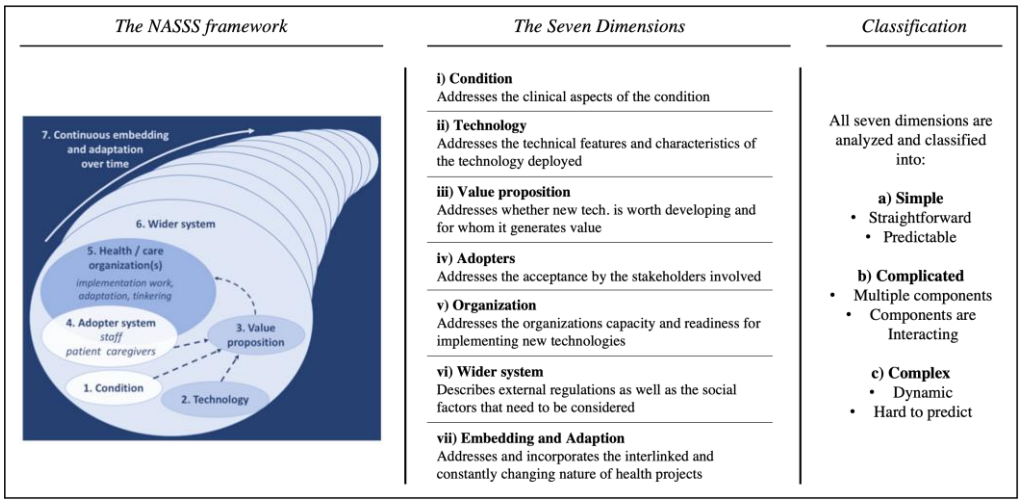

Figure 1. The Dimensions of the NASSS Framework and their Classification

We decided to use the NASSS framework in our study due to two aspects. First, given the characteristics of health crises outlined earlier, this framework appears to be particularly useful for our research endeavor as it integrates all relevant and required elements of a health projects managerial assessment, thus also for a CIS. Second, the NASSS framework incorporates the analysis of various factors affecting surrounding stakeholders, rendering it as a promising tool to analyze current pandemic-based CIS. Thus, the identified methodology can represent the stakeholder perspective highlighted above

3 Research Approach

3.1 Case Study Research

To understand the current approaches and weaknesses in terms of government-initiated CIS, we decided to draw on critical realism-informed case study research. Based on the key characteristics of case studies by Benbasat et al. (1987), we believe that case study research is well-suited to our problem for two reasons. First, case study research allows us to analyze government-initiated CIS in a natural setting. This means that no control is exerted over the participants or the processes in which they are involved. This is crucial for the study since the starting point of our analysis is, that there is a significant gap between imagined and realized outcomes of government-initiated CIS. Second, case research is useful for the examination of multiple entities (person, group, or organization). As described, our study aims at analyzing the stakeholders of government-initiated CIS and more importantly, the interdependencies between them, which form shortcomings and corresponding propositions for the overall CIS. Conducting this staged case study research through the lens of critical realism helps us to cope with the complex social, organizational, and technological environment of healthcare (Smith, 2006; Mingers et al., 2013). Under these circumstances, the critical realist approach

opens up the possibility of understanding underlying structures exhibiting causal powers within the CIS, in contrast to just analyzing actors' individual and subjective experience (Donald Wynn, 2012). Hence, this approach provides a broader range of causal explanations concerning success factors of government-initiated digital health projects.

3.2 Case Setting

The case studies were conducted in cooperation within the COMPASS and B-FAST projects (Case A and Case B, respectively) initiated by the Netzwerk Universitätsmedizin (NUM) during the COVID-19 pandemic. The aim of NUM is to connect Germany's university medical centers and leverage their joint expertise to gain a better understanding and handling of the pandemic. To do so, 13 projects were funded by the Federal Ministry of Education and Research, including case A and case B.

Case A aimed to develop a technical open-source app framework as well as best practices for the implementation of research compatible applications in a pandemic context. The best practices were established by incorporating regulatory (i.e., GDPR, Medical Device Act, and Infection Protection Act) and ethical requirements and guidelines. A major part comprised the development of two reference implementations, drawing on the established app framework. Both implementations, i.e., native-web and iOS & Android applications, focused on pandemic preparedness and were made available to as a blueprint for further applications. The core of the project constituted the development of an open-source technological platform, containing all delivered outcomes of the project, i.e., framework, reference implementation, and best practices. This platform's goal was twofold. Firstly, the complementation and extension of existing research databases and platforms. Secondly, facilitating a more efficient usage of health apps, including already existing ones as well as new developments. Furthermore, it included an automated compliance check, verifying the interfaces and record structures of pandemic apps and indicating conformity to the guidelines. The platform was to be published and made available as an open-source project at the end of the project. Realization of the project was done by nine university medical centers, and industry, and academic partners. In the context of the German health care system, case A belongs to a set of supportive crisis management tools that have an indirect link to the actual German health care system. By providing a framework, public health crisis management and preparation is indirectly supported by the aim of pandemic preparedness.

Case B targeted the development of a technical surveillance platform. The objective was to systematically collect and interlink information and findings on pandemics, especially COVID-19. This included the development of an integrated platform for information distribution, and testing and surveillance strategies for different settings, such as the general clinics, schools, nursing facilities, travel activities, and working environment. The consolidated assessments of testing methods and the development of surveillance approaches thereby pursue the goal of achieving pandemic preparedness, i.e., "a continuous process of planning, exercising, revising and translating into action national and sub-national pandemic preparedness and response plans" (WHO, 2021). Thus, addressing the development of surveillance and testing strategies that are sustainable, scalable, and transferable to future pandemics. The platform being developed integrates all findings into an interconnected system providing relevant information and recommendations to stakeholders of NUM. The rollout of the platform to additional participants was also conceptualized. Case B was carried out by a total of 24 university medical centers and by numerous other industry and research partners. Case B possesses a direct and integrated link to the German healthcare system. The strategies provided via the platform impact active crisis management and response. Furthermore, the connection of the platform in relevant bodies of the health system, e.g., hospitals, assumes a major role in public health crisis management.

3.3 Data Collection and Analysis

Given the focus of the case analysis on CIS management, most of the data used for the analysis consists of official, non-publicly available documents and project specifications. In a two-stage process, we analyzed the relevance of both documents and their contents. First, to identify the relevance of individual documents and document sections, we conducted a screening process that

adhered to Greenhalgh's (2017) seven dimensions (see Figure 1). In case documents and their contents could not be assigned to any dimension, a second in-depth review was performed. Only then non-relevant documents and document sections were removed from the result set. Second, we developed an initial broad categorization of the contents of the documents. Again, we adopted the seven dimensions as a guidance. Content that was solely of a project-organizational or technical nature was excluded. Finally, a full text analysis of the remaining data was performed. All information considered relevant to the seven dimensions after this phase served as the foundation for the case analysis. In addition, observations of internal and outbound processes, including both users and stakeholders, were conducted during the project period. These observations of the processes aimed at assessing the project dynamics. Emphasis was placed on the dimensions of adopters, embedding and adaption, and organization (iv, v, and vii in Figure 1), as their salient characteristics can often only be discovered by analyzing the ongoing project operations and development (Greenhalgh 2017, 2018). Furthermore, related to the ongoing project activities, modifications of requirements and project progress, five meetings were held with a project leader. During these meetings, focused discussions were held on the sustainability plans of the projects as well as on identified challenges and problems that existed in the creation of a long-term utilization of the established structures. Thus, these meetings aimed at finding solutions to overcome non-adoption obstacles. Based on the proximity to the NASSS framework, the both the results and discussions were of utmost relevance for the case analysis. The authors were also involved in all consortium meetings as part of both projects, in which all project partners reported on current statuses and development reports. Thus, adopting the perspective of observational study (Göran, 2019).

Drawing on James et al. (2021), this result set was then first processed inductively to identify overarching characteristics across challenges, issues, and capabilities of both cases. To cover all nuances of the underlying framework, we subsequently followed recent literature and deductively analyzed the content generated in the previous step to the seven dimensions of the NASSS framework (Thomas et al., 2022). Reference was also made to Greenhalgh's (2018) sub-dimensions and characteristics, permitting a thorough incorporation of the frameworks' aspects. The final mapping was then reviewed and verified by a discussion with authors and project members. Finally, a cross-case analysis was performed. We decided to use Eisenhardt's (1989) dimension-based case comparison approach. Since our underlying framework defines dimensions, this approach is suitable for our evaluation (Eisenhardt, 1989). Following this procedure, similarities in the individual cases, corresponding to our case analyses, are determined initially. Afterwards, these findings are compared in an overall case analysis to identify differences and similarities between the cases (Eisenhardt, 1989). We leveraged both the seven dimensions (see Figure 1) and the degrees of Greenhalgh et al.'s (2017) classification heuristic, i.e., simple, complicated, and complex, as overarching analysis criteria. In the following, the results of this inner case analysis as well as the cross-case analysis are presented.

4 Case Analysis and Preliminary Findings

4.1 Project Analysis Case A

Both cases are developing CIS to counteract the covid *i) condition* or to achieve pandemic preparedness in eventual outbreaks. COVID-19 is a novel disease that although has been studied to a high degree (Muenchhoff et al., 2020), is subject to uncertainties (Muenchhoff et al., 2020). Symptomatic manifestations are identified as diverse and multifaceted (Muenchhoff et al., 2020). Its characterization is therefore highly variable and lacks distinct boundaries.

The *ii) established* technologies include the developed app framework, the automatic conformity check, and the two reference implementations constituting the web- and mobile (iOS & Android) applications. They demand a high number of support regarding the alignment of the technology to new requirements, e.g., operation system updates or app-framework adjustments to novel regulations. Thus, not only the support but also the troubleshooting and the ongoing maintenance of the developed apps and the app framework are crucial. The continuous development of the framework and apps

require a diverse field of know-how in technical and regulatory areas. Integrating the app framework leads to a dependency on new developments and potential users. Users rely on the app framework's underlying structure, meaning that seamless implementation in higher-level systems (e.g., app interfaces) must occur. A close embedding of the app framework needs to be performed to be able to leverage the benefits of the developed platform. Due to the project structures, dependencies on service providers and developers exist. As the app framework and the reference implementations are carried out by different partners, tacit knowledge is generated, complicating the ongoing development by other service providers. Thus, dependencies can be identified regarding withdrawals from partner companies.

As part of the *iii) value proposition*, case A describes an open-source platform that will be published after the completion of the development phase, supported by a vivid community. One assumption, which is only taken care of to a minor extent in the context of the project, is the establishment of such an app-framework developing community. It is assumed that an intrinsic motivated open-source community will be available after the end of the project, implicitly assuming its continued development. Thus, despite the development of the app framework in a scope of a closed project, the final platform is expected to draw on an open-source driven business model. Comprehensive app development by means of using the framework is anticipated from potential customers (e.g., SMEs developing COVID-19 apps). The value proposition therefore indirectly involves the provision of a plug-and-play product. The nature of the app framework, however, contradicts this idea. New app development and alignment with the framework implies not only further development steps but also a change in behavior among users in terms of development work. A high dependency exists between the use of the framework and the app developments.

The *iv) adopter system* comprises a variety of stakeholders. Firstly, the open-source community, which is responsible for the further development of the app framework, automatic conformity checks, and reference implementations. Particularly, in this case, it is necessary to appeal to this community. Although they may be direct consumers of the app framework by implementing iOS or Android apps, they are mainly working on the open-source project on a voluntary basis. Due to the emergence of entirely new work processes in the context of a potential open-source community, a significant level of resources is required. Firstly, the community must be established and, secondly, the expectations towards it, i.e., the active extension and development of the framework, must be fulfilled. The organization and management of further open-source platform development are implicitly assumed. Furthermore, companies and app developers may be adopters that can utilize the app framework for facilitated and regulatory conform development. Nevertheless, the adopters are expected to replace their previous ways of implementation with those of the framework.

Concerning the *iv) organization*, various vulnerabilities, and risks can be identified within the capacity to innovate. On the one hand, there is a high level of dependency on funding authorities and consequently considerable pressure about the resources available. These structures also severely restrict the dynamic deployment of resources to incorporate crucial updates, and the rapid adaptation to new legal requirements regarding the app framework or automatic conformity check. Budgets, which must be considered for the above-mentioned maintenance and support of the app framework after the end of the project, are particularly important in this regard. Due to the funding structures, which are limited to a fixed period, the ongoing maintenance and support of the app framework and comprising technical features can only be integrated insufficiently if at all. Due to the context-specific development during the COVID-19 pandemic, an additional risk arises. Further adjustments and context-specific changes to the developed framework will be impacted by the events of the pandemic.

Like the organization, the COVID-19 specific boundary conditions must be mentioned within the scope of the *vi) wider system*. They impact financial, as well as regulatory requirements and pose challenges that can only be predicted to a limited extent. In turn, legal requirements in different areas, notably in Germany, have attracted discussion due to the COVID-19 pandemic. Thus, the fundamental regulations of the app framework inform the Infection Protection Act, GDPR and the Act on Medical Devices Further may change, leading to crucial changes in the value of the framework. Furthermore, financial support is highly dependent on how the Covid-pandemic will progress. With continued

interest from funders in the development of the app framework further development can be expected. Hence, the surrounding environment and the wider system are rather of a dynamic nature which is difficult to predict.

Due to the general conditions outlined above, *vii) embedding* and adaptation to new requirements over time is not or not sufficiently emphasized in the project. A sharp focus is exerted on meeting stipulated demands. Thereby, dynamic actions to react to topical events, such as changes in the GDPR, are only insufficiently integrated. Thus, dynamic structures, caused by various characteristics of the project, remain unaddressed. By providing the framework as an open-source product, a risk emerges that no possibility exists to centrally react to requirements and initiate suitable measures. However, case A did not address what steps would be performed if the environmental conditions changed.

4.2 Project Analysis Case B

While case B's *i) condition* is identical to case A, distinct characteristics in the context of *ii) technology* must be noted. Case B draws on existing non-public data management information systems, integrating the three key components of surveillance information, test, and infection control. Furthermore, interfaces to existing surveillance systems and related pandemic preparedness projects are integrated, rendering the technology landscape dependent. Accordingly, the further development and support of the underlying structure is requiring specific expertise. Since the intertwined surveillance landscape must be considered when changes are made, knowledge of the effects on other technological factors is necessary for sufficient support capability. Since interfaces and surveillance components are developed or integrated by various stakeholders, the risk of partner withdrawal exists. Within case B, governance concepts and scenarios are generated as to how the long-term operation of the CIS can be designed to meet the requirements of further development and growth.

In terms of the *iii) value proposition*, the goal of the emerging CIS in case B is to establish a central database that distributes information to various stakeholders. It is intended to provide pandemic surveillance strategies, which in turn can be used at the various partner locations. The explicit assumption of the project is that the platform participants will continue to use and support the product after the end of the project, both financially and non-financially. However, neglectable effort is made within the project to substantiate this assumption.

The *iv) adopters* of the resulting platform in case B include all stakeholders interested in employing pandemic surveillance strategies and their associated information. While the implementation of the CIS in form of a platform entails a relatively small impact on existing processes for the stakeholders, the underlying technological surveillance landscape requires substantial initial effort. Thus, there is a hurdle to first-time utilization due to the alignment with the technological landscape. Furthermore, it is expected that new adopters are willing to undergo this effort to be able to leverage the benefits, i.e., information, strategies, and test concepts for surveillance, of the platform. It is also assumed that the current participants in the overall CIS project in form of project partners have a high level of interest in the emerging platform. Resulting in the assumption of continued use and intrinsic support.

Like case A, the structures in the *v) organization* in the case B is rather rigid and do not allow for the dynamic management and deployment of resources. A limited number of possibilities exist for incorporating changes in requirements regarding the implementation of surveillance systems. In turn, the dependency on the government in form of budgets for support and maintenance is amplifying this aspect. This point is intensified by the dynamic nature of COVID-19, which is not addressed at any time in the project case. Thus, changes in demands induced by the dynamic nature of the condition are rather complicated to integrate on an ad-hoc basis. Concerning the *vi) wider systems* and the *vii) embedding and adaption* over time to the government-initiated nature, both cases constitute a similar dependency structure to the adjacent systems and to the general conditions for subsequent adaptation and adjustment over time. Thus, the aforementioned aspects of the case A analysis can be applied to case B accordingly.

4.3 Cross-Case Synthesis

The findings of the analysis are now classified in a cross-case analysis using a complexity perspective by leveraging the NASSS. This analysis assists us in understanding government-initiated CIS in two ways. On the one hand, we can elaborate whether the cases dimensions are simple, complicated, or complex landscapes and the factors that shape them. On the other hand, against the background of the actual project implementation, it allows us to identify shortcomings, that can subsequently be leveraged to propose recommendations for action in future government-initiated CIS (see Table 1).

Dimension	Analysis	Classification	Key Shortcoming
i) condition	novel, dynamic, unpredictable	complex	Considering a yet uncharted condition as simple/complicated
ii) technology	dependencies, expert support, withdrawal risk, mostly condition agnostic	complicated	No mechanisms to respond to environmental conditions
iii) value proposition	speculative, dependent, implicit assumptions	complex	Missing active integration of key users
iv) adopters	value network presumption, user dependency	complex	Lack of community motivation and alignment
v) organization	resource pressure, project view, rigid	complex	Inadequate resource allocation for underlying complexity
vi) wider system	novel, dynamic, unpredictable	complex	Lack of continuous monitoring of the wider system
vii) embedding and adaptation	Development hurdles, adaptational uncertainties	complex	No activities dedicated exclusively to sustainable adaptation

Table 1. Findings of Cross-Case Synthesis & Classification

Due to the uncertain, diverse, and dynamic disease setting of the two CIS (Kouidou et al., 2020; Muenchhoff et al., 2020; Wolf et al., 2020) the *i) condition* can be depicted as complex. Although this condition can be identified as complex, no resources, tools, or capabilities are provided within either case to address these dynamic and non-static circumstances. Both case structures provide a fixed boundary state not changeable at any time during the project. A central shortcoming can be identified. Even though a complex illness is being addressed, it is *considered to be rather complicated*. Thus, resulting in potential risks that jeopardizes the CIS' development and its operational success.

The CIS being developed have similar characteristics in terms of *ii) technology*. In particular, it is noticeable that both technology dimensions are not plug-and-play products but consist of many interfaces and heterogeneous expertise sources. This in turn affects the simplicity of future maintenance and servicing (Greenhalgh et al., 2017). In both case A and case B, seamless advancement of the resulting implementations is only possible with expert knowledge. Due to the fact that a large number of partners cooperate within the compound, its effect is amplified and a withdrawal risk (Greenhalgh et al., 2018), resulting in a potentially adverse impact on the CIS, is imminent. In addition, numerous dependencies of the users lead to a high level of interference between changes in the CIS and changes in usual processes. While this close embedding might be rated as complex, we identify a more complicated and simple classification in the domain of technology regarding the generated knowledge. While both systems are directly related to the condition, they either measure observational data or lack disease-specific knowledge. Accordingly, the technology dimension can be rated as rather complicated. Against the background of the complex illness, which may lead to significant changes in the technology (Bellavista et al., 2021), a key shortcoming can be identified. It is noticeable that in neither case the possibility of being able to *address environmental conditions* after the project duration was provided. Despite indications of measures required to be implemented at a later stage, neither of the two cases provided any means of addressing these conditions.

The supply-side goal is to achieve pandemic preparedness. For the demand side, improved handling of and capabilities for pandemic events are promised. In both cases, the *iii) value proposition* consists of

the provision of a platform which is implicitly expected to be maintained, developed, and supported by the users in the subsequent course of utilization. Drawing on the stakeholder perspective and related platform literature, it emerges that users will play a central role and generate substantial impact on the actual success of the CIS (Jansen and Cusumano, 2012; Fehrer et al., 2018; Hein et al., 2020). This is why an early engagement with the users regarding the benefits to be provided to them is advisable (Spagnoletti et al., 2015). The synthesis of both case analyses reveals a key shortcoming: Although both projects envision the end user as a central component, there is *no active and overarching integration* into the development process. This highly speculative and community-based approach indicates that a high degree of complexity exists. Particularly since the benefit of such developments is strongly dependent on the current disease situation, an adverse structure can be identified.

An analysis of the *iv) adopters* indicates that in both cases the long-term, sustained operation of the CIS is dependent on the contribution of potential participants. Thus, constituting a complex adopter environment by implicitly assuming an established value network (Greenhalgh et al., 2018). In contrast to conventional products, they not only comprise the end users of a product but also fulfill the purpose of continuing to develop and generate value for the CIS (Barrett et al., 2016). As a result of this importance, it can be assumed that, if this premise is not met, the business model of the CIS' lacks viability. Therefore, we identify that motivating adopter of the CIS to use, participate and contribute is a success factor. However, both projects *only marginally align their business orientation with addressing their targeted community*. This in turn represents a critical shortcoming for successful market entry and persistence in stakeholder-driven information systems (Fürstenau et al., 2019).

Compared to the NASSS framework (Greenhalgh et al., 2018), the *v) organization* considered in our paper represents a special entity. Rather than constituting a company developing a product or service, its role involves that of a government, requiring to take measures to counteract the occurrence of a pandemic. The scope set for the projects is rigid, oriented to a fixed period, and not flexible at any time. Accordingly, activities that are dynamic in other dimensions cannot be addressed. Referring to other dimensions, we identify that a structural contrast exists between the organizational setting of the project owner and the *requirements needed for the complex implementation* of the project.

Due to the tight integration and dependency of both projects with regulatory requirements, a complex relationship with the *vi) wider system* prevails. When legislation changes or is amended, new requirements must be met, making them of central importance due to their criticality regarding the usefulness of the CIS. However, the projects do *not have a dedicated plan on responding to such requirements*, including the responsibility and form of potential funding.

Lastly, *vii) continuous embedding and adaption* over time is mostly being *overlooked in both cases*. Given the iterative and dynamic development of a CIS, we identify this as a key shortcoming in reaching sustainability and adoption.

By reviewing crisis research, we further identified four distinct requirements for their successful management. These serve as a baseline for assessing the extent to which the examined cases satisfy the prevailing conditions of crisis management. Besides the analysis through the NASSS lens, we generate more in-depth, crisis-specific insights to facilitate the identification of challenges. The four requirements, (1) long-term technical availability, (2) permanent interconnection, (3) provision of up-to-date information, and (4) ongoing integration with institutions and agencies, imply that durability and longevity need to be addressed by CIS in several respects. In particular, the shortcomings regarding *iii) value proposition*, *iv) adopters*, *vi) wider system*, and *vii) embedding and adaptation* indicate strong contradictions with these goals. Both cases reveal that during the development period as well as scheduled long-range activities, only a small proportion of the community (*iii*, *iv*) is engaged. However, this is a necessary component of public health CIS (2,4), as stakeholders and their integration constitute a pivotal role. Furthermore, we recognize that the cases CIS' provides only limited support for the necessary adaptations to crisis-induced changes (*vii*). Missing plans to sustain and enhance CIS in turn decreases the chance of successful crisis management due to the constrained timeliness of relevant information (3). Finally, due to the project characteristics of the cases, limited

financial and organizational resources are available for future strategic and operational planning (*vi*). A characteristic that is necessary for long-term technical availability for crisis management (1).

5 Discussion and Implications

The cross-case synthesis has indicated that specific features of establishing a sustainable CIS, characterized by a highly complex nature, are only addressed to a limited extent by contemporary projects. Furthermore, considering crisis-specific characteristics, we identify a mismatch between the requirements imposed on CIS for crisis management and the actual CIS' developed. Drawing on these shortcomings and mismatches, we identify various propositions to enhance the development of CIS in public health crisis management. Before discussing in-depth propositions, we identify a pivotal structural problem involving the perspective of government-initiated projects on each dimension of the NASSS framework. Traditionally, healthcare projects are conducted through a time, financial, and organizational constrained scope. Although this approach has advantages (Eom et al., 2020), we discover contradictions with a CIS' needs, which are driven by complex characteristics. This implies that changes lead to unpredictable changes in requirements (Cohn et al., 2013), that actors behave in non-stable relationships (Plsek and Greenhalgh, 2001), and that needs, and success depend on dynamic conditions (Maylor and Turner, 2017). In this context, the landscape of governmental CIS authoring does not integrate complex circumstances. In turn, attempts are made to frame complex developments as manageable "complicated" components, aiming to handle them within the scope of traditional project management. This practice in particular, given the dynamic nature of crisis management (Pan et al., 2012), inherently introduces risks that jeopardize sustainable operations and business. Thus, we argue, that the longevity of government-initiated CIS is inconceivable in the lens of project management when viewing projects as "a temporary assemblage of resources to solve a one-of-a-kind problem" (Jurison, 1999). Against this backdrop and the aim to achieve long-term pandemic preparedness through CIS, we propose a change in the project perspective on complex issues:

PP 1: *To incorporate and address key elements of dynamic and variable systems in government-initiated projects in the context of crisis, especially CIS, a shift from a simple & complicated-driven to a complex-driven approach is imperative*.

Furthermore, we observe that different assumptions are made in the value proposition and in the underlying technological infrastructure, which are not substantiated by actual activities. In both cases, the community is perceived as a matter of fact. Implicit anticipation arises that the community has an intrinsic motivation to expand, support, and use the conceptualized CIS. However, the development and fostering of this community during the project period only occurs to a minor extent. In turn, contemporary literature demonstrates that engaging and motivating activities are central to the success of a stakeholder-based information system (Constantiou et al., 2017; Bork et al., 2019). If these community-building efforts are neglected, it is likely that the CIS will fail after a transition phase, jeopardizing the goal of long-term pandemic preparedness (WHO, 2021). Our literature review of CIS requirements further underpins the relevance of stakeholder engagement. Thus, we propose the necessity of engaging stakeholders outside the project at an early stage:

PP 2: *When conceptualizing government-initiated CIS to manage crises, community-building and strengthening activities should be initiated during the development phase.*

A third aspect to note is the constrained funding due to the nature of government-initiated projects. The budget traditionally provided for the completion of a time-constrained project (Lenfle, 2008) is not suitable for the development of a CIS in the context of crisis. Thus, prior to commencing efforts to develop a crisis, the following questions should be answered: (1) Can the budget be provided for the transition phase of a CIS, i.e., development to operation (2) What are the alternative funding possibilities besides government financing? Both cases indicate the shortcoming in that answers to these questions must been found in advance of the CIS development. As a result, financing structures can be established during the development, counteracting any threat to sustainable operation. Thus, we propose the necessity of establishing and implementing alternative financing structures:

PP 3: *Identification of financing options for the transition phase of a crisis-situated CIS prior project launch, and the implementation of alternative financing structures for core CIS activities.*

Fourth, considering the complexity of the condition, we identify a proposition for future government-initiated CIS addressing similar illnesses. Even though COVID-19 can be classified as a highly complex condition (Greenhalgh et al., 2017), both CIS implicitly assume its ongoing relevance in the future. In turn, since a CIS' value in the context of a crisis is dependent on the current extent of the targeted illness (Liu Zhi, 2009), we identify a mismatch. While the potential users might cancel utilizing the CIS in these times, no actual measures are conceptualized to deal with this challenge. This, contradicts the cases' pivotal goal of achieving pandemic preparedness (WHO, 2021). Thus, it is necessary to determine what benefits can be generated by transcending context and identifying value through synergy-creating alternative business cases. Hence, we propose:

PP 4: *While maintaining the main objective (e.g., pandemic preparedness), the question should be addressed how the CIS is able to add value to users in times of low crisis activity.*

Last, by applying and extending the NASSS framework to crisis management, and thus examining crises with a complexity theory-based approach (Greenhalgh et al., 2017, 2018), we identify a proposition for literature and theory. We highlight that the requirements for CIS posed to prepare for and respond to a crisis overlap with the classifications and suggestions of the NASSS. Our analysis demonstrates that CIS to achieve pandemic preparedness of health crises are complex in nature. We thus extend existing literature (Plsek and Greenhalgh, 2001; Ostern et al., 2021) and suggest:

PP 5: *Future research investigating CIS should adopt a lens of complexity to reflect the multi-faceted nature of crisis management and thus contribute to complexity theory in crisis situations.*

6 Concluding Remarks

COVID-19 has shattered global mankind and resulted in the loss of many lives. Reflecting on the pandemic, while recognizing the looming threat of further crises, we identify deficiencies in governmental health crisis management. To achieve future crisis and pandemic preparedness, in this paper we aim to examine the underlying challenges and issues, particularly those related to crisis management through CIS. Adapting a complexity lens through the NASSS in the scope of government-initiated projects, we examine two German CIS that emerged during the COVID-19 pandemic. Answering RQ1, we observe that the specific characteristics of solving complex-driven crisis issues are only reflected to some extent in the actual planning and development phase. Hence, in reference to RQ2, we derive propositions that offer practitioners and researchers guiding principles covering crucial elements in the elaboration and development of a government-initiated CIS in the context of health crises. Nonetheless, our findings have limitations. The NASSS framework, originally developed as a patient-facing framework, has been conceptualized to fit our context. Subsequent research should validate and extend our outcomes by applying additional frameworks. Further, we must note that the findings presented are interrelated to the German healthcare system and the respective unique challenges. Hence, future research should apply and test the presented propositions in other settings (e.g., countries), to build more generalizable findings for the management of CIS. Our paper contributes to the identification of shortcomings of the current government-initiated CIS landscape and offers guidance for a comprehensive revision of current paradigms by conceiving them as complex systems.

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