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Designing for the future in the age of pandemics: a future-ready design research (FRDR) process

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ABSTRACT

The recent pandemic has painfully reminded us the need for IS design to be informed by possible futures and conscious of undesirable futures – Within months, many of the nice-to-have IS functionalities have become must-haves; Technology solutions in response to the pandemic have raised privacy and equality concerns. Although design science research fundamentally focuses on shaping artefacts and events to create a more desirable future, there has been limited guidance on how futures should be accounted for. This article addresses the gap by integrating insights from future-oriented IS research and futures research to develop guidelines for engaging with futures throughout the design science research process. The future-ready design research (FRDR) process prompts researchers to be more aware of futures, to foster the innovative foresight for actively pursuing the preferred future, and to espouse the responsible foresight for consciously avoiding undesirable futures. The guidelines are illustrated with a design science research project on outbreak analytics and the instantiated system's subsequent adaptation and utilisation in COVID-19.

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Pandemic; futures; foresight; design research; IT artefact; impact

1. Introduction

The pandemic caused by the Coronavirus Disease of 2019 (COVID-19) has catapulted us into a future that was believed to be a lot more distant. Hospitals and general practitioners are now expected to offer telehealth services – more than a third of consumers had indicate in recent market surveys that they would switch providers to access virtual care (e.g., Sage Growth/Black Book Research, 2020); Organisations suddenly have to contend with a newly remote workforce and coordinate work through personal devices and insecure networks; More than ever before, manufacturers must have real-time visibility of their supply networks and digital access to suppliers in order to put themselves first in line to secure raw materials and components as soon as a potential disruption is detected. Within months, many of the nice-to-have information system (IS) functionalities have become must-haves. Not surprisingly, organisations that have been more aware of the future potentialities of information technology and engage with possible futures for innovative foresight in their IS design have demonstrated better resilience against exogenous shocks due to COVID-19.

The rapid routinisation of new IS functionalities in response to crises carries immediate and long-term socio-technical risks, as vividly experienced in the recent pandemic. For example, COVID-19's infection and death curves are perhaps the most widely known data models in human history now. Although the models are intended to inform public health interventions for reducing disease burden rather than to provide specific numerical estimates of the pandemic's magnitude, the general public and media often focus on the latter and this has generated undue anxiety and overreactions (Jewell et al., 2020); Digital contact tracing in COVID-19 has exposed cheating partners and extramarital affairs leading to a spike in divorce; The emerging concept of blockchain-based immunity passports could compound existing gender, race, ethnicity, and nationality inequities by restricting social, civic, and economic activities (Phelan, 2020). To minimise the undesirable impacts, they should be anticipated and prevented as much as possible through responsible IS design rather than tackled only as an afterthought. It is not always possible to predict all risks, but many can be consciously avoided with some foresight in IS design. This is exemplified by the BlueTrace protocol, a digital contract tracing protocol that was prudently designed to minimise privacy risks by using Bluetooth technology rather than Global Positioning Systems (GPS), and by incorporating multiple privacy safeguards such as local storage of encounter history and revocable consent (Bay et al., 2020).

The recent pandemic has painfully reminded us the need for design decisions to be informed by possible futures and conscious of undesirable futures. Although it is recognised that design science research fundamentally focuses on "shaping artefacts and events to create a more desirable future" (Boland, 2002; March & Storey, 2008), existing research methodologies are

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relatively muted about how futures should be accounted for in the design research process. This gap was observed in one of our projects that designed an outbreak analytics system for managing Influenza A in a metropolis. The system was expected to improve responses to existing outbreaks caused by known viruses, as well as preventing future outbreaks caused by mutated or novel viruses. To ensure that futures were adequately considered in our design, we consulted futures research for insights on its nature, purpose, and application. This led to a design research process that was more aware of futures and actively pursued the preferred future while avoiding undesirable ones. In the recent COVID-19 pandemic, despite confronting a novel coronavirus with significantly different clinical and transmission features (Petersen et al., 2020), the system demonstrated resilience in its role of accurately forecasting the spread, effectively informing public health interventions, and swiftly containing the outbreak.

This invaluable experience provided the opportunity to reflect on how a more future-ready design research (FRDR) process could support the design and development of IS that are more responsive to sudden shocks and, more generally, promote research on the emerging phenomenon of digital resilience. This article proposes guidelines for surfacing and incorporating innovative and responsible foresights throughout an IS design research process, based on future-oriented IS research and futures research. As shown later, the guidelines are mapped to typical IS design activities (e.g., problem identification) and are applicable to different design science research methodologies to the extent that they require these activities. The guidelines are illustrated with our project on outbreak analytics and the instantiated system's subsequent application in COVID-19. FRDR's applications and implications for future research are also discussed.

2. Futures in IS and design science research

There have been calls for more future-oriented IS research that goes beyond the goal of being relevant to current practice to strive to be relevant to future practice (Chiasson et al., 2018; Conboy, 2019; Gray & Hovav, 2008; Markus & Mentzer, 2014). IS scholars have begun to propose initial intellectual structures for engaging with futures. For example, Chiasson et al. (2018) discussed how Feenberg's philosophy of potentiality and actuality of technology provides a foundation for ethical inquiry into sociotechnical futures and illustrated with big data applications; Hovorka and Peter (2019) provided an epistemic categorisation of approaches to studying futures – those that seek to discover futures, create a future through choice and action (future making), develop sociotechnical imaginaries encompassing power, social orders, and justice, and expose ideals and values enacted in perfect and imperfect futures. Foresight approaches that are applicable to IS research, especially on sociotechnical issues such as digital divide, privacy, ethics, and sustainability, have also been demonstrated (Gray & Hovav, 2008; Markus & Mentzer, 2014). A couple of studies have described possible futures – Gray and Hovav (2007) identified four scenarios of the IS organisation of 2020 based on differing assumptions about the reliability of telecommunications and alignment of IT with business and socio-economic conditions, to help managers consider the alternative futures they face and allow them to update their vision as the world evolves; Focusing on responsible IS, Stahl (2011a) provided an overview of the social issues and ethical consequences arising from emerging IT, as well as recommendations for developing ethical reflexivity in decisions related to future technology development and governance.

In IS design science research, there is growing, albeit still limited, attention on futures. For example, the elaborated action design research process model (Mullarkey et al., 2019) identified "evolution" as the final stage involving problem re-formulation, technology advancements, refactoring, and continual re-engineering to further develop the artefact as the problem environment changes. De Leoz et al. (2018) suggested an ex-ante social feasibility analysis to evaluate the potential social impacts of an IS artefact in order to increase its potential to thrive when implemented. The analysis prompts researchers to identify the scenario that is likely to occur when the artefact is received into an existing social structure. Costa et al. (2020) studied the design of digital platforms for small and medium enterprises and emphasised future trends and prospective markets in one of their design propositions. They expected foresight to improve platform outcomes by providing market intelligence and potentiate digitally enabled collaborations. Kloör et al. (2018) developed a decision support system in which future scenarios constituted a vital construct of the IT artefact. The system improved decision quality by identifying optimal situations for repurposing electric vehicle batteries. Pan et al. (2020) specified design principles to pre-empt and reduce animal poaching for a wildlife management system. Taken together, these studies indicate the relevance and value of accounting for futures throughout the design research process rather than only at the end of the process or as an element of the instantiated IT artefact. Conboy (2019) noted that design research, given its applied nature, is particularly pertinent and a critical enabler of "Promethean leaps" towards radical and even transcendental innovations for the betterment of humanity.

To achieve this, researchers need to be more forward-looking and future-oriented throughout the process of study.

3. Conceptual foundations of futures research

Futures research is an established field with its own epistemology, methodologies, journals, and degree programmes worldwide. The field emerged after World War II and initially focused on the scientific inquiry and rationalisation of futures using statistical tools, modelling, scenarios, and technological forecasting. Around the 1970s, futures research developed into a global institutional practice, with methodologies for interrogating futures widely adopted by businesses for environmental scanning, financial forecasting, product development, and technology development. Since the 1990s, there has been an increasing specialisation of futures studies, evident in the proliferation of subfields differing in terms of participants, objects of analysis, and scope (e.g., transnational, corporate, environmental; Son, 2015). A wide range of topics has been explored using futures methodologies, including sustainable development, strategic management, the future of work, and digital humanity.

As a "paradigmatic turning point in the production and use of knowledge" (Slaughter, 1998, p. 373), futures research recognises the future as a fundamental principle of present actions. The future is often complex, dynamic, and unknowable and might not always be an extrapolation or extension of the past and present. Futures research rejects the idea of a single, predestined future that must be uncovered. Instead, futures are open and can be influenced by human actions. As Dator's states, "the future cannot be 'predicted' but alternative futures can be 'forecasted' and preferred futures 'envisioned' and 'invented' continuously" (Dator, 1996). The main goal of futures research is to systematically explore and assess ideas about possible and desirable futures to improve present decisions, and analyse the consequences of the decisions (Glenn et al., 2007). It is important to note that the non-evidential and non-existent future is not and cannot be the object of empirical inquiries in futures research. Rather, the analytical focus is on the existing dispositions and beliefs about desirable and undesirable futures, or any of a range of ideas and images about the future (Bell, 1997).

The focus of futures research is delineated in terms of four laws (Sardar, 2010). The first law states that "futures studies are wicked" in that they deal with wickedly complex problems. Such problems occur in an uncertain, changing environment and have interdependencies that could lead to new problems when solved. The complexity often makes it necessary for researchers to draw from multiple disciplines, while maintaining a systematic mode of critical inquiry. The second law emphasises that futures studies should ensure "mutually assured diversity". This includes recognising that there are many different ways to be human and therefore diverse paths to the future. It is imperative to remain open to different potentialities and possibilities and ensure that those who have to bear the consequences are involved in the social construction of futures. The third law recognises that "future studies are sceptical", of existing assumptions, prevailing expectations, and simple solutions. Other than rejecting the idea that the future can be known with certainty, scepticism in futures studies can be an instrument of positive change. Doubt serves as a tool to prevent simple or dominating forecasts that attempt to foreclose the future. The fourth law is "futures studies are futureless". The real relevance of futures research lies in the present rather than the future which we have no true knowledge of – "they can change peoples' perceptions, make them aware of dangers and opportunities ahead, motivate them to do specific things, force them to invent or innovate, encourage them to change and adjust, galvanise them into collective social action … " (Sardar, 2010, p. 184). Accordingly, the present impact of future explorations should be assessed.

Since a main purpose of futures research is to inform current decisions and actions, it can "be considered an action science in the fullest sense of the term" (Bell, 1997). Action science studies how people design their actions in difficult situations to achieve intended consequences (Argyris et al., 1985). When actions are taken, not only to achieve the intended consequences, but also to openly interrogate and possibly transform the governing variables, a deeper double-loop learning ensues. Some futures researchers have used the term "design science" to capture the construction of decisions and actions (Niiniluoto, 2001; Rubin & Kaivo-Oja, 1999). Rather than being a purely intellectual exercise, futures research is strongly connected to practical action and deeply involved in the shaping of future. Like design science research in IS, the futures research process is inherently iterative and incremental, looping forward into the future as the present understanding guides decisions and actions shaping the future, and looping back to the future as it is realised and becomes the present.

4. Future-ready design research (FRDR) process

Futures research offers useful insights for design science research to achieve its fundamental aim of shaping artefacts and events to create a better future (Boland, 2002; March & Storey, 2008). In this article, we crystallise the insights into guidelines for design science researchers to simultaneously engage with futures in design decisions and activities while tackling a problematic situation. The future-ready design research (FRDR) process achieves this by prompting researchers to be more aware of futures, to foster the innovative foresight for actively pursuing the preferred future, and to espouse the responsible foresight for consciously avoiding undesirable futures.

Innovative foresight helps researchers look beyond the problem situation as currently observed, by questioning existing assumptions, identifying technology emergence, and accounting for futures in the conceptualisation of IS theories. For example, Gray and Hovav (2008) suggested creating the future through IS innovation by questioning the underlying assumptions or the rules of the game through scenarios. Stahl (2011c) focused on the description and prognosis of emerging technologies, including how an artefact can emerge in terms of usage and application, through participative technology assessment. These understandings are necessary for innovation, research, and policymaking, as "we are now looking at unknown information technology for an unknown future . . . At the same time, however, we need to make decisions based on assessments of the future that will then, in turn, influence the way the future will turn out in practice" (pp. 95). Frank (2017) proposed designing possible futures with a conception of IS theories that goes beyond the description of the objective past. Such theories are needed to capture the pivotal role of IS and provide an orientation for digital transformation. Olla and Choudrie (2014) showed that innovation diffusion strategies for mobile technology in developing countries could be formulated by rapidly identifying scenarios of the future through a participatory ethnographic approach.

Responsible foresight prompts researchers to anticipate risks early, as the solution is being designed and developed. For example, Belanger and Xu (2015) suggested that IS research should take a more active role in shaping the future of information privacy by design, through developing more information privacy artefacts for privacy protection, privacy behaviour measurement, and behaviour elicitation. Hovorka and Peter (2019) argued that IS researchers should be engaged in "doing futures" by providing a critical voice in current technology developments and implementations. The unintended consequences of IS have also been identified. For instance, Di Gangi et al. (2018) described the potential risks of using social media in organisations through the Delphi method. They found that most existing social media policies had not accounted for three critical risks: unintended exposure of information, damage to consumer confidence, and decreased productivity; Stahl (2011b) discussed how emerging IT could betray the implied assumptions about individuals, society, and technology. Their analyses of governmental and policy discourses around funding plans led to the conclusion that such awareness is vital for making the right decisions, both in terms of technology and policy development.

FRDR leverages innovative foresight and responsible foresight in design activities and decisions throughout the research process. Different design research processes have been proposed in IS research. In the oft-cited methodology developed by Peffers et al. (2007), the process includes six activities: identify problem & motivate, define objectives of a solution, design and development, demonstration, evaluation, and communication (see Table 1). Later, noting that the methodology had not fully recognise the role of organisational context in shaping the design and the deployed artefact, Sein et al. (2011) proposed the Action Design Research (ADR) methodology. ADR considers the process as "containing the inseparable and inherently interwoven activities of building the IT artefact, intervening in the organization, and evaluating it concurrently" (p. 37). ADR was subsequently elaborated by Mullarkey et al. (2019) with the multiple entry-points described by Peffers et al. (2007), based on an experience of applying ADR in an immersive industry-based project. Even though the structure of design research process and relationships among activities vary in different methodologies, our comparison (see Table 1) shows that the set of key activities has remained largely consistent and fully covered by those identified by Peffers et al. (2007). Therefore, this article discusses the guidelines for FRDR in terms of the activities described by Peffers et al. (2007). Nevertheless, the guidelines are applicable to other methodologies composed of these activities.

5. Guidelines for activities in future-ready design research (FRDR)

This section discusses the guidelines for engaging with futures in each of the key design activities, developed based on futures research as well as future-oriented IS research (see Figure 1). The guidelines are illustrated with our experiences in a design science research project in the section 6.

5.1. Identify problem & motivate

This activity focuses on defining a specific research problem and justifying the value of a solution (Peffers et al., 2007). Problems can be described in terms of unmet needs or targeted performance improvement, based on knowledge of the practical domain and research field. Diagnosing the problem with an awareness of possible futures helps to ensure that the project targets a relevant problem and the IS artefact being instantiated is not just addressing a temporary symptom of the root problem. This can be achieved by challenging current assumptions and problem framing, as indicated by futures research and captured in our first guideline.

Guideline 1: Reverse assumptions about the future. This involves unpacking existing assumptions around the initial problem and considering alternatives or opposites (see Table 2). For example, "healthcare services always involve face-to-face consultations with physicians" would become "healthcare services do not always involve face-to

Table 1. Design research activities in existing frameworks.

Authors*	Framework	Activities (Description)					
March and Smith (1995), Hevner, March, Park and Ram (2004)	Research Framework for IT	Theorise (The construction of theories that explain how or why something happens)	Build (The construction of an artefact for a specific purpose)		Evaluate (The development of criteria and the assessment of artefact performance against those criteria)		Justify (Gathering of scientific evidence that supports or refutes the theory)
Peffers et al. (2007)	Design Science Research Methodology	Identify problem & motivate (Define the specific research problem and justify the value of a solution)	Define objectives of a solution (Infer the objectives from the problem definition and knowledge of what is possible and feasible)	Design and development (Create the artefact)	Demonstration (Demonstrate the use of the artefact to solve one or more instances of the problem)	Evaluation (Observe and measure how well the artefact supports a solution to the problem; Iterate back to design if necessary)	Communication (Communicate the problem and its importance, the artefact, its utility, etc. to researchers and other relevant audiences such as professionals)
Sein et al. (2011)	Action Design Research	Problem formulation (Identifies and conceptualises a research opportunity based on existing theories and technologies)		Build, intervention, and evaluation (Realise design of the artefact)		Reflection and learning (Reflect on the problem framing, the theories, and the emerging ensemble)	Formalisation of learning (Develop learning into general solution concepts for a class of field problems)
Mullarkey et al. (2019)	Elaborated Action Design Research	Problem formulation/ planning (based on Sein et al., 2011)		Artefact creation (based on Sein et al., 2011)	Evaluation (based on Sein et al., 2011)	Reflection (based on Sein et al., 2011)	Learning (based on Sein et al., 2011)

*** Frameworks are listed in reverse chronological order**

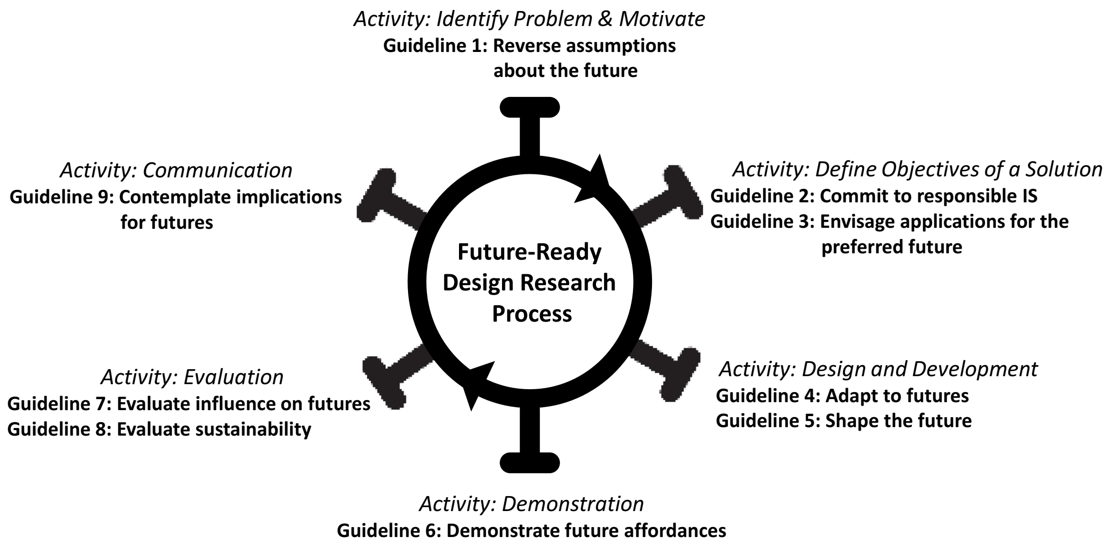

Figure 1. Guidelines for future-ready design research.

Table 2. FRDR guidelines and overarching questions to consider during IS design.

FRDR Activity and Guidelines	Questions to Consider
Identify Problem & Motivate (1) Reverse assumptions about the future	• To what extent are reversed assumptions possible in future? • To what extent does the problem remain valid?
Define the Objectives of a Solution (1) Commit to responsible IS (2) Envisage applications for the preferred future	• How to minimise sociotechnical risks? • Other than the targeted users, who might have access to the IS artefact? How to minimise the sociotechnical risks due to unintended use? • How can the IS artefact be (part of) a more holistic solution towards realising the preferred future?
Design and Development (1) Adapt to futures (2) Shape the future	• How can the design adapt to future needs? • How can the design shape decisions or strategies to realise the preferred future?
Demonstration (1) Demonstrate future affordances	• How can users adjust the IS artefact in future? • How to use the IS artefact for decisions that shape the future?
Evaluation (1) Evaluate influence on futures (2) Evaluate sustainability	• To what extent does the IS artefact influence (decisions that shape) the future? • How sustainable is the IS artefact technically and sociotechnically?
Communication (1) Contemplate implications for futures	• Which aspects of the final IS design are informed by futures? • What risks and opportunities should further research consider in future-oriented IS design?

-face consultations". Listing key assumptions and articulating the opposite help remind design researchers that assumptions are not facts set in stone but could well be beliefs written in sand. Obsolete assumptions can undermine critical decisions and eventually the design and knowledge generated. Reversing assumptions broadens the perspective in problem identification and formulation by increasing awareness of different scenarios of the future and potential changes. It also stimulates thinking about the core problem underlying observations. This consciousness is central to futures research, which emphasises an open systems approach with anticipatory assumptions that account for human agency and emergent novelty, rather than viewing systems as closed, deterministic, and controllable (Ahvenharju et al., 2018). In line with Sardar's third law of futures research, being sceptical of existing assumptions enrich or transform the worldview of design researchers, leading to disruptive knowledge or constructive perturbations that reveal blind spots. Challenging assumptions serves as a way to "provide new insights into the potential of the current world as a way to embrace complexity, heterogeneity and the pertinence of spontaneous actions that put values into practice" (Miller, 2007, p. 348). This enables researchers to work on problems and solutions relevant to possible future needs of users and develop a design that can respond and cope with changes better. Nevertheless, it must be noted that assumptions should only be discarded after careful deliberation to avoid repeating painful and expensive learning processes.

5.2. Define the objectives of a solution

In this activity, the problem identified should be translated into more specific performance objectives, based on knowledge of what is possible and feasible (Peffers et al., 2007). Objectives can be quantitative (e.g., cost savings) or qualitative (e.g., satisfaction), and should capture how the IS artefact is expected to tackle the problem identified. Incorporating responsible foresight and innovative foresight into objectives helps to ensure that the solution does not generate greater problems and remains valuable as the problem situation evolves or technology advances.

Guideline 2: Commit to responsible IS. Technology can have unintended negative consequences that cause more problems than it solves, such as eroding privacy and amplifying inequality in new ways (Majchrzak et al., 2016). It is often not the introduction of new IS that raises a hazardous issue, but the lack of concern over their controversial impact on the people involved. If we agree that IS must be researched, developed, and deployed in a responsible manner, we must confront possible socio-technical risks by not just exposing them, but also establishing active procedures to minimise the damaging effects (Jirotka et al., 2017). Although it is impossible to anticipate and address all risks, a conscious effort is still needed to avoid knee-jerk reactions. By specifying objectives to minimise the possibility of negative effects, design science researchers can develop better IT artefacts that are not just efficient and efficacious, but also effective within the broader context or environment of its practical operation. The need for responsible foresight is highlighted in the first law of futures research stressing its wicked nature. Solutions designed to tackle a problem should not cause new problems more troublesome than the original concern (Sardar, 2010). This requires going beyond a reactive approach of "what went wrong" to proactively minimise "what could go wrong". In the same vein, there has been an "anticipatory shift" in futures research, which promotes the confrontation of potential ethical, social, and legal implications at early stages of innovation and factoring them into research and technology development (Alford et al., 2012). For instance, futures researchers have begun to prognosticate the risks of blockchain technologies when applied to sustainable development initiatives, such as inadvertently reshaping "the relationship between the individual and society in favor of total, immutable transparency, thus benefiting efforts of centralized control" (Schulz et al., 2020, p. 10). It is suggested that anticipatory governance should be used to manage risks.

Guideline 3: Envisage applications for the preferred future. In defining the objectives of a solution, the second law of futures research on ensuring "mutually assured diversity" (Sardar, 2010) suggests that future-ready IS design should recognise the diversity of actors involved and be open to different potentialities. It is important to remember that the future affects everyone living in it and one cannot design without taking into considering those influenced by the resultant artefact. This law calls for understanding that there are many ways of being human, but all should be considered equal in the design process. The IS designer-researcher needs to be able to decentre oneself and develop knowledge about the interrelations in order to arrive at "unity-in-diversity" – the common values and commensurate ideas enacted in diverse ways. In the context of IS, researchers have begun to recognise the use of artefacts by unanticipated users (Quinones et al., 2013), who were never targeted by designers but have real impact on practices surrounding the artefact. Considering such users can lead designers to explore opportunities for future growth and evolution that may be missed based on their preconceived notions of who the users are.

Remaining open to future potentialities is important in the discovery process of technology innovation (Callaghan, 2018). The "mutually assured diversity" law suggests that openness is necessary for the co-evolution of capabilities to manage emergent and boundaryless technologies at an accelerating rate. Futures studies bring with it an understanding that a problem often has multiple solutions. Thus, an innovative foresight is required to develop possible solutions based on fringe technologies, emerging trends, and probability. Like design in general, IS design involves a process of "mental window shopping" that researchers explore by envisioning improved practices and artefacts. In line with this, IS researchers have started to explore the generativity of digital artefacts, in the form of properties embedded in social structure that invite actors to create unanticipated outcomes or patterns of events that lead to evolutionary dynamics producing unanticipated change (Eck & Uebernickel, 2016). IS design with strong generativity allows the artefact to extend and improve in myriad ways as it evolves to contribute towards a more holistic solution of the problem. Although the future, like the Promethean fire, is on a scale that we cannot possibly envisage at the present (Conboy, 2019), we can still identify the preferred future and attempt to realise it (Dator, 1996).

5.3. Design and development

This activity focuses on determining the IT artefact's desired functionality and architecture (Peffers et al., 2007). Design can draw upon multiple design theories to construct a nexus for developing effective problem-solving artefacts, especially when the problem is ill-structured or wicked (Pries-Heje & Baskerville, 2008). Based on futures research, we identified two guidelines to ensure that design decisions are informed by possible futures and actively shape a better future.

Guideline 4: Adapt to futures. Sardar's (2010) fourth law of futures research calls attention to its "futureless" nature, that is, the future is fundamentally unknowable and we can only change the present. Such perspectives often have little interest in the likelihood of envisaged futures. Instead, the broader task is to promote critical thinking about alternative trajectories of change without falling prey to the impossible task of predicting the future. For IS design, this suggests the need to be aware that functions will change, new functions might need to be added, and the architecture relating them will evolve. Awareness of futures helps to determine the extent to which a design needs to be flexible and responsive to potential changes in order to remain relevant and valuable in future (Kumar & Stylianou, 2014). Flexibility can be multidimensional – Structural flexibility reflects the ability of IS to adapt to changes and is proactively designed, while process flexibility is the ability of users to make changes to the IS (Nelson & Ghods, 1998). For example, Mikalef et al. (2020) showed that IT flexibility due to modular IT functions enables the dynamic capability of responding to emerging threats and opportunities in the external environment. Modularity allows new systems of configurations by adding new or recombining existing functions, which accelerates the process of learning and strategic repositioning. Although adaptive methods of IS design and development such as agile IS are well established, their value in supporting the evolution and coevolution of problem and solution space in design science research is rarely recognised and realised (Conboy et al., 2015). In FRDR, being adaptive is integral since the future cannot be fully envisaged in the present.

Guideline 5: Shape the future. A more constructive approach to futures indicated by Sardar's (2010) fourth law is to deliberately pursue the most preferred future. "Futureless" means that the challenging work of eliminating problems needs to be done in the present and not retrospectively in the future. The focus of contemplating about futures is not one of predicting but of applications and endeavours – the doing of our inquiries. For IS design, this prompts the development of IT functions that are not just useful for addressing the problem when it occurs, but also minimising or even preventing its recurrence. Such functions might work by sensing and warning users of a pending recurrence of the problem, analysing historical data to offer deeper understanding of conditions triggering the problem, or educating users on how to prevent the problem from recurring. A growing number of IS studies are developing functions that provide such capabilities for action: Lin et al. (2017) designed a Bayesian multitask learning approach to analysing patient data, allowing healthcare providers to identify future adverse health events and provide preventive care; Kretzer and Maedche (2018) developed social nudges to steer users of a business intelligence system towards reusing relevant recommended reports rather than choo
sing between recommended reports randomly; Lowry et al. (2017) showed how specific IT design features that promote identifiability, monitor and evaluate awareness, and increase social presence can prevent cyberbullying; Silic and Lowry (2020) demonstrated how a gamified design of internal security training helped to change employee behaviour and prevent phishing incidents.

5.4. Demonstration

In the design science research process, showing users how the resultant IS artefact can be used to solve one or more instances of their problem helps them appreciate its value and motivates adoption (Peffers et al., 2007). As discussed in preceding guidelines, incorporating futures throughout the design process leads to an IS artefact that is more ready to adjust to changes. This should be demonstrated to users as well, as specified in the following guideline.

Guideline 6: Demonstrate future affordances. IS that is flexible allows users to change its materiality to achieve changed goals (Leonardi, 2011). The extent to which users change the composition of the materiality or their routines depends on their construction of a perception that the technology affords the possibility of achieving new goals. The concept of technology affordance refers to an action potential; that is, what an individual with a particular purpose can do with an IS artefact (Gaver, 1991). One key role of design is to make affordances easily perceptible to would-be users. In FRDR, this includes de monstrating current as well as future affordances, which are potentialities that could be materialised when necessary. Users should be made aware of how the IS artefact can be adjusted in response to changes in future and how it shapes the future through influencing present decision-making. For example, scenarios describing adaptations of the IS artefact (identified based on guideline 4) when initial assumptions change (identified based on guideline 1) can be presented; simulations that allow targeted users to visualise how decisions influenced by the IS artefact shape the future (identified based on guideline 5) can be provided; potential users who were not targeted but might find the artefact valuable for other purposes (identified based on guideline 3) could be invited to participate in demonstrations.

5.5. Evaluation

To measure how well the IS artefact supports a solution to the problem, this activity involves comparing the objectives of a solution to actual observed results (Peffers et al., 2007). In line with the purpose of engaging with futures in IS design activities to shape artefacts for creating a better future (Boland, 2002; March & Storey, 2008), the evaluation should include the extent to which the resultant IS artefact influences decisions shaping the future and the IS artefact's sustainability into the future.

Guideline 7: Evaluate influence on futures. As highlighted in Sardar's (2010) fourth law, the value of contending about futures lies in the present. The Futures Research Task Force Standards (Kuusi et al., 2015) specified "reference to action" as one of the key items, to emphasise that futures inquiry should inform decision-making and actions influencing the future. Just as choices made in the past determine the opportunities accessible today, decisions in the present generate path dependencies that influence the future. Futures research demands reflections on how the awareness of futures informs current decisions and actions to realise the preferable future (Glenn, 2009). In FRDR, this awareness is embedded in the design of the IS artefact. Evaluation of the IS artefact should therefore consider the extent to which it influences decisions shaping the future of the problem. Indicators of the influence include the significance of decisions, variety of decisions supported, reduction in uncertainty, weight in decisions, and adoption of decisions. Even IS artefacts that do not aim to provide decision support can lead to decisions impacting the future. For example, Silic and Lowry (2020) designed a gamified system with the objective of motivating users to embrace computer security training using various game design elements. Although the system does not detect the security risk of a computer behaviour, it is expected to strengthen users' knowledge of computer security and help them make more secured behavioural decisions in future.

Guideline 8: Evaluate sustainability. The evaluation of the resultant IS artefact should also engage with futures by assessing the extent to which it is proactively designed to minimise risks and will continue to be useful in future. The need to minimise sociotechnical risks and consciously avoid creating worse problems is highlighted in Sardar's (2010) first law on the wickedness of futures, while the importance of remaining open to new potentialities and possibilities is emphasised in the second law of mutually assured diversity. These criteria are also increasingly considered as significant IS quality requirements for sustainability. For example, concerned with both non-technical and technical longevity and evolvability, Lago et al. (2015) identified social sustainability and environmental sustainability to be among the key dimensions of software sustainability. The social dimension covers communities of people and organisations and factors that affect trust, social equality, justice, democracy, etc., while the environmental dimension is concerned with the long-term effects of human activities on natural systems, such as resources depletion, climate, and pollution. Through a study involving IS researchers and practitioners, Condori-Fernandez and Lago (2018) found that relevant indicators of social sustainability include confidentiality and mitigation of security or safety risks, while useful indicators of environmental sustainability include reusability and resource utilisation. Focusing on technical sustainability, which refers to the capacity to endure in changing environments, Venters et al. (2018) highlighted the importance of design decisions in structuring the system and its elements and their long-lasting effects that might increase the costs of revision. Accordingly, technical sustainability can be measured in terms of indicators such as modularity, understandability, portability, and modifiability.

5.6. Communication

This activity focuses on sharing design knowledge – detailing the problem and its importance, the artefact, its utility and novelty, the rigour of its design, as well as its effectiveness to researchers and other relevant audiences such as practising professionals (Peffers et al., 2007). As part of FRDR, this communication should also reflect the insights gained from accounting for futures throughout the design science research process.

Guideline 9: Contemplate implications for futures. In addition to documenting the design knowledge enriched with an awareness of futures guided by Sardar's (2010) laws, such as any revised assumptions around the problem, objectives leading to more responsible IS, applications realising the preferred future, adaptive artefact components, or functions that contribute to preventing or eliminating the problem in future, we suggest design science researchers to draw upon the inquiry into futures to describe risks and opportunities identified but not yet accounted for in the IS design. Even when it is not possible to address all issues in the initial design, it is important to envision them in order to generate improved versions of design that follow a responsible innovation path. They will become sources of ideas for further research, and more importantly, increase awareness about futures that can guide the design of emerging IS artefacts. Just as we can refer to technology foresight studies conducted by futures researchers to develop perspectives about the future, we can learn from one another's experiences as IS design researchers to collectively generate and refine imageries about IS futures. Barata et al. (2019) provided some suggestions for discussing the implications of IS research in terms of futures. Many of them are useful for FRDR as well: Clearly differentiate the discussion of futures from other parts of an article, preferably in a separate section; Clarify the purpose of the discussion (e.g., issues that require solution through further research or issues that should be accounted for in future IS design?); Identify the nature of futures discussed (e.g., probable or preferable IS futures?). Ultimately, the purpose of this communication is to uncover the meanings, interests, and social structures underpinning different perspectives of the future for building a cumulative knowledge base that promotes a more future-oriented approach to design science research.

6. Designing an outbreak analytics system using FRDR guidelines

The FRDR guidelines were applied to a design science research project aiming to instantiate an outbreak analytics system for managing the spread of Influenza A, an infectious respiratory disease. Initiated in January 2017, the project was a collaboration among researchers studying information systems and data science, a provincial health authority, and a healthcare technology company specialised in data-driven solutions. The outbreak analytics system was expected to improve the accuracy of modelling a metropolis occupying more than 2,000 square kilometres and populated with about 11 million people (among the world's 25 largest metropolis). It became clear early in the project that modelling accuracy is affected by virus mutation, which is a natural trait that

allows viruses to evade drugs or the human immune system. Therefore, the outbreak analytics system must be ready to deal with emerging respiratory diseases with unexpected clinical features. This prompted the project team to review both design science research and futures research for guidance on how to develop a more future-ready IS design. Insights from the review were crystallised into actionable FRDR guidelines (as detailed in the previous section) and applied throughout the design research process. The system was completed in December 2017 and went into operation in March 2018. In Jan 2020, the system was adapted and deployed to manage the spread of the Novel Coronavirus disease. This section details the sys
tem's design using FRDR and illustrates FRDR's value in terms of evidence related to the system's subsequent utilisation in COVID-19.

6.1. Identify problem and motivate

In this first design activity, we identified the practical challenge and its motivation, as well as the related class of research problems. Following FRDR, we listed key assumptions and reversed them to refine the problem statement accordingly. The practical challenge our project grappled with was to improve the accuracy of forecasting Influenza A in a metropolis. The metropolis saw an increase in positive cases by 98% since the previous year (January 2016) and the trend was expected to continue. Along with other respiratory patho
gens such as Middle East Respiratory Syndrome Corona virus (MERS-CoV), and more recently, Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), Influenza A viruses have been of concern because of the ir high transmissibility and history of global spread. Epidemic forecasting informs public health authorities and service providers about the potential geographical sp read and scale of such diseases for the planning of interventions and allocation of medical resources (Scarpino & Petri, 2019). Forecasting complements traditional surveill ance systems that present descriptive analyses and now-casting systems that provide real-time estimates by supporting prospective, rather than just reactive, decision-making.

The acceptance of forecasts by decision-makers and decision quality are critically affected by the accuracy of forecasts (Scarpino & Petri, 2019). In the metropolis targeted in our project, forecasts had been generated using the classic SIR model (Hethcote, 2000). The widely used model forecasts the spread of infections by assigning the population into compartments based on whether they are susceptible, infectious, or removed (recovered or deceased). The size of each compartment changes over time depending on clinical features such as a virus's infectivity, rate of recovery, and infection rate (fraction of the population that will be infected per unit time). It was observed in the metropolis that the SIR model had been overestimating infections in the early stages of an outbreak while underestimating infections in the late stages. The forecasts were generally not trusted by authorities and rarely utilised in actual decision-making.

To improve modelling accuracy for the metropolis, the project team diagnosed the need to better estimate the infection rate with data about people's contact with one another. This called for integration of clinical data with other data of different nature and sources, pointing to the class of IS problems on epidemic modelling with big data. Accordingly, the research problem was specified to be: How to improve the accuracy of outbreak modelling for a metropolis with big data? This problem continues to be significant in the long term: 68% of the world population is projected to live in cities by 2050 (United Nations, 2018); Epidemic modelling remains necessary as viruses tend to mutate genetically or recombine into new viruses to outfox human immunity (Petersen et al., 2020); Modelling accuracy will also continue to be a moving target due to this genetic nature of viruses.

Applying **Guideline 1** (reverse assumptions), the project team noted that several assumptions around the research problem no longer or could not be expected to hold permanently. First, as viruses mutate, new clinical features may emerge that require additional compartments in SIR modelling. For example, some viruses have a long incubation period during which the infected individuals are not able to transmit the pathogen to others. To better model the spread, a new compartment of "exposed" individuals should be considered. More generally, this suggests that epidemic models should be adaptable to "disease X". Second, SIR assumes a well-mixed population, that is, an individual is equally likely to come into contact with any other individuals in the population (Hethcote, 2000). This overlooks the fact that contacts are much more likely among individuals who are geographically and socially closer. Further, in a large metropolis, there are often many spatially segregated sub-populations connected by an urban mobility network rather than a homogenous population. This suggests that an epidemic model for metapopulation is needed. These considerations due to Guideline 1 led us to refine the research problem to: How to improve the *adaptability* of outbreak modelling for a metropolis *metapopulation* with big data (see Table 3)?

6.2. Define the objectives of a solution

Based on the research problem formulated, it was obvious that the objectives should include increasing system adaptability, modelling accuracy, and user confidence in decision-making. Applying FRDR guidelines foregrounded two other objectives that were not initially clear. Following **Guideline 2** (commit to responsible IS), we contemplated the potential socio-technical risks and set objectives to minimise them.

Table 3. Design decisions affected by FRDR.

Design Activity	Initial Design Based on DSR (Peffers et al., 2007)	Design Enhanced with FRDR Guidelines	Design's Usefulness in COVID-19
Identify problem and motivate	**Problem**: How to improve the accuracy of outbreak modelling for a metropolis with big data? **Class of IS problems**: Outbreak modelling with big data **Motivation**: Accurate modelling supports prospective decision-making in the planning of health interventions and medical resources	**Assumptions reversed**: As viruses mutate, new clinical features may emerge that require additional compartments in SIR modelling; A metropolis consists of sub-populations connected by an urban mobility network rather than a homogenous population **Problem reframed**: How to improve the *adaptability* of outbreak modelling for a metropolis *metapopulation* with big data?	The system was adapted to account for the asymptomatic population in outbreak modelling
Define the objectives of a solution	**Objectives**: Increase modelling accuracy, confidence in decision-making, and system adaptability **Solution**: An adaptable epidemic model incorporating urban mobility	**Commit to responsible IS**: Privacy should be preserved when using mobility data; Be aware that members of the public and businesses might use the forecasts for unintended purposes **Envisage applications for the preferred future**: Promote preventive behaviours by providing a flu index service based on epidemic forecasts **Added objectives**: Preserve privacy, promote preventive behaviours **Revised solution**: An adaptable epidemic model incorporating urban mobility *without requiring individual data*, with accompanying *flu index*	COVID-19 forecasts provided by the adapted system had satisfactory accuracy; The adapted system provided the earliest forecasts available in the country
Design and development	**IS artefact to instantiate**: Outbreak analytics system embodying the epidemic model designed **Functions**: Model and estimate spread, calculate flu index, adjust model to emerging viruses	**Adapt to futures**: Use modular design, avoid hardcoding, ensure scalability **Shape the future**: Leverage the proposed epidemic model for interactive simulations	The system was scaled up to analyse data updated daily and provide national forecasts
Demonstration	Functions of practical interest to targeted users: Model and estimate spread, calculate flu index, simulate spread	Functions to demonstrate future affordances: Adjust model to emerging viruses	Users were aware of and actualised the system adaptability for COVID-19
Evaluation	Evaluate objectives, e.g., modelling accuracy, perceived privacy	Evaluate influence on decisions affecting the future and sustainability	The system was used to simulate the impact of lockdowns and safe-distancing measures for decision-making
Communication	Communicate knowledge generated	Communicate how engaging with futures influenced the proposed epidemic model and the design of outbreak analytics systems; Discuss implications for designing the future	Awareness of sociotechnical risks prompted the provision of interpretations in natural language when publishing forecasts on social media

Specifically, the mobility data used in our epidemic modelling included GPS-based taxi trajectory data and cellular mobile station data. Although they were anonymised, it was still possible to identify individuals through cross-referencing. With the objective of minimising any privacy risks, we decided to design an epidemic model using only aggregate data. Two aggregate values representing mobility were chosen after experimentations: traffic volume of taxies that carried passengers between sub-population zones (derived from the taxi trajectory data) and number of visitors between zones (summed from the mobile station data). This design eliminated any privacy concern as the instantiated system would not require any individual-level data as inputs.

Prompted by Guideline 2, we also looked beyond the targeted users to consider other potential users or stakeholders based on the scenario that the model forecasts would become publicly available on the Internet. Other than the targeted users of public health authorities and healthcare service providers, we realised that individual members of the public and for-profit businesses might be interested in the forecasts and this could generate some sociotechnical risks. Individuals might use the forecasts to decide how they access healthcare resources – they might travel to areas deemed less infected or more resourceful in a bid to get faster medical attention. It is well established that people would travel even long distances for medical care (Connell, 2013). This movement could alter the disease transmission dynamics and worsen the spread of infections. Businesses might use the forecasts to predict the supply of raw materials and demand for their products. This has sometimes led to hoarding of supplies or price gouging with unethical consequences for consumers (Rapp, 2005). We documented these potential risks with the intention of informing the development of new objectives in future as the system evolves in use.

As suggested by FRDR **Guideline 3** (envisage applications for the preferred future), the project team conceived the proposed epidemic forecasting model as part of a more holistic solution to outbreak management that serves to eliminate respiratory diseases. To stop infections, preventive behaviours such as vaccination, regular hand sanitisation, and safe distancing from symptomatic individuals are among the most effective (Wu, 2003). Accordingly, the team recognised an opportunity to use the model forecasts to promote preventive behaviours by designing a flu index service. The index provides an easy-to-interpret indicator of the prevalence of flu in the community. To be published weekly on the provincial health authority's website, the index consists of four levels defined in terms of the expected number of infectious people and offers straightforward behavioural suggestions for each level of flu prevention, such as ensuring good air circulation and avoiding crowds.

6.3. Design and development

Based on the formulation of problem and definition of objectives in the preceding design activities, the IS artefact to be instantiated was specified to be an outbreak analytics system embodying an epidemic model based on mobility data. The key functions should include modelling and estimating the spread of infections, calculating flu index, and adjusting the model to emerging viruses. In modelling and estimation, we first developed a complex network model based on power-law distribution and mobility data to infer metapopulation mobility (Wang et al., 2018). The network model was then used to extend the classic SIR model to account for metapopulation and transmission dynamics among sub-populations. Finally, the infections were estimated using a semi-supervised Proximal Gradient Descent algorithm.

FRDR guidelines prompted us to design a more adaptable architecture, even though it was not a system requirement for the project. Following **Guideline 4** (adapt to futures), we intentionally adopted a modular design and avoided hardcoding when developing the outbreak analytics system, to allow for the addition of unforeseen functions or potential integration with other systems used by the provincial health authority (Kumar & Stylianou, 2014). For example, visualisations of the epidemic model and estimations were created using a responsive design that automatically adjusts to different computer screen size. The system was also designed to be scalable to accommodate larger datasets.

The application of **Guideline 5** (shape the future) ins pired the team to explore how the proposed functions co uld be further enhanced to support decision-making and strategy formulation more directly. This led to the recognition of an opportunity to leverage the proposed epidem ic model for simulations. Simulations allow users to visu alise the spread of a disease in different conditions and sce narios (Chao et al., 2010). Interactive simulations are use ful for experimenting with different outbreak management decisions and strategies before the actual impleme ntation. For example, our proposed model would allow users to visualise how the magnitude and location of initial infe
ctions would affect the subsequent spread of a disease and explore different measures to limit population mobility.

6.4. Demonstration

As in a typical design science research project, we demonstrated the outbreak analytics system to targeted users, that is, staff members of public health authorities and healthcare providers. Functions that were of immediate and practical interest to users were explained, including modelling and estimating spread, calculating flu index, simulating spread, and customising visualisations. To increase users' confidence in the system, we explained how forecasts were made, how to interpret forecasts, and how well the forecasts performed. The users provided suggestions for improving the interface design of the system, such as the organisation and data labelling of charts. As recommended by FRDR **Guideline 6** (demonstrate future affordances), we highlighted how the system could be adapted in future, while being mindful of the fact that users have limited time, attention, and memory for the demonstration. Instead of presenting all possible ways the system could be adapted in future, we focused on getting the key message across by showing how the epidemic model can be adjusted to account for new clinical features and referred users to documentations for other possibilities and scenarios. Overall, the demonstration was designed to increase users' awareness that the system can be adjusted in future when the need arises.

6.5. Evaluation

According to the objectives identified earlier, the outbreak analytics system was evaluated in terms of modelling accuracy and perceived privacy. Modelling accuracy was assessed in two ways: (1) Comparing our epidemic model based on Power-Law Distribution with models based on classic time series forecasting techniques such as Autoregressive Integrated Moving Average (ARIMA) and Long Short-Term Memory (LSTM) in terms of Mean Absolute Percentage Error, and (2) Comparing our model estimations with the actual spread of Influenza A during May to July 2017 in terms of Cosine Similarity (see Figure 2). Perceived privacy was evaluated qualitatively after demonstrations – all participants agreed that there was very little privacy concern.

As suggested by FRDR **Guideline 7** (evaluate influence on decisions), we evaluated user confidence in decision-making. Users unanimously believed that the system was more accurate than that based on SIR and they were more confident of its estimations. The provincial health authority adopted the system for planning healthcare resources and started providing the flu index service on its website since 2018. Following **Guideline 8**, we evaluated sustainability: The proposed epidemic model was as efficient as existing models in terms of processing time; Users agreed that maintenance of the frontend was straightforward and appeared to be minimal; They also considered the system to be more portable, as it could be adapted to estimate the spread of emerging viruses with new clinical features and be extended with additional functions.

6.6. Communication

The key knowledge generated in the project includes the metapopulation epidemic model incorporating mobility data and design principles for outbreak analytics systems. FRDR had substantial influence on the resultant knowledge. For the epidemic model, reversing of assumptions (Guideline 1) led us to focus on metapopulations and incorporate mobility data, while committing to responsible IS (Guideline 2) foregrounded the requirement to preserve privacy. For the outbreak analytics system, reversing of assumptions (Guideline 1) prompted us to consider adaptability as a key design principle, while envisioning of applications for the preferred future (Guideline 3) highlighted the importance for such systems to promote preventive behaviour; Without FRDR, we would have missed the opportunity to incorporate the valuable function of simulation (Guideline 5).

Following **Guideline 9**, implications for futures were also drawn. As identified earlier, the epidemic forecasts could become publicly accessible. For future IS design, risks related to the misinterpretation and misuse of forecasts by unintended users should be carefully mitigated before publishing forecasts; For future IS research, this calls for the development of solutions that facilitate the accurate interpretation of data models. An example of

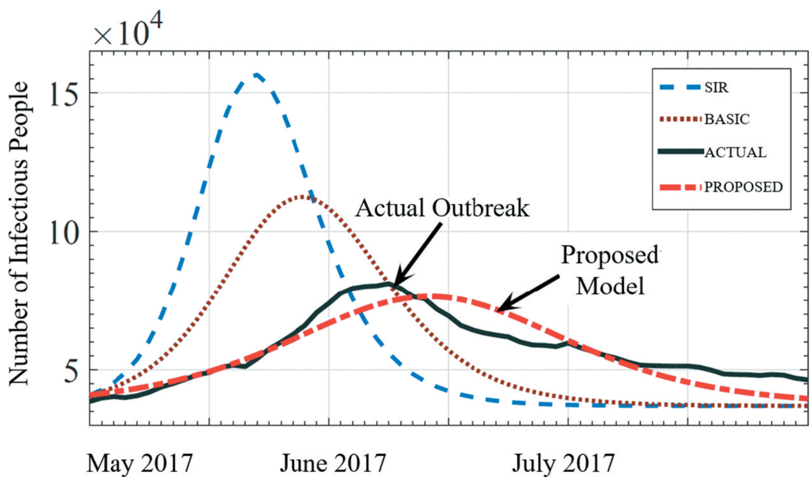

Figure 2. Comparison of estimated outbreak with actual outbreak.

such research incorporated natural language processing – Srinivasan et al. (2018) proposed a system that augments data visualisations with interactive data facts in natural language to aid users with varying expertise and experience. Regarding the use of the outbreak analytics system, a preferable future is one in which all densely populated metropolises and geographical regions adopt similar systems to prevent the spread of respiratory infections. While this is necessary as viruses do not respect borders, it can be challenging due to the political concerns around data access and sharing. For IS research, a deeper understanding of the sociotechnicality of government and public-private data sharing is needed. For example, Lnenicka and Komarkova (2019) proposed a conceptual foundation for such work by identifying the essential elements of a big and open linked data analytics ecosystem and describing the interactions among stake holders in terms of transparency, engagement, legal, technical, social, and economic dimensions.

6.7. Application of the outbreak analytics system in COVID-19

In December 2019, a novel coronavirus causing atypical pneumonia was identified and reported to the World Health Organisation. Human coronaviruses have been the main pathogens of respiratory infections, and the novel coronavirus was found to be significantly different in genome sequencing compared to the six existing types (SARS-CoV, MERS-CoV, HCoV-OC43, HCoV-229E, HCoV-NL63, HCoV-HKU1; Chen et al., 2020). In late January 2020, it was observed that asymptomatic persons were potential sources of infection, warranting a reassessment of the virus's clinical features and disease transmission dynamics (Rothe et al., 2020). The disease was named COVID-19 by the World Health Organisation on 11 February and declared a pandemic on 11 March. In response to the pandemic, our outbreak analytics system used to manage Influenza A was adapted to estimate the spread of the novel coronavirus. This section describes the observed impacts of our FRDR-guided design on the system's resilience against the emerging outbreak and effectiveness in informing public health response to a new disease.

Owing to users' awareness of the system's adaptability to viruses with different clinical features, the outbreak analytics system was swiftly adjusted to model the spread of infection by accounting for the asymptomatic population. Specifically, the original epidemic model was expanded to consider an additional "undiagnosed (but infectious)" compartment. The number of people in this compartment was estimated based on the virus's infectivity and the number of patient contacts. The resultant model had satisfactory accuracy – for example, it was able to forecast one-week spread with 4.64 percent error and two-week spread with 6.89 percent error in February (see Figure 3). The forecast was also the earliest available in the metropolitan among the six provided by different organizations. Overall, users appreciated the ease and speed with which the system could be adapted to estimate the spread of a novel virus (see the third column of Table 3).

To increase accessibility and enable rapid public health response, the forecasts were published on social media. In view of the risks of misinterpretation and misuse by non-experts as identified earlier in the project, interpretations for the estimations and suggestions were provided in natural language. During the pandemic, the system was scaled up in two ways: It was used to analyse data updated daily rather than weekly; It was also used to

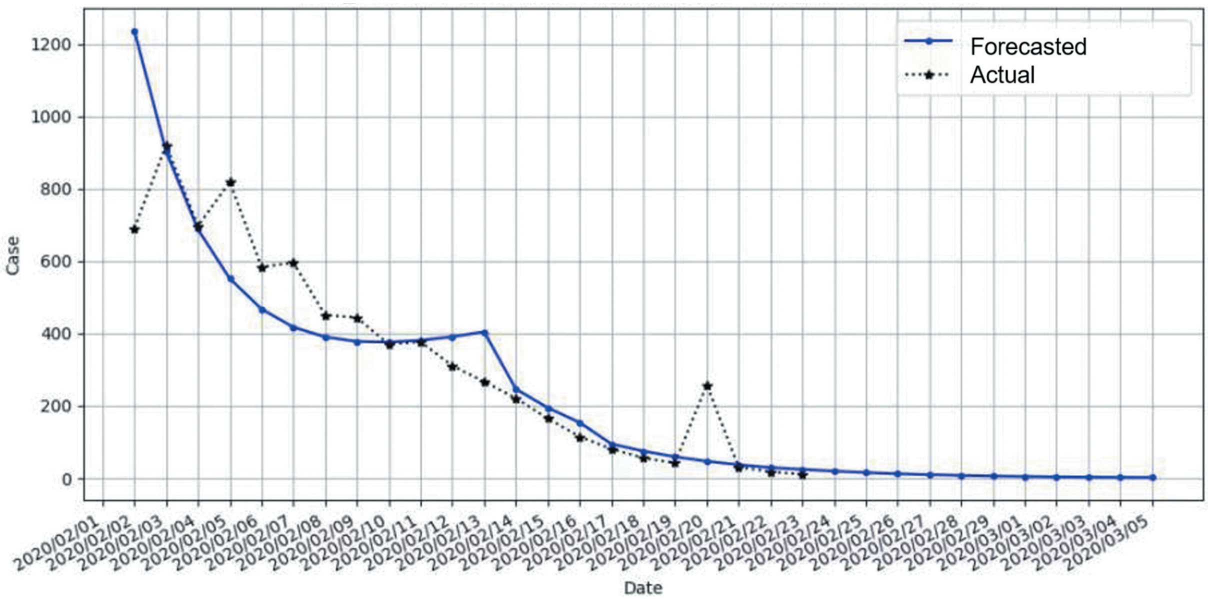

Figure 3. Forecasted versus actual number of confirmed cases.

estimate the spread of infection at the national, rather than just metropolitan level. The modified epidemic model was also used internally to simulate the impact of lockdowns and safe-distancing measures to inform the authority's decisions. Despite being one of the first places hit by the novel coronavirus in the country, the metropolis was able to flatten the infection curve within 26 days of the first confirmed case and kept the total infection to 40% below the national average.

The outbreak analytics system instantiated based on a FRDR-guided design process was evidently instrumental in the pandemic, even though the system was initially designed for managing Influenza A with different clinical features. The system was quickly adapted and used to estimate and simulate the spread of infections with high accuracy. Without the FRDR guidelines, the resultant system would have been less responsive and more limited in functionality (see Table 3). In our case, FRDR has led to a malleable IT artefact that is in a better position to respond to new demands and challenges and exploit opportunities.

7. Discussion

This article has identified a set of guidelines for future-ready design research, in response to practical needs for more resilient IS and calls for more future-oriented IS research that is relevant to the current as well as future practice (Chiasson et al., 2018; Conboy, 2019; Gray & Hovav, 2008; Markus & Mentzer, 2014). We have discussed the epistemic assumptions about futures that are well accepted in futures research but largely foreign in traditional IS scholarship. Integrating insights from future-oriented IS research and futures research, we have articulated guidelines that help design science researchers engage with futures in design decisions and activities while tackling a problematic situation. FRDR prompts researchers to account for futures throughout the design process, rather than treating futures as a discrete activity or merely as opportunities for follow-up projects. Given that design science research aims to shape artefacts and events to create a better future (Boland, 2002; March & Storey, 2008), we argue that futures is at least as important as the technical, social, and organisational elements of design emphasised in existing methodologies (e.g., Mullarkey et al., 2019; Peffers et al., 2007; Sein et al., 2011). The FRDR guidelines aim to increase researchers' awareness of futures that the design might need to adapt to. It also enhances IS design with a responsible foresight of sociotechnical risks, as well as an innovative foresight of the preferred future and its proactive realisation. In FRDR, foresight is not crystal ball gazing – it is the ability to adapt to the future and to drive changes with decisions and strategies that create a better future.

Our experience applying the FRDR guidelines suggests a cumulative effect – the more guidelines incorporated, the better the resultant IS artefact can avoid undesirable futures and play an active role in pursuing the best future. Many guidelines in FRDR are different from those that currently exist in design science research by prompting researchers to engage with futures earlier in key design decisions and activities. Specifically, the "reverse assumptions" guideline goes beyond acknowledging that assumptions can change to requiring researchers to examine new assumptions. This should be done earlier in the design research process, not just only in the evaluation activity as described by Hevner, March, Park and Ram (2004), because assumptions can affect problem framing. The "commit to responsible IS" guideline for defining objectives asks design researchers to take proactive steps in the present to minimise sociotechnical risks in the future, in addition to considering and identifying potential harm (Myers & Venable, 2014). The "envisage applications for the preferred future" guideline encourages researchers to shift from the typical problem-solving stance to considering how IT artefacts can be designed to prevent or even eliminate the problem for a more ideal future. To the best of our knowledge, prior design science research has mostly focused on demonstrating what an IT artefact is designed to do but not what it could be adapted to do in future ("demonstrate future affordances"), including studies that focus on affording users sensemaking support in terms of extrapolations and predictions (e.g., Seidel et al., 2018). The other guidelines, such as "adapt to futures" and "shape the future", are less unique to FRDR and have been mentioned or discussed in disparate articles, but they are integral to FRDR in that omitting them will prevent the meaningful incorporation of futures into the IT artefact instantiated and communication of future-oriented design knowledge generated.

Design science research can generate both descriptive and prescriptive knowledge. Descriptive knowledge includes observations, classifications, and measurements of natural, artificial, and human-related phenomena, as well as sensemaking relationships such as natural laws and theories; Prescriptive knowledge includes design constructs, models, design theory, or instantiations (Gregor & Hevner, 2013). The IS design knowledge generated through an FRDR-guided process is more future aware, forward-looking, and responsible. In our project, the new assumptions about epidemic modelling constitute a form of descriptive knowledge that is future aware – they focus on the use of artefacts in specific contexts, open our minds to new ideas, and serve to inform the formulation of research questions in further studies. Metapopulation is a construct of the proposed epidemic model representing prescriptive design knowledge that is forward-looking, as it significantly improves the model's predictive power and accounts for ever more connected mobility in the future. The design principle of preserving privacy is a form of prescriptive knowledge that promotes the responsible design of epidemic modelling systems in general. This also led to the development of a novel model that is more accurate but requires only aggregate data.

For the practice of IS design and development, FRDR facilitates the development of solutions and systems that are more adaptable, socially acceptable, and active in forg ing a path towards the preferred future. In particular, COVID-19 has cast a clear and sombre spotlight on the importance for IS to be adaptable and resilient. If anything is certain, it is that change is certain. Beyond the pa ndemic, the risk of deglobalization, driven by rising econ omic complexity, geopolitical divisions, and global recession, would further test the digital readiness of organisations. The future is seldom an immutable extension of the present and organisations are often unprepared to deal with sudden changes or ill-equipped to take advantage of unforeseen opportunities. Not accounting for externaliti es harms an organisation that does not do its homework in thinking about the future. IS researchers can contribute by going beyond being observers and sha
pe the future more actively. For the practice of design sci ence research, which is often costly in terms of time, effort, travel, and money, FRDR helps to ensure that the endeavour leads to IT artefacts that do not become outdated as soon as they are completed.

Although the future is always unknown, we cannot just sit and hope the best will happen. The divergent future may surprise us but our chances to endure depend on our readiness. We must remember that to some extent, decisions can be made today that influence the outcome of our future options. The future is unknown yet simultaneously we are active designers of the future. The underlying aim of FRDR is not to describe one true future but to enlarge the choices and opportunities, to set priorities and to assess impacts and efforts towards a desirable future. By engaging with futures throughout the design process, researchers can participate in reframing and recalibrating current IS design and development to provide a critical perspective while enabling the emergence of preferable futures. We believe that IS research and practice are best served by not separating discourses of futures from the central discourses of IS design, especially when seeking to generate usable, in-use, and useful (3U) impact on the direction taken by individuals, organisations, and societies (Pan & Pee, 2020). IS scholars increasingly recognise that technology encompasses actualities as well as potentialities that are unrealised yet realisable through alternative technical codes (Feenberg, 2010; Majchrzak et al., 2013). With the proposed FRDR guidelines, we hope to promote and support the shift from retrospective research to designing the digital future through active participation.

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