Human Factors and Ergonomics and the management of existential threats: A work domain analysis of a COVID-19 return from lockdown restrictions system

Paul M. Salmon | Nicholas Stevens | Scott McLean | Adam Hulme | Gemma J. M. Read

Centre for Human Factors and Sociotechnical Systems, University of the Sunshine Coast, Sunshine Coast, Queensland, Australia

Correspondence
Paul M. Salmon, Centre for Human Factors and Sociotechnical Systems, University of the Sunshine Coast, QLD 4558, Australia. Email: psalmon@usc.edu.au

Abstract
Following strict "lockdown" restrictions designed to control the spread of the COVID-19 virus, many jurisdictions are now engaged in a process of easing restrictions in an attempt to stimulate economic and social activity while continuing to suppress virus transmission. This is challenging and complex, and in several regions, new outbreaks have emerged. We argue that systems Human Factors and Ergonomics methods can assist in understanding and optimizing the return from lockdown. To demonstrate, we used work domain analysis to develop an abstraction hierarchy model of a generic "return from lockdown restrictions" system. The model was assessed to identify (a) issues preventing a successful return from lockdown; and (b) leverage points that could be exploited to optimize future processes. The findings show that the aim of continuing to suppress virus transmission conflicts with the aims of returning to pre-virus economic and social activity levels. As a result, many functions act against each other, ensuring that the system cannot optimally achieve all three of its primary aims. Potential leverage points include modifying the goals and rules of the system and enhancing communications and feedback. Specifically, it is argued that moderating economic aims and modifying how social and community activities are undertaken will result in longer term suppression of the virus.

KEYWORDS
cognitive work analysis, COVID-19, pandemics, systems thinking, work domain analysis

1 | INTRODUCTION

In most jurisdictions, the pre-vaccine response to the COVID-19 pandemic involved the implementation of a series of restrictive infection control measures commonly referred to as lockdown measures (Lonergan & Chalmers, 2020; Sahin et al., 2020). The specific nature of these restrictions has varied across countries and regions; however, common measures include physical distancing, use of personal protective equipment, self-isolation and quarantine, border closures, travel restrictions, and closure of schools and the service industries such as tourism, hospitality, entertainment, and fitness facilities. In many regions, the lockdown measures were successful and contributed to a stalling or reduction in the number of new cases; however, there were also significant adverse economic and social impacts (Lonergan & Chalmers, 2020; Pak et al., 2020; Sahin et al., 2020). As a result, worldwide an easing of lockdown restrictions has begun, with varying levels of success. Though some areas have managed to continue to suppress the virus, in many areas, such as Greater Melbourne in Australia (McGowan & Remikis, 2020) and Leicester in the United Kingdom (Murphy & Walker, 2020), easing of lockdown restrictions was followed by new outbreaks. This has resulted in a return to stricter lockdown measures, often more stringent than those enforced initially. How to ease lockdown restrictions in a way that supports continued suppression of the virus while...
stimulating economic and social activity is a complex and challenging issue that is currently subject to widespread debate (Raboisson & Lahermi, 2020; Sahin et al., 2020).

Systems thinking is a popular approach for responding to highly complex problems and as such has been identified as a suitable approach to help policy makers understand and respond to the COVID-19 pandemic (Blakely et al., 2020; Bradley et al., 2020; Sahin et al., 2020). Systems analysis and modeling methods such as causal loop diagrams (Bradley et al., 2020; Sahin et al., 2020), system dynamics (Ibarra-Vega, 2020), and agent-based modeling (Blakely et al., 2020) have been used in various applications to understand the factors influencing transmission and control of COVID-19. In recent times, systems Human Factors and Ergonomics (HFE) methods have also become popular in efforts aiming to understand and optimize complex systems (Hulme et al., 2019; Karsh et al., 2014; McLean et al., 2019; Salmon & Read, 2019; Salmon et al., 2017; Siemieniuch & Sinclair, 2014; Waterson, 2020). In this article, we argue that systems HFE methods can also be used to help inform governmental and societal responses to the COVID-19 pandemic. Systems HFE methods are suited to these applications as they support the description of entire systems, their component parts, and importantly the relationships and interactions between these parts. This form of holistic understanding enables analysts to identify so called "leverage points"; places in the system where small interventions could have significant impacts on a system's behavior (Meadows, 2008). The explanatory power of systems HFE methods is such that there are growing calls for their use as part of multi-disciplinary efforts which aim to respond to major global and societal issues, such as global pandemics and other existential threats (e.g., Salmon, Stanton, et al., 2019; T. Thatcher et al., 2018; A. Thatcher et al., 2020).

This article builds on these calls by presenting the findings from a study in which a popular systems HFE method, Work Domain Analysis (WDA; Naikar, 2013; Rasmussen, 1985; Vicente, 1999), was used to develop a model of a generic "return from lockdown restrictions" system. The aim was to describe the complexities surrounding the return from lockdown and to identify leverage points which could be exploited to support successful future easing of lockdown restriction processes. While the work was undertaken in Australia the intended audience is global, hence, the development of a generic WDA model.

More broadly, an aim of the study was to test recent assertions that systems HFE methods could be used alongside traditional public health approaches to respond to major global and societal issues (Salmon, Stanton, et al., 2019; T. Thatcher et al., 2018).

## METHODS

This study involved the use of WDA to develop an abstraction hierarchy model of a generic "return from lockdown restrictions" system.

### 2.1 Cognitive work analysis (CWA) and work domain analysis

CWA (Vicente, 1999) is a popular systems analysis and design framework that is typically used in applications that aim to understand and/or optimize complex systems (Bisantz & Burns, 2008; Stanton et al., 2017). The framework comprises five phases and provides a series of modeling approaches that focus on identifying the constraints imposed on behavior within the system under analysis (Vicente, 1999).

The first phase, WDA, is used to develop an event- and actor-independent model of the system under analysis (Naikar, 2013; Rasmussen, 1985; Vicente, 1999). This involves using the abstraction hierarchy method to describe the system across five levels of abstraction to identify the primary goals of the system, the processes and functions that are undertaken within the system, the values and criteria that are used to determine whether the system is achieving its goals, and the objects that are used when undertaking processes and functions. The aim is to describe the functional structure of the system of interest as well as its purposes and the constraints imposed on the actions of any actor performing activities within the system (Vicente, 1999). WDA has been applied in many areas for purposes ranging from the design of work processes (Lintern & Naikar, 2000), displays and devices (Ahstrom, 2005) to the design and analysis of regulatory frameworks (Carden et al., 2019), road environments (Read et al., 2017), and sports organizations (Hulme et al., 2019). Increasingly, the approach is being applied as part of systems HFE efforts to develop models of large-scale societal systems such as road transport systems (Salmon, Read, et al., 2019), cities (Stevens & Salmon, 2015) and even the world (Salmon, Stanton, et al., 2019).

The abstraction hierarchy method is used to describe systems according to the following five levels (Naikar, 2013):

1. **Functional purpose**: The overall purposes of the system and its reasons for existence;
2. **Values and priority measures**: The values that are assessed and used to measure the system's progress toward the functional purposes;
3. **Purpose-related functions**: The general functions of the system that must be undertaken to achieve the functional purposes;
4. **Object-related processes**: The processes that the physical objects within the system enable; and
5. **Physical objects**: The physical objects within the system that are used to undertake the object-related processes.

#### 2.1.1 Means-ends links

Abstraction hierarchy models use means-ends links to show the relationships between objects, processes, functions, values, and functional purposes. Within the abstraction hierarchy model, the linked nodes at the level above a node describe why that node is required, and the linked nodes at the level below describe how the node is achieved. For example,
for a particular function at the purpose-related functions level the nodes linked above represent the values and priorities that the function aims to support, and the nodes linked below represent the object-related processes that are undertaken to achieve the function. This is demonstrated in Figure 1 with a simple return from lockdown restrictions example showing the means-ends links associated with the function “Physical distancing.”

2.2 Abstraction hierarchy development

Initially, the aims of the analysis and analysis boundaries were defined. The aim of the analysis was specified as being to “develop a model of a generic return from lockdown restrictions system” which could be used to (a) help understand why returning from lockdown restrictions may not be successful, and (b) identify leverage points which could be used to optimize future returns from lockdown restrictions.

The boundary of the analysis was determined to be the purposes, values, functions, processes, and objects relating specifically to the easing of lockdown restrictions within developed countries. The model was to be both actor- and event-independent, meaning that it was not to include actors (e.g., politicians, infected people, healthcare practitioners), and was not based on a specific return from lockdown restrictions scenario in a specific country or jurisdiction. This condition was introduced to ensure that the conclusions and strategies identified were applicable across countries and jurisdictions. As a result, the focus of the analysis was on a generic return from lockdown restrictions system.

An initial draft of a return from lockdown restrictions abstraction hierarchy model was developed by the first author who has extensive experience in applying WDA in a range of domains (e.g., Jenkins et al., 2008; Salmon, Read, et al. 2019; Salmon, Stanton, et al., 2019; Stanton et al., 2017). Development of the draft abstraction hierarchy involved systematically building each abstraction hierarchy level using Naikar’s (2013) prompts to identify relevant nodes (see Table 1, e.g., prompts for each level of the abstraction hierarchy). This process involved starting with the functional purposes level and work down through the abstraction hierarchy levels. Publicly available documentation and peer-reviewed literature regarding COVID-19 lockdown restrictions or ways in which restrictions were being eased was used to support this process (e.g., Bradley et al., 2020; Ibarra-Vega, 2020; Sahin et al., 2020; World Health Organization, 2020). Examples of publicly available documentation include government and specialist agency documents providing advice on restrictions, physical distancing, mask wearing, travel, ongoing support, advice for specific populations (e.g., aged care) as well as resources such as fact sheets and situational updates. As the model was generic, the review of documentation covered multiple governments as well as international agencies such as the World Health Organization.

Once a draft set of nodes were identified, means-ends links were used to specify the relationships between nodes at different levels of the abstraction hierarchy. This process resulted in a draft abstraction hierarchy model.

Each of the additional four co-authors independently reviewed the draft abstraction hierarchy model and provided feedback. As shown in Table 2, each co-author has extensive experience in applying WDA in different areas, including global existential threats (Salmon, Stanton et al., 2019), regulatory systems (Carden et al., 2019), transport (Read

**FIGURE 1** Example social distancing means-ends links
et al., 2017; Stevens & Salmon, 2016), elite sport (Hulme et al., 2019; Mclean et al., 2017), and land use planning and urban design (Stevens & Salmon, 2015). The first author subsequently revised the model based on the feedback provided, leading to the creation of a second draft version of the model. A workshop involving all five co-authors was then held to finalize the model. This involved working through each level of the model and discussing each of the nodes to confirm their inclusion in the model and finalize the terminology used. Additional nodes were added as necessary where omissions were identified. Where there were disagreements, discussion was held until there was agreement on all nodes.

### 2.3 | Evaluation of the model

The final version of the model was evaluated in two ways. First, a subset of Read et al.’s abstraction hierarchy prompt questions from Read et al. (2016) were used to identify issues such as conflicting functional purposes, values and functions and poorly supported purposes, values and functions (Table 3). This involved applying the prompts from Table 2 to the relevant level of the model and recording the resulting insights.

Second, the abstraction hierarchy model was reviewed to identify specific leverage points that could potentially be exploited to optimize return from lockdown restriction systems. Leverage points are defined as places in the system where a small change can lead to a large shift in system behaviour (Meadows, 2008). Meadows describes 12 leverage points that range from simply changing system constants and parameters, through to changing societal mental models and paradigms (Meadows, 2008). Of these, Meadows argues that most leverage can be found in information and control elements of the system rather than its physical parts. Accordingly, we reviewed the abstraction hierarchy model to identify instances of eight of the leverage points outlined by Meadows (Table 4). Only eight of the 12 leverage points were used as the remaining four represent physical structures which are less powerful when attempting to enact changes in system behavior (Meadows, 2008).

### 3 | RESULTS

#### 3.1 | COVID-19 return from lockdown abstraction hierarchy

The return from lockdown restrictions system abstraction hierarchy is presented in Figure 2.

#### 3.1.1 | Functional purposes

Three distinct functional purposes of the return from lockdown restrictions system were identified. “Continue to supress virus trans- mission,” “Return to pre-pandemic economic activity levels,” and “Return to community and social norms.” Continuing to supress virus transmission involves preventing new cases and maintaining the number of active cases below a set threshold. Returning to pre-pandemic activity levels involves stimulating the economy to a point at which the production and trading of goods and services returns to levels seen before the virus appearing. Returning to
3.1.2 | Values and priority measures

Sixteen values and priority measures were identified. These can be broadly grouped into four groups of values and priorities. The first group relates to the prevention of virus transmission and mitigation of its adverse health impacts, which include minimizing physical interactions, new cases, and deaths. The second group addresses the need to maximize stakeholder and community awareness. The third group includes a set of economic values and priorities, such as maximizing economic activity, minimizing job losses, and minimizing debt. The fourth group focuses on reputational values and priorities, with an emphasis on maximizing political capital and local reputation, while maximizing community and consumer confidence.

3.1.3 | Purpose-related functions

Thirty-one purpose-related functions were identified. These can be categorized into five groups of functions, including those relating to community and social norms, as well as those supporting economic and social activity. The purpose-related functions include physical distancing, personal hygiene, use of personal protective equipment, and personal protective equipment, as well as restrictions, contact tracing, self-isolation, and implementing quarantine programs. These functions are designed to support the prevention of virus transmission, including physical distancing, personal hygiene, and use of personal protective equipment. These functions are essential for maintaining community and consumer confidence, while maximizing economic activity and minimizing debt.

Table 2: Author demographics and experience in systems HFE, WDA, and public health

| Author | Gender | Age | Current position | Year PhD award and topic | Years’ experience applying HFE methods | Number of WDA applications (peer-reviewed publications) | Number of systems HFE applications (peer-reviewed publications) | Number of public health applications (peer-reviewed publications) |
|--------|--------|-----|------------------|--------------------------|----------------------------------------|--------------------------------------------------------|-----------------------------------------------------------------|------------------------------------------------------------------|
| Author A | Male | 43 | Professor human factors | 2008, HFE | 20 | 38 | 10 | 97 |
| Author B | Male | 48 | Senior research fellow, land use planning and urban design | 2013, land use planning | 6 | 11 | 19 | 7 |
| Author C | Male | 43 | Research fellow human factors | 2017, HFE and sports science | 4 | 8 | 22 | 4 |
| Author D | Male | 33 | Research fellow human factors | 2017, epidemiology and systems HFE in sports injury | 4 | 3 | 25 | 20 |
| Author E | Female | 38 | Associate professor human factors | 2016, HFE | 13 | 13 | 31 | 18 |

Abbreviations: HFE, Human Factors and Ergonomics; WDA, Work Domain Analysis
commerce,” “freight,” “Tourism and hospitality,” “education,” “transportation and travel,” “sport, leisure and physical activity,” “recreation and play,” and “continued sustainable development.” Purpose-related functions to support communication with the community include “Communicate guidelines and restrictions” and “Community education and reporting.” Finally, purpose-related functions undertaken to provide basic services include “provide healthcare,” “provide mental health services,” “infrastructure and services,” and “crime and anti-social behaviour prevention.”

Given the large number of physical objects that could potentially be included in the model, the physical objects level includes groups of related physical objects rather than the specific objects themselves. Specifically, groups of objects were defined as the set of objects that are used together to undertake required processes. For example, “private residential objects” and “public residential objects” are required to house individuals and families and also support the processes of “separation,” “quarantine,” and “personal hygiene.” The groups of physical objects are diverse and range from work, retail, health care, and education system physical objects to finance, research and development, policing and government system physical objects. In total, 29 groups of physical objects were identified along with 29 associated object-related processes.

### Table 3: Sociotechnical system design prompts (Read et al., 2016)

| Abstraction hierarchy level | Prompt |
|-----------------------------|--------|
| Functional purposes         | - Are there multiple purposes specified for the system? Do these conflict? |
|                             | - What factors within the system most positively influence the purpose/s? |
|                             | - What factors within the system most negatively influence the purpose/s? |
|                             | - Are any purpose/s of the system not well supported? |
| Values and priority measures| - Are there conflicting values and priority measures within the system? |
|                             | - Are the value and priority measures currently measured? |
|                             | - Do the value and priority measures have the potential to encourage functioning that does not support the purpose/s? How? |
| Purpose-related functions    | - What functions are well-supported by the object-related processes? |
|                             | - What functions are poorly supported by the object-related processes? |

#### 3.1.4 Abstraction hierarchy prompts

The findings from the analysis of the abstraction hierarchy using Read et al. (2016) prompts are presented in Table 5. The analysis revealed that the functional purpose of “Suppress virus transmission” and its related values and priorities and purpose-related functions conflict with the functional purposes of “Return to pre-pandemic economic activity levels” and “Return to community and social norms” and their related values and priorities and purpose-related functions. Specifically, conflict here means that it is not possible to fully achieve all three functional purposes. Rather, achieving one purpose will have a detrimental impact on attainment of the others. For example, at the time of writing (pre-vaccine) it is not possible to fully suppress virus transmission while at the same time returning to pre-pandemic levels of economic activity and community and social norms.

The analysis also identified several values and priority measures that are either not currently formally measured by authorities, or at least not reported as such, including physical interactions, personal hygiene, community and consumer confidence, compliance with restrictions, and local area reputation. In addition, it was identified that there are issues associated with the accuracy of the data gathered to measure certain

### Table 4: Leverage points (adapted from Meadows, 2008)

| Leverage point                  | Description |
|--------------------------------|-------------|
| Balancing feedback loops       | A stabilizing, goal seeking, regulating feedback loop which opposes or reserves change within a system, for example, using preventative medicine, exercise, and good nutrition to prevent disease |
| Reinforcing feedback loops     | An amplifying or enhancing feedback loop which reinforces the direction of change, for example, population growth whereby increases in the population result in increases in the birth rate which, in turn, increases the population and so on |
| Information flows              | The structure of who within the system does and does not have information |
| The rules of the system        | Incentives, punishments, constraints, rules and regulations |
| Self-organization              | The ability to add, change or evolve system structure, for example, adding new physical structures, balancing or reinforcing loops, or new rules |
| The goals of the system        | The purpose or function of the system |
| Paradigms                      | The mindset out of which the system, its goals, structure, rules, delays and parameters, arises |
| Transcending paradigms         | The ability to realize that no paradigm is true and that each paradigm is severely limited |
values and priorities, such as the number of new cases, and transmissions and outbreaks. Finally, an analysis of the number of supporting means-ends links revealed that, according to the model, the top three supported purpose-related functions are trade and economic activity, provide economic stimulus, and enforce restrictions. The least supported purpose-related function is continued sustainable development.

3.1.5 | Leverage points

Analysis of the abstraction hierarchy model revealed a number of potential leverage points (Table 6). As shown in Table 6, examples of seven of Meadows’s eight most effective leverage points were identified.

| Prompt                                                                 | Finding                                                                                                                                                                                                 |
|------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Are there multiple purposes specified for the system? Do these conflict? | Yes, three functional purposes were identified. The “Suppress virus transmission” purpose is in direct conflict with the “return to pre-pandemic economic activity levels” and “return to community and social norms” purposes |
| What factors within the system most positively influence the purposes?  | Suppress virus transmission: values, functions, processes, and objects relating to lockdown restrictions such as physical distancing, personal hygiene, management of borders, testing and tracing, and communication and enforcement of restrictions. Return to pre-pandemic economic activity levels: values, functions, processes and objects relating to economic activity such as work and employment, the provision of economic stimulus and welfare payments, and trade and commerce. Return to community and social norms: values, functions, processes and objects relating to the resumption of industry and basic services, including education, tourism and hospitality, sport, leisure and physical activity, recreation and play, and infrastructure and services. |
| What factors within the system most negatively influence the purposes?  | Suppress virus transmission is negatively impacted by factors relating to Return to pre-pandemic economic activity levels and Return to community and social norms. Return to pre-pandemic economic activity levels and Return to community and social norms are negatively impacted by factors relating to Suppress virus transmission. |
| Are any purpose/s of the system not well supported?                    | The three functional purposes are generally well supported; however, increasing support to the Suppress virus transmission functional purpose will have adverse impacts on the Return to pre-pandemic economic activity levels and Return to community and social norms functional purposes and vice versa. |
| Are there conflicting values and priority measures within the system?  | Yes. Some of the values surrounding Suppress virus transmission are in direct conflict with values surrounding Return to pre-pandemic economic activity levels and Return to community and social norms. For example, minimising physical interactions and maximising compliance with restrictions are in conflict with maximising economic activity and minimising job losses. |
| Are the value and priority measures currently measured?                | Many of the values and priorities are currently measured, such as the number of new cases, outbreaks, and deaths, economic activity, and debt. However, the accuracy of some of the measures is questionable (e.g., number of new cases). Values not currently formally measured include physical interactions, personal hygiene, community and consumer confidence, compliance with restrictions, and local area reputation. |
| Do the value and priority measures have the potential to encourage functioning that does not support the purposes? | Yes. Many of the values around economic activity and community and social norms encourage behaviour that does not support the functional purpose of suppressing virus transmission and vice versa. |
| What functions are well-supported by the object-related processes?     | The following purpose-related functions have the most directly linked object-related processes (5 and above): - Trade and economic activity - Provide economic stimulus - Enforce restrictions |
| What functions are poorly supported by the object-related processes?   | The following purpose-related functions have the least directly linked object-related processes (one): - Continued sustainable development |

Table 5: Analysis of abstraction hierarchy using Read et al.’s (2016) prompts
| Leverage point       | Examples within model                                                                 | Example interventions                                                                 |
|---------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Balancing feedback loops | The system is driven by a continuous balancing feedback loop whereby restrictions are put in place, virus transmission and cases decrease, restrictions are eased to stimulate economic and social activity, and virus transmission and cases increase, leading to a return to stricter restrictions | Disruption of this balancing loop by focusing the easing of restrictions not on stimulating the economy but on on increasing social activities which do not adversely impact virus suppression |
| Reinforcing feedback loops | Spread of the virus, for example, more cases lead to an increase in transmissions which, in turn, leads to further new cases and so on. Economic downturn, for example, the downturn in the economy caused by lockdown restrictions leads to further downturn in the economy as people lose jobs | Introducing further suppression measures and not easing restrictions until cases are either extremely low or eradicated completely. Changing social norms around how people interact, for example, encouraging online communications and exploiting technology to enhance online interactions. Slow the rate of unemployment through job keeper payments and small business subsidies |
| Information flows | Values, purpose-related functions, object-related processes and objects relating to “Communicate guidelines and restrictions” and “Community education and reporting” | Improvements to data collection and analysis tools and to the reporting and communication of key information. The provision of predictive forecasts around the likely future number of cases, hospital admissions, and deaths. The provision of additional community feedback mechanisms regarding restrictions, testing protocols, economic issues, and the ability to engage in community and social activities |
| The rules of the system | The restrictions put in place to suppress virus transmission such as physical distancing, self-isolation and quarantine, and closure of borders. The rules and regulations used within the various subsystems such as work systems, healthcare systems, transportation systems, education systems, finance system, and so on. | Modification of restrictions to focus on suppression of virus transmission and returning to community and social norms with less emphasis on returning to pre-pandemic levels of economic activity. Modifications to the rules around testing, such as allowing anybody to be tested and incentivising testing |
| Self-organization | Innovation and redesign. Various examples of self-organization within the purpose-related function of innovation and redesign. For example, small businesses such as restaurants and personal fitness instructors innovating and redesigning themselves to enable continued operation within lockdown restrictions and schools and universities moving to on-line learning. Social interaction. Various examples of self-organization within the purpose-related function of social interaction. For example, the use online communications platforms to support social events. | Investment and support for innovation through education, mentoring, and reducing constraints on small businesses |
| The goals of the system | The functional purposes “Suppress virus transmission,” “Return to pre-pandemic economic activity levels,” and “Return to community and social norms” represent the three core goals of the easing of lockdown restrictions system. | Modify the goals of the system to make virus suppression the primary goal, reduce the emphasis on economic activity, and modify the ways in the goal of returning to community and social norms can be achieved. Democratize rule-making by allowing the public to vote on the rules of the system. This could engender more buy-in for compliance. The expected consequences of decisions would need to be clearly articulated. For example, chose option 1 and we expect 1000 deaths (with a booklet showing 1000 photos and short bios of people who might be victims. Alternatively, chose option 5 and 50% of businesses go bankrupt, resulting in 10,000 job losses and 500 suicides (again, using photos of those affected) |
achieving functions such as physical distancing, self and gathering of people, which, in turn, increases the difficulty of likelihood of virus transmission. This is because many require the movement and commerce, and recreation and play combine to increase the like-
such as sport, leisure and physical activity, tourism and hospitality, trade elsewhere (Pak et al., 2020) and arguably leaves policy makers with two
tension between economic and health imperatives has been noted
vaccine, it is not possible to fully achieve all three functional purposes.

| Leverage point                  | Examples within model                                                                                                                                                                                                 | Example interventions                                                                                     |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| Paradigms                       | The core paradigms present within the system are a public health/prevention paradigm (e.g., “Suppress virus transmission”), an economic paradigm (e.g., “Return to pre-pandemic economic activity levels”), and a social paradigm (e.g., “Return to community and social norms”) | Acknowledge public health and social paradigms represent the primary purposes of the system and that the economic paradigm is better supported in the long term through attainment of the public health and social goals within the system |
| Transcending paradigms          | Removing any attachment to existing paradigms and acknowledging their limitations, allowing flexibility to choose whichever paradigm helps achieve system purposes                                                                 | Use of a tailored paradigms system in which certain sectors are restricted to one paradigm, such as restricting aged-care, hospitals, and vulnerable populations to a public health paradigm, but enable other parts to operate under an economic paradigm, such as the education and tourism and hospitality sectors. In addition, the profits from sectors operating under relaxed restrictions could be used to support sectors operating under stricter restrictions |

4 | DISCUSSION

The aim of this study was to apply a systems HFE method, WDA, to develop a generic return from lockdown restrictions abstraction hierarchy model. The findings are discussed below in relation to the abstraction hierarchy model and the issues and leverage points identified.

4.1 | Health versus the economy

The abstraction hierarchy developed by the authors indicates that the underlying structure of the return from lockdown restrictions system is based on three core functional purposes: one relating to public health, one to the economy, and one to community and social activities. The structure of the model suggests that the functional purpose of continuing suppression of virus transmission conflicts with the aims of returning to pre-pandemic economic activity levels and community and social norms. Many of the related values and priorities are also in conflict with one another and several purpose-related functions work against each other. For example, purpose-related functions that are designed to help minimize spread of the virus, such as physical distancing, self-isolation, quarantine, and border and travel restrictions also have the effect of limiting economic activity and community and social norms. This is because they are designed specifically to prevent people from gathering within the community. On the contrary, purpose-related functions designed to help initiate economic activity and community and social norms, such as sport, leisure and physical activity, tourism and hospitality, trade and commerce, and recreation and play combine to increase the likelihood of virus transmission. This is because many require the movement and gathering of people, which, in turn, increases the difficulty of achieving functions such as physical distancing, self-isolation, enforcement of restrictions, and management of borders.

A conclusion from the model is therefore that, without an effective vaccine, it is not possible to fully achieve all three functional purposes. This tension between economic and health imperatives has been noted elsewhere (Pak et al., 2020) and arguably leaves policy makers with two options until an effective vaccine is developed and sufficient numbers of the population are vaccinated: first, accepting that virus transmission can only be fully suppressed by removing or moderating economic and social imperatives (the “aggressive suppression” strategy; Coatsworth, 2020); or second, identifying an acceptable level of cases that can be effectively managed while efforts are taken to gradually increase economic and social activity (the “Goldilocks” strategy, Daley & Duckett, 2020). While both are viable options, the contents of the model suggest that any strategy which places an emphasis on facilitating economic and social activities as well as virus suppression will be unlikely to succeed from a public health perspective.

4.2 | Measures and the accuracy of data

The use of various measures to determine how well the return from lockdown restrictions system is performing was demonstrated. Indeed, such measures play a critical role in determining whether restrictions are relaxed or tightened. Analysis of the model using Read et al. (2016) prompts revealed that while some values and priorities appear to have associated measures and data, others may not be measured at all, or there are legitimate concerns over the accuracy of the data being gathered. For example, early analyses suggest that measures around virus transmission, such as testing for new cases, may not be totally accurate. Based on an analysis of the data presented in seven published studies, Kucirka et al. (2020) report that over 20% of cases may be being missed by testing due to false negatives and others have reported sensitivity rates as low as 59% (e.g., Ai et al., 2020). This is problematic as the number of cases is one of the key criteria used to determine how well the system is performing, and thus dictates whether restrictions are made stricter or are relaxed further. The findings from this study are thus in agreement with the widespread understanding that comprehensive and accurate measures relating to virus transmission are critical, as these will ultimately influence consumer confidence, further easing of restrictions, and levels of economic and social activity. This suggests that vaccine development work should be supplemented by efforts to enhance the
evaluate the model also revealed other core values and priorities relating to aspects of behavior that are potentially not being measured. These include physical interactions, which are not directly measured in most jurisdictions and are difficult to determine without technologies such as mobile phones (Mbunge, 2020). Moreover, there are often privacy and security concerns associated with contact tracking and tracing apps (Mbunge, 2020). As a result low sign-up rates have been reported for COVID tracking and tracing apps (at the time of writing Iceland’s Rakning C-19 penetration rate of 38% of the population is reported as being the highest worldwide (Johnson, 2020)). Likewise, personal hygiene is an important value and priority, however, is ostensibly not currently measured in any meaningful way. While there are obvious difficulties in obtaining accurate data on such values and priorities, the model suggests that the most comprehensive and accurate measures within the model relate to economic activity rather than virus suppression. This represents a clear challenge when attempting to manage virus suppression and thus it is recommended that exploration be made into the development of appropriate measures for the health-related values and priorities within the model.

4.3 | Leverage points within the return from lockdown restrictions system

Analysis of the model based on Meadows’s leverage points (Meadows, 2008) revealed various opportunities to optimize return from lockdown restriction systems. The first leverage point to note is the continuous balancing feedback loop which acts to prevent achievement of all three functional purposes. This is important as it explains the dynamic oscillation in cases as deaths and as the outcomes of pursuing conflicting functional purposes. Specifically, it is apparent that restrictions such as physical distancing, quarantine, and border closures are put in place, resulting in a decrease in virus transmissions and a subsequent relaxation of restrictions designed to stimulate economic and social activity. As a result of the desired increases in economic and social activities, virus transmission and cases increase again, leading to a need to return to stricter restrictions. This balancing feedback loop prevents the virus from being eradicated, and results in oscillations in the level of restrictions imposed. Without disruption of this balancing loop it is likely that many jurisdictions will remain in a cycle involving the continual tightening and easing of restrictions. As indicated by the other leverage points identified within the model, there are various ways to disrupt this balancing feedback loop.

According to Meadows, the goals of a system often present one of its most effective points of leverage. This is apparent in the return from lockdown restrictions system with the three functional purposes creating conflict and preventing the system from functioning optimally. The specific goals of return from lockdown restrictions systems are, therefore, a key leverage point which could be modified to achieve improved outcomes. This could involve either removing or moderating economic goals or modifying the targets associated with each functional purpose (e.g., identifying an acceptable and manageable number of cases). Importantly, while moderating the economic goals and focussing on virus suppression will likely create significant short-term adverse economic impacts, it has been suggested that this could be followed by rapid recovery and high levels of economic growth (Nicola et al., 2020). It is concluded that moderating the economic goals when returning from lockdown systems and restricting community and social activities to align with virus suppression measures could potentially have dramatic effects, including eliminating the virus completely.

The purpose-related function of community education and reporting supports the highest number of values and priorities, suggesting that it represents another leverage point. This is supported by Meadows who outlines information flows and their structure as an effective leverage point, with missing feedback identified as one of the most common causes of system failure (Meadows, 2008; Stanton & Harvey, 2017). Indeed, clarity of reporting and communication have been identified as an issue limiting the effectiveness of the response to COVID-19 (Verhagen et al., 2020). Further, risk awareness at the community level has been labeled as one of the most effective ways to slow or prevent transmission of COVID-19 (Chatterjee et al., 2020). This suggests that clear and effective communication and reporting around risks, restrictions, changes to the restrictions, and virus transmission is required to support a successful return from lockdown. In addition, the provision of accurate predictive forecasts around the likely future number of cases, hospital admissions, and deaths is useful. The use of multiple feedback channels is critical to ensure that all members of the population have access to relevant information. Interestingly, the use of social media for community education and reporting is shown in the model; however, the inability to verify accuracy and validity of information suggests that it may not be appropriate as a means for communicating critical information such as levels of transmission, restrictions, and advice on testing and quarantine. This finding aligns with other research which has demonstrated the detrimental effects of social media and fake news during the COVID-19 pandemic (Apuke & Omar, 2020; Islam et al., 2020).

Other leverage points were identified. The purpose-related function of innovation and redesign is an important function within the model and is characteristic of Meadows’s self-organization leverage point (Meadows, 2008). Evidence of self-organization has been seen with various instances of businesses modifying practices to continue to function within restrictions as well as families and friends shifting social activities into online forums. Encouraging further innovation and redesign could potentially be a key leverage point, particularly around community and social norms and how these can be achieved in compliance with virus suppression restrictions. This would be particularly powerful in conjunction with the reduced emphasis on economic goals suggested above, as it would allow the achievement of the remaining two functional purposes of virus suppression and returning to pre-pandemic community and social norms. Self-organization of the community whereby social activities are modified to enable safe interactions is thus one avenue that could potentially have significant positive effects in return from lockdown restriction systems.
4.4 Systems HFE and global issues

A secondary aim of this study was to further test the capacity for systems HFE methods to contribute to the management of major global and societal issues. The analysis provides further support for the notion that systems HFE methods can be used to help describe, understand, and respond to, highly complex global public health issues (Salmon, Stanton, et al., 2019; T. Thatcher et al., 2018; A. Thatcher et al., 2020). It is acknowledged that any HFE input should be made as part of multidisciplinary efforts involving a range of analysis methods; however, the capacity to develop in-depth models of overall systems, their components and how they interact to drive behavior is a key strength of systems HFE methods that should be exploited. Despite this, there is little evidence that HFE experts are directly involved in multi- and transdisciplinary programs which aim to develop strategies to manage and mitigate the impacts of major threats such as global pandemics. While the overarching aim of HFE is to optimize human health and well-being, and many of our methods allow us to understand and respond to highly complex issues, it seems that HFE is being overlooked when it comes to large-scale global issues that threaten humanity (Salmon, Stanton, et al., 2019). Further work, which aims to facilitate the contribution of HFE to the response to such issues, is therefore encouraged.

4.5 Study limitations

While the abstraction hierarchy was developed by a team of analysts with expertise in WDA, HFE, and systems thinking, and experience in apply systems HFE methods in various areas of public health, the model was not validated by experts from other areas such as disease transmission or economics, or from lower- to middle-income countries. Further research should explore conducting a formal model validation study through avenues such as subject matter expert workshops or a Delphi study. While the present analysis was intended to be a proof-of-concept analysis, the authors plan to engage in further work to further refine and validate the model.

5 CONCLUSION

This study has demonstrated the utility of using systems HFE methods to support the development of strategies designed to optimize the return from COVID-19 lockdown restrictions. WDA was used to develop a detailed model of a generic return from lockdown restrictions system and this was subsequently used to identify issues preventing a successful return from lockdown and leverage points that could be exploited to optimize future return from lockdown processes. It is concluded that there is a strong conflict between functions undertaken to achieve the aims of suppressing virus transmissions and returning to pre-pandemic levels of economic and social activity. Indeed, without an effective vaccine, the findings suggest that it will not be possible to achieve all three functional purposes. Rather, it is argued that reducing the emphasis on the economic aim, and modifying how social and community activities are undertaken, will result in more effective virus suppression. As demonstrated by this analysis, systems HFE methods such as WDA are useful to support government decision making around complex societal issues. It is, therefore, recommended that the HFE community use systems HFE methods and engage with other disciplines as part of the response to global and existential threats such as climate change and environmental degradation, extreme weather, overpopulation, food and water security, inequality, antimicrobial resistance, and instability in the world’s economy (Salmon, Stanton, et al., 2019).

ORCID
Paul M. Salmon https://orcid.org/0000-0001-7403-7086
Nicholas Stevens http://orcid.org/0000-0003-0046-9362
Gemma J. M. Read https://orcid.org/0000-0003-3360-812X

REFERENCES

Ahlstrom, U. (2005). Work domain analysis for air traffic controller displays. Journal of Safety Research, 36(2), 159–169.
Ai, T., Yang, Z., Hou, H., Zhan, C., Chen, C., Lv, W., Tao, Q., Sun, Z., & Xia, L. (2020). Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: A report of 1014 cases. Radiology, 2020, 200642. https://doi.org/10.1148/radiol.2020200642
Apuke, O. D., & Omar, B. (2020). Fake news and COVID-19: Modelling the predictors of fake news sharing among social media users. Telematics and Informatics, 45, 101475.
Bisantz, A. M., & Burns, C. M. (2008). Applications of cognitive work analysis. CRC Press.
Blakely, T., Thompson, J., Carvalho, N., Bablani, L., Wilson, N., & Stevenson, M. (2020). Maximizing the probability that the 6-week lock-down in Victoria delivers a COVID-19 free Australia. Medical Journal of Australia. https://www.mja.com.au/journal/2020/maximizing-probability-6-week-lock-down-victoria-delivers-covid-19-free-australia
Bradley, D. T., Mansouri, M. A., Kee, F., & Garcia, L. M. T. (2020). A systems approach to preventing and responding to COVID-19. EClinicalMedicine, 21, 100325. https://doi.org/10.1016/j.eclinm.2020.100325
Carden, T., Read, G., Goode, N., & Salmon, P. M. (2019). Sociotechnical systems as a framework for regulatory system design and evaluation: Using work domain analysis to examine a new regulatory system. Applied Ergonomics, 80, 272–280.
Chatterjee, R., Bajwa, S., Dwivedi, D., Kanji, R., Ahammed, M., & Shaw, R. (2020). COVID-19 Risk Assessment Tool: Dual application of risk communication and risk governance. Progress in Disaster Science, 7, 100109.
Coatsworth, N. (2020). Eliminating COVID is a false hope, but ‘aggressive suppression’ is working. The Age. https://www.theage.com.au/national/eliminating-covid-is-a-false-hope-but-aggressive-suppression-is-working-20200715-p55ce8.html
Daley, J., & Duckett, S. (2020). Australia’s endgame must be total elimination of COVID-19. Grattan Institute. https://grattan.edu.au/ news/australias-endgame-must-be-total-elimination-of-covid-19/
Hulme, A., McLean, S., Read, G., Dallat, C., Bedford, A., & Salmon, P. M. (2019). Sports organisations as complex systems: Using cognitive work analysis to identify the factors influencing performance in an elite netball organisation. Frontiers in Sports and Active Living—Sports Management and Marketing, 1, 1–56.
Ibarra-Vega, D. (2020). Lockdown, one, two, none, or smart. Modeling containing Covid-19 infection. A conceptual model. Science of the Total Environment, 730, 138917.
Islam, A. K. M. N., Laato, S., Talukder, S., & Sutinen, E. (2020). Misinformation sharing and social media fatigue during COVID-19: An affordance and cognitive load perspective. Technological Forecasting and Social Change, 159, 120201.
