USING SIMULATION GAMES TO ASSESS CRITICAL INFRASTRUCTURE RESILIENCE IN CASE OF PAYMENT DISRUPTIONS

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Abstract

This paper presents a theoretical outline, and a tentative assessment approach, for resilience in the fuel, food, and finance systems needed to create a gaming simulation environment. The purpose of developing the simulation gaming environment is to provide team-training to decision-makers in handling crisis situations in a multi-organisational context. Gaming simulation aims at representing reality and enabling an individual actor or a group of actors to experience the dynamics of the simulated system. The concept of core values and resilience value networks will be used to guide the simulation approach so that all core functions of a resilient system, as well as coping strategies, will be addressed in the gaming sessions.

1 INTRODUCTION

Infrastructures for fuel, food and payment systems become increasingly entangled (Ansell, Boin, & Keller, 2010) by being dependent on each other and on a large variety of support systems as well as other systems that provide services crucial for the function of the overall system. When a disturbance occurs, the resilience of these infrastructures depends on the ability to produce collaborative responses from individuals with diverse backgrounds that may not be familiar with side impacts in totally different areas. This is a challenging task in a complex environment such as the fuel, food and payment systems, and preparation in terms of training and development of strategies is crucial for the management of disruptions.

This paper presents the outline for a project (Creating Collaborative Resilience Awareness, Analysis and Action for Finance, Food and Fuel Systems in INteractive Games, CCRAAAFFFTING) aiming to develop a simulation gaming (a combination of role-playing games and computer simulation) that can be used to better understand how resilience is achieved and maintained during disruptions in the payment, food, fuel and finance system. The ultimate purpose of developing the gaming environment is to provide team-training to decision-makers in handling crisis situations in a multi-organisational context. Gaming-simulation (Laere, Vreede & Sol, 2006) aims at representing reality and enabling an individual actor or a group of actors to experience the dynamics of the simulated system. Given the variety of interpretations of resilience (Bergström, van Winsen & Henriqsen, 2015), resilience is hard to operationalize into useful strategies and measurable indicators. Lundberg and Johansson (2015) have therefore proposed the Systemic Resilience Model (SyRes) model as a way to describe process, functions and strategies on a conceptual level in an effort to synthesize different perspectives in the field of resilience research. The SyRes-model will be used to guide the simulation approach so that all core functions of a resilient system, as well as coping strategies, will be addressed in the gaming sessions. The project started in 2016 and initial data collections based on document studies, interviews and workshops with experts from the food, fuel and financial sectors reveal seven challenges for collective cross-functional critical infrastructure resilience that need to be dealt with: 1) Shortage of food, fuel, cash, medicine; 2) Limited capacity of alternative payment solutions; 3) Cities are more vulnerable than the countryside; 4) Economically vulnerable groups in society are more severely affected; 5) Need to maintain trust and prevent panic; 6) Crisis communication needs; 7) Fragmentation of responsibility for critical infrastructures across many actors (Laere et al, 2017). This paper presents the theoretical outline for understanding resilience in the fuel, food, and financial systems needed to create the gaming simulation environment, as well as an assessment approach for evaluating resilience in the gaming sessions.

2 UNDERSTANDING RESILIENCE IN CRITICAL INFRASTRUCTURE

"Resilience" as a term is certainly in vogue, and most any business, governmental agency or public actor has joined the chorus of aiming to become more resilient. However, the term is often used in a general fashion, without stating in what way something (a "system") should be resilient. Both Lundberg and Johansson (2015) and Bergström, van Winsen and Henriqson (2015) list that resilience amongst others can refer to: bouncing back to a previous state, or bouncing forward to a new state, or both; absorbing variety and preserve functioning, or recovering from damage, or both; and being proactive and anticipating, or being reactive (when recovering during and after events), or both. This is not surprising as the term largely emerged as a consequence of the realization that not all disturbances or threats towards a system can be predicted. Hence, safeguarding known or foreseeable threats will never be sufficient for coping with events that an increasingly complex environment potentially can throw at you. This has been discussed thoroughly in for example Hollnagel's description of Safety I vs Safety II (Hollnagel, 2013). Further, the term has been defined and re-defined so many times that it almost has become diluted, causing confusion and uncertainty regarding what actually is meant by resilience and what being resilient comprise.

Lundberg and Johansson (2015) made an effort to merge and compile different points of view in the field of disaster and crisis response resilience into one systemic model, the *Systemic Resilience Model* (SyRes). The model departs from the idea that the coping with an unwanted event can be seen as a downward spiral activating certain basic resilience functions (anticipation, monitoring, responding, recovery and learning) and their associated strategies (where the strategies are the actual manifestation of the functions, or their 'form', which may differ from system to system). Further, Lundberg and Johansson (2015) suggest that resilience is needed to protect *core values*, i.e. values central for the existence of the system in focus, or their "rational". In safety-critical systems, such core values usually take the form of maintaining safety, such as avoiding harm to humans or critical infrastructures. For a commercial business such as a grocery store, a petrol station or a bank, a core value is typical to create revenue, i.e. to assure a higher income than outcome. Without this profit, the business will seize to exist. This core value will manifest itself in a number of practical activities which usually take the form of different flows such as goods, money, services etc.

If we accept that all threats cannot be foreseen, and hence coped with by creating barriers, procedures and protection systems, then being resilient must be about what a system need to protect and preserve, its core values, instead of what threats it should be able to cope with. How to "invest" in resilience will therefore be a question about understanding what these core values are and in what way flexible approaches to protecting and upholding these values can be created. According to the SyRes-model, basic resilience functions such as anticipation, monitoring, response, recover and learning, with their associated strategies (the manifestation of the functions) can be coupled to each core value as a means for resilience. Naturally, the nature of the core value will impact in what way the function becomes manifest in terms of strategies, as well as what type of strategies are meaningful in relation to the specific core value. Also, the possibility that harm can come to the system and its values must be acknowledged. Investing in detecting and coping with potential threats is thus not enough. The system must be able to maintain core values also when situations occur that disrupt existing functions. For example, a business must be able to continue generating revenue even when payment systems fail, or at least assure that existing assets are not depleted and that readiness exists for rapid re-establishment of payment processes. As the reader probably already understands, this implies a set of core values for each system of interest, a *core value ladder*.

Asking a business owner what his or her core values are will probably render a number of answers ranging from the well-fare of employees, customer satisfaction, sustainable business plans, shareholder benefits and so forth. However, historical financial crisis situations have shown a surprising versatility when it comes to re-arranging businesses with the ultimate survival (on the market) as the primary objective. Firing large proportions of the workforce, moving business units to other countries, merging with similar firms, or simply selling of large proportions of the business are all well-known strategies for coping with unfavourable conditions. A disruption in the payment system may, at least for a small business, be at least as devastating for a smaller business as a financial crisis, especially if it occurs during an expected peak in sales. However, businesses, like most open systems, do not exist in a vacuum. Instead, the very pre-conditions for their existence are the exchange of flows with other systems (for the sake of the argument, we will henceforth describe each business as a "node" in the larger financial system).

Basole and Rouse (2008) looks at how "service value" can be created in a network context and how the structure and dynamics of the network, as well as customer expectations influence the complexity of the service eco system. Their approach aims to describe the nature, delivery and exchange of service value and direct and indirect relationships between value network actors. In a similar fashion, value networks can be used for understanding how networks of actors can create and consume resilience in a network. In the model of Basoule and Rouse (2008), consumers (although forming their own networks) are always the ones that realize value, as provides of service have no real purpose unless there is a consumer. In the case of resilience, there are differences regarding what "value" is and how it is exchanged between different actors. For example, in a situation where the credit card terminal fails, alternative payment solutions may be invented by customers, effectively rendering the customers the source of resilience rather than the business in itself. It should also be noted that while service value networks also have a degree of dynamics in terms of how relations between nodes emerge and disappears, a resilience value network often has to be initiated rapidly in a time of dire need, suggesting that the actual structure of the network may be hard to predict. Further, as core values of individual nodes may change in a crisis situation (according to the value ladders of each node), the *resilience value network* may also change (see Figure 1).

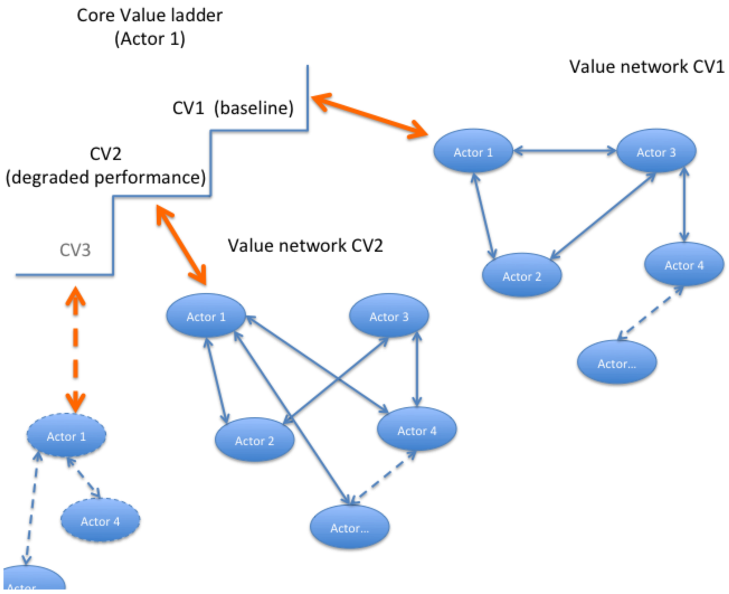

Figure 1. The core value ladder of an individual node in the resilience value network can potentially cause changes to the network if a node moves from one step on the core value ladder to another

Likewise, if the supplier flow of goods is interrupted for some reason, stores may be able to temporarily counter-act this by moving goods between themselves. This will help sustaining revenue, but the strategy will only provide resilience as long as there are collective resources in the network to pull from.

A basic condition for understanding the resilience value network is to understand how collaboration works, as collaboration allows for resilience "pooling". During a crisis event, stakeholders need to come together and seek solutions to problems. In the case of disturbances in the financial system, actors that do not normally cooperate may have to work together to create processes that help them uphold core values in their respective systems. Collaboration, in turn, is based on trust, the willingness to exchange information and the ability to take on roles that are responsible for specific aspects of problem solving. In practice, co-located actors need to form one or more teams that jointly try to cope with the problem at hand.

3 GAMING SIMULATION

A possible way of both investigating and improving system performance could be to challenge one or several actor(s) core values in a sufficiently detailed simulation. By adapting a learning-by-experience-based approach, stakeholders can be presented with challenging situations in a safe environment where they can test different approaches to coping with unusual or even unexampled events (Wachs et al., 2016). Such a simulation can take many forms, from tabletop exercises to full-scale exercises involving multiple actors. The latter approach can provide many opportunities for identifying how a resilience value network develops between different actors, but it is also a challenge as it may be difficult to capture and understand interactions between the involved entities. Indeed, it may be demanding and costly to create such a simulation as it can require involvement of very many actors, a large and cumbersome simulation management and a multitude of expert analysts in order to evaluate what actually took place and what it means. On the other hand, synthetic task environments "...can facilitate research in a safe and inexpensive setting and can also be used for task training and system design in support of tasks" (Cooke & Shope, 2004, p. 264). Caluwe et al (2012) and Daalen et al (2014) discuss extensively how simulation games successfully have been used to study the interaction between stakeholder decisions in complex design problems. Simulation-games can be used for exploring the feasibility of future policy alternatives, for studying and motivating organizational change, and as research tools to study the processes or organizational change, policy-making and stekaholder interaction.

Scenarios that are intended to be used for improving resilience must present events that *challenge the participating actors in such a way that they are forced to engage in collaborative problem-solving*. In typical training or exercise scenarios, participants are encouraged to apply known procedures or skill sets. This would not be the case when training to become more resilient. Rather, the capacity of the involved organizations needs to be challenged in situations that have not been prepared in advance. Preferably, *the scenario should demand information exchange with other actors or entities that they do not normally interact with as a way of challenging (and invoking) the resilience value network*. Creating events within the scenario that challenge these aspects is thus a core task for the scenario designer. Rome et al. (2016) models resilience in a gaming-simulation by distinguishing the impact of mitigating actions. For example, when citizens in case of a flooding either are informed to take preventive measures or evacuated in time, less damages and injuries/fatalities occur. Players can go back to earlier moments in the simulation and in that way explore alternative action paths and see the difference in consequences of their different mitigation strategies. Kurapati et al (2015) take a different approach and model resilience as balancing actions that serve individual department score versus the organizational score (the common interest of all departments). When the players collaborate (share information with the right departments, choose actions that serve the common interest) the overall organizational score benefits, and the organization is seen as more resilient.

4 ASSESSMENT

When doing any type experiments or evaluations of human (or system) performance, it is always challenging to identify appropriate performance measures. When assessing resilient performance, this is possibly even more challenging as there are few descriptions of what successful resilience *is*, how it manifests itself in terms of strategies and behaviours, apart from what can be found in different definitions such as to "recognize and adapt to handle unanticipated perturbations" (Woods, chapter 2 in Hollnagel, Woods & Leveson, 2006). A well-known paradox in all safety related activities is that what can be assessed before a critical event always has to be the potential for safety or resilience as it by definition is impossible to say if implemented measures are going to make a difference before an undesired event actually has taken place. In real-world situations, manifested resilience can naturally be assessed post-facto, but such an assessment may not be very informative as there always will be a high degree uncertainty in relation to how similar future events will unfold.

Another challenging aspect is to determine what "good" performance is from a resilience point of view? To successfully cope with an unwanted situation is naturally a potential indicator but avoiding the situation altogether would be an even better outcome. Success must always be related to some form of criteria. Using the SyRes-model and the concept of core values as a point of departure, we can conclude that a system can be seen as resilient if it can uphold its core value(s) by implementing successful strategies before the situation spirals out of control. The ultimate goal of a system must always be survival, and hence even moving on the core value ladder can be seen as resilient behaviour as long as it is done in a graceful and controlled fashion.

This suggests that in order to assess resilient capability, even in a simulation, a thorough understanding of what a system must protect and preserve must be achieved when designing the simulation and the scenarios used in it. After this, sufficiently challenging events must be presented in the simulation so that the involved participants must cope with them by innovation and collaboration. Coping with challenges to core values by applying resilience strategies should hence be the main task for the participants.

In terms of assessment points, this tells us something about what can, and should, be assessed when applying scenario-based simulation approaches for training and researching resilience in the financial system. One crucial aspect will be to assess whether the participants were able to protect their core values. What strategies did the participants implement to handle the situation? Could they avoid undesired outcomes of the critical events designed into the scenario? If not, it should be assessed what happened if they failed – was the core value abandoned for another value further down the core value ladder? If so, how did this transition take place? In case of a complete breakdown of a core value, what were the consequences? Could the participant(s) recover and regain their earlier core values?

Further, it should be assessed if they managed to cope with specific events that were designed to challenge their ability to innovate and collaborate. If the event was designed in such a way that it demanded collaboration in order to be solved, how quickly was this collaboration established? Could the participants agree upon actions to be taken? Furthermore, if collaboration is required to uphold the core values and the collaboration with other actors failed, does this lead to cascade effects in other organizations and how can these be assessed?

On the behavioural level, assessments need to be made that evaluate if the participants develop and maintain sound team processes and a shared understanding of the current problems. There are several team cognition approaches that can be applied to assess these aspects (see for example Wildman et al, 2013). Of specific interest is shared understanding on the strategic level, as it provides an understanding of how well the team of participants share goals and objectives (Berggren, Johansson & Baroutsi, 2016). From a learning perspective, it is important that the learning goals are defined and assessed, and that the simulation environment allows for feedback and reflection. Both feedback and reflection are considered as fundamental for organizational learning (Gabelica et al., 2014; Knipfer et al., 2013). Feedback is also a central aspect to monitor and regulate work, as described in resilience theory (Hollnagel, Woods & Leveson, 2006; Lundberg & Johansson, 2015).

5 DISCUSSION

"Resilience Engineering" has existed as a term for at least ten years (Hollnagel, Woods & Leveson, 2006). The approach emerged as a reaction to the increasing complexity and intractability of socio-technical systems, as well as the inability of the contemporary theories and methods on safety to explain, and cope with, the same unpredictability. During the course of the last ten years, a multitude of theories and conceptual models explaining what resilience is have been developed (Bergström, van Winsen & Henriqsen, 2015; Soden et al., 2015). Unfortunately, less effort have been put in the "engineering" of resilience engineering, the development of methods and approaches aimed to strengthen the resilience of a system (Anderson, Ross & Jay, 2015; Wears & Bradley Morrison, 2015). This is perhaps not all that surprising, as some ambiguity still exist regarding exactly what is meant by resilience. Indeed, less focus needs to be put on collecting success stories and instead focus on "understanding how build adaptive capacity; how and when to trigger it; how to control it, and by what types of control architectures; and how to husband it for future use (as opposed to squandering it on the everyday)." (Wears & Bradley Morrison, 2015, p. 57). This paper has described an effort to develop experience-based training for improving resilience in collectives of organisations that jointly must cope with disturbances in critical infrastructures needed for upholding the fuel, food and payment systems.

However, as governance of infrastructures in the payment system is a poorly understood area, our objective is two-folded in the sense that the simulation and training environment can be seen as a "digital playground", where researchers and stakeholders can investigate various relationships between factors in the payment infrastructures. Encouraging stakeholder collaboration in a simulated gaming environment can thus be seen as a resilience-enhancing intervention, while at the same time providing an opportunity for researchers to collect unique data that can increase the understanding of resilience in highly networked environments. By adapting a simulation and gaming approach, the objective is to strengthen inter-organisational resilience by training decision makers through an experience-based training approach. This involves identification and development of methods for assessing resilience-related measures that can be used to assess training in the simulated environment.

Utilizing a simulated environment further allows for investigating the relationship between potential resilience and manifested resilience. It can naturally be argued that simulations never will be able to reflect the intricate complexity of real-world situations (Brehmer & Dörner, 1993). However, claiming that simulated environments are useless for investigating how resilience manifests itself in different situations is also flawed. Rather, it is the model underlying the simulated environment and the participation of relevant stakeholders that decide what conclusions that can be drawn from findings from such studies. In this case, our effort is to create an understanding of the core values of the stakeholders as well as the interdependencies between the different stakeholders and their ability to create resilience within their network(s). By understanding what the stakeholders in the payment system wants to protect and what trade-offs they are willing to engage in to preserve their core values, we will hopefully increase our understanding of what resilience means in these system(s).

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