Ex-ante evaluation of disaster information systems: a gaming-simulation approach

Nitesh Bharosa
Delft University of Technology
n.bharosa@tudelft.nl

Marijn Janssen
Delft University of Technology
m.f.w.h.a.janssen@tudelft.nl

Harry Bouwman
Delft University of Technology
w.a.g.a.bouwman@tudelft.nl

ABSTRACT

Failures in coordination and information sharing between relief agencies have increased the number of calls for innovative information system (IS) designs. While both the academic and the industrial communities have proposed many IS designs, methodologies for the ex-ante evaluation of such IS designs are scarce. Consequently, disaster IS architects are offered little guidance in the ex-ante evaluation process. Not only is it difficult to evaluate IS designs in practice, it is also difficult to include the conditions of disaster situations in the evaluation process. This paper explores the difficulties of ex-ante evaluation and discusses the suitability of the gaming-simulation methodology for the evaluation of principle-based IS designs. Gaming-simulation entails the use of professionals, scenarios and prototypes and can be adapted to a quasi-experimental form enabling researchers to control contextual interferences and rule out alternative explanations. This paper concludes with some discussions on the advantages and pitfalls of employing gaming-simulation for IS evaluation.

Keywords

Principle-based design, gaming-simulation, quasi-experiments, IS evaluation, disaster response

INTRODUCTION

Previous research (e.g., Bharosa, Lee, & Janssen, 2010) mentions several obstacles for information sharing in disaster response networks including inconsistent information sharing procedures, processes, standards, and use of information technology. Complementary to the research on the obstacles in disaster information management there is an increasing amount of research being conducted on the design of innovative IS for addressing these obstacles (e.g.,Chen, Sharman, Rao, & Upadhyaya, 2007; Meissner, Luckenbach, Risse, Kirste, & Kirchner, 2002; Turoff, Chumer, Van De Walle, & Yao, 2004). These scholars have proposed various principle-based IS designs, often suggesting principles for improved coordination, information management and information quality. In this sense, principles are normative and prescriptive statements that are meant to guide IS architects and disaster managers in the design of innovative IS. Despite the potential of such IS designs for improving disaster information management, existing research has contributed little on evaluating principle-based designs. Moreover, many IS evaluation methodologies such as field testing, cost-benefit analysis and service level monitoring assume the implementation of such IS in practice and are therefore only employable for ex-post IS evaluation. Recently, the gaming-simulation methodology has been proposed for the ex-ante evaluation concepts and designs in large scale supply chains (Meijer, 2009). Gaming-simulation is a often applied methodology for awareness creation and learning in strategic management and policy formulation (Duke & Geurts, 2004). In the context of disaster management this methodology has proved to be useful for training emergency preparation (i.e., Walker, Ruberg, & O'Dell, 1989) and response (Belardo & Wallace, 1989; Kuwata, I. Noda, Ohta, Ito, & Matsuno, 2002; Mendonça, Beroggi, van Gent, & Wallace, 2006). However, existing literature provides limited insights into the advantages and pitfalls that can be anticipated when employing this methodology for the evaluation of principle-based IS designs. Accordingly, the objective of this paper is to explore the difficulties of ex-ante evaluation and discusses the suitability of the gaming-simulation methodology for the evaluation of principle-based IS designs. This paper contributes to existing literature by exploring the advantages and pitfalls of gaming-simulation for the evaluation of principle-based IS designs. This paper

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proceeds with a discussion on principle-based IS designs. Then we outline the key elements of gaming-simulation methodology, followed by the potential advantages and pitfalls.

PRINCIPLE-BASED INFORMATION SYSTEMS DESIGNS

Many scholars choose to communicate their disaster IS design in terms of principles. Principles are different from patterns that are often extracted from the comparison of several existing technical designs. Principles are often the result of experiences and cover both the social and technical layers of future designs. For instance, Turoff et al. (2004) published a set of general and supporting principles and specifications for a dynamic emergency response management information system (DERMIS). An example of a DERMIS principle is "the system directory should provide a hierarchical structure for all the data and information currently in the system and provide a complete text search to all or selected subsets of the material". Drawing on their experience in the US Military, Alberts and Hayes (2007) propose four high level IS design guidelines based on the concept of network-centric operations (NCO), which according to them and others (Van de Ven, Van Rijk, Essens, & Frinking, 2008) are also applicable to the disaster management domain. An example of an NCO based principle is "everyone should be empowered to download and upload information in the network". Taking a supply chain coordination perspective, Chen et al. (2007) discuss a set of principles focusing on the coordination of the multi-agency response process. Later, Bharosa and Janssen (2008) specified seven IS design principles such as "find the in-all-situations-necessary-information at the start of each disaster and post these at the information buffers". The following figure illustrates the use of principles in IS design.

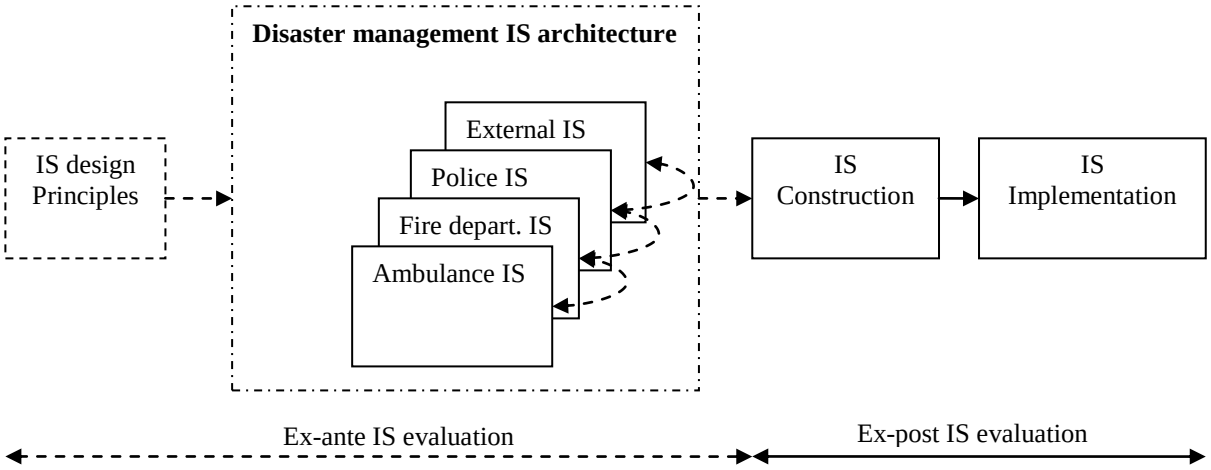

Figure 1: Principle-based IS design

In figure one the dotted lines illustrate the areas of concern in principle-based IS design, while the full lines indicate the area relevant for ex-post IS evaluation. The principles discussed earlier suggest some kind of improvement in the coordination and information sharing process between the autonomous IS. Instead of prescribing the development of a new IS, principles prescribe some reconfiguration or adaptation of architectural components such that a specific goal can be achieved (Bharosa & Janssen, 2008). However, even if the source of principles (i.e., historical events, experience and case studies) is well established and agreed upon, the principles themselves are difficult to evaluate in a direct way. There are two main reasons for this difficulty. First, principles by them self are generic and do not allow for any falsification without taking into account the specific context in which they are to be used. Hence, any evaluation method used should somehow recreate and incorporate the context of use in the evaluation process. For disaster management this means that a (part of) of disaster response network consisting of multiple agencies and ISs needs to be incorporated in the evaluation process. A second reason why principle-based designs are so difficult to evaluate lies in the lack of interaction with the end-users. Often, end users, or in this case relief workers, do not have any knowledge of the principles behind an IS. The relief workers can only judge the outcome of an information management process (i.e., the quality of the information shared) or the ease of use of a software application (interface). Hence, researchers cannot ask relief workers to judge the effect of the principles directly. When this type of direct evaluation is impossible, researchers can only measure the effect of applying principles by comparison to effects of not applying them. Accordingly, evaluating principles requires some form of quasi-experimentation in which at least two situations (with and without principle application) are compared. Based on these constraints, the evaluation of principle-based designs demands a methodology that: (1) includes the context of use in the

evaluation process and (2) allows for quasi-experimentation. Previous work (i.e., Meijer, 2009; Mendonça, et al., 2006) suggests that the gaming-simulation methodology is the only methodology that meets both constraints. We outline the key elements of this methodology in the next section.

GAMING–SIMULATION FOR PRINCIPLE-BASED IS DESIGN EVALUATION

The distinction between simulations and games is blurred and the two terms are often used inter-changeably (Kleiboer, 1997). According to Greenblatt (1988) games reflect players characteristics (goals, activities, constraints on what can be done and payoffs) and player decisions are important. Games are intended to let the individual participants gain certain insights and skills, within or without a specific context. Systematic feedback to participants is a crucial aspect of gaming, especially when they are used for teaching, training and planning purposes. Simulations on the other hand are operating models reflecting the core features of a real or proposed system, process or environment (Greenblatt, 1988). Simulation can be defined as "a conscious endeavor to reproduce the central characteristics of a system in order to understand, experiment with and/or predict the behavior of that system" (Duke, 1980). Hence, simulations can entail virtual participants since they are intended to generate output values related to different choices. Kleiboer (1997) mentions that two types of distinctions are relevant when designing simulations for research in the domain of disaster management. The first distinction involves the research objectives for which simulations are used. Researchers can use simulations for theory development or for more practical, applied problem solving. The second distinction concerns the methodological strategy. Here, simulations in which researchers explore phenomena in order to arrive at potentially relevant hypotheses (exploratory simulations) should be distinguished from simulations designed to test existing hypotheses (testing simulations). In these types of simulations, analysts attempt to probe aspects of crises by simulating them under controlled conditions in a laboratory. By systematically holding some conditions constant and manipulating others in successive runs of a simulation, the analyst can observe and measure the potency and assumed relationship between certain variables.

Based on above stated characteristics of games and simulations we can conclude that not all simulations are games and not all games are simulations, in the sense that they are not necessarily designed to epitomize part of the real world. There is also a hybrid form of gaming and simulation labeled 'gaming-simulation' mentioned in literature (e.g., Meijer, 2009; Mendonça, et al., 2006). Since we are also looking for ways to evaluate the performance of an IS, albeit in the form of principles (using simulation) in a quasi-realistic setting with real relief workers (using gaming), we prefer to use the term "gaming-simulation" to denote the evaluation research methodology we present in this paper.

Gaming-simulations are a simplification and condensation of a real system, allowing real participants to experiment safely with (future) technical and institutional designs, and reflect on the outcomes whatever type of simulation is used (Meijer, Hofstede, Omta, & Beers, 2008). In gaming-simulations, participants face quasi-realistic disaster situations and are asked to control the course of events as best they can. For example, Kraus et al. (1992) have developed the so-called Hostage Crisis Simulation to test hypotheses in crisis decision making. Their ultimate objective was the creation of a prototype automated negotiator based on a strategic model of negotiations. Over the years, gaming-simulations have taken different forms, yielding various blends of human actors and software applications. Starting from a baseline scenario ($t = 0$), gaming-simulations confront participants with a series of inter-related sequences including developments and problems that require decisions and actions on their part at times $t = 1$, $t = 2$, . . . $t = n$. These occasions for decision are fed to participants by the controllers (researchers) of the gaming-simulations according to a more or less fixed-script. Each new input into the gaming-simulation should serve a particular purpose and should be the focal point for observations, analysis and post-exercise feedback on the part of the controllers. The participants in gaming-simulations are usually enacting roles. As a group, they may be called upon to place themselves in the position of an individual or team operating in the given disaster context.

Anticipated advantages and pitfalls when employing gaming-simulation for IS design evaluation

Using gaming-simulation for IS design evaluation purposes has advantages for both participants and researchers. Let us start with the advantages for participants. Participants in the proposed style of gaming-simulation can experience the introduction of principles in a relatively safe environment. Gaming-simulations present participants with a setting that generates real-life experiences. In such settings, participants may discover that certain organizational or technical resources are lacking in their current practices. Moreover, participants may discover the needs of their agency they were initially unaware of, explore dilemmas, and begin to develop plans for the future. In addition, a gaming-simulation offers the unique experience of "sitting in the hot seat"—an experience that can otherwise only be gained by managing a real-life crisis (Flin, 1996). This is an important

advantage of gaming-simulation since most participants may have very limited experience with real disaster situations. A well-designed gaming-simulation generates the necessary awareness that disasters can actually occur and the required motivation to assess and improve the situation.

Researchers may also expect advantages when employing the gaming-simulation for evaluation purposes. First and foremost gaming-simulations offer researchers a safe and controlled environment in which to experiment with innovative IS concepts, albeit in the form of principles. Secondly, in contrast to other evaluation methods such as case studies and surveys, gaming-simulations are versatile and can be executed as quasi-experiments. As a quasi-experiment, gaming-simulations offer a relatively large degree of control on the part of the researcher. For instance, when planning subsequent rounds in a gaming-simulation, each round can entail different scenarios, choices and resources (i.e., information technology) allowing for a controlled issue of a specific treatment (IS design). Researcher can shape the controlled conditions in such a way as to resemble the characteristics deemed salient in the reference situation. For evaluation purposes, all the internal validity criteria, for instance as discussed by Shadish, Cook & Campbell (2002) are relevant, and have to be considered when evaluating the results of the gaming-simulation. Finally, for researchers, gaming-simulations can be very helpful in bridging the proverbial gap between theory (i.e., in the form of principles) and practice. Both the creation and the execution of gaming-simulations can provide researchers with new and additional insights with regard to disaster management related processes, including decision-making, coordination and information sharing.

However, in spite of all the merits and usefulness, researchers should consider at least four pitfalls when using gaming-simulations for evaluation purposes. First and foremost, simulations always differ from reality (Boin, Kofman-Bos, & Overdijk, 2004). Real disaster situations pose more problems and dilemmas than a simulation designer can imagine and incorporate in the gaming-simulation. Consequently, gaming-simulations cannot fully reenact the dramatics of real life-or-death decisions. In other words, "the distinction between major and minor issues is therefore always a bit more difficult to detect in simulations" (Ibid.). The second pitfall when employing gaming-simulations is that they follow fixed or pre-determined scenarios. From the very beginning, it is clear that the situation will escalate no matter what participants decide. An overload of pre-formulated messages and pre-designed interventions by the simulation staff almost guarantees that the participants will act and decide in accordance with the preconceived outcome of the scenario. This rigidity in format can easily undermine the success of the gaming-simulation, as participants begin to act in a resigned or lethargic manner when another disaster is imposed on them. A third pitfall is the lack of control of stakeholder preferences and motivation. In contrast to more controlled evaluation approaches, gaming-simulation requires broad and active stakeholder involvement. The use of such a stakeholder approach, and the adoption of users' satisfaction as a key evaluative measure, raises an interesting fundamental question in the hypothesis that there exists a strong relationship between users' satisfaction and system effectiveness (Klecun & Cornford, 2005). Consequently, a good IS design perceived to be poor by the stakeholders becomes a poor IS design. If the purpose of the gaming-simulation is to reach general conclusions rather than to train people, then human participation may even create much noise. For instance, a player can show inferior performance not because he is supplied with poor information but because he lacks 'feeling', gets bored, is confronted with superior opponents, etc. General conclusions require repeated runs with the gaming simulation. However, repeated runs are expensive or may even be impossible because of lack of players and resources. Moreover, repeated runs are not completely comparable since the players show learning, fatigue and so on. Note that relief workers are often occupied with daily operations and therefore may have very little time to participate in a multi-hour gaming-simulation. A fourth pitfall lies in the high level of control of the experimental conditions by the researchers mentioned as an advantage earlier. In contrast to pure laboratory experiments, not only the researchers, but also the participants, can change these conditions. For example, at the beginning of a gaming-simulation the rules of communication between players are usually outlined. During the course of the gaming-simulation, however, communication patterns may arise which deviate from the original rules set by the instructor; interaction between participants generates new rules and conventions.

DISCUSSIONS AND FUTHER RESEARCH

This paper is concerned with the evaluation of principle-based IS designs for disaster response. In contrast to the growing body of work in developing IS for disaster management, there is a dearth of research on how to evaluate these principle-based IS designs. There is a growing recognition in the disaster research community that IS evaluation should be concerned with more than just simple 'efficiency' metrics (such as cost-benefit metrics). Metrics capturing effectiveness and human factors are becoming equally, if not, more important. Compared to other IS evaluation methodologies (code testing, surveys and case studies), gaming-simulations allow for controlling contextual interferences and ruling out alternative explanations as prerequisites for construct and external validity. Despite these advantages, some pitfalls need to be considered which could influence the outcomes. These include respondent selection bias, moderation effects, and the potential of

learning effects. Drawing on the gaming-simulation methodology, this paper contributes to existing literature with a framework outlining the essential elements of a gaming-simulation design. Information system architects and researchers can apply and extend this framework in constructing and employing a gaming-simulation suited for evaluating IS designs. This framework has not been evaluated yet and sketches avenues for further research, for instance on the criteria for selecting participants and for appropriate scenario design, specifically addressing the danger of participant learning throughout the sessions. This papers puts forward a number of issues that complicate the evaluation of IS designs based on principles. Perhaps we raise more issues than we address in this paper. This reflects the dearth of research on evaluating IS designs prior to their implementation in practice. Therefore, we encourage both researchers and practitioners to apply, test, and extend the framework presented in this paper. Our future research includes the application of gaming-simulation for the evaluation of principle-based designs in the Netherlands. Some initials results will be discussed during the conference.

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