Complexity challenges of critical situations caused by flooding

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Abstract

In cases of flooding many authorities and organizations become involved and it can be a problem to take in the whole situation and have a common picture when many incidents are happening at the same time. There is also a lack of efficient tools that show critical buildings and constructions in combination with actual and forecasted water levels. When handling critical situations people face challenges of complexity, uncertainty, and unpredictably. Such management and decision-making activities are normally supported by various models and support tools. However, complexity is normally not explicitly addressed in such models and tools. In this paper we analyze and discuss different kinds of complexity, which are a challenge in critical situations caused by flooding.

Introduction

When lakes and watercourses are flooded the water level increases so much that normally dry territories are put under water. Even areas that usually are not bounded by water can be flooded. Globally, flooding is the type of natural catastrophe that every year causes the most victims and the greatest economic effects. In Sweden and other European countries we suffer few big flooding catastrophes and death caused by flooding is relatively unusual. Damage to tangible assets and the cost to society are, however, considerable when flooding does occur.

High water levels and the power of gushing water can cause great damage to settlements and infrastructure. Buildings are often water damaged both by direct flooding and by water rushing in through overloaded systems of water mains and outlets. Ground that is saturated with water combined with erosion can cause landslides, damaging settlements, roads, railways, and bridges. Destroyed and flooded roads cannot be driven down and communications are disturbed. Flooded cables and signalling stations can lead to interruptions in electricity supply and telecommunications. Damaged water supplies and destroyed cables and pipes are a threat to society and if water-purification plants are hit, people’s health and the environment might be jeopardized.

As several authorities and organizations become involved in cases of flooding, they may not be able to take in the whole situation and gain a common picture because many incidents are occurring at the same time. Priorities are hard to allocate as there is a lack of efficient tools to show critical buildings and constructions such as roads, railroads, water-purification plants, and so on in combination with actual and forecast water levels. Furthermore, coordination between the authorities and organizations concerned is normally not as effective as it could be.
The CRISSI project

The aim of the CRISSI project is to present a visualization model for critical situations caused by flooding, and to develop a computerized system for simulations based on the model.

Questions at issue are:

- Which authorities and organizations are affected by such critical situations?
- Which are the critical factors or variables on which the system must be based?
- How can visualization of a critical situation improve the understanding of that situation?
- Can visualization of dynamic processes contribute to understanding?
- In what way can multimedia and GIS (geographic information systems) contribute?
- Which calculation models (for example hydrological) are useful?

Table 1

*Critical factors in the CRISSI system (Asproth & Håkansson, 2006)*

<table>
<thead>
<tr>
<th>Secrecy</th>
<th>Common</th>
</tr>
</thead>
<tbody>
<tr>
<td>resources</td>
<td>Public service</td>
</tr>
<tr>
<td>provision</td>
<td>Innovation</td>
</tr>
<tr>
<td>systems</td>
<td>Historical</td>
</tr>
<tr>
<td>information</td>
<td>Physical</td>
</tr>
<tr>
<td>health</td>
<td>Water</td>
</tr>
<tr>
<td>reservoirs</td>
<td>Energy</td>
</tr>
<tr>
<td>reserves</td>
<td>Communication</td>
</tr>
<tr>
<td>processes</td>
<td>Washed-away</td>
</tr>
<tr>
<td>roads</td>
<td>Critical or risky</td>
</tr>
<tr>
<td>industries</td>
<td>Areas disposed to landslips</td>
</tr>
<tr>
<td>Home defense</td>
<td>Water levels</td>
</tr>
<tr>
<td>Resources (people, etc.)</td>
<td></td>
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<tr>
<td>Laws and regulations</td>
<td>Sustainability</td>
</tr>
<tr>
<td>Educational systems</td>
<td>Media processes</td>
</tr>
<tr>
<td>Cultural processes</td>
<td>Forest reserves</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Spreading of the flood</td>
</tr>
<tr>
<td>Logjams in water courses</td>
<td>Purification plants</td>
</tr>
<tr>
<td>Owners of land and buildings</td>
<td>Military forces</td>
</tr>
<tr>
<td>Stream rates</td>
<td>Population registers</td>
</tr>
<tr>
<td>Interfaces</td>
<td>Production processes</td>
</tr>
<tr>
<td>R&amp;D systems</td>
<td>Soft early warning</td>
</tr>
<tr>
<td>procedures</td>
<td>Population processes</td>
</tr>
<tr>
<td>Vegetation processes</td>
<td>Soil deposits</td>
</tr>
<tr>
<td>Industries</td>
<td>Passable and blocked roads</td>
</tr>
<tr>
<td>Blocked areas</td>
<td>Undermining of roads</td>
</tr>
<tr>
<td>Position of the police</td>
<td>Other actors in the area</td>
</tr>
<tr>
<td>Rising</td>
<td>Precipitation</td>
</tr>
</tbody>
</table>

- How can anticipation contribute to the system?
Which existing tools are useful for inclusion in the system?

In earlier work we have approached problems concerning decision support for spatial planning (Asproth, et al., 1999, 2002), spatial modeling and simulation (Asproth, et al., 2005b), water regulation (Asproth, et al., 2001), visualization of spatial decision situations (Asproth, et al., 2002), and simulation and anticipation in critical situations caused by flooding (Asproth & Håkansson, 2006). So far in the project, we have identified the critical factors to be included in a model for visualization of situations caused by flooding (see Table 1).

We have used the multi-modal systems method, as developed by J. D. R. de Raadt (2000), to be able to grasp the full width of human life and any human activity system. The main idea of the multi-modal systems method is that for any sociotechnical system to develop in a positive way, all its modalities have to be considered in a balanced fashion. In contrast, if some modalities are constrained while others are overemphasized, the system will express malfunctions and retrogression. The method may be seen in contrast to conventional well-established sciences, which normally focus on just one modality. Figure 1 shows de Raadt’s modalities and how they are grouped.

Interviews were carried out with representatives of authorities and organizations with experience of earlier flooding. The interview questions followed the multi-modal systems method in order to cover as many aspects as possible. Documentation of earlier flooding was also examined (Asproth & Håkansson, 2006).

Schwaninger (Espejo & Schwaninger, 1993) has made the interesting observation that control variables at higher logical levels of management have a predictive power over variables at lower levels. However, in multimodal systems thinking de Raadt (2000) has shown that the influences go in both directions. Higher modalities have an inspirational influence on lower ones and those, in their turn, have a restrictive effect on higher ones. Eriksson (2001) and Veronica de Raadt (2001) have shown practical applications of those insights. When going from operative level to strategic and normative level, the complexity increases.

In this paper we discuss the complexity challenges of the critical factors to be included in the model for visualizing situations caused by flooding.

Complexity

In Asproth, et al. (2005a) we identified the core dimensions of complexity for decision making in spatial situations. These are as follows.

![Fig. 1: Figure 1](https://journal.emergentpublications.com/wp-content/uploads/2015/11/bdc5a3c9-0811-64e4-c85e-47743d9c820b.png)

*De Raadt’s modalities*
Actor and negotiation complexity

One important complexity dimension is due to different actors and their different values and goals. There will often be conflicting interests between organizations and between individuals and groups. Negotiation support systems (Raiffa, 1982; Bacow & Wheeler, 1984) permit different points of view and positions to be joined, differences to be reconciled, and compromise solutions to be suggested.

Process and structure complexity

One dominating difficulty in managing “geographical space” is the great delays between an action in one point of the system and the effects eventually emerging in quite another one. Furthermore, in any planning system it is necessary to have some sort of model of the geographical space of concern. Such a model is often implemented in the form of a classical geographical information system (GIS), but the model of the space, its activities, and actors may also take the form of a more sophisticated modelling and simulation tool developed by help of the multi-modal systems method.

Space complexity

Spatial planning is currently facing a multiplicity of challenges. There are problems related to visualization and presentation of geographical space. In its present classical map form the communicated picture will be far too rigid and “clean,” rigid in the sense that only one fixed system state may be expressed.

Using (model) complexity

A model can be seen as a more or less realistic and objective representation of a part of reality (system in focus). That is probably the most common conception of a model. An alternative conception is to see the model as a representation of a user’s current understanding of a situation or system in focus.

Tools complexity

Turning to artificial planning support tools, the complexity emerges in yet another form. There is an unavoidable tradeoff between relevance, complexity, and uncertainty (Klir, 1996). This means that in order to be relevant, or useful, a tool cannot be too complex at the same time as not exhibiting too great a degree of uncertainty.

Another way to look at the issue of complexity comes from Warfield (1999, 2002). He has identified twenty laws of complexity, which can be categorized in three main categories: behaviorally based, media based, and mathematically based (see Table 2). We have

Table 2

| Categories of the laws of complexity (Warfield, 2002) |

Emergence: Complexity and Organization
here analyzed the CRISSI system and its critical factors according to the twenty laws.

### Triadic compatibility

Human beings cannot process interrelationships among sets of factors if more than three components are involved. The reason is that the mind is incapable of recalling into the short-term memory more than about seven items.

*Challenge:* To deal with this limitation in the human mind, a computerized system can be of help. In the CRISSI system it is necessary to minimize the number of factors to be handled at the same time. This on the other hand demands that the factors selected must have a high degree of relevance.

### Requisite parsimony

Due to the limitations focused in triadic compatibility, it is essential to have enough time for sequentially presented information to be interpreted.

*Challenge:* Although a critical situation also might be time critical, the decision makers must be able to influence the CRISSI system to get enough interpretation time.

### Structural underconceptualization

The outcomes of ordinary group processes will be underconceptualized.

*Challenge:* To deal with this, some computer support for developing the formal logic structure must be used when developing the CRISSI system.

**Limits**

To any activity in the universe there exists a corresponding set of limits on the activity, which determines the
feasible extent of the activity.

*Challenge:* It is essential to discover the limits and analyze what effects these limits will have on the CRISSI system and its use.

**Requisite saliency**

The situational factors that require consideration are seldom of equal saliency.

*Challenge:* It is necessary to identify which factors should be emphasized more than others. To obtain that a focused dialog and a methodologically well-carried-through design of the system are necessary.

**Organizational linguistics**

As an organization grows, linguistic separation grows both laterally and vertically. Higher levels in the organization tend to become progressively disconnected from the relevant components at lower levels. In a strictly hierarchical organization most of the communication occurs within rather than across organizational layers. Intra- and inter-organizational communication is necessary for effective action in emergency situations.

*Challenge:* The planned system must be designed to facilitate communication within and between organizations.

**Vertical incoherence**

There are invisible but potentially discoverable patterns of vertical coherence in the organization. A large number of key features can be structured into categories, which in their turn can be structured into areas. The three levels of pattern are strongly correlated to the three organizational levels, operational, tactical, and strategic.

*Challenge:* The planned system must be able to help in the structuring to show the right aggregated level to decision makers at different levels.

**Induced groupthink**

Individuals put under pressure by the group to produce results within time limits might end up in induced groupthink. Enough time for interpretation and reasoning must be guaranteed. Every person must act as an independent decision maker.

*Challenge:* Though the time pressure is hard, enough time for interpretation and reasoning must be guaranteed. Every person must be able to act as an independent decision maker.

**Forced substitution**

Structural underconceptualization and inherent conflict lead to policy vacuums in an organization. Those in
authority then inject forced substitution for absent and inadequate conceptualization.

*Challenge*: There will be significant pressure on the decision makers in an emergency situation, which will be relieved in the short run by taking action. To avoid bad decisions they have to have the most relevant information visualized in order to give the best possible support for the decisions they take.

**Diverse beliefs**

The individual members of a group will have diverse beliefs about the issue and the situation will remain uncorrected in the absence of a group learning experience. People must share the same linguistic domain to be able to express the same point of view.

*Challenge*: In a critical situation caused by flooding, people from different organizations have to cooperate. To bridge the differences in views, practice beforehand in using a common tool will help in understanding each other and speaking a common language. The system must hence be developed in a joint structured project.

**Universal priors**

The human being, language, reasoning through relationship, and archival representation are universal priors to science.

*Challenge*: When designing the CRISSI system the four parts must have the same priority to be able to succeed.

**Inherent conflict**

There will be inherent conflicts within the group stemming from different perceptions of the relative significance of the factors involved in the complex issue. This law reminds us a lot of the law of diverse beliefs.

*Challenge*: Through structured practice and following up the results, it is possible to get a deeper understanding of each other’s roles and need for information in the mission.

**Small displays**

Complexity cannot be displayed in small display media.

*Challenge*: A system for decision support in complex critical situations cannot be visualized in small media. A headquarters with a large display is necessary.

**Validation**

Validity depends on substantial agreement within the community of meaning, but there is no observer-independent “objective knowledge.”

*Challenge*: The CRISSI system must be a dynamic system, a system that it is possible to change over time.
Gradation

Any conceptual body of knowledge can be graded in stages, such that there is one most simple stage, one most comprehensive stage, and intermediate stages whose content lies between the two extremes. The comprehensive stage may be seen as the best alternative, but that takes with it the more comprehensive and the more complex.

*Challenge:* This law affects the entire CRISSI system.

Success and failure

Inadequacy in any of the seven critical factors that are necessary for success in the design process — leadership, financial support, component availability, design environment, designer participation, documentation support, and design processes that converge to informed agreement — may cause failure.

*Challenge:* All critical factors must be considered to avoid failure.

Uncorrelated extremes

During the design process, the initial opinion concerning a number of factors and the final opinion about the same factors will be uncorrelated. That shows that significant learning takes place through the application of the design process.

*Challenge:* The answer to that is the same as for validation: The CRISSI system must be a dynamic system, a system that it is possible to change over time.

Requisite variety

A design specification exhibits requisite variety if the designer has correctly identified and specified the dimensions of the system. That means that the behavior of the design should be that which the situation can absorb and which the designer can control. No more, no less.

*Challenge:* It is necessary to identify and implement requisite variety in the CRISSI system.

Triadic necessity and sufficiency

Relationships are characterized by the number of distinct relational components, but no matter how many such components a relationship may have, the (complex) relationship can always be expressed by component relationships having no more than three relational components.

*Challenge:* As for triadic compatibility, that demands that the relational components selected must be highly relevant.
Precluded resolution

An organization must have an effective methodology for learning about the issue, before the design process
starts. Either that or the individual’s particular uninformed perceptions about the issue will be the basis for the
actions. That will definitely exhibit structural underconceptualization, inherent conflict, and diversity of beliefs,
dysfunctional organizational linguistics.

Challenge: A methodological step for learning about critical situations caused by flooding must be performed.

Conclusion

In presenting part of the CRISSI project we have analyzed and discussed the complexity challenges in critical
situations caused by flooding.

The method used for the inquiry, the multi-modal systems method, was helpful to understand the breadth of the
problem, and to catch the most vital input variables to the system, variables that were not obvious in the first
place, such as commitment, secrecy, sustainability, and wellbeing.

We chose to use Warfield’s (1999, 2002) twenty laws of complexity to understand and cover as many aspects as
possible of the complexity in the CRISSI system and its total environment, including organizations and human
beings. That is particularly important when developing a system to be used in situations where many
organizations, and thereby many individuals, are involved in addition to the advanced system and its complex
content (data, models, and calculations). Naturally, we cannot be sure we have covered all aspects of
complexity, but when using an approved model we can design a better system, a system that is established
among the organizations involved.

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