Improving Crisis Response by Interconnecting Data Worlds

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Abstract: Gathering information to improve decision making during crises is the core business of crisis information officers. In this paper a case study is presented, along with an analysis of the influence of information on crisis management in order to improve crisis response. This analysis shows that interaction between the activities of i. leading crisis response and ii. obtaining a good information position is required in order to improve the effectiveness of the crisis organisation. Interaction between the two is necessary to optimise and tailor the information position in a specific situation, resulting in situational awareness.

By combining the efforts of crisis information officers, developers of the Dutch crisis management system (LCMS) and two European FP7 research projects, a balancing platform was provided to study the complexity of cross border and cross sector information sharing. Over a hundred officers and experts from more than 10 countries had gathered to see the results of that action. The officers and the water experts also saw added value in using the instrument for preparative discussions and meetings to explore each other's domain and organisational concerns. The combination of cascade modelling, applied semantics, National base-registry data, and European satellite imaging, was well received by the Dutch and German crisis teams, and by the Dutch command and National Security Council. The application of standards, a controlled vocabulary of icons and symbols has been documented in a guideline that will be made a mandatory Directive by the Dutch National Security Council. The combination of semantic reasoning and Geographic search has been translated into a W3C/OGC best practice.

Keywords: crisis management, leadership, information management, situational awareness, crisis response, crisis management system

1. Introduction to the topic and the research problem behind the platform

Figure 1: A Dutch-German emergency team discussing options based on a common (Dutch German) operational picture about the flooding

The Dutch have faced challenges of Flooding throughout the ages. Until recently, these dangers came from the seas and we knew how to keep them at bay. Nowadays the rain and the rivers have become equally significant problems behind the dikes. This arena is different from the coast in the sense that many more aspects of society have to be taken into account when making crisis management decisions for inland locations (density, continuity of industrial processes, etc.). Our Dutch government agencies have to collaborate with many agencies, both governmental and non-governmental, national and international, to make proportional and fitting decisions regarding safety investments and countermeasures. The Dutch regional safety agencies together have already invested a large effort in the establishment of a Spatial Data Infrastructure consisting of i. a registry of addresses (BAG), ii. vital infrastructures (BGT) (Ministeries van Binnenlandse Zaken en Koninkrijksrelaties (BZK); Economische Zaken (EZ), 2017), iii. vulnerable objects; the so called riskmap (Inter Provinciaal Overleg (IPO), 2017) and iv. all our water channels (LIWO) (Rijkswaterstaat, 2017). The research question is whether a platform could be designed to support this complex crisis management scenario where many aspects have to be balanced against each other in a very short time.

Figure 2: Emergency team information experts setting up the common operational picture from many data sources

Many discussions among academics, developers and crisis officers address the issue of the prediction and mitigation of 'cascading effects' during a crisis. European funded projects like Fortress (Fortress, 2017), Sector (Sector, 2017), Snowball (Snowball, 2017), Predict (Predict, 2017) and Driver (Driver, 2017) are examples of EU funded research on this topic. Crisis information officers take the viewpoint of 'situational awareness' (e.g. see (Alberts, et al., 2001) and they seek to inform the commanders in charge about the likelihood of imminent dangers to people and vital services. The challenge to move from raw data to

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meaningful and timely support of such key-decisions are numerous. The core problem is to achieve a level of government and specialist information processing that enables the crisis managers to evacuate people and take action in proportion to the danger. These decision makers will face public opinion afterwards, and so are sensitive to public expectations. The case of the "Domino Platform" described here demonstrated the state of the art in aggregation, combination, translation and presentation of the data in a manner that could set an example for digitally assisted government decisions worldwide. It was also the first time that European instruments for emergency management based on satellite imaging (European Commission, 2017) were combined with 'Local' Dutch and German emergency management instruments such as LCMS and LIWO, thereby showing the potential of future synergy.

This case study illustrates the influence of information on the management of a crisis and shows that improvement to information via combination of sources in a shared space improves the management of a crisis. This is operationalised using indicators such as relevance, proportionality and alignment with established plans of action. Recognising these improvements and incorporating them into the crisis organisation is of crucial importance in order to exploit the benefit of the improved situational awareness.

2. Influence of information on the management of a crisis

The volume and the speed of information sharing are constantly increasing, leading to changed expectations of citizen towards first responders and crisis managers. As a result, crisis organisations face a challenge to adapt to this changing role of information within the organisation so as to further optimise the effectiveness of crisis response. A further critical success factor in increasing effectiveness is the agility with which the crisis organisation can adapt to the ever changing information environment.

Figure 3: Model for Crisis effectiveness

In his research Spaling describes this influence of information management on the leadership of the crisis organisation as situational awareness (Spaling, 2017). His research shows that to achieve effective crisis response it is important to do the right things – relevant and in proportion to the seriousness of the effects of the incident - but also to do the things right – being able to connect the risk estimate and elements of the incident situation to the agreed protocols, capacities and plans of action. These two aspects need to be in equilibrium. A good information position is key to a well performing crisis organisation (Alberts, et al., 2001). Clear leadership is the second factor that is required for good crisis management. The interaction between the activities of leading crisis response and of obtaining a good information position is required to improve the effectiveness of the crisis organisation. Spaling stipulates that the interaction between the two takes place in two major areas. Firstly, to optimise and tailor the information position in a specific situation, resulting in Situational Awareness. Secondly, the effectiveness of crisis response is enhanced if decisions and actions are monitored to make sure they are executed in the way they were intended. Spaling visualised this in the Crisis Effectiveness Model (see Figure 3). Besides the primary focus on the interaction between leadership and information position, the red circle in the model represents three types of prerequisites that need to be fulfilled in order to be able to achieve an effective crisis organisation. The leadership manifests itself in the ability to constantly monitor and adapt existing protocols and plans of action to the changing needs of the situation as presented by all connected digital systems that constitute situational awareness. Elements of importance are competences, the state and readiness of plans and procedures, and a robust network to connect all the systems and actors.

The case presented here requires such monitoring and constant adaptation because of the increasing pressure of society to maintain a proportional level of disruption in relation to the situation. Wilson and Peters (Wilson & Peters, 2017) have argued that such proportionality could be measured by the timeliness of de-escalation of actions such as evacuation, resource allocation and blockades of transportation routes and other infrastructures. They also observed that many barriers of information transfer exist among systems and people that hinder a timely and proportional decision to de-escalate (Disaster, 2017).

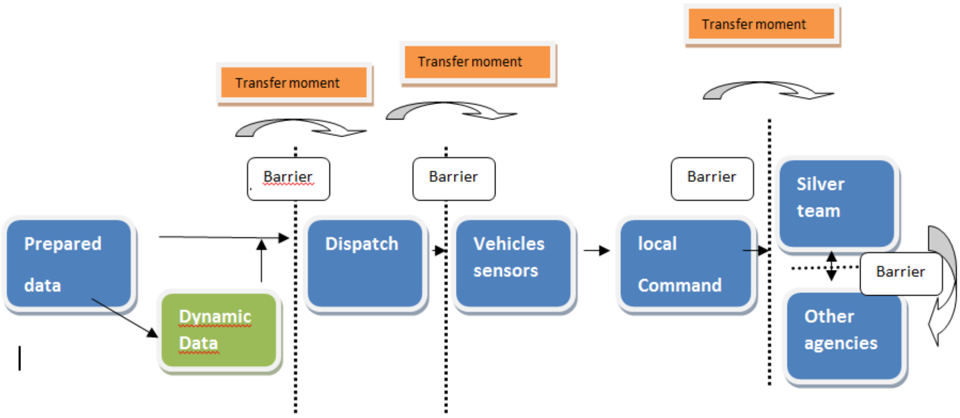

Figure 4: Information transfer barriers during incident management (Disaster, 2017)

An evaluation framework of the case was constructed by combining the crisis effectiveness model of Spaling (Spaling, 2017) and the aforementioned de-escalation metric (Wilson & Peters, 2017) in order to provide the observers of the incident simulation with a common set of indicators. The metric is also a first attempt to measure the contribution of ICT and the improved information provision to the decision-making process at a precise point in time during the crisis.

3. Case description

In order to create the Domino balancing platform a core team of Dutch officers, water board experts and technicians combined their efforts with two European FP7 research projects (Fortress (Fortress, 2017) and Sector (Sector, 2017)) addressing cascading effects. The infrastructure consisted of the LCMS National Dutch Crisis management System (LCMS, 2017), the LIWO National water monitoring system (Milieu, 2017), the FIET cascading modelling interface (Fortress, 2017), the Geo4oov geo crisis information and aggregation database (Geo4OOV, 2017), the eGeos Satellite system (e-GEOS, 2017) that is part of the European Civil Protection mechanism (Mechanism, 2017), the Firebrary semantic interoperability platform (IFV, 2017), and the Thales identity platform.

The LCMS National emergency management system has been in operation in The Netherlands for almost five years and provides a common focus for improvement and development for the 400+ emergency information officers in the Dutch Safety regions. The Domino platform is the second major improvement project, where additional modules, such as cascading effects projection and integration with larger partner information sets using semantics such as LIWO (flood information) are tested for future operation. The newly operational LIWO database consisted of 11.000 map layers that together formed the common operational picture covering almost all water that flows through the delta that constitutes The Netherlands. An intention was to test interoperability of this new and vital service in conjunction with the new National LCMS geodatabase – Geo4oov - that visualises the emergency area on a shared crisis map. A demonstration of the Domino platform was provided at the second Domino conference in Tiel, in 2016 using the Fire Brigade Mobile Command Containers and Ships as a joint 'Field laboratory' for evaluation.

Figure 5: Emergency managers, water experts and developers meet at Domino I to discuss the information needs

4. Barriers encountered and how they were overcome

4.1 The barrier of a common reference framework

When working together to make information technology more interoperable, a significant challenge among people from different backgrounds and organisational cultures is to create a focus by providing a common reference framework that helps all members of the team to contribute to the same platform, whilst also allowing for differences in language, knowledge and perspectives. The solution chosen for this problem was to introduce a common reference scenario that describes the events leading to a major crisis - in this case detailed around the narrative of long snowfall in the Alps and rising levels of the rivers Rhine and Maas.

4.2 The Barrier of aggregation

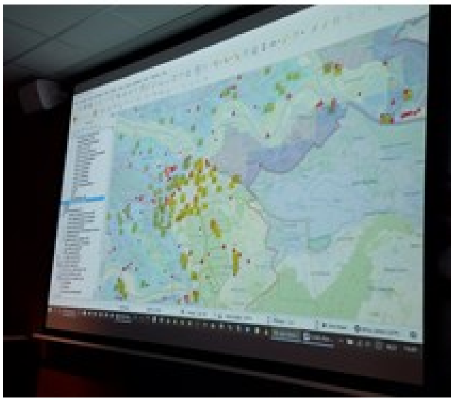

Figure 6: Aggregation and correlation of digital information using maps

One of the major problems for sense-making based on aggregated data from water authorities, emergency management authorities, and vital service providers, is that interpretations and terms vary in meaning without the actors realising the gaps. For example, a risk in water terms could imply a temporal scope of years, while the risk perception of emergency managers is often targeted towards days. The solution for this problem was to exactly define the legend of the map layers and to enable immediate search of the definitions and interpretations used in those models. This search was enabled by simple and user-friendly interface to an online open library following open semantic standards.

There can be confusion in an emergency team if a model creates a blue coloured layer on a map indicating a land area covered with three meters of water, while the model behind such a map - with its devastating consequences - is not made abundantly clear within a very short time period. Experience shows that the political decision to evacuate will be postponed by key decision makers if they are faced by uncertainty in the digital tools. The delay in decision can and will cost lives. The opposite is also true; evacuation based on over estimation of the seriousness of the emergency effects can and will cause societal and economic damage. The challenge of matching and exchange of clear definitions, as part of the emergency maps, is not only in the interaction design, but also in the maintainability of the effort. Clear definitions in native domains need to be shared and interconnected to achieve this common understanding. SKOS-XL standard (W3C, 2017) was applied in a new semantic environment called 'Firebrary' to achieve this.

4.3 The barrier of cross border collaboration

Holland is a small country, bordered by Germany and Belgium. The rivers reach the Dutch borders only after a long journey through other countries and agencies. The Collaboration between the German officers and the Dutch officers is therefore crucial, and the notion of a common operational picture can only be achieved by sharing each other's data.

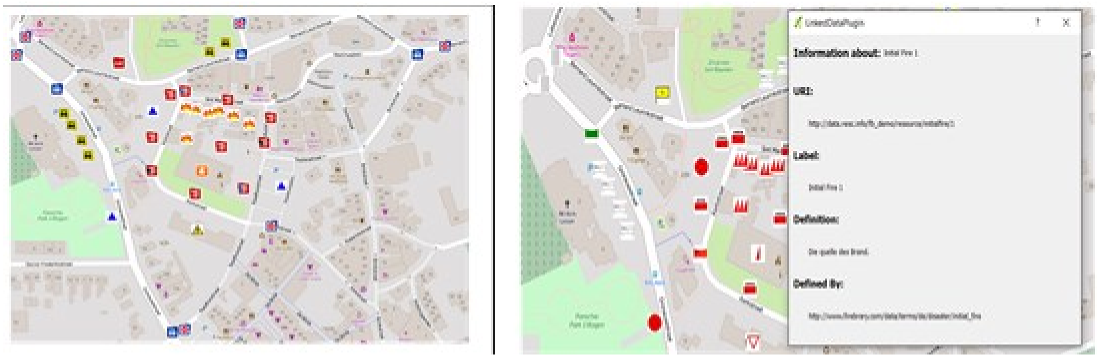

Figure 7: The cross border collaboration enabled by on-the-fly translation of local emergency icons during a crisis

Once the data is shared, another challenge arises, which is the problem of semantics and iconography. Simply said: the German colleagues use different terms for the same objects and people, and these objects and people are represented on maps with different symbols. This difference first became evident during a previous collaborative response to cross border forest-fire and is regarded as a potential cause for additional disaster. The solution chosen for this problem is to apply on-the-fly translation of these symbols using state of the art semantic web technology.

4.4 The barrier of presentation of cascading effects

The notion of one incident, such as a power break down, leading to another effect, such as water pump failure and hospital discontinuity, is well understood. One of the major challenges is to reduce complexity of models and variables (achieved by choosing the most relevant ones) and to ensure maintainability of the data (achieved by ensuring the data sources are part of the infrastructure). The result has to be presented to officers in a user-friendly way, and this requires combinations of maps, variables and models in the same interface.

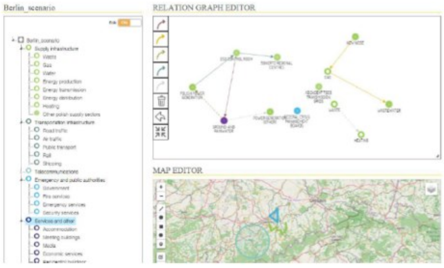

Figure 8: The Relation Graph Edior

This challenge was addressed by the use of the reference scenario, along with the iterative development of cascade models through collaboration of researchers during several design workshops. The reference scenario provided a focus for a large group of experts, officers and developers to advise upon, and to refine, the same design. This activity also triggered a discussion about the metrics of digitalisation support in relation to emergency management and compartmentalisation of emergency management. Common and well described Reference scenario's enable splitting up of the whole build-up and mitigation into standard segments of emergency management, which in turn enable chunked training, performance measurement and improved learning process for the entire sector.

4.5 The barrier of trust

Emergency management is often regarded as a hush-hush debate within secretive systems, and officers are used to a hierarchical structure where the commander determines what to do. This position is hard to maintain when the events follow each other in quick succession, and where time is critical. To share knowledge and factual information in cross sector and cross border situations requires trust. The chosen approach to overcome this barrier was to introduce the doctrine of Netcentric Working, which has been adopted from modern military practices (Alberts, et al., 2001). The idea is that horizontal information sharing is always more productive and faster than hierarchical information channelling and filtering. This doctrine is proven in the field but requires the building of trust among partners to enact non-hierarchical and cross border and cross sector mechanisms within a traditional setting. Trust was initially built via the realistic exercises conducted at the Domino I and Domino II field trial and crisis exercise events (iNowIT, 2017).

5. How the research proceeded

The overall reception of the demonstrations and exercises at Domino II was very positive. Over a hundred officers and experts from more than 10 countries had gathered to engage with the technology and test its contribution to the achievement of a common operational picture and situational awareness. The combination of European Satellite imaging, the Dutch LCMS Geo platform, the LIWO water maps, and semantic translation "on the fly" were very well received. The Dutch are familiar with object data but did not know the possibilities of combining with instant satellite imaging.

Figure 9: The field tests outside operation, using command containers

One of the unexpected results of the Domino platform simulation exercise and related discussions was not technical but organisational. It was found that the officers and the water experts defined the experience in working with the tool not only as a crisis management tool, but also as an added value instrument for preparative discussions and meetings to explore each other's domain and organisational concerns. It was also found to be an ideal way to interconnect remote experts to collaborate on developing scenarios embedding scarce knowledge that could not be easily accessed by other means, and then engaging experts on response planning, based on such scenarios, in ways that could not previously be achieved. This common finding inspired a range of new ways of meeting needs, and the insight that the best technology, as well as solving exchange problems, can facilitate inter-organisational and cross-border collaboration in new and creative ways. As a result, crisis management benefits from this effort, plus there is added value in creating a shared situational awareness in the preparation of crisis mitigation planning. Leadership improves in the way prepared plans are applied in a crisis situation, and the adoption of new technology is stimulated in the preparation phase.

6. The objectives achieved and how they were measured and evaluated

The evaluation of the field test was organised by The Institute of Physical Safety (IFV) in a structured and repeatable manner. Pre-test workshops were organised in 2015 at the first Domino conference. Pre-test cross border workshops were used to explore the nature of the technical and other barriers, and to establish requirements. A detailed report is publicly available through the FORTRESS project (Fortress, 2017). Development of cascade scenarios was achieved within the FORTRESS project, by training crisis planner staff in the safety regions, and these scenarios and cascade models were used as the basis of cross border trials in Domino II in 2016.

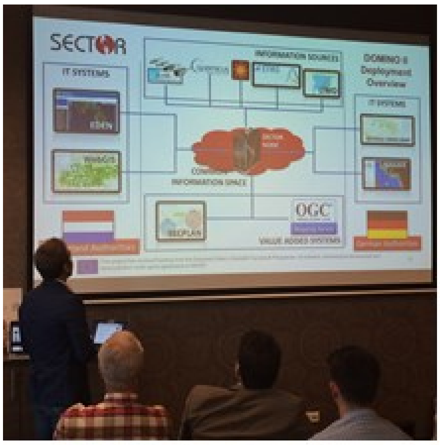

Figure 10: The Domino Platform discussed by the developer crews of several European Research projects

Measurement was achieved by placing observers within crisis teams (six teams) during realistic field exercises, using standardised criteria for observation, such as accuracy of the situational awareness, proportionality of actions, leadership in adapting existing plans and protocols, timeliness of escalation and de-escalation , and then conducting interviews with individuals post-exercise to more fully understand the "observed" results.

Learning outcomes can be summarised as:

- Development of common scenarios and cascade models ensures a common focus built on shared knowledge and data. This in turn supports integration and interoperability of the technology;
- Use of tools to build scenarios and cascade models allows inter-organisational and cross-border team building that are perceived as hard to achieve otherwise;
- Access to precious knowledge is allowed by engaging remote planning experts as part of the collaborative process (preparative phase), and this delivers more precise and well accepted models that inform the joint operations at response phase;
- Successful integration of several technical systems can deliver an enriched common operational picture and is a necessary basis or intellectual trust (right information);
- Successful integration of experts (people) through shared models and plans can deliver a relevant and proportional cross-organisation and cross-border planning and response capacity fit to meet challenges from nature.

7. Lessons learnt in a broader perspective

The combination of cascade modelling, applied semantics, National base registry data, and European satellite imaging, has been well received by the Dutch and German crisis teams, and by the Dutch command and the National Security Council. The application of standards, a controlled vocabulary of icons and symbols have been documented in a guideline that will be made a mandatory Directive for data exchange by the Dutch National Security Council (cross border policy initiation). The leading commanders have decided to further investigate the potential of the combination of (Copernicus/Galileo) satellite imaging and the existing geo platform - especially infra-red and night vision images that can provide added value. The Dutch-German collaboration in the area of water and flooding management will be widened towards other domains of safety and information sharing. The German crisis management Training Centre in Munster defined this flooding theme and its digital support as a way to push the digitalisation agenda in Nord Rhine Westphalia further. This collaboration and uptake is important to both the technical developments of the tools, and for the development of a future market that is substantial enough to enable suppliers and other European countries to benefit from this digital government best practice example. The Netherlands itself is perhaps too small for suppliers to invest further, and so a geographical broadening is a logical step to development of shared resources.

The combination of semantic reasoning and Geographic search has been translated into a W3C/OGC best practice (Leeuwen, 2017). The Fire brigade are the first to express the need for the functionality and thus the standard, and hopefully INSPIRE (Inspire, 2017) and others will examine and adopt the approach.

8. What future work might be necessary as a result of what has been learned?

This case study shows that crisis management can benefit from a better information position, especially to achieve proportional action and less disruption. The collaborative effort among the Dutch Fire brigade, Ambulance and Police officers to co-develop around the LCMS emergency system is unique in Europe. This is opening up to other sectors, such as water management and health care, as well as vital service providers and is recommended as a fruitful approach. The Domino platform shows that technical and trust barriers can be overcome to support sensible cross-institutional and cross-border emergency management to save lives and avoid unnecessary societal damage. The team of officers and developers involved were invited and attended the ISCRAM (Albi, 2017) conference in Albi, France to discuss the potential of reference scenario's for that established scientific community, and so contribute to future collaborative working through exercises and practices. A significant problem being addressed is that of scenario standardisation, and the need for objective metrics with respect to information management, digitalisation and the effectiveness of crisis management (Spaling, 2017) (Wilson & Peters, 2017). It is unusual for Fire brigade officers to join academic debate, but it is of vital importance to engage with researchers who can help to further improve the effectiveness of the crisis organisation. Spaling has investigated this influence in his research (Spaling, 2017), and through case research and interviews has shown benefits for information management and the effectiveness of crisis response arising from such collaborations. The FP7 flagship research project DRIVER adopted the challenge of improved metrics and reference scenario's in its second phase (Driver, 2017).

Objective determination of the influence of information on crisis response effectiveness is initiated in this case study, and the main areas for further research are identified:

- Further research is required on how the effectiveness can be measured objectively;
- The crisis organisation needs to cope with the ever-changing environment of information availability. Further investigation is needed on how this influences the agility of the crisis response organisation in balancing protocols and plans against shifting situations.

Collaboration between the scientific community, developers and end users are required to conduct future research.

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