SII FOR EMERGENCY RESPONSE: THE 3D CHALLENGES

Sisi Zlatanova

Delft University of Technology, Jaffalaan 9, 2628 BX Delft, The Netherlands - s.zlatanova@tudelft.nl

Commission VI, WG VI/8

KEY WORDS: Disaster, Infrastructure, Platforms, Open Systems

ABSTRACT:

Emergency response is the disaster management phase with the most extreme requirements. During the crisis management, several organizations coordinate their work based not only on well-defined policies and procedures (product of careful preparation) but also on the outcomes of the decision-making process. Much progress has been booked in the last years in providing the decision-making process with tools, which help in optimal and adequate crisis response. The importance of geo-information is appreciated at many levels and various initiatives were funded to support research and development of systems utilizing geo-information. Many countries have started development of Spatial Information Infrastructures for emergency response and early warning. However, most of these developments are mostly 2D.The paper elaborates on the need for 3D information in the view of several projects carried on in the Netherlands. The results of the user investigations have shown increased interest in 3D visualizations and extended functionality. Questionnaires and interviews with emergency response users and urban planners have show demand for systems utilising standardized models and services. Based on these requirements, recently started research on 3D BIM model and an interior model is briefly discussed. The paper concludes on research and developments in the 3D domain toward developing user-centric, context-aware applications.

1. INTRODUCTION

There is little doubt about the importance of Spatial Information Infrastructure (SII) for the entire disaster management cycle. Use of spatial (or location data) has become an integral part of the decision-making process. Numerous activities have been initiated toward creating SII considering technical and non-technical aspects (von der Dunk, 2008). The Open Geospatial Consortium (OGC) and ISO/TC211 have provided domain-independent standards, as well as standards within a particular theme/domain, e.g. ISO/TC204 for transportation, ISO/TC190 for soil data, Land Administration Domain Model (Lemmen and van Oosterom 2006). Large initiatives like INSPIRE in Europe are working on harmonisation of domain models. Parallel to standards, metadata and web-services are under rapid development.

SII is discussed in disaster management domain either for risk management and capacity building, or for emergency response or even for integrated disaster management (Köhler and Wächter, 2006). As emergency response requires an integration of data from other domains, existing domain models are extensively used for crisis purposes. But many disaster domain-specific initiatives are progressing as well, e.g. GEOS, UNSPIDER and DHS Geospatial model of US Department of Homeland Security. Large EU projects have been working on developing web-services (ORCHESTRA), data model (WIN) and managing and processing sensor networks (OASIS).

Most of these activities however are still restricted to 2D spatial data (maps), or when available to simple 3D representations. As often discussed (Kolbe et al 2008, Lee and Zlatanova, 2008, Zlatanova et al 2005, Zlatanova et al 2006, Zlatanova et 2007), disaster management can greatly benefit from 3D dynamic analyses and visualisation. 3D data are easily produced by various sensors and some of them are available real-time (Kerle et al 2008, Li and Chapman 2008, Zhang and Kerle, 2008). Standardisation activities in building domains (aiming at developing models for the entire life cycle of buildings) provide alternatives for 3D indoor building models (e.g. Industrial Foundation Classes, Isikdag, 2007). This inevitably means large amounts of 3D dimensional data will be increasingly available for disaster management. Additionally, user investigations give strong indications that disaster management users are prepared to face the third dimension. It is questionable whether standards and services are readily available for 3D SII.

This paper presents results of resents user requirements investigations performed in the Netherlands. The paper analyses the readiness of SII to respond to these requirements. Next Section provides a short overview on organization of emergency response in the Netherlands. Section 3 presents the studies and analyse the results. Section 4 addresses 3D research on 3D models of importance for emergency response. Last section draws conclusions and recommends areas for research.

2. EMERGENCY RESPONSE IN THE NETHERLANDS

Situated at a delta of two big rives, the country has been struggling from various floods caused from high river or see level. Two large floods had a large influence on risk prevention and emergency response policies: 1953 and 1995. After the first one many dykes were built, after the second, the construction works on the big rivers (Delta Plan) were completed. The first organisation (named Protection of the population) for crisis management has been established in 1952 under the jurisdiction of the municipality. This organisation has been active until 1980, since when the current structure is being developed.

The first document to address emergency organisation and coordination comes in 1975, followed by several other legislation acts like for the fire brigade (1980) and the Low for disaster and large incidents (1981). Shortly after that, the municipalities are given the responsibilities and obligations in case of emergencies. In the years 1995-2000, further organization improvements have been taken place either within a response sector or between the sectors. For example, after the fireworks disaster in Enschede 13th of May, 2000 (and several other large incidents), the safety regions were synchronized.

At the moment, the Netherlands consists of 12 provinces, which are further subdivided into 24 safety regions (www.rivm, Diehl and Heide 2005). The fire brigade, (para)medical teams, municipality and police are the first responders to be involved in the management of the emergency. The disaster types of importance for the country are 19 subdivided in 7 categories (incidents with transport, disaster with dangerous substances, epidemics and other health-related problems, incidents with infrastructure, problems with large groups of citizens, natural disasters and remote disasters). The disasters are managed by processes as each emergency response sector is responsible for a cluster of processes. Each process is also very well-defined with respect to actors and tasks to be performed. The levels of emergency can be scaled from 0 (normal accident) to 4 (national coordination) (Diehl et al 2006).

Having a relatively short history, the Dutch emergency response has developed to a well-organised system in legislation and organisational aspects. In the last few years, nine large national projects where funded for using spatial information and developing SII. GDI4DM (www.grdi4dm.nl) is developing a SII for Command and Control based on web services (Scholten et al 2008), VIKING (www.programmaviking.nl) is a cross-border project with Netherlands for monitoring and prevention of floods, GeoRisk (www.georisk.nl) for improving risk management by extensive use of geo-information, etc. Geonovum (www.geonovum.nl), formed recently as the executive body of the Dutch NSDI (National Spatial Data Infrastructure) is responsible for developing domain models (including a model for safety). Several data providers, for example the Dutch Cadastre and the Directorate-General for Public Works and Water Management (Grothe et al 2008) are re-organising their internal structures to be able to better respond to emergencies by providing web-services. The risk map containing risk and vulnerable objects according to the SEWESO directive (but including also flood risk) are completed and available on internet (Basta et al 2007).

The necessity of SII for disaster management is well-understood by geo-specialists and spatial data providers. Similar tendencies are observed also world wide (Parker et al 2008, Johnson 2008, Kevany, 2008, Brecht 2008). There is agreement on several critical aspects of SII:

- Data should be kept by the provider and accessed via web-services.
- Standards must be available
- Operational data have to be recorded and provided to all the participants in the incidents
- Situational awareness is important factor in decision-making, location is critical
- Data should be available 24 hours per day through the whole year.

The acceptance of spatial information has drastically increased since initial user investigations in 2005 (Diehl and Heide 2005, Diehl et al 2006). Identification, authorisation, authentication and billing are most of the hot discussion points at the moment.

3. DEMAND FOR THIRD DIMENSION

Several studies were performed in the last year on the request and usefulness of 3D data in emergency response, of which two will be discussed here: use of advances of 3D visualisation by emergency responders (Shoeren 2007) and perception of 3D visualisation by urban planners (Kibria, 2008).

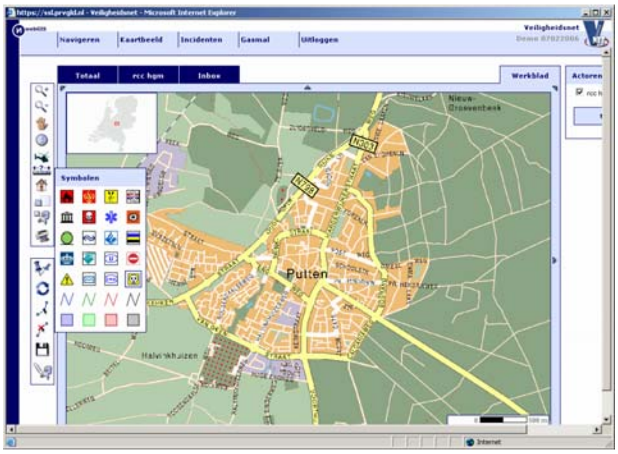

Figure 1. CCS VNet in safety Region Midden Gelderland

3.1 Emergency response users

Snoeren, 2007 has investigated 71 users directly involved in the emergency response (fire brigade 27, police 11 and municipality 33) within one of the safety regions, Midden Gelderland in the Netherlands. This region was selected because they had already an experimental geo-based Command and Control System VNet (Figure 1) for coordination and communication. Using provided symbols all users logged in the system can record and exchange spatial and non-spatial information. Once sent to the server the data is available for all users. The user population was diverse: 13 of them were working on the field, 11 in the operational team, 21 in the call centre, 20 in the regional operational team and 30 were holding different responsibilities by the municipality management team. Most of them (52 users) were familiar with GIS and were using it in their work with variable frequency. All of them were using also the CCS VNet.

Among the various questions related to the cooperation and communication during emergencies, two groups of questions were related to 3D data: 3D visualisation and 3D models. 3D visualisation is considered important by 62% of the users, which quite high result is bearing in mind that half of the users are not familiar with GIS. Visualisation within Google Earth is considered important by 55% of the users, use of panoramic images of 42%, use of animations (with prognosis about the disaster) of 67% and use of video of 79%. It should be notices that the results were very much influenced by the familiarity of the users with the manner of visualisation. For example, video transmission was ranked high, but the call centre of this safety region has good facilities for watching real-time videos. In contrast, the use of tangible table (Scotta et al, 2006) was not that well-accepted (29%). Later tests (Hofstra et al 2008), at which the hardware device was available and tested by the users, have shown much more positive results (70%).

The second group of 3D questions focused on 3D models: simple 3D block models of buildings (as on Figure 2), indoor models and underground structures. It was encouraging to see that about 64% of the users consider indoor models and underground structures important during disaster. Currently, the fire fighter trucks are equipped with books containing floor plans of the first floor of all large buildings in the area they are responsible for (which soon will be replaced with digital maps). The added value of the 3D models is seen by most of the questioned users. The existing hesitations are more about availability and accurateness of the models, cost to obtain them and performance of the systems. 3D models of environment and outside the building structures were considered important of respectively 60% and 58%. The explanation for the relatively low percentage could be in the relatively low quality of 3D (extrusion) models, which are mostly available by the municipalities.

Figure 2. TU Delft campus: LOD 1

Important findings from this study (not specifically related to 3D) are the need of extended functionality, e.g. 70% of the users welcome connection between GIS and CCS (70%) and guiding navigation (avoiding blocked roads and dangerous areas (72%). The acceptance of context-aware software is still low (46%). Most of the users (49%) prefer to receive all available information when they log in the system. The importance of the timely response is recognised by 53% of the users.

3.2 Urban Planners

Kibria, 2008 completed an extended study on the need and use of 3D models within the municipalities. Although the study was focused on the urban planning process, the results are highly relevant for crisis response, since the municipality is legally responsible for managing the disaster. The municipalities posses and often maintain most of the spatial information available for the city. Urban planners are not directly involved in emergency response, but they are the most important actor in risk management as they should take into consideration risk factors and vulnerable objects (Basta et al 2007).

This study investigated 3D information that would be necessary for urban planners with respect to realism and resolution, i.e. Level of Details (LOD) and 3D functionality, i.e. level of interaction with such a municipality system. The investigation did consider a municipality system that can serve different phases of urban planning process (and not a public participation system). Therefore the users were predominantly people responsible for urban design and not citizens. The total number of participants was 30 as most of them came from Rotterdam, Amsterdam, Groningen and other four smaller municipalities, and five housing companies in the Netherlands.

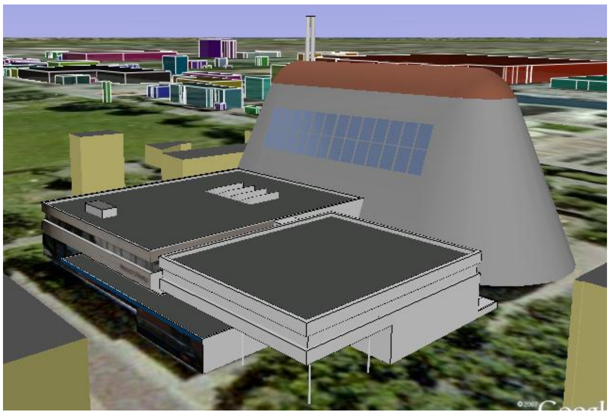

Figure 3. TU Delft campus: LOD3

The investigations have shown that 54% of the users use daily Google Earth in their work (either for investigating areas or for presenting models), as 13% of them visit it *very often*. In general the acceptance of desktop virtual reality tools (VR) is estimated as very high. 75% of the users consider that a municipality system has to have walk-through, fly-over facilities and several windows to observe different views 2D/3D graphics, images. 3D animations are ranked also very high. Similar to the first study, the user considers access and authorization critical. More that 75% of the investigated population require controlled access.

Figure 4. TU Delft campus, LOD 3

Within the study, different models were created and discussed either directly with the users or during the workshop. The models follow the concept of LOD of CityGML (Kolbe et al 2008). The discussions revealed that the users do consider detail representations (Figure 3 and Figure 4) clearer and better acceptable compared to LOD 1 (Figure 2). The more schematic representations, the more attention is concentrated on the entire environment. Some interviewed indicated that the orientation in LOD1 models is quite difficult and somehow confusing. This conclusion is quite important for managing crisis situations. If only a global view have to be created, LOD 1 details would work, but any other (street level) navigation should be performed on more detailed models. Similar findings are reported by Essen 2008. The textured models (Figure 4) are considered most appropriate for 3D visualization (60%), while block models (LOD1) for analysis (58%). The study has considered shadow analysis (as they are most important for urban planners).

Indoor models are coming of importance only if the interior has to be investigated. Many of the users (60%) considered query (by mouse click) of objects important for better orientation and understanding of the presented model.

The general concussion from the two studies was that the third dimension is accepted and there is a demand for increased level of interaction with models. The progress compared to earlier studies from 2005 (Diehl et al 2006) is apparent. The models are interesting not only for 3D visualization but also for analysis (route navigation, buffering, overlap, etc.) and query of thematic/attribute information. Building of SII based on standards, services and domain models is considered advantage. The emergency responders do have preferences for simple interfaces, but mostly due to expectations for low performance. As frequently discussed in the literature (e.g. Neuvel and Zlatanova 2006), the two studies have revealed time as the most critical difference between the two phases: risk management and emergency response. Theoretically a system for emergency response may serve (without major modifications) risk prevention but vice versa would not be true. The timely response is not an issue for urban planners.

The acceptance of the third dimension is relatively high and this is not a surprise. It should be recognized that technologies such as Google Earth, Virtual Earth, Second Life, and similar have greatly contributed to understanding and recognizing the benefit of the third dimension. Users need time to get familiar with new tools to be able to appreciate them, but the tools have to be developed and given to the users.

4. 3D SII FOR EMERGENCY RESPONSE

3D aspects should not be overlooked and should be simultaneously developed while addressing any of SII components: standards, metadata, services and policies. 3D standards and 3D services are most critical for achieving 3D SII from a technical point of view. The possible standards to exchange 3D information are limited and domain dependent, the provided services with small exceptions 2D. Research on 3D extensions is going on, e.g. extending the OGC Styles (Neubauer and Zipf, 2008).

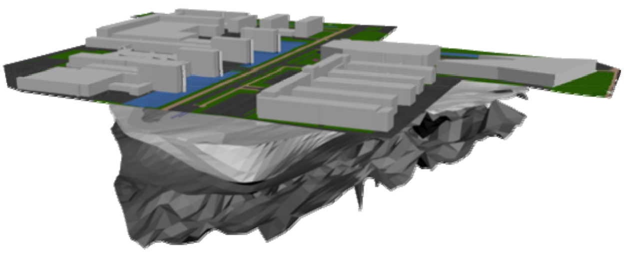

Figure 5. TU Delft model in LOD1 (from Emgard and Zlatanova 2008a)

The most significant 3D initiative in terms of standards is the development of CityGML (Kolbe at all, 2008) and the OGC activities within the BIM WG group. Tests within the OWS-4 testbed have demonstrated that data from Industrial Foundation Classes (IFS) and CityGML can be integrated in one visual (virtual environment) via web services (Lappiere and Cote, 2008). The very strong characteristic of CityGML is that it incorporates semantics (theme) and geometry. Semantic aspect of information is critical for crisis management because of semantic heterogeneity at different levels: data, organization, task/responsibility, etc. (Pundt, 2008, Xu and Zlatanova 2007). Therefore 3D models like 3XD might not be appropriate for emergencies (except for pure visualization). KML (recently approved as OGC standard) has gained popularity because of Google Earth. It will serve 3D visualization tasks above the ground but it falls short in dealing with underground data.

We consider the concept of CityGML highly appropriate for representing real-world features (as a domain independent core model), but it still has to be extended to comprise subsurface structures. We have recently begun research on extending this concept with underground features. New features were introduced for geology formations, utilities and underground constructions. Specific intersection features on the earth surface define the intersection between the above and below surface features with the earth surface. These additional intersection features allow defining relationships and maintaining consistency between all the features. A number of rules were developed, e.g. all the features on the earth surface must form a non-overlapping full partition. The 3DBIM model is intended as a data model to store data and as an exchange model between different domains. Two alternatives were tested in Oracle Spatial (Emgard and Zlatanova, 2008). Figure 5 shows the test area of the TU Delft campus organised according to the 3DIM.

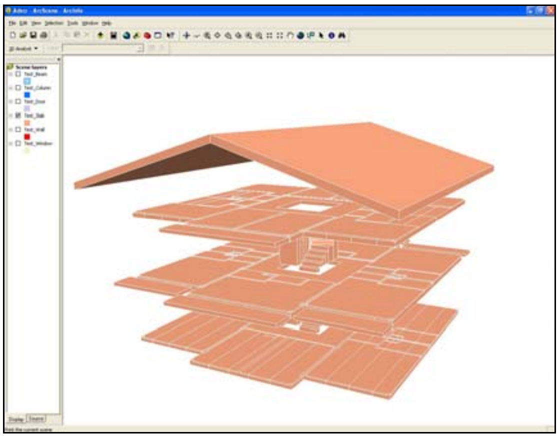

Figure 6. Roof and building from BIM (IFC) models (from Isikdag 2008)

The second very important missing aspect is indoor standard. Interiors of large buildings are important for navigating rescue forces to the place of incident and to give directions to citizens for evacuation. Relatively limited research is carried out in this area. Some initial ideas could be borrowed from CityGML LOD4. Relation structure with the support of Poincare Duality theory, which treats a 3D entity as a topological node and the shared face as a topological link is presented by Lee, 2001. Meijers et al, 2005, presented a semantic model representing 3D structuring of interiors to be used for an intelligent computation of evacuation routes. Slingsby and Raper, 2008, have

investigated a surface model containing only parts of real-world surfaces that are needed for walking and realistic visualisation. Semantic models to represent the interiors with the purpose of emergency response are discussed Lee and Zlatanova, 2008.
The general idea is to deliver those elements from buildings (and other types of constructions), which are important for giving directions such ad doors, windows, stairs. Is it needed to be a specific model or the parts can be derived on the fly? To investigate this question, we have initiated research on deriving those elements form BIM (IFC) as discussed in Isikdag 2007 (Figure 7). BIM models are supposed to maintain information during the entire life cycle of building, which will make them an attractive option for emergency response. Generally, BIM models will be always updated and reach of semantic data. These models can be 'translated' to the 3DBIM semantic model for analysis, computations of routes and realistic 3D visualization when appropriate (Pu and Zlatanova, 2008).

5. OUTLOOK

This paper reported investigation of user requirements on needs for the third dimension in emergency response in the Netherlands. The output is interesting with respect to the emergency response developments in the country. The country has good organisational structure, well-defined actors performing clearly-specified tasks, a successful start for creating National SII (also for support of emergency response). Under these conditions, the interest in the third dimension is well understandable. New emerging technologies such as Google Earth, Virtual Earth have also contributed to better acceptance of 3D visualisations.

It is not disputable anymore that disaster management is a domain that has to be separately modelled. Emergency response can benefit from many domain models, which can be integrated via translation to a domain-independent model (e.g. CityGML based), but operational information still requires good formalization. The operational model could become very complex depending on the type of disaster to be monitored. The model should be definitely spatio-temporal, representing thematic nature of the real-world phenomena causing the incident (flood, earthquake, air pollution). 3D representations of such phenomena, e.g. of gas plume, 3D buffer around malfunctioning pipe, etc. are still to be investigated. Research on 3D TEN models is very well-suited (Penninga and Oosterom, 2008)

Operational model is closely related to storing/archiving 3D data (row data from sensors as well as 3D models from real-time reconstruction). Such data may become major bottleneck for data integration and analysis if standards outputs and agreements on LOD are not available also for data acquisition techniques.

3D services should provide tamely response. Besides technology requirements, context-aware supply of data is expected to bring significant acceleration by reducing the data to only that information, which is needed for the specific task. The user investigations did not revealed great enthusiasm about context-aware filtering, but good examples are also not available. On the other hand emergency managers (operators, decision-makers) do require simple intuitive interfaces with simple methodologies for communication and data access. This could be an indication that if 3D models provided, the users would consider context-aware aspect especially with respect to LOD.

The requirements for extended (GIS) functionality although not related to 3D has increased. It should be taken into consideration that more functionality would require more training and preparation. In situations of stress, system operators place more reliance on their own judgment and the judgment of other human beings than they do on any form of artificial intelligence. The best solution would use of the systems in daily routine work. As often mentioned, working with a non-familiar system increases stress which may lead to 'expensive' errors when mobilising emergency resources to life threatening situations.

Extended technologies as augmented reality and tangible interfaces have increasingly been under consideration for discussions and decision-making in high-level operational teams. Recalling the results of user requirements investigations, acceptance of technology is higher if the users have the chance to put hands on it. In this respect, it is important to prepare 3D SII prior the need for it becomes apparent.

The success of 3D SII for emergency response is in modular, easily employable 3D services and standards, which allow for access to and visualization on both specialized software and well-accepted internet tools.

ACKNOWLEDGEMENT

Special thanks to Ludvig Emgard, Shuman Kibria, Umit Isikdag Gineke Snoeren, and all the researchers from the project GDI4DM (www.gdi4dm.nl).

REFERENCES

Basta, C., J.M.M. Neuvel, S. Zlatanova and B. Ale, 2007, Risk-maps informing land-use planning processes: A survey on the Netherlands and the United Kingdom recent developments, *Journal of Hazardous Materials*, 145, pp. 241-249

Brecht, H, 2008, The application of Geo-technologies after the hurricane Katrina, in: *Remote sensing and GIS technologies for monitoring and prediction of disasters*, Springer, Heidelberg, pp. 23-34

Diehl, S. and J. van der Heide, 2005, Geo Information Breaks through sector think, in: *Geo-information for disaster management*, Springer Verlag, Heidelberg, pp. 85-108

Emgard, L and S. Zlatanova, 2008, Design of an integrated 3D information model. In: *Urban and regional data management: UDMS annual 2007*, Taylor & Francis Group, London, UK, pp. 143-156

Emgard, L. and S. Zlatanova, 2008a, Implementation alternatives for an integrated 3D information model, in: *Advances in 3D Geoinformation Systems, LNGC*, Springer-Verlag, Heidelberg, pp. 313-329

Isikdag, U., 2006, Towards the implementation of Building Information Models in Geospatial Context, *PhD Thesis*, University of Salford, 2006

Grothe, M.J.M, H.C. Landa& J.G.M. Steenbruggen, 2008, The value of Gi4Dm for transport and water management, in: *Geospatial Information Technology for Emergency Response*, Taylor & Francis Group, London, pp. 313-328

Kerle, N, S. Heuel and N. Pfeifer, 2008, Real-time data collection and information generation using airborne sensors, in: *Geospatial Information Technology for Emergency Response*, Taylor & Francis Group, London, pp. 43 – 74

Kevany, M. J., 2003, GIS in the World Trade Center attack-trial by fire. *Computers, environment and urban systems*, 27(6), 571-583

Kibria, S, 2008, Functionalities of geo-virtual environments to visualize urban projects *GIMA MSc Thesis* (Utrecht Univ., TU Delft, Wageningen Univ., ITC), The Netherlands, 124 p. available at: http://www.gdmc.nl/

Kolbe,T.H. G. Gröger & L. Plümer, 2008, CityGML – 3D city models and their potential for emergency response, in: *Geospatial Information Technology for Emergency Response*, Taylor & Francic Group, London, pp. 257-238

Köhler, P., and J. Wächter, 2006. Towards an open information infrastructure for disaster research and management: Data management and information systems inside DFNK. *Natural hazards, 38*(1-2), 141-157

Lapierre, A. and P. Cote, 2008, Using Open Web Services for urban data management: a testbed resulting from an OGC initiative offering standard CAD/GIS/BIM services, in: *Urban and Regional Data Management; UDMS Annual 2007*, Taylor and Francis, London, pp. 381-393

Lee, J., 2001, 3D Data Model for Representing Topological Relations of Urban Features, *Proceedings of the 21st Annual ESRI International User Conference*, San Diego, CA, USA.

Lee, J. and S. Zlatanova, 2008, A 3D data model and topological analyses for emergency response in urban areas, in: *Geospatial information technology for emergency response,* Taylor & Francis

Lemmen, C. and P. van Oosterom 2006. Version 1.0 of the FIG Core Cadastral Domain Model, XXIII International FIG congress, Munich, October 2006, 18 p

Li, J., and M.A. Chapman, 2008, Terrestrial mobile mapping towards real-time geospatial data collection, in: *Geospatial Information Technology for Emergency Response*, Taylor & Francis Group, London, pp. 103-142

Meijers, M., S. Zlatanova and N, Preifer 2005, 3D geoinformation indoors: structuring for evacuation, in: *Proceedings of Next generation 3D city models*, 21-22 June, Bonn, Germany, 6 p.

Neubauser, S and A. Zipf, 2008, Suggestion ofr extending the OGC Styled Layer Descriptor specification into 3D – Toward visualisation rules fro 3D city models, in: *Urban and Regional Data Management; UDMS Annual 2007*, Taylor and Francis, London, pp. 133-142

Neuvel, J. and S. Zlatanova, 2006, The void between risk prevention and crisis response, in: *Proceedings of UDMS'06* Aalborg, Denmark May 15-17, pp. 6.1-6.14

Parker, C.J., R. MacFarlane and C. Phillips, 2008, Integrated emergency management: Experiences and challenges of a national geospatial information provider, Ordnance Survey, in: *Geospatial Information Technology for Emergency Response*, Taylor & Francis Group, London, pp. 275-310

Penninga, F. and P.van Oosterom, 2008, First implementation results and open issues on the Poincare-TEN data structure, in: *Advances in 3D Geoinformation Systems,* LNG&C, Springer-Verlag, Berlin, Heidelberg, pp.177-198

Pu, S. and S. Zlatanova, 2005, Evacuation route calculation of inner buildings, in: *Geo-information for disaster management*, Springer Verlag, Heidelberg, pp. 1143-1161

Pundt, H., 2008, The semantic mismatch as limiting factor for the use of geospatial information, in: *Geospatial Information Technology for Emergency Response*, Taylor & Francis Group, London, pp. 243-255

Scotta, A., H. Scholten, S. Zlatanova and E. van Borkulo, 2007, Tangible user interfaces in order to improve collaborative interactions and decision making, in: *Proceedings of the 3rd International symposium on Gi4DM*, 22-25 May, Toronto, Canada, CDROM, 10 p.

Scholten, H., S. Fruijter, A. Dilo, and E. van Borkulo, E, 2008 Spatial Data Infrastructure for emergency response in Netherlands. In *Remote Sensing and GIS technology for monitoring and prediction of disaster*, Springer-Verlag, Heidelberg, pp.177-195

Slingsby, A. and J. Raper, 2008, Navigable pace in 3D City Models for pedestrians, in *Advances in 3D Geoinformation Systems*, LNG&C, Springer-Verlag, Berlin, Heidelberg, pp.49-64

Snoeren, G. 2007, User Requirements for a Spatial Data Infrastructure for Emergency Management, *GIMA MSc Thesis*, (Utrecht Univ., TU Delft, Wageningen Univ., ITC),.the Netherlands, 179 p.

Togt,R., E. Beinat, S. Zlatanova, and H.J. Scholten, 2005, Location interoperability services for medical emergency operations during disasters, in: *Geo-information for disaster management*, Springer-Verlag, Heidelberg, pp. 1127-1141

Von der Dunk, F.G, 2008, Legal aspects of using space-derived geospatial information for emergency response, with particular reference to the charter on space and major disasters, in: *Geospatial Information Technology for Emergency Response*, Taylor & Francis Group, London, pp. 21- 40

Van Essen, Maps Get Real: Digital Maps evolving from mathematical line graphs, to virtual reality models, in: *Advances in 3D Geoinformation Systems*, LNG&C, Springer-Verlag, Berlin, Heidelberg, pp.3 – 18

Xu, W. and S. Zlatanova, 2007, Ontologies for Disaster Managmement, in: *Geomatics Solutons for Disaster Management*, LNGC, Springer-Verlag Berlin, Heidelberg, pp. 185-200, London, UK pp. 143-168

Zhang, Y. and N. Kerle, 2008, Satellite remote sensing for near-real time data collection in: *Geospatial Information Technology for Emergency Response*, Taylor & Francis Group, London, pp. 75-102

Zlatanova, S., 2005, Crisis designs, *Geospatial Today*, 4 (1), pp. 30-36

Zlatanova, S., A. Fabbri, A. and J. Li, 2005, Geo-information for Disaster Management: Large scale 3D data needed by Urban Areas, GIM International, 19 (3), pp. 10-13.

Zlatanova, S., P.van Oosterom and E. Verbree, 2006, Geo-information supports management of urban disasters, *Open House International*, 31(1), pp.62-79

Zlatanova, S., D. Holweg and M. Stratakis, 2007, Framework for multi-risk emergency response, in: *Advances in Mobile Mapping Technology*, Taylor&Francis, London, pp. 159-17