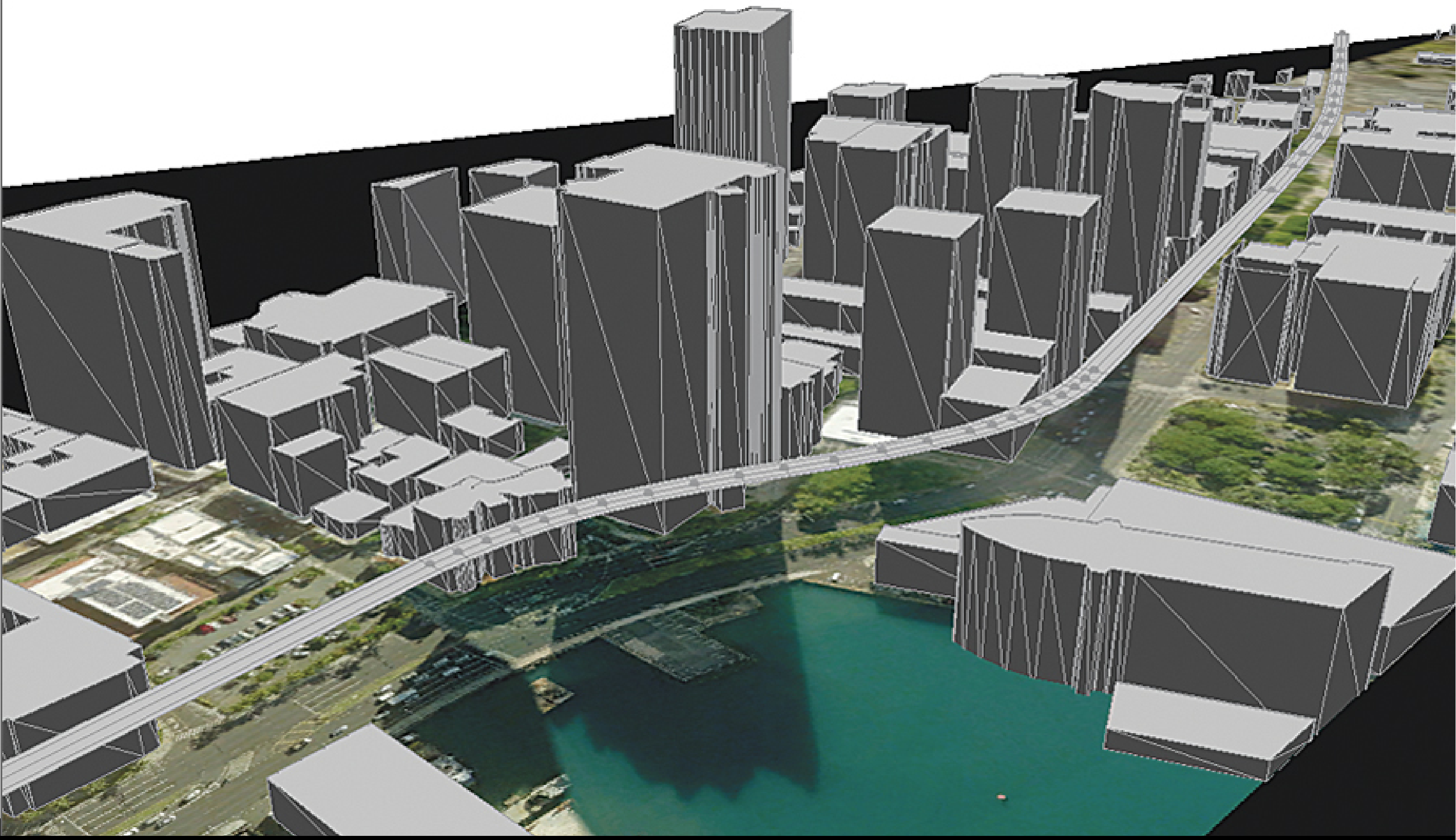

Visualisation conformity of three dimensional IMGeo for emergency response

Thesis
Master Geomatics

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Visualisation conformity of three dimensional IMGeo for emergency response

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Geomatics master thesis, a part of the Geomatics master programme at the Delft University of Technology.

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Foreword

In the second year of the Geomatics master programme at the Delft University of Technology all students have to participate in a thesis project. In this thesis project, most of the subjects taught in the master programme should be combined and used to individually perform a research. The thesis runs for a period of nine months and is concluded with a final presentation.

The main objective of this thesis was to development a conceptual extension for IMGeo for 3D emergency response, containing user requirements.

The thesis showed me how to combine the aspects of Geomatics and provided a social context for all that was taught during the past few years. Even though the research took a while longer than initially planned, due to multiple circumstances, I enjoyed doing my own research for my Master and contributing to the academic world.

I would like to thank dr. ing. S. Zlatanova for her help, her enormous support, her time and her endless patience. Without her advice and participation this thesis would not have been completed.

I would also like to thank prof.dr.ir. P.J.M. van Oosterom, and ir. F. Welle Donker for providing me with feedback and support during the thesis project. And finally I would like to express gratitude to ms. E. Fendel for her care and patience and to drs. Peters for his suggestions.

Delft, January, 2014
Elise Tierie

Abstract

The past seventy years the number of disasters that occur, man-made and natural, has increased. This problem requires suitable and efficient means to control and respond to emergency situations. Currently, the emergency responders use maps and software that allows for two dimensional visualisations of situations. Meanwhile the development of visualisation software continues. In the Netherlands the interest in CityGML, software for 3D city visualisation, has vastly increased after the 3D pilot 'NL', coordinated by Geonovum. As a result of this interest, Geonovum has set up a Dutch CityGML format, which is an extension of the existing 2D IMGeo format. This extension contains the standard 3D objects that make up a city, but might lack objects that are required specifically for disaster fighting. A three dimensional environment could provide a better overview of a location than a 2D map and also allow for 3D, and thus more realistic, computations such as 3D distance, 3D flow computation, 3D visibility analysis and for example flood simulations. These possibilities could have profits for emergency responders but might require extensions of the IMGeo information model and its data before IMGeo can be used for emergency response. This leads to the research question of this thesis:

To what extent do IMGeo and CityGML comply with the user needs in a 3D emergency response model, and what is missing?

This gives way to the main objective of this thesis: **To development a conceptual extension for IMGeo for 3D emergency response, containing the user requirements.**

The research conducted consisted of a literature study, interviews with experts and an insight analysis based on the previous stated elements. The literature exists of various studies conducted on user requirements for (3D) visuals for emergency response. The interviews with experts were personally executed and consisted of open questions and multiple choice questions supported with images to excite their imagination.

This research discovered that IMGeo and CityGML comply with the basic needs of emergency response but it also came up with important concepts for both extensions and expansions. The extensions covered multiple code lists that were incomplete (e.g. specific type of bridges) or missing. Code lists that are currently not in IMGeo but necessary for emergency response purposes are: tunnel ventilation, tunnel function, building construction, building function and bridge material. The expansion set up for 3D emergency response modelling is so called "Scenario based modelling". The government has divided disasters and emergencies into different categories, e.g. flood or large fire. These categories form the base of the scenario based modelling for the expansion of IMGeo for emergency response. These pre set scenarios, with three dimensional objects related to the scenario, will be efficient for the user of the information model to use because the model is already set up for certain situations. This efficiency will save time and could reduce risks and mistakes made in decisions. The scenarios are to be worked out into UML diagrams that can be linked to IMGeo and CityGML and thus make an effective and efficient model for 3D visuals for emergency response.

Another important addition is 3D symbolisation. One of the software currently used contains 2D symbols that can be placed on the map to allow quick identification of certain locations and organisations. This function was assessed as very useful. For a 3D information model, the symbols are to be transformed to 3D symbols so they can be seen easily in a three dimensional environment.

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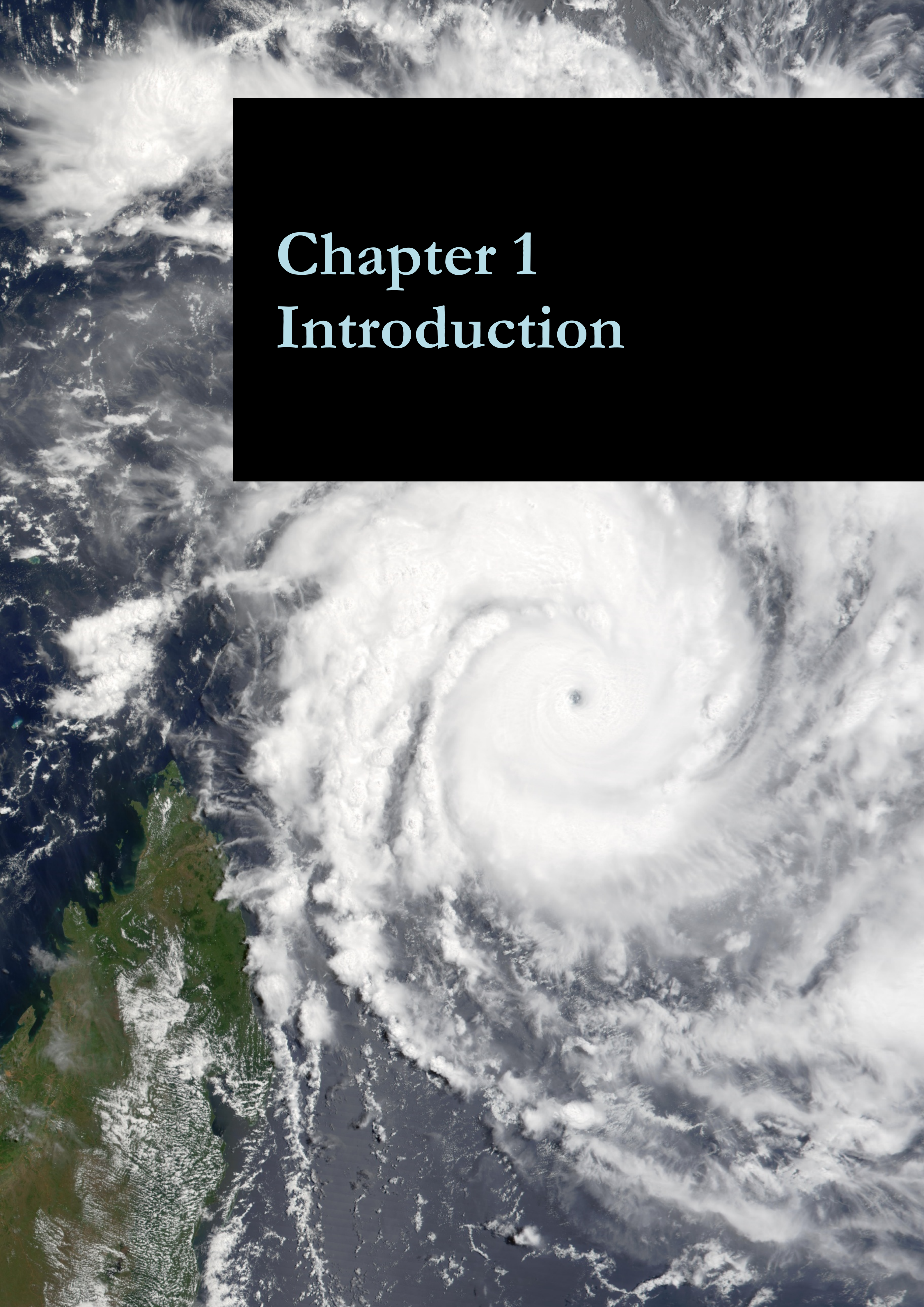
Glossary

3D	Three dimensional
AHN2	Actueel Hoogtebestand Nederland 2 **(**Current Dutch Height File Version 2)
BAG	Basisregistratie Adressen en Gebouwen (Base Registration for Addresses and Buildings)
BGT	Basisregistratie Grootschalige Topografie
CityGML	A data model for the representation of urban objects in 3D
COP	Common Operational Picture
COPI	Commando Operational place incident
CRS	Coordinate reference system
DTM	Digital Terrain Model
GBKN	Grootschalige Basiskaart van Nederland
GDI4DM	Geographical Data Infrastructure for Disaster Management
Geometry	A branch of mathematics regarding questions of shape, size, relative position of figures and the properties of space
GHOR	Geneeskundige Hulpverleningsorganisatie in de Regio (Medical Assistance in Accidents and Disasters)
GIS	Geographical Information System
GML	Geography Mark-up Language
GRIP	Coordinated Regional Incident Abatement Procedure
IMGeo	Information Model Geography
KLIC	Kabels en leidingen Informatie Centrum (Cables and Pipes Information Center)
LiDAR	Light Detection And Ranging
LOD	Level Of Detail
OGC	Open Geospatial Consortium
ROT	Regional Operating Team
Semantics	The study of meaning
Stakeholder	A person, group organisation who affects or can be affected by an organisation's action
TCA	Time-critical applications
Topology	A major area of mathematics concerned with the most basis properties of space
Virtual reality	A term that applies to computer-simulated environments that can simulate physical presence in places in the real worlds and in imaginary worlds.
UML	Unified Modelling Language

Chapter 1
Introduction



1. Introduction

Everyone encounters some kind of an accident or a disaster during their lifetime. A disaster is a sudden, calamitous event bringing (great) damage, loss, and destruction to life and/or property.

1.1 Introductive information

Generally, there are two types of disasters: natural and man-made. Based on the devastation, these are further classified into major and minor natural disasters (e.g. cyclone/thunderstorms) and major and minor man-made disasters (e.g. epidemic/road accident) (Brebbia et al., 2011). Both major and minor disasters need managing and controlling. During the managing of an emergency or a disaster and its consequences, different assisting- and controlling activities take place, depending upon the type of disaster and its effects. Emergency response is a complex matter. Rescue services can be at a major incident or disaster within minutes, altering their daily routine to an intensive cooperation. From various disciplines, a team must be developed that is able to adequately control the incident. In addition to fire fighters, police and the Medical Assistance in Accidents and Disasters (in Dutch abbreviated as GHOR), the municipalities are also an important part of the multidisciplinary emergency management team.

Disaster management is commonly understood to consist of four phases: Mitigation, Preparedness, Response and Recovery. Mitigation describes processes aimed at reducing the occurrence of emergency situations. Preparedness focuses on preparation among rescue forces for emergency situations and instructions. Response is the phase occurring right after the event. Recovery includes all engagements to handle damage and loss. (Zlatanova, 2008). The combination of four phases is called emergency control

Figure 1: The four phases of disaster management (Amdahl, 2001)

The Emergency response consists of processes that are divided into clusters based on the nature of the incident. Each cluster has one department, fire department, police, GHOR or municipality, who has the responsibility (Snoeren, 2006). Depending upon the severity of the calamity, the scale can be just municipal/local or escalate up to provincial or even national or international. Disasters typically do not respect national borders. Although outside the scope of this thesis, cross border regional calamities present an extra difficulty in terms of communication, (lack of) joint procedures and confusing jurisdiction matters. In the Dutch system a secondary entity in the system, almost parallel to the province, is the dyke- and polder board or body of surveyors of the dikes and waters (RWS), with a crucial role in all water management related matters. The importance of their role is frequently underestimated. Even though they are not part of the organisations that handle emergencies directly, they are a crisis partner when the emergency or disaster relates to (excessive) water. The RWS is called in for their additional information and expertise.

The mentioned clusters are stated in appendix A. Each cluster contains processes that will allow assisting and controlling the situation (e.g. fighting fire and emission of hazardous substances by a fire department in the cluster *source- and effect control*). In controlling an emergency situation, organisations rely on information that is present and on newly acquired (spatial) data. The new data are processed, shared and can be put into a database, a map or a computer model. Based on the information organisations take decisions which are made on how to proceed in a specific situation. "The timely provision of spatial information can greatly help in this decision-making process, save lives and aid citizens" (Zlatanova, 2008: xi).

3D modelling and mapping are being used by an ever increasing and varied range of consumers, for purposes as diverse as city planning and architecture, utility management, transportation, tourism and emergency response (figure 2) (Pegg, 2012). A geographic information system (GIS) integrates software and data for capturing, managing, analyzing and displaying all forms of geographically referenced information for these purposes. It brings together our complex data and knowledge and makes it accessible. Systems and organisations can use one another's services, thus dynamically integrating our common spatial knowledge. The GIS output can be visualised in 2D or 3D maps or simulations, depending on the user requirements and the guidelines of display.

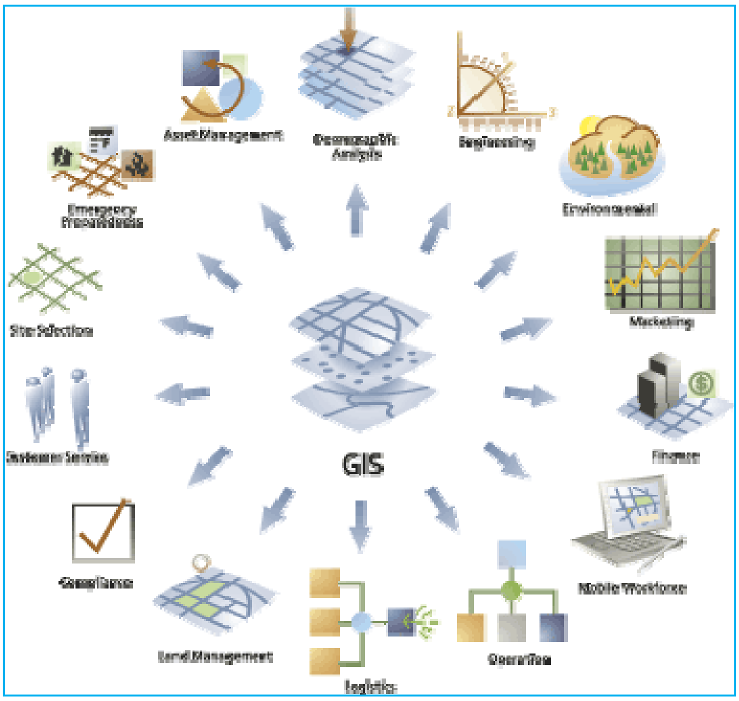


Figure 2: GIS Element wheel (North Augusta, 2012)

But with the enhancements in technology causing 2D maps to develop at a rapid rate, there has been little time for determining guidelines for the design and presentation of 3D maps. While much research has been done on the technology and creation of 2D mapping products, no official design principles exist for 3D representations. For classical 2D, they were created mappings created a long time ago. Unfortunately there is still not enough knowledge about the users' requirements of 3D maps. "As with most cartographic products, it is imperative that the user's needs, skills and perceptions are understood and cartographic principles are derived from that understanding" (Pegg, 2012: 5). 3D map users' perceptions and behaviours are largely unknown, and this must be resolved to enable the cartographer to develop a successful 3D visualisation (Badrova, 2005).

1.2 Dilemma

3D spatial information has always been a challenge due to a variety of data models, resolutions, details and ways of representation. Since the 9/11 disaster, the interest in 3D information models for emergency responses is increasing ever more (Zlatanova, 2008). A predicament with 3D mapping is that there are currently no adequate standards or design principles to guide cartographers in creating functional, user friendly 3D maps and a little knowledge of a map reader's requirements (Schobesberger, 2007). For matters concerning symbol recognition, scale altering, atmospheric conditions, seasonal variances, viewing points and illumination, settings are all currently up to the user (Pegg, 2012). These aspects combine into a 'Computer generated imagery' (CGI). This is the application of computer graphics to create or contribute to images in computer games and simulations. The visual scenes may be dynamic or static, and may be 2D, although the term "CGI" is generally used to refer to 3D computer graphics used for creating scenes or special effects in films and simulations. Besides the technical aspects of a 3D model we need to look at the subtler aspects that can enhance users' understanding and comprehension of a landscape or building depicted in a 3D way. All mapping relies on understanding the requirements of the user and the objectives of the individual or organisation who commissioned the map as to what they want the map to display.

"A socio-technical viewpoint has been adopted that means that spatial data infrastructures are being regarded as worthwhile only if they are meeting genuine user needs. The users' need are the driving force for spatial data infrastructure development therefore the user requirements need to be defined in the initial phase of the development process" (Snoeren, 2007).

For emergency response learning objectives, it can be very useful to practise with virtual geo-specific environments. When these geo-specific environments are needed, they can be custom made in 3D by a gaming company, which for custom made scenarios can be very expensive and time consuming. According to Campen et al. in their research in 2011, the use of existing 3D models face many challenges:

Multiple file formats exist, making the integration of different parts very difficult. Also, most information models are pure geometric representations of the real world and don't have attributes such as material of a wall or roof etc. Finally, the models have different resolution and accuracy. An example is stated where some parts of the city are modelled with a very high resolution while other are represented very schematically. The absence of these standards creates a dilemma and with that the foundation of this thesis.

"With growing population and infrastructures the world's exposure to natural hazards is inevitably increasing" (Bournay, 2007: 1). This is particularly true as the largest population growth is located in coastal areas, with greater exposure to floods, cyclones and tidal waves. On top of that, most land that remains available for urban growth is prone to risk regarding flood plains or steep slopes subject to landslides (Bournay, 2007). In order to mitigate, prepare for, response to or recover from a disaster, it is of great importance to have a quick information flow and good communications channels.

Spatial data acquisition and integration that is continuously updated with newly collected data from the field can be very critical for monitoring the disaster events and giving instructions to the people involved.

From a database point of view, this practice requires 3D position devices to determine the event locations, and instantly propagating the information to all the users; Dynamic and multi-dimensional representation of physical and human processes allows for quicker understanding of (urban) structures and can support in decision-making (Lee, 2008). "The fact that CityGML is available as a data model is expected to encourage data providers to organise their 3D city information models according to the CityGML standard, i.e. containing a rich variety of semantic, geometric and appearance properties. The database storage will further facilitate the seamless, consistent and robust management of large data sets. Several other CityGML implementations for databases were discussed as well (Emgard, 2008a)" (Campen et.al., 2011:9).

In the Netherlands the interest in CityGML has vastly increased after the 3D pilot 'NL', coordinated by Geonovum. As a result of this interest, Geonovum has set up a Dutch CityGML format, which is an extension of the existing 2D IMGeo format (Campen et.al., 2011). But as many stakeholders are involved in the CityGML development process it could be that evolving the CityGML standard takes more time than expected. According to Campen et al. in his research in 2011, well thought through coordination of meetings and development research by the TU Delft can greatly mitigate this risk. As stated in the introduction, all mapping and modelling relies on the understanding of the requirements of the user. When a user cannot operate a system or a system does not function in a way the user needs it to, then a system is useless. Therefore it is important to know what opportunities there are for 3D visualisations and information in emergency response, without the complexity of the information model becoming too large for the user or not meeting the user's requirements.

1.3 Research

A three dimensional environment could provide a better overview of a location than a 2D map and also allow for 3D, and thus more realistic, analyses. These possibilities could have profits for emergency responders but might require extensions of the IMGeo information model and its data before IMGeo can be used for emergency response. This leads to the research question of this thesis:

To what extent do IMGeo and CityGML comply with the user needs in a 3D emergency response information model, and what is missing?

By dissecting the core research questions, the secondary questions to guide through the research are formulated as follows:

- Who are involved in emergency response?
- How can IMGeo, and with that, CityGML contribute to the emergency response procedure?
- What are the user requirements for a 3D emergency response model?

Beside research questions, research goals provide actionable information and knowledge by guiding the researcher through phases to obtain all the data. The main objective of this thesis is:

To development a conceptual extension for IMGeo for 3D emergency response, containing user requirements.

The application demand extension objects that were found missing in CityGML but necessary for emergency respond purposes can be added to this conceptual model. The objective can be divided into sequential sub-objectives:

- To research current information models regarding 3D information
- To investigate which geo-spatial information components are to be added when establishing a conceptual information model for emergency response in 3D.

With the context and the goals of the project defined, a first approach can be determined. The research approach is guided by finding answers to the secondary questions and thus achieving the goals that were set. To accomplish these goals and present an answer to the core research question, a certain work flow can be wielded. In figure 3 this research's work flow diagram is depicted, describing the organizational hierarchy of the process. It contains blocks of processing steps, each block being a prerequisite of the following block.

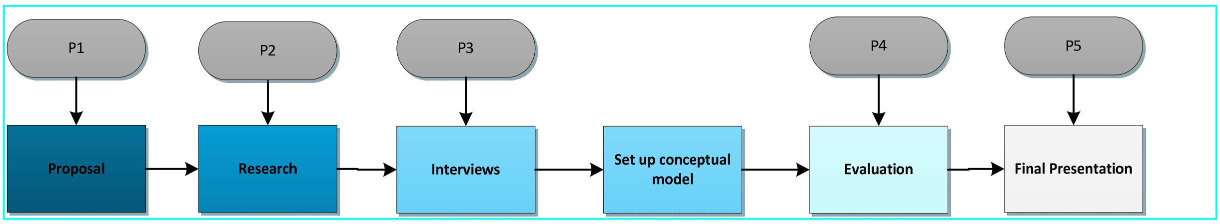


Figure 3: Workflow

The proposal phase presents the preliminary research, literature study and the writing of the project plan. This project plan contains the core research question, the scope of the thesis, the objectives of the research and the plan of approach to answer the core research question and present a plan for IMGeo as a future 3D information model for emergency response.

The research phase will describe the emergency management more elaborately. It will provide more insight in the stakeholders and their tasks. Furthermore the current systems and models will be described and which geo-information they use. This includes the user requirements set up thus far and the potential of extending the 2D models to 3D models. A combination of literature study and interviews with experts will provide insight in the data and information models already being used and which user requirements an emergency response model has.

Interview

The interview phase exposes the researcher directly to the stakeholders involved in emergency response. This interview consists of so called open questions and multiple choice questions. The questions will be placed in topics with sub-topics to allow for a systematic and structured way of working and preclude misunderstandings about the questions. The interviews will be conducted in person on specialists that participate in real time situations. By carrying out the interview in person, it will allow the specialist to tell more than the interview might cover. Specialists from the three organisations, police, fire department and medics, will be interviewed to be able to design IMGeo for emergency response, and that is usable by different stakeholders. From the organisations police and fire department, five specialists each will be interviewed and two medics who handle disaster scenes will be questioned.

The answers given in these interviews will be processed and analysed by means of a content analysis. The results of this content analysis will, fictionally, be applied to the model and then presented to the interviewed asking for confirmation and feedback. A feedback loop will eventually lead to changes for IMGeo before it complies with the requirements of emergency responders.

Set up conceptual model

Designing a conceptual model is about creating is a representation of concepts and the relationships, constraints, rules, and operations to specify data (semantics) for emergency response in. This model is based on existing geo-spatial information components in 2D, how the geo-spatial information components are used and which supporting functionalities of geo-virtual environments are required to visualise the information a stakeholder wants for decision making during an emergency in 3D. Each of these aspects have become clear during the research and the interviews, or at least allows for a set up of an conceptual model that will support 3D models for emergency response and are visualised in a schematic overview. This schematic overview will grant structure, behaviour, and more views of the emergency response or disaster control. Perhaps the exchange of the models between stakeholders allows for better emergency response and management. By determining who else can use the information and in which standard, it can boost interoperability between the stakeholders.

Evaluation

In the evaluation phase the concepts for the extensions of IMGeo will be presented to random stakeholders to confirm their ideas and requests and make adjustments if desired. This evaluation is a feedback loop in which the IMGeo alterations are flexible for changes and requirements.

Final Presentation

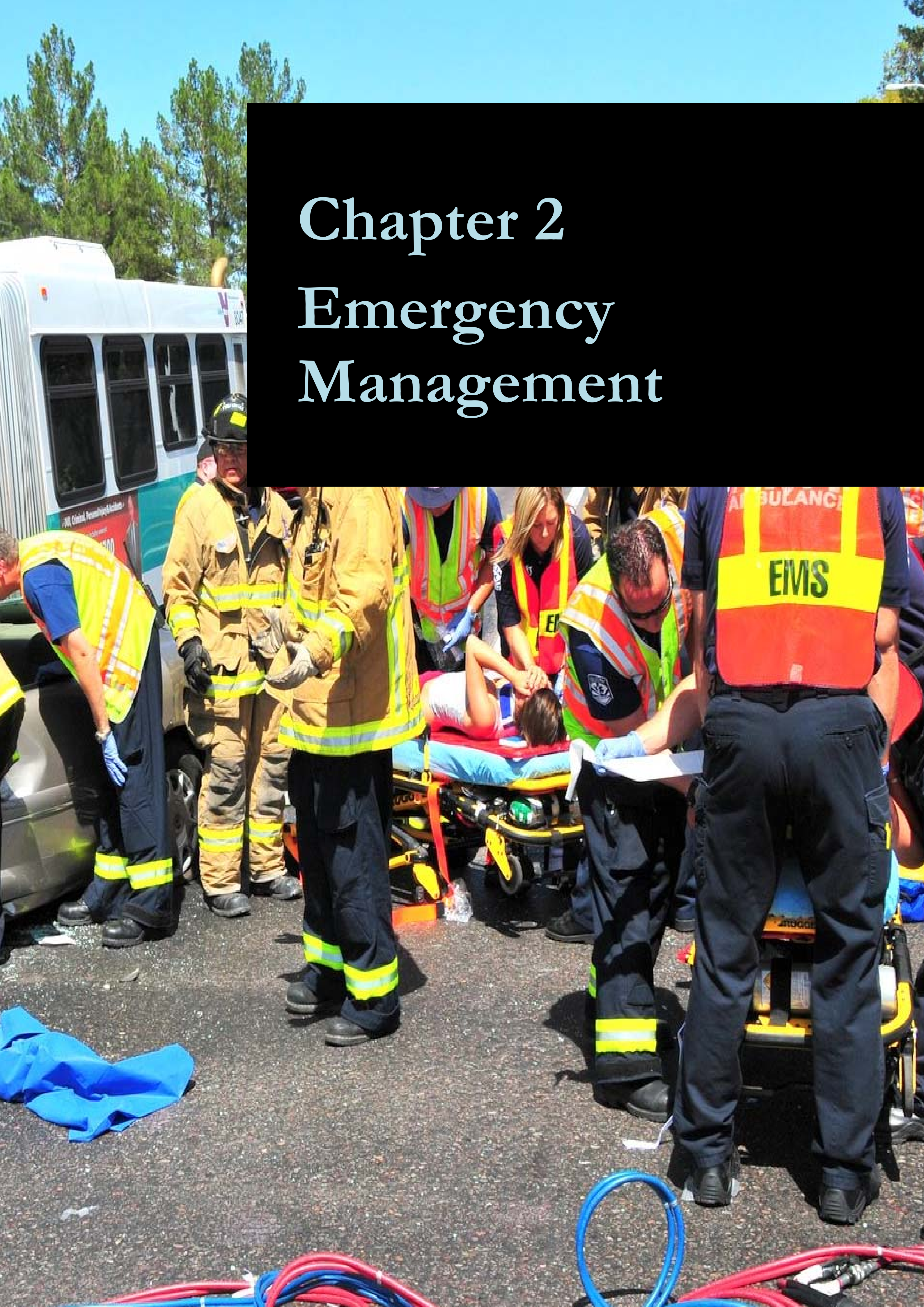
The final presentation is the end of the thesis. This includes the technical presentation at 'P4' and the final public presentation at 'P5'. The final presentation will include all that stated is in this thesis and will be presented according to the chapters present in the documented research.

The focus of this thesis will be on the usability of 3D software for emergency responders in the Netherlands. The research will be conducted based on the experience and methods of expert in or around the Safety Regions in Rijnland-Rotterdam, Kennemerland, Utrecht and Overrijsel. These areas are chosen based on its prominence, size and their preparedness to participate.
This thesis includes the user requirements, both functional and visual, in geo-referenced 3D computer Generated Imagery (CGI). Although the taxonomy of (visual) functionalities is achieved through the analysis of requirements, a concept version is presented in appendix D: breakdown of a 3D information model. In this figure the visual functionalities are: level of detail (LOD), texture, 3D objects and geo-reference. Besides that, this thesis concentrates only on virtual reality and excludes augmented reality. Its focus lies with visual means and not with tactile and other possibilities for immersion. The results of this thesis are based on expert opinions from the Safety Regions and other organisations involved in emergency response. Figure 1 shows how emergency control consists of four phases. This thesis will focus on the emergency response, because this is the main task of the Safety Regions. The thesis consists of an requirements analysis of different functionality designs that professionals need for their geo virtual environments found through interviews and literature. The development of the information model for 3D functionalities during emergency control will be based on an existing IMGeo and other models for the Safety Regions and on the results from the user requirements analysis. This information model will provide more insight into which data is needed and when it is needed.

1.4 Structure

First the emergency management and its stakeholders are mentioned and elaborated upon. This contains information on the emergency response procedures, who is involved and which rules apply. After this, (3D) information models in emergency control are discussed. The fourth chapter will provide insight in the user requirements of these models. Collecting these insights will be done through a literature study and consulting with experts. Then, based on the user requirements, the 3D IMGeo information model will be extended and expanded for emergency response. The next chapter, chapter six, will be about scenario based modelling. Finally the discussions, conclusions and recommendations are stated.

Chapter 2 Emergency Management



2. Emergency management

This chapter will shed light on the emergency response procedure, the stakeholders involved in this procedure and their tasks.

2.1 Emergency response procedure

The emergency is called in at the emergency room (mostly 112 in Europe or 911 in the US). Here it is determined which services are needed and where. The parties that are required are informed of the situation and mobilised. Coordinated Regional Incident Abatement Procedure (in Dutch abbreviated as GRIP) is the name of the procedure that determines how the coordination between emergency services runs and is divided into different alarm coordination phases. The central concept of this procedure is that larger incidents are to be handled differently than smaller ones, because more resources and administrative levels are involved. Going from one level of GRIP to another is called up-scaling.

The GRIP scheme has its origin in the Rotterdam-Rijnmond region but is now used nationwide. With the advent of GRIP, there are now national guidelines for up-scaling. This creates more uniformity in the scaling of emergency response in the fire department, police, GHOR and municipalities. The procedures regulate scale operational levels around the site of the incident and also at the policy level of municipalities involved (Rijkswaterstaat, 2010). The GRIP phases are listed in table 1.

Table 1 GRIP phases

Phase	Scope of the incident
GRIP 1	Source Control. Incident of limited dimensions. Coordination between the various disciplines necessary
GRIP 2	Source and effect control. Incident with clear emanation to the surrounding area.
GRIP 3	Threat to the welfare of (large groups of) the population within a single municipality.
GRIP 4	Cross-border municipality and / or threat of expansion and / or possible shortages of basic necessities or other matters.

Each coordination alarm phase has its own characteristics, which are based on the associated tasks, powers and responsibilities of the stakeholders. The scaling procedure can be started by any manager of the operational services or when the mayor indicates to work according to the structure of the municipal emergency plan, making the actual scaling an administrative responsibility.

Table 2 shows which three dimensional data could be relevant per GRIP phase. The potential 3D required per grip as stated in table 2 is a rough hypothesis. Depending on the GRIP phase, and thus the scale of the emergency, it is an estimation of which three dimensional data will be needed to support emergency response. As the GRIP is up scaled, the information of the previous GRIP remains.

Table 2 GRIP phases with 3D expansion

Phase	Examples of potential 3D required
GRIP 1	Information on building floors, construction of buildings and bridges
GRIP 2	e.g. (gas)pipes underground
GRIP 3	3 dimensional street view like Google Earth
GRIP 4	See GRIP 1,2,3

During emergency control there are stakeholders involved at the site of the emergency and there are stakeholders at the office, coordinating from behind their computers. This division is based on a fixed distribution of the stakeholders and their tasks.

2.2 Emergency response stakeholders

There are many organisations, stakeholders, involved in emergency response. A stakeholder or interested party is a person or organisation that experiences influences (positive or negative) or can influence a specific organisation, government decision, a new product or a process (Karim et al, 2007).

The main stakeholders consist of the strategic coordination, the policy stakeholders, whom make decisions from a workstation, and the operational stakeholders, whom assist and control the emergency on site. A scheme of the stakeholders, their Supremes and their supporting function is given in appendices B and C. Policy stakeholders are the (local) government. Emergency management is an indispensable function of local governments that is supported by both state and national government because it is seen as a public good. The operational stakeholders are the police, the fire department, the medics and third parties.

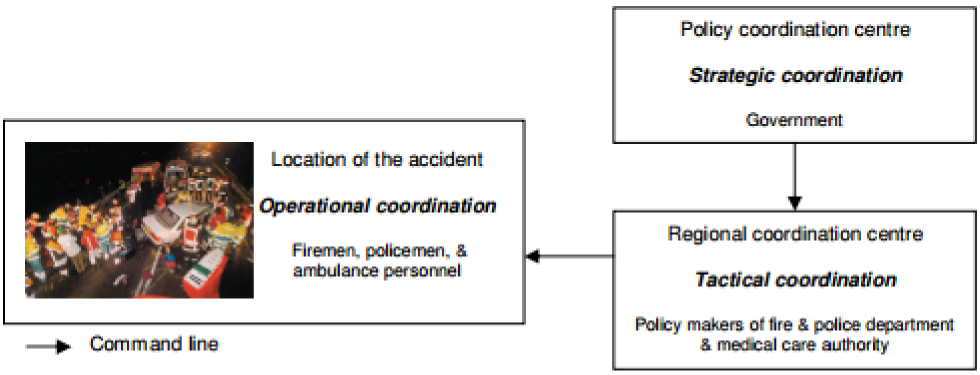


Figure 4: Distinction between operational, tactical and strategic coordination (Snoeren et al., 2007)

Most of these stakeholders will, at a certain point, come into contact with spatial data information during an emergency and will therefore have to be able to work with it. Internet and governmental databases offer an increasing amount of publically available 3D information models of buildings and/or geo-specific environments for use in emergency response (training) by companies, municipalities and other governmental institutions (Zlatanova et al., 2010). In a so called Safety Region, the fire department, the medicals teams, the police and the municipality co-operate and join forces to improve the fire services, medical assistance and the police at regional level together, in order to prevent and control crises and disasters. The realisation of these Safety Regions are in full swing since the finalisation of the Law on Safety Regions. There are 25 Safety Regions in the Netherlands that control the approach of large accidents, disasters and crises, such as floods, epidemics and terrorism.
While at local level they are faced with different specific challenges, the Safety Regions are broadly similar. The issues are therefore also to a certain extent similar.

The multiple organisations participating in the safety regions create leading teams consisting of stakeholder from all the participating organisations. These leading teams are:

- COPI, Commander at Place of Incident
- ROT, the Regional Operational Team
- BT, Policy team

In these 25 Safety Regions the municipalities and the emergency teams cooperate with other organisations, the so called crisis partners. Examples are of these crisis partners are:

- Body of surveyors of the dikes and waters;
- Public Prosecutor;
- Regional Services Department of Public Works;
- Regional Military Command: army, navy, air force, marines, military intelligence

Besides these, there are other (private) organisations that could, due to their essential function in the society and their expertise and capacity, play an important role in crisis control. For example:

- Hospitals
- Royal Dutch Rescue Society (KNRM, focused upon open sea search and rescue);
- Red Cross;
- ProRail, NS;
- Companies: utilities (power), industrial (chemical accident). The utilities regarding power and gas are especially important. They provide goods that can be very hostile in emergency situations and may need to be switched off immediately.

Each of these stakeholders could benefit from having 3D data for information to execute their tasks. Adding height coordinates to maps or displaying surroundings will create a three dimensional environment (x,y,z coordinates) that could look like reality very much. This virtual reality can, for example, provide a better sense of orientation, provide extra (in)sight in locations and speed up the response process.

2.3 Stakeholders and tasks

There is always a statistical certainty, small or large, that a disaster will take place and therefore there is need for emergency forces and a task division (Neuvel & Zlatanova, 2006). In the Netherlands 18 different types of disaster can take place (Ministerie BZK, 2003)(Snoeren et al., 2007).

- Disaster in relation to traffic and transport
    1. Aviation accident
    2. Accident on water
    3. Traffic accident on land
- Disaster with dangerous material
    4. Accident with inflammable/ explosive material (in open air)
    5. Accident with toxic gasses (in open air)
    6. Nuclear accident
- Disaster in relation to public health
    7. Treat to public health
    8. Dispersal of disease
- Disaster in relation to infrastructure
    9. Accidents in tunnels
    10. Fire in big buildings
    11. Collapse of big buildings
    12. Disruption of utility
- Disaster in relation to population
    13. Panic in large groups
    14. Large-scale disturbance of public peace
- Nature disaster
    15. Flood
    16. Nature Fire
    17. Extreme weather conditions
- Disaster on distance
    18. Incident out of city boundaries, in which citizens of that city are involved

These disasters are monitored and controlled by the tactical coordination teams, the Safety Regions. The board of the Safety Region is responsible for the design of the main structure of the disaster and crisis management which consists of the following components:

- Emergency room;
- A command or incident location, lead by the fire department;
- A team population care, lead by the GHOR;
- A regional operational team, lead by the police department, and
- A municipal policy team at a local disaster or crisis, or a regional policy team at a top local disaster or crisis.

By structuring these components, the Safety Regions are capable of risk control, incident control and to standardise the hectic situation. In the fight against disaster, depending on the type of disaster and its effects, various help and control activities shall take place. Set-related activities can be described as processes. The disasters and their management processes are divided into clusters. For each cluster is a group: fire department, police, GHOR or municipality responsible. The disaster control processes and their clusters are shown in Appendix A (Snoeren, 2006).

Figure 5: Fire department on sight

Table 3 shows who is responsible for which cluster of situations.

Table 3 Stakeholders and their clusters

Who	Responsible for cluster:
Fire department	Cluster A: Sources and Effects Control
Police	Cluster C: Legal procedures and traffic
GHOR (Medics)	Cluster B: Medical Help
Municipality	Cluster D: Population Care

Cluster A: Sources and Effects control

The stakeholders involved in Sources and Effects control are (Snoeren, 2006),

- Emergency room: The dispatcher receives the message (s) of the incident and alerts the commander and, if the CvDB. In addition, a dispatcher provides the radio connections between the different parties, especially between the commander and the DTC.
- Commander: The commander is the first to be alerted by the dispatcher. He goes with his (Fire engine) team to the place of incident.
- OvDB (Duty Officer of the Fire): coordinate of the incident location. He has contact with the commander (s) and the centralized control room.
- CvD (Commander of Department): In the event that multiple DTC's are present at a site, a CvD will come.
- ROT (regional operating team): In the case of a larger disaster (GRIP-phase from 2 with an impact area) the ROT will be used. The ROT aligns the assorted emergency services

Their tasks include:

- Fire fighting and emission of hazardous substances fighting
- Rescue and extrication
- Disinfect human and animal
- Disinfecting vehicles and infrastructure
- Observing and measuring
- Alerting the population
- Making sites accessible and clean up of sites

The information needed that is needed for cluster A is stated by Snoeren et al. in Rampenbestrijdingsprocessen, stakeholderen, werkwijze, data and is lined up in table 4. Some of these aspects can be modelled in 3D and may be of added value in emergency response information models.

Table 4 Sources and Effects control information (Snoeren et al., 2006)

Sources and Effects control information
Location fire
Nature fire
Size fire
Location fire department units
Area under threat
Meteorological data
Access site
Water supply site
Infrastructure
Population
Urbanism
Risk sites
Terrain
Background and orientation
Special objects

Schematic representation processes cluster A

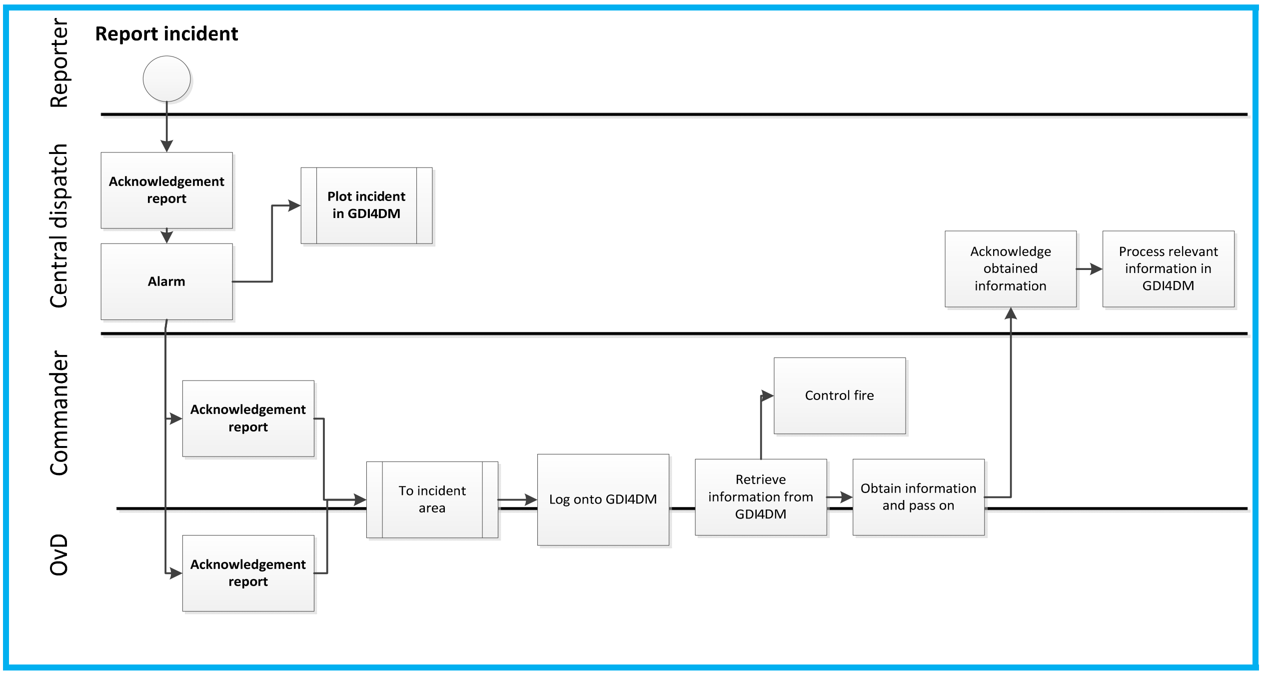


Figure 6: Cluster A (Snoeren, 2006)

Data that can be modelled and visualised in three dimensions are objects related to the infrastructure, urbanism, risk sites, terrain and special objects. Modelling the buildings, or urbanism, in 3D could provide more information regarding the collapse risk of that structure and the damage that it could inflict. A higher building will cause more damage to its surroundings than a smaller one. So at the same time, if the buildings near a building on fire are modelled in 3D it can give additional information on possible casualties and damage. This could be calculated with a 3D buffer zone or distance computations and help out the tasks of the fire department regarding rescue operations, technical assistance and alerting the right population. The height of the buildings and structures around a fire can also have an effect on smoke distribution, so to see the buildings in 3D can provide additional information on where smoke will travel. I.e. allow for a 3D flow computation of smoke or toxic clouds. This would give a more accurate estimation and allow for better emission fighting and observing and measuring. A terrain that is modelled in 3D can give a much quicker overview of a site than a map with height markings. The height of terrain could co determine where to access or exit a site and where safer places are with respect to hazardous places. Also to know how the water flows:

- through the rivers and canals;
- after a dike break;
- after a heavy downpour of rain;
- below ground;

for flood and water runoff calculations.

Risk sites modelled in three dimensions could also provide a quicker overview and a better insight into the site. Emergency responder would not have to look up what the structures/sites look like and where the risks is located on a map, but they could walk through the virtual environment or view the structures in 3D from any angle they prefer.

Cluster B: Medical help

The stakeholders involved in Medical help are (Snoeren, 2006),

- *Emergency room*: The dispatcher receives the message (s) of the incident
  Deploying additional regional ambulances;
  Alerting / recall of relevant key officials within the GHOR;
  Coordinating with the central stations of firemen and police;
  The activation of the alarm schemes;
  Alarm of one or more Mobile Medical Teams;
  Requesting ambulance assistance in the neighbouring regions;
  To warn and / or alerting hospitals;
  To implement the distribution plan wounded;
  The use of a coordinator of victims transport
  Register of actions taken,

Regularly transmitting position reports to the HS-GHOR.

- RGF: Regional Medical Officer: It is the task of the RGF to lead to the overall process health assistance. He / she advises, as a member of the Policy Team, the Mayor (s) concerning the policy of the GHOR. On behalf of the public administration is he/she also responsible for the coordination of the GHOR processes.
- HS-GHOR: Main section GHOR: He/she leads, on behalf of the RGF, the section GHOR in the ROT and he/she gives on behalf of the RGF, from the ROT directly led to the medical organization.
- OvDG: Duty Officer Medical: From the scaling idea GHOR OvDG is the coordinator of the GHOR processes at the location of the incident.

Their tasks include:

- Medical Assistance-somatic
- Preventive Public Health (including collecting infected goods)
- Medical Assistance psycho-social

The information needed that is needed for cluster B is stated by Snoeren et al. in Rampenbestrijdingsprocessen, stakeholderen, werkwijze, data and is lined up in table 5. Some of these aspects can be modelled in 3D and may be of added value in emergency response information models.

Tabel 5 Medical help information

Medical help information
Location incident
Nature incident
Size incident
Development incident
Location fire department units
Area under threat
Meteorological data
Access and exits site
Number of victims
Location hospitals
Infrastructure
Terrain

Medical help, cluster B, is perhaps in lesser need of 3D modelling than other clusters. Medics often do not enter buildings during disasters, but wait for the police or fire fighters to free people. For ambulances and medics the road and infrastructure to a location is the most important. 3D Terrain could also partly determine the access to locations to allow for a faster medical assistance. By modelling data like terrain and infrastructure in 3D, the medics have a quicker overview. Everything that makes any procedure faster, and allows the quality to be the same, seems better in case of saving lives or providing other medical aid.

Schematic representation processes cluster B

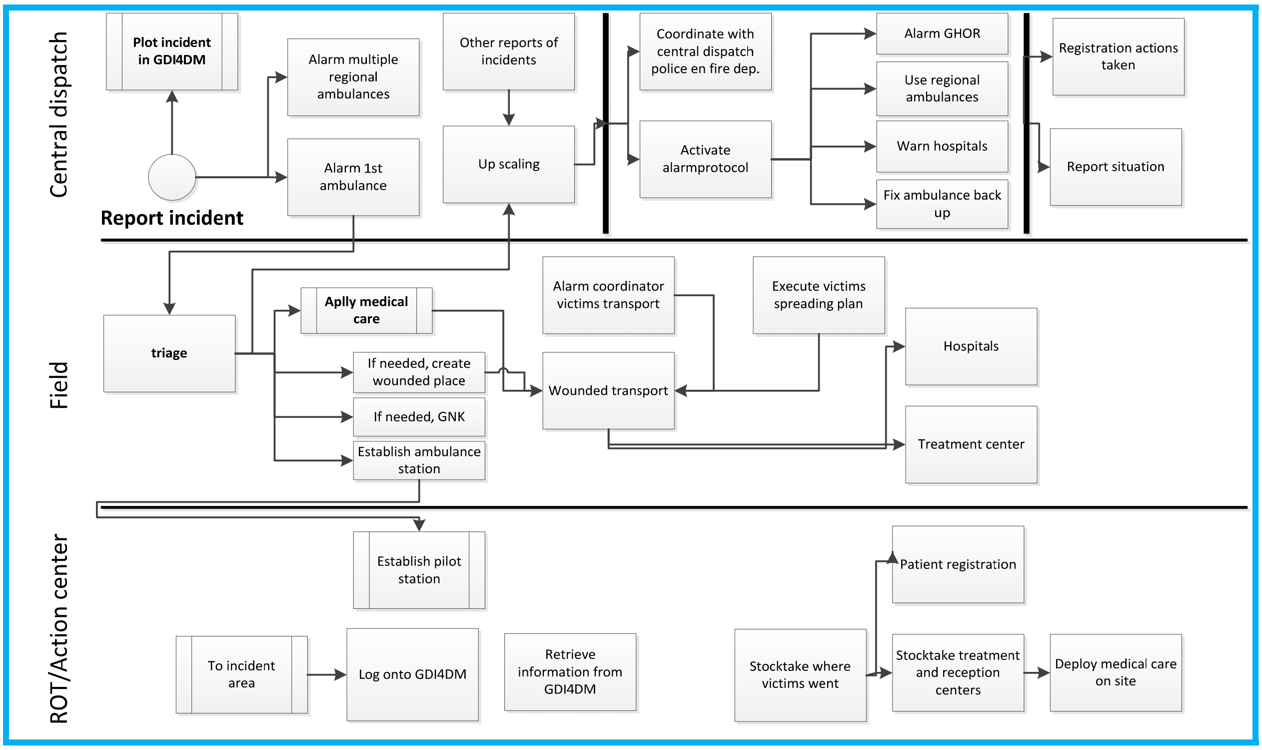


Figure 7: Cluster B (Snoeren, 2006)

Cluster C: Legal procedures and traffic

The stakeholders involved in cluster C are (Snoeren, 2006):

- Fire fighters. The fire department determines which area should be evacuated and plays a role in informing and guiding the public.
- Municipality: The municipality is an important stakeholder in legal and traffic procedures. The municipality determines where the reception centre will be established and analyzes which people and objects will be evacuated.
- General Commander: The general commander of the police, the ultimately responsible to the police. He/she will alert and inform the appropriate chefs for the disaster management processes that will take place.
- COPI: The COPI determines whether evacuation is necessary
- Duty officer of the policemen (Ovd-p) is the senior officer at the incident location. He sends people in the field.
- Police officers in the field: they provide current information and execute tasks.

- Policy Team (BT): The policy team sets the boundaries of the area to be monitored, points out objects to be monitored and assigns a priority to these objects.

Their tasks include:

- Clear sites and evacuations
- Roadblocks and shielding
- Traffic control
- Maintain public order
- Identify victims
- Guidance
- Criminal investigation

The information needed that is needed for cluster C is stated by Snoeren et al. in Rampenbestrijdingsprocessen, stakeholderen, werkwijze, data and is lined up in table 6. Some of these aspects can be modelled in 3D and may be of added value in emergency response information models.

Table 6 Legal procedures and traffic information

Legal procedures and traffic information
Location incident
Nature incident
Size incident
Development incident
Expansion area
Location fire department units
Area under threat
Meteorological data
Access and exits site
Number of people on site
Number of victims
Location hospitals
Materials on site
Infrastructure
Assistance locations
Special objects
Background, terrain and orientation
Actions taken
Risks involved

Land use
Urbanism

For legal procedures and traffic information, and thus for the fire department and the police, multiple landscape elements seem to be of importance to have on a map. Traffic information, in terms of disasters or emergencies, could involve a large traffic accident or an evacuation on a larger scale. So for cluster C the same arguments follow as the ones for cluster A and B. 3D terrain, buildings, bridges and infrastructure could fasten the analysis of a location and move along an evacuation more quickly. The buildings in 3D can be used to determine lines of sight, i.e. visibility analyses, for shooting, witnesses and camera imaging that can be used in crime investigations.

Schematic representation processes cluster C

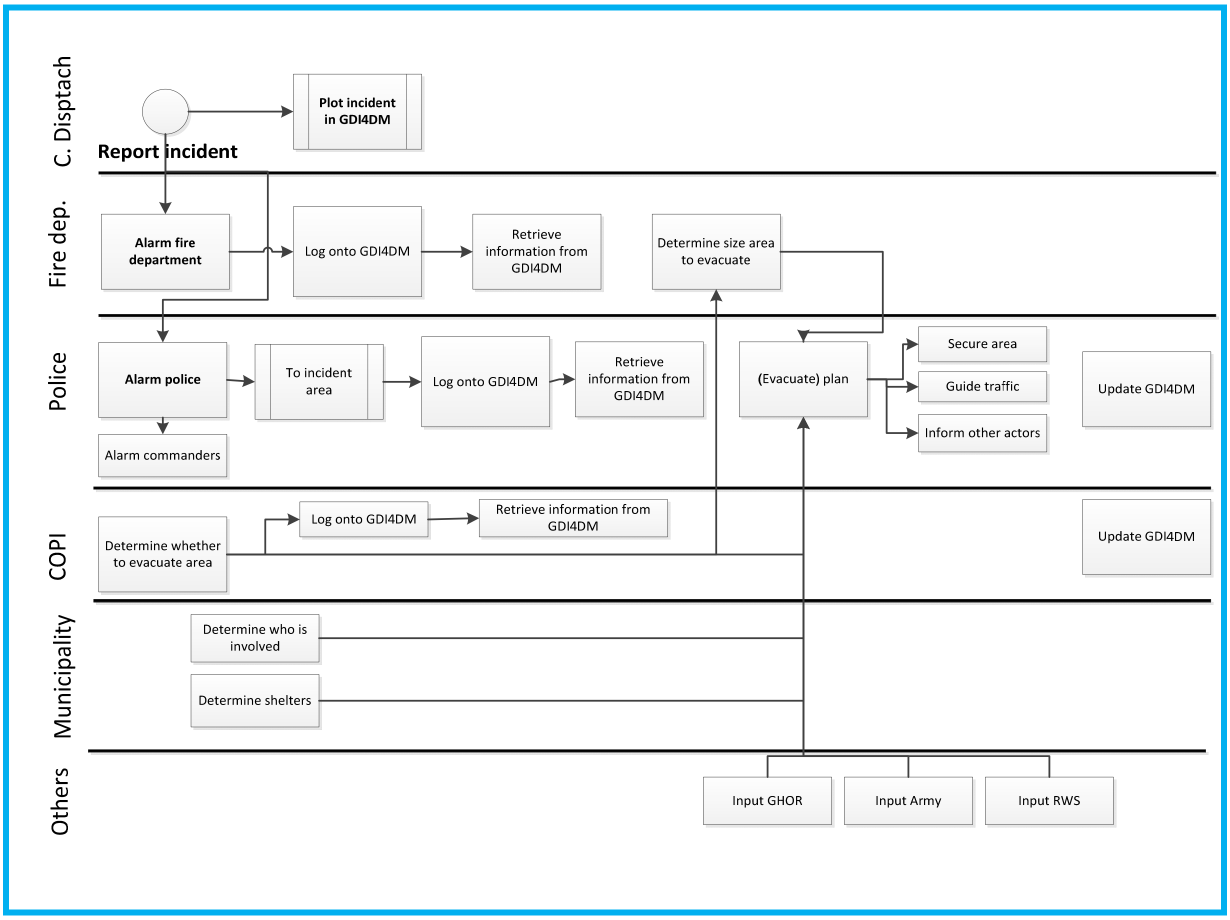


Figure 8: Cluster C, based on Snoeren 2006.

Cluster D: Population Care

The stakeholders involved in cluster D are (Snoeren, 2006):

- Media-watcher: Works under the direction of the Coordinator Action Information Centre and creates a summary of given information about the incident.

- Officer disaster area: Works under the responsibility of the officer in the ROT. If the action centre information is not yet operational work he/she is under instruction from the coordinator COPI. He/she supervises and provides authorized information to the media.
- Other action centres of the municipality, police, fire and medical services, for the alignment.
- Main Reception and Care: he/she will sit in the Municipal Management Team. As a part of this task, he/she alerts and instructs the Coordinator action centre "Collecting and Caring".

Their tasks include:

- Educate and inform
  Shelter and care
- Undertaking
  Registration of victims
- Basic necessities
- Registration of damage and handling
- Environmental
- Aftercare

The main information that is needed is a general overview map. This is dynamic information: i.e. these maps are made during the disaster and will be based on information collected during the disaster.

Schematic representation processes cluster D

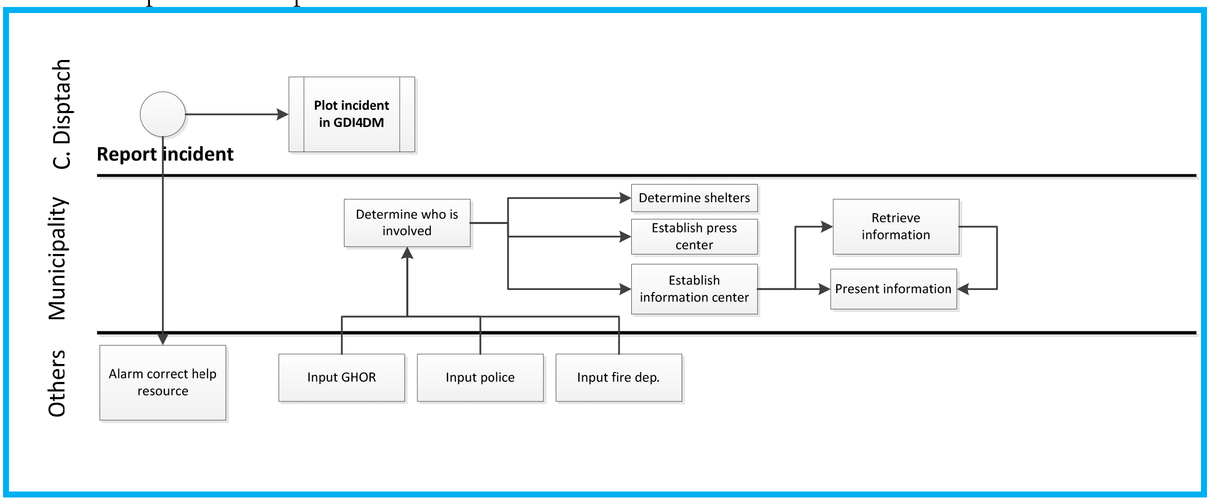


Figure 9: Cluster D, based on Snoeren 2006

Non-clustered organisations

The leading teams are not committed to a certain cluster but who are an umbrella to all of them. Prominent examples of these are the ROT, BT and COPi.

- *COPI*: Incident Command Post (in Dutch abbreviated to CoPi) is the operational command at the scene of an incident according to the Coordinated Regional Incident Abatement Procedures. An incident command Post instead (CoPI) is responsible for the operational management on site, coordination with other stakeholders and advising the regional operational team. The CoPI usually has sitting in a temporary on site commando building, though it may also meet at other places. The occupation of the CoPI consists at least of the following officers, supplemented by external parties and support staff if necessary (Crisisweb, 2013):
    - CoPI leader, coming from one of the emergency services, but often a Chief of Service of the fire dep.
    - Officer of Fire Service
    - Medical Duty officer
    - Police Duty officer
    - Information Officer (from one of the emergency services, often the police)
    - Public safety officer of the municipality
    - Information Manager

- ROT: A Regional Operational Team (ROT) is responsible for the operational management, the coordination with other involved in the disaster or crisis parties and advising the municipal or regional policy team. A regional operational team consists of a:
    - Regional Operational leader;
    - Section fire;
    - Section GHOR;
    - Section police;
    - Section care population;
    - Section information management, and
    - Information officer regional operational team.

- BT: A municipal policy team (GBT) is composed of executives from the fire, the GHOR, the police and the public care. A municipal policy team supports the Mayor in disaster and crisis (Crisisweb, 2013).

2.4 Emergency response regulations

The law of disasters and mayor incidents (abbreviation in Dutch as 'WRZO') used to constitute the legal framework of disaster control. This law appointed the responsibilities and tasks of the distinguishable levels of governance (National, Provincial and Municipal) in the context of disaster control, in addition to the regular responsibilities and tasks as laid down in sectoral legislation (Rijksoverheid, 2003).

The WRZO provided a legal framework for:

- The powers and duties of the various governing bodies to combat a disaster or major accident;
- The preparing for a disaster;
- The content of the statutory planning figures (contingency, emergency response plan and provincial coordination plan) in the context of disaster management;
- Disaster in exceptional circumstances; and
- Government funding to municipalities for responding to a disaster or major accident.

The WRZO regulated the powers of administrative bodies. The operational stakeholders were subject to their own regulations, such as the Dutch Fire Department law 1985, the medical assistance in accidents and disasters law (wet GHOR) and the Police law 1993.1. The legislations that apply during disasters and serious accidents are spread over a large number of laws and regulations. These laws and regulations were administrated by the parliament.

But in 2009, a bill was discussed that allowed for the WRZO and the wet GHOR to be replaced with the Safety Regions Act (WVR). An efficient and high-quality organisation of fire fighting, medical assistance in accidents and disasters, disaster and crisis management under a regional government. The WVR would regulate the Safety Regions. Through the coordinated approach to assistance services it is better and easier to control the situation. This Safety Regions Act was adopted in 2011. The law includes administrative embedding and basic requirements for the organization of emergency services, which tasks the board of a security region have, what are the minimum requirements for workers at the regional fire and medical services and the equipment they use (Rijksoverheid, 2012).

The decision of Safety Regions establishes rules about safety and the fire service. There are for example agreements on the so-called arrival time at the fire and the time the fire department needs to post a notification on the site of an incident to arrive.

Every region has to establish a regional crisis plan according to the WRZ law.
The board of the Safety Region establishes this plan based on a number of documents (Rijksoverheid, 2013):

- Regional risk profile: this is an inventory and analysis of existing risks, including relevant risks from adjacent areas;
- Policy plan: this is how the Safety Region executes its administrative tasks. The regional risk profile is the base for the policy plan;
- Crisis plan: plan for the general approach of disasters and crises in the region, such as a flood;
- Disaster control plan: plan for dealing with disasters on special locations, such as an airport, or chemical companies (BRZO) with hazardous substances.

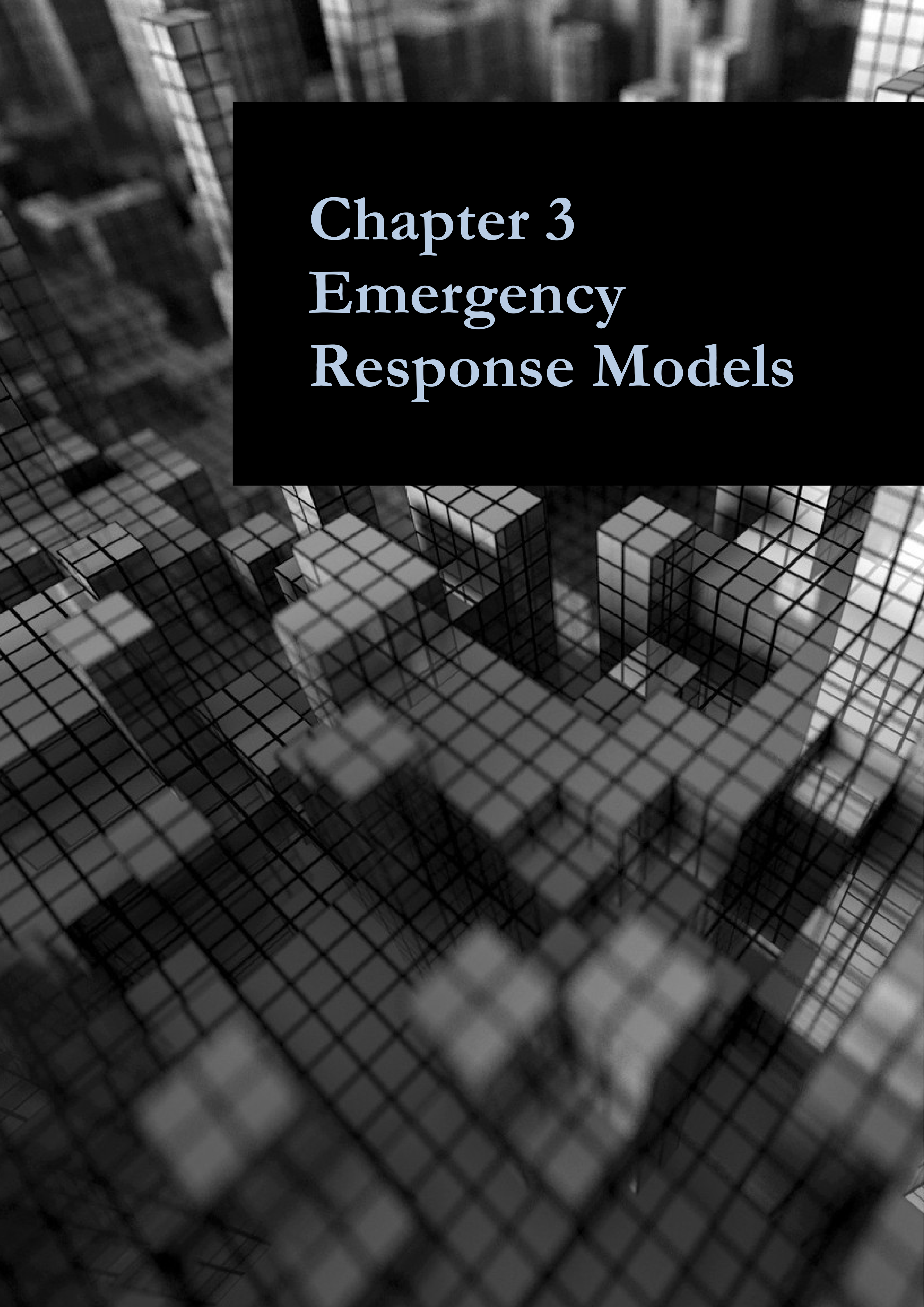
To help regions with the preparation of their organizational crisis and crisis plans, the Reference Regional Crisis Plan 2009 (RRCP) was established. By provides such a framework for regional planning, it creates a generic control mechanism of available capacities for executives and supported work, which, moreover, includes the quality demands and the preconditions of the processes (Regionaal crisisplan, 2013).

Figure 10: Multi disciplinary consultation

2.5 Conclusion

The stakeholders involved in emergency response are numerous and they all have their own separate tasks. This makes emergency response and control an even more complex situation, beside the disaster at hand. Each GRIP, level of emergency, has its own characteristics, which are based on the associated tasks, powers and responsibilities of the stakeholders of that GRIP. Most of these stakeholders come into contact with spatial data information during an emergency and databases offer an increasing amount of publically available 3D models of buildings and/or geo-specific environments for use in emergency response. 3D information could fasten the analysis of a location and move along disaster control more quickly. In a so called Safety Region, the fire department, the medicals teams, the police and the municipality co-operate and join forces to improve the fire services, medical assistance and the police at regional level together, in order to prevent and control crises and disasters. These organisations are regulated by national plans and laws, such as the national crisis plan and the safety regions act.

Chapter 3
Emergency Response Models



3. Models

Customarily, municipalities use 2D paper maps, CAD drawings, textual and oral information, and physical 3D models to present plans to citizens. Most municipalities use websites for the distribution of local spatial plans, but these are generally 2D maps with static visualisation (Zlatanova et al., 2010). The emergency response teams also have multiple 2D models or software that they can use. Recently, Geonovum developed IMGeo: a national standard for 2D and 3D topography containing object definitions for large scale representations of Dutch roads, water, land cover, bridges and tunnels. This CityGML extension could provide for a geographical data infrastructure for disaster management (GDIDM). This chapter will look into the models that (could) lie at the base of a three dimensional emergency response information model.

3.1 Geographical Data Infrastructure for Disaster Management

The Dutch models for emergency response are the Geographical Data Infrastructure for Disaster Management (abbreviated in Dutch GDI4DM) and the Information Model for Safety and Security (abbreviated in Dutch IMOOV). IMOOV was developed as a data exchange format and GDI4DM as a data model (to be stored in the data base). The two models are derived from the Dutch emergency response procedures (Zlatanova, 2011). Figure 11 shows a GDI4DM data model according to Diehl et al, with all of its situational information. GDI4DM has as goal to set up the Geographical Data Infrastructure, which allows different stakeholders to receive the right information and make quick decisions. By wielding standards, both static and dynamic information can be easily exchanged amongst emergency control services. In contrast to GDI4DM, IMOOV contains information about existing data. The IMOOV model also includes information related to mapping, such as symbols, and processing of data. Both models have acceptable good semantics, 2D geometry, use of standards and neither do supports topology (Zlatanova, 2011). In developing the GDI, it focuses on three points: the overall service architecture, the management of dynamic information and appropriate user interfaces for different user groups.

Beside the models that are formalised for emergency response, there are several systems used for support during an emergency or disaster. The main software, acquired by the Safety Regions is a geographical data infrastructure with visualisation software named the National Crisis Management System (in Dutch abbreviated to LCMS).

This crisis management system covers most workers at national level in support of a crisis, and is based on a so-called 'netcentric working' system (Crisisplein, 2013). In netcentric working, the levels within an organisation form an information network. Within those levels information is exchangeable with each other and is simultaneously shared. Larger municipalities have recently implemented systems that allow for the presentation of interactive digital maps to the public in so called Web Map Services (WMS).

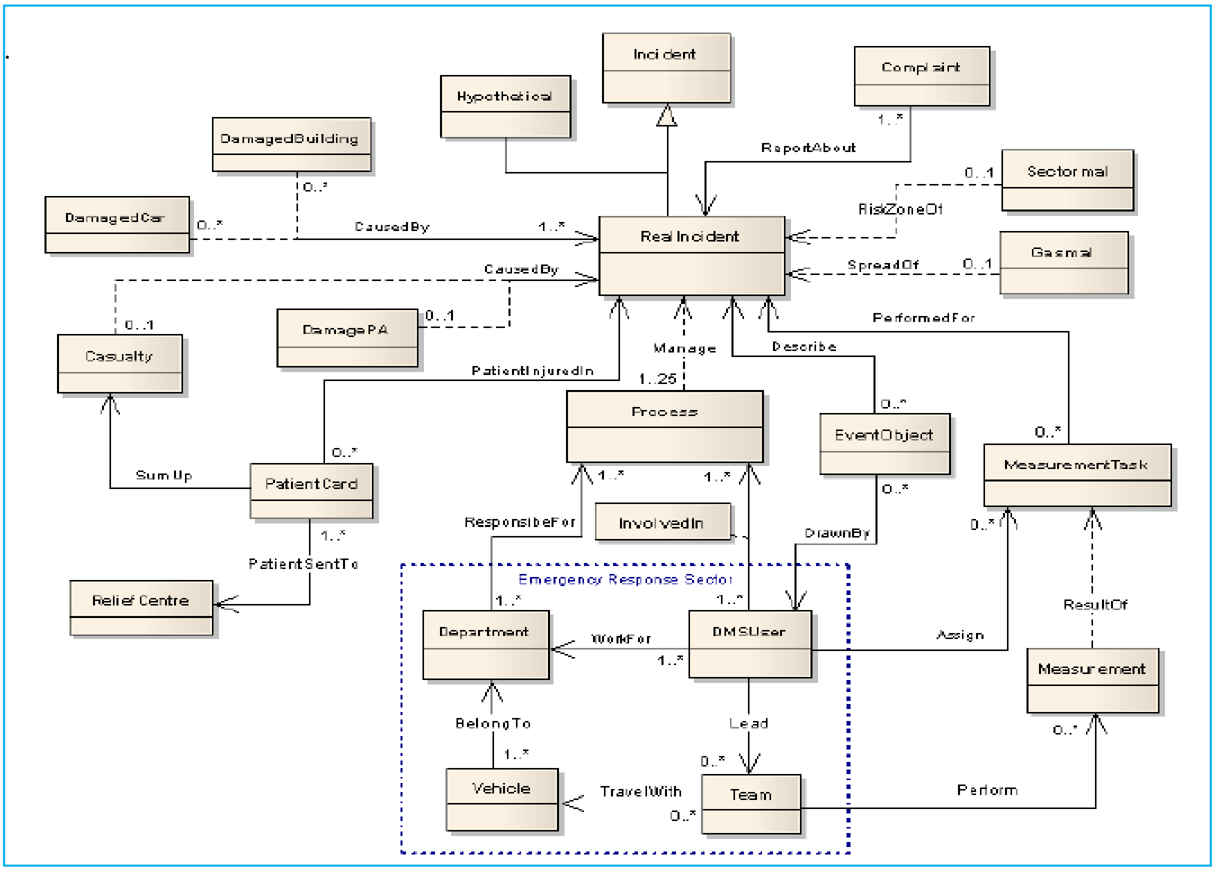


Figure 11: GDI4DM data model for emergency response in NL by Zlatanova and Dilo (2010).

3.2 Currently available

Currently, multiple models are available for use and support. The most prominent ones are described in this paragraph to provide insight into their content and their functions.

3.2.1 Landelijk Crisis Management Systeem

The National Crisis Management System (LCMS) is used in a crisis, major incident/accident or event and provides all the stakeholders involved around the Safety Region with the same up-to-date information that can be visualised only in 2D. The users of LCMS can log on the site, where they will find a report of the situation and a tab where they can add their own information, based on the organisation they are a part of. The current LCMS offers the following functionality:

- Current multidisciplinary total picture (text and graphic plot) with running journal
- Tracking and monitoring actions
- Message exchange between individuals and teams
- Same online clock for excellent timing
- See who is online

- Search like Google
- Preparative information such as disaster management plans

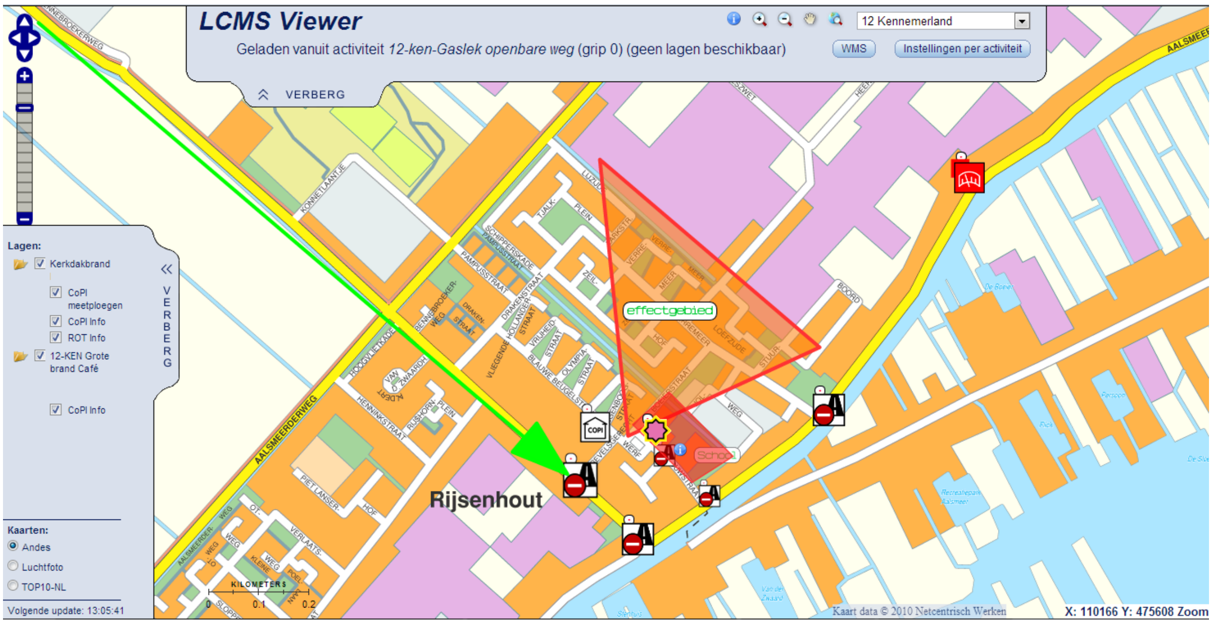


Figure 12: LCMS Viewer basic map example with gas leak.

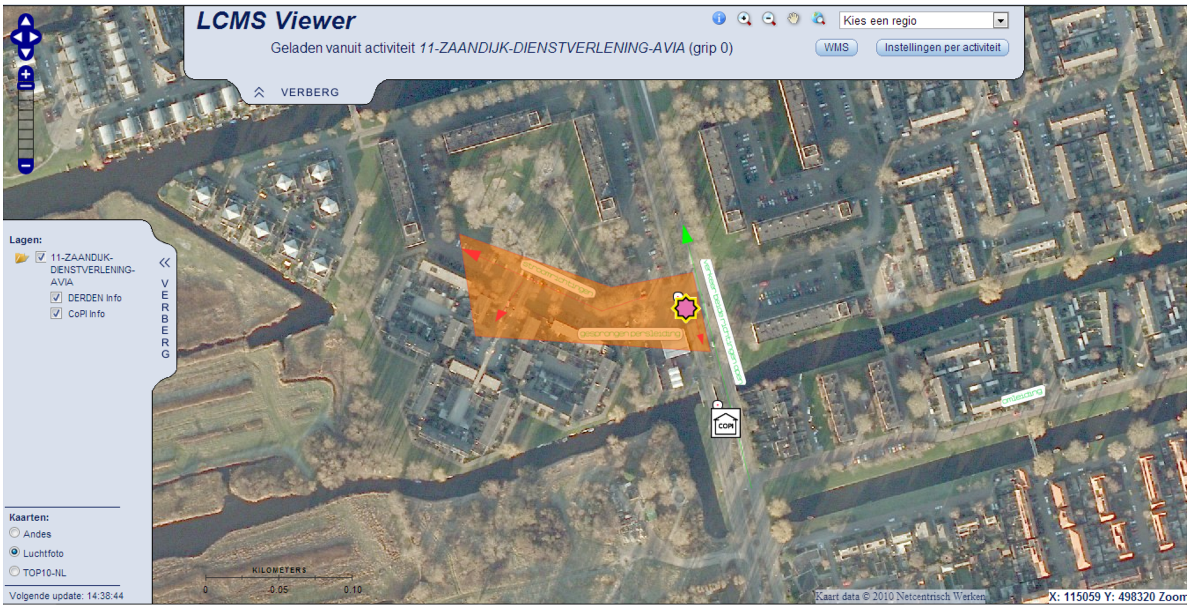


Figure 13: LCMS Viewer air photo example with flood due to pipe leak.

These functionalities are visualised in different tabs. The user can click on their profession or on the tab of others users, who have updated their part. These tabs contain textual information and frequent updates of the situation. The multidisciplinary total picture, also known as the plot or the LCMS viewer, shows a 2D map of the area with some icons to illustrate where specific attributes or sites can be found. Examples of these icons are sites with hazardous goods, gas lines, water pumps, electricity houses, etc. This symbolisation is assessed as very useful. To ensure that the map is correctly comprehended, the plotter can place text on the map to name an attribute or location. Figure 13 shows an example of this, where the effect region is marked red and also named "effect region".

The basic map can be viewed as a drawn map, a photo with an aerial photography layer or with the TOP-10 NL. On this basis map, several layers can be placed to emphasize on specific aspects of the situation or provide extra relevant information. It is also possible to connect to a WMS server, either by selecting one or adding it through an URL. As illustrated in the figures 12 and 13, it is possible to place extra icons in the map during an exercise or a crisis. In figure 13 COPI (white icon) has set up their command box near the site and by placing the icon at their location, organisations know where to find them. The drawing- and icon functions provide an important supporting role in bringing across data to different sectors. The map also has a zoom function, but the details on the map do not change according to the scale.

The most important advantage of an inter-specialty map or software, like LCMS, is having a common operational picture (COP). By using a COP, significant time savings can be booked in the reporting, verification and driving phases (Steenbrugge et al., 2012). A COP is created by all the partners in the information chain contributing to the picture of the situation by supplying new information, update outdated information and improving misinformation. This information is available in real-time for all the chain partners. With a COP the probability is high that accurate information is distributed amongst all emergency responders, and that is the first condition for taking right decisions and taking the right actions according to Steenbrugge et al. (2012). Using COP is an example of net-centric working.

3.2.2 VeRA

VeRA is the reference architecture for the Safety Regions. Reference architecture is an instrument to create coherence in the information of government sectors and enable possible co-operation. VeRA, which is short for Veiligheids Regio's Referentie Architectuur, gives the Safety Regions a guideline for the direction of the integral information management on an administrative organisation's level, the preparation to set in emergency responder en for up scaling an emergency within a Safety Region. It also provides a guideline on national level to ensure optimal information exchange.

The main goal of VeRA is to name the general elements in the information management of Safety Regions. Because some of the Safety Regions differ in their organisation and regions, VeRA focuses on the collective characteristics and principles. Information managements of Safety Regions can use VeRA as a base to create internal organisation reference architecture.

This could help standardize initiative in information management within the Safety Regions, which thereafter eases the co-operation. At this moment VeRA only includes the business functions and applicative functions that are organisational characteristics of a Safety Region. VeRA 1.0 does not include (geo) data and is not concerned with 3D data. However, it provides a framework of a complex organisation that will allow for further developments. For Vera 2.0, probably released at the end of 2013, data models are gathered. The new VeRA will contain: landscape data, basic registrations, connecting planes, semantics and standards. Landscape data will include data streams, process descriptions, information needs, department crossing chains, geographical information and symbols. The basic registrations concern BAG, BGT, trade register and laws. The connecting planes, an ICT term, elaborate on the exchange between organisations and the outside world.

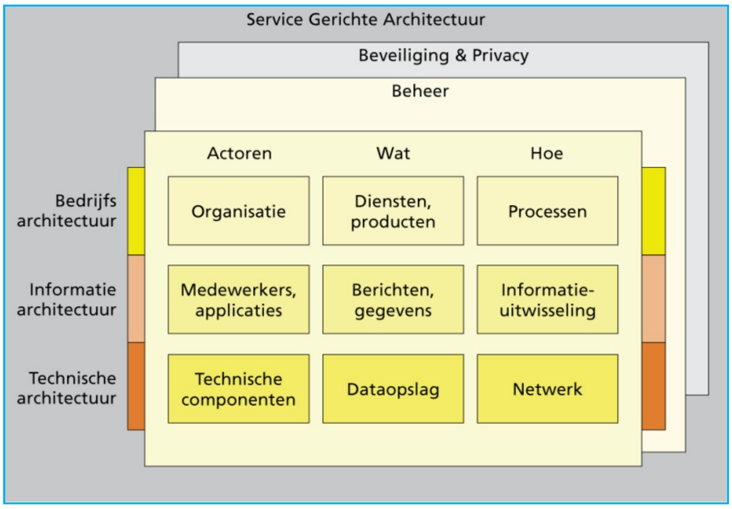


Figure 14: Architecture framework NORA 2.0 and VeRA

Furthermore, VeRA would like to incorporate standards for: messages, documents, metadata, knowledge exchange, geographical information. The expansion of VeRA will provide a broader base for emergency response communication and data exchange. The future implementation of 3D data in emergency response information models would also require a place for 3D data in future VeRA (3.D).

3.2.3 I-Bridge

I-Bridge is of 2009-2012 the multidisciplinary innovation platform for emergency response, crisis management and public order and safety. In the field of information management and information, various innovations are realized. The goal of this platform was solving major social issues. In the safety and security program the input of know-how, innovation and entrepreneurship for solving social issues was the central subject. I-Bridge started as collaboration between the Dutch Ministry of Defence and the Dutch Ministry of the Interior, within the Civil – Defence cooperation program. It is based on the concept that communication components can be linked in various combinations using internet protocols (I-Bridge,

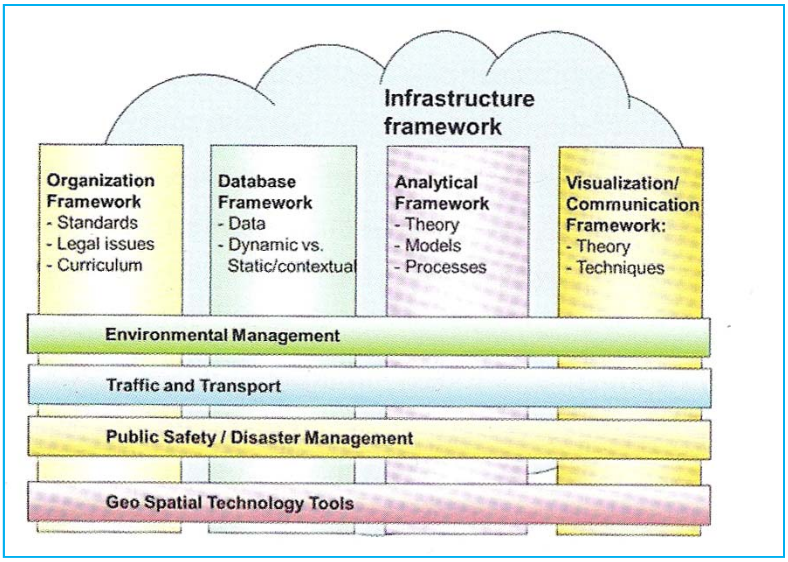


Figure 15: Generic Geo-ICT framework (I-Bridge, 2013), (Scholten et al, 2009)

2013). This can be put in a theoretical framework as described u Schulte et al. in 2009. They describe three different frameworks to use Geo-ICT: geo-database, geo-model and geo-map. I-Bridge has added: the organisational framework and the infrastructural framework. Both of these support the other frameworks that were already present. Figure 14 presents the overall theoretical framework of generic Geo-ICT.

The objective of I-Bridge is three fold: showing innovations in the public safety domain, involving industry in these innovations and finding a practical use that may lead to possible industrial activity. These objectives lead to I-Bridge's most prominent goal: to improve crisis management by developing, testing and evaluating new technologies on their usability and added value. It offers a platform to the security and safety sectors with the possibility to test their newest technologies. Its main focus is on the Safety Regions; the fire department, the police, the medical services (GHOR) and the government. I-Bridge functions as sort of intermediary for demand and supply and supports the translation from requirements into functionalities.

I-Bridge generic processes are displayed in figure 16:

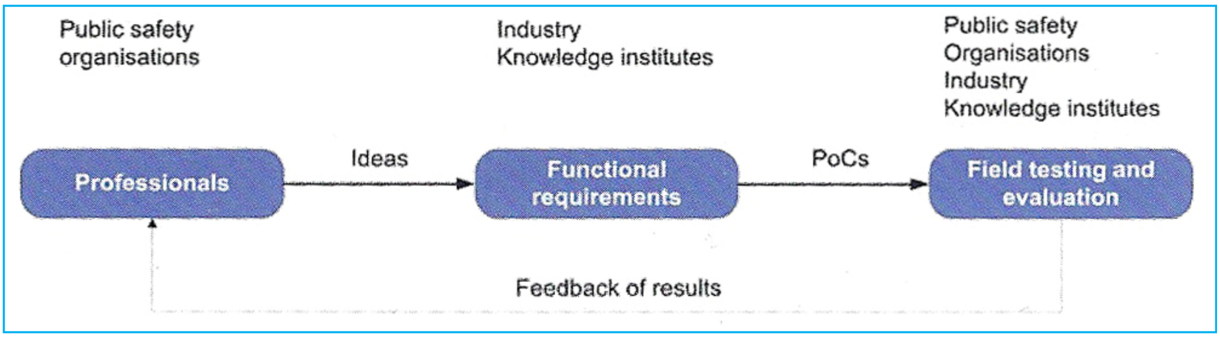


Figure 14: generic I-Bridge processes (I-Bridge, 2013)

3.2.4 CityGIS

CityGIS is in the emergency room not just a map viewer. It is a full GIS databases including the ability to set up and maintain your own data on the map. It is also possible to accommodate multiple map layers in this GIS. In the Netherlands, it's common that map layers are included in the National Mapping Agency and the scale Base Map of the Netherlands, the GBKN. There are also aerial photographs available, such as the ones in Google maps (City GIS, 2013).

The CityGIS server manages a national server on which police, fire department and medical vehicles can communicate. CityGIS establishes a link with the emergency room, after which incidents, locations of colleagues and dynamic roadblocks can be directly seen in the Navigator. This concept enables mobile data communication via GPRS, UMTS and Mobitex (City GIS, 2013). This system is called CityNav (CityGIS Navigator) and combines some information with navigation. Its basic functions are presented in table 7. “For the future we hope that CityGIS will help us to integrate Local map layers with 'cold' processes in SharePoint and the National LCMS system” (Peters, 2013).

Table 7 Standard functions CityGIS Navigator (CityGIS)

Standard functions CityNav
Routable map with monthly map updates if desired.
Incidents automatically go to the navigation.
Aerial photographs, topographic map (Top10NL) and GBKN in the vehicle
OMS objects with additional information, such as attack plans.
Ability to draw
Ability to share.
Option to see colleagues position.
Possibility to include Private lands on the map through the Cartographic Department of CityGIS.

Supposedly the future of emergency response information models lies with 3D visualisations. As with the "3D Buildings" layer in Google Earth, stakeholders could view 3D models of buildings, monuments, bridges, towers and vegetation. The points of the objects would have three co ordinates (x,y,z) on the map instead of two (x,y), thus creating a third dimension allowing users of the model to rotate around an object on the map.

3.3 In development

At the moment there are also models that are in their development stage. CityGML, although already in use for some functions, is still being further developed to make it applicable for different fields of expertise. This information model included the shift from 2D visuals to support decisions to 3D visuals. It is a transition that is based on the advances in technology in combination with a constant demand for more and accurate information. The possible benefits that arise from these three dimensional models are partially stated in the previous chapter and will be further elaborated on in the next chapter. But in short they provide information that 2D information models or map cannot render or could only give with much more time and effort. In case of a disaster that includes power failure such computer models will obviously not be of use and one would return to paper maps and other primitive resources with the assistance of non-geo trained emergency staff.

3.3.1 CityGML

The following paragraph is about 3D city information models and CityGML, based on the paper *representing and Exchanging 3D City Models with CityGML* by Thomas Kolbe (2009).

3D city models embrace, besides the spatial and graphical aspects, the ontology of objects, including thematic classes, attributes and their relationships. Objects are decomposed into parts or objects based on logical criteria instead of graphical considerations, which follow structures that can be observed in reality.

For example, a building will be decomposed into different building parts, such as different roof types, floors with different functionalities and their own entrances if they have any.

The modelling of cities requires the suitable qualification of 3D data. From an economic viewpoint, the semantic modelling of cities only makes sense, if the data can be used by different customers within multiple applications. This would then require finding a common information model for the different users and thus different applications.

"The aim of CityGML was to reach this common definition and understanding of the basic entities, attributes and relations within a 3D city model. By providing a core model with entities and relationships which are relevant to many disciplines the city model can become a central information hub to which different applications can attach their domain specific information. Information exchange between different disciplines can then be aligned with the objects of the city model" (Kolbe, 2009: 2).

The City Geography Markup Language (CityGML) is a new and pioneering concept for the modelling and exchange of 3D city and landscape models that is quickly being implemented on an international level. CityGML is a widespread information model for the representation of 3D urban objects (CityGML, 2012). CityGML is developed for a 3D topographic model of the real world containing semantics, geometry, topology and appearance. It is composed to enhance the 2D topographic maps that have been used for multiple applications such as urban planning, civil engineering works, transportation, navigation, disaster management, etc. (Gröger, 2005). The development of CityGML was set off by the increased need for 3D information in all domains that require spatial data representing the real world (Kolbe, 2008).

At first, CityGML was developed only as an exchange file format, but in the last few years a database model was also provided. CityGML can, as a result, be seen as a conceptual model that can be used for both exchange and management of data and can contribute to situational awareness (Stadler et al., 2008).

Where situational awareness is the perception of environmental elements with respect to time and/or space, the understanding of their meaning and the projection of their status after some variable has changed. It is also a field of study concerned with perception of the environment critical to decision-makers in complex, dynamic areas and/or situations. In short, Situational awareness is often described as the ability to see objects in time and/or space through multiple perspectives and interpretations.

CityGML is seen as a very promising standard for an emergency response information model. CityGML represents four different aspects of 3D city models: semantics, geometry, topology and visualisation (Kolbe, 2008).

Semantics

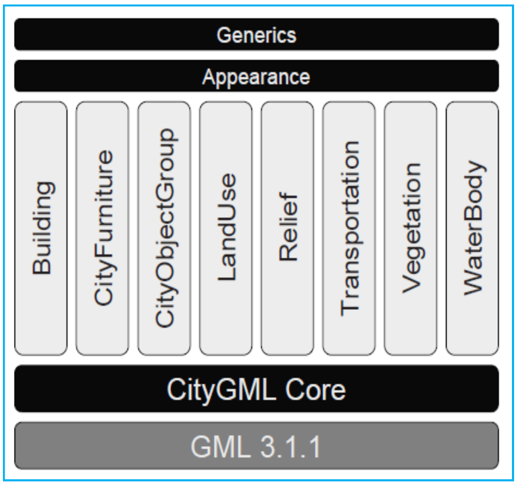


Figure 17: Modularization of CityGML 1.0.0. by Lee et al. (2009)

The semantic model of CityGML makes use of the ISO 19100 standards for the modelling of geographic features, which are modelled in class diagrams. CityGML provides class definitions and explanations of the semantics for the most significant geographic features in a 3D city models such as buildings, water bodies, and city furniture. Figure 17 depicts the top level classes of a CityGML semantic model. The base class of all thematic classes is the class *CityObject*. Every CityObject may be linked to objects in other datasets or external databases by a number of *ExternalReferences*. These external references can for example be other representations of an object in cadastres or other application specific datasets. *CityObjects* can be aggregated to build a *CityModel*.

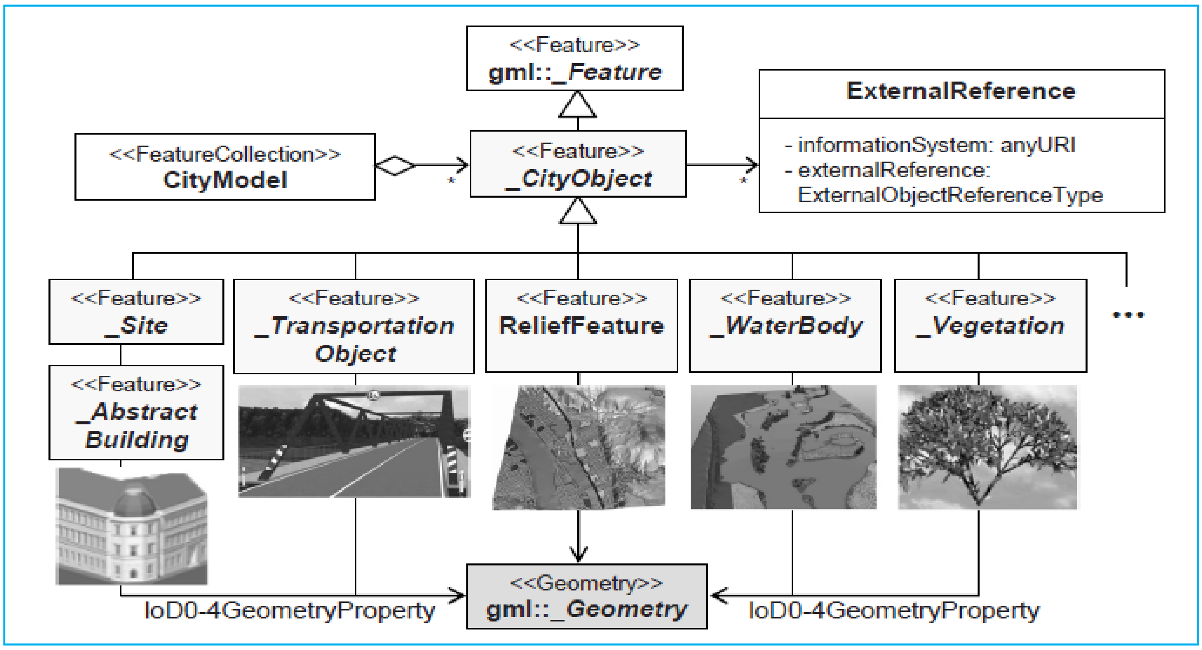


Figure 18: Class diagram of the top level classes of CityGML by CityGML

Geometry

CityGML uses a part of the GML3 geometry model which is an implementation of the ISO 19107 standard (Herring, 2001). According to ISO 19107 and GML3, geometries of geographic features are represented as objects and have an identity and other geometric substructures. Thomas Kolbe describes this paragraph in his paper *representing and Exchanging 3D City Models with CityGML* (2009:7).

"GML3 provides classes for 0D to 3D geometric primitives, 1D-3D composite geometries, and 0D-3D geometry aggregates. Composite geometries such as *CompositeSurface* must be topologically connected and isomorphic to a primitive of the same dimension. Volumetric geometries are modelled according to the Boundary Representation, where each solid is bounded by a closed surface. All coordinates must belong to a world coordinate reference system (CRS) and no local transformations are allowed. The advantage of having only absolute coordinates is that each geometry object belongs to exactly one fixed place in space. This allows easily creating and maintaining spatial indexes in geo-databases or geo-information systems. A big disadvantage however, is that shape definitions cannot be reused like with CSG and scene graphs. For example, if a city model would contain 100 street-lamps or trees, 100 different, but equally shaped geometries would have to be created. In order to overcome this drawback, CityGML provides an extension to the GML3 geometry model called *ImplicitGeometry*. *ImplicitGeometries* refer to a shape geometry in a local coordinate system (to be reusable) and additionally provide a transformation matrix and an anchor point in a world CRS. According to ISO 19109 geographic features can be assigned more than one spatial property. This is generally being used in CityGML where most feature classes such as *AbstractBuilding* or *Room* are assigned individual geometries for the different LODs by multiple associations to the same geometry class."

Topology

For a given city model it is often not known, whether the data is topologically sound. For example, the boundary surfaces of buildings may not be closed or contain additional surfaces, which do not belong to the boundary of the volume. For many applications topological correctness of the object geometries is crucial. For example, the surfaces bounding a building must be closed in order to be able to compute its volume (Kolbe, 2008). As CityGML should be able to represent purely geometric models on the one hand and geometric-topological models on the other hand, usage of the GML3 topology model would significantly increase the complexities of both the data model and concrete instances, i.e. datasets. On the other hand, it is sufficient to re-use the common wall surface of two adjacent buildings. This can be implemented in CityGML through GML, by providing the definition of the surface geometry inline within the specification of the solid geometry (bounded by a composite surface) of either building (Kolbe, 2008).

Visualisation

All objects can be represented in up to five different levels-of-detail (LOD0-4) (Kolbe, 2008), where LOD0 is a two and a half dimensional digital terrain model and LOD4 is an architectural model with detailed wall and roof structures and added interior structures. The objects become more detailed with increasing LOD regarding both geometry and thematic differentiation. The LOD categories make spatial data comparable and thus the user gets an idea of the data resolution, complexity, and accuracy (Kolbe, 2008). Texture mapping is a method for adding details, surface texture and colour to the objects in a 3D information model.

Texture can be assigned in different ways (Geonovum, 2013):

1. From image information

2. From the average point colour per surface
3. From the IMGeo visualisation.

1. The process of constructing texture information from image information consists roughly of the use of image information from classic aerial photos; oblique aerial photos or panorama photos videos. A process interesting from a technical cost perspective is only reached if all of the orientation data are known.

2. In some cases, image information can be used in a highly simplified form (one surface receives a single colour which is the average of the colour of the pixels projection on the corresponding surface).

3. 3D geo information's semantic properties can also be used (a surface receives the colour red, because it is a roof surface)

To make sure your application, and more importantly visualisation, meets user requirements, it is important to determine what these user requirements are.

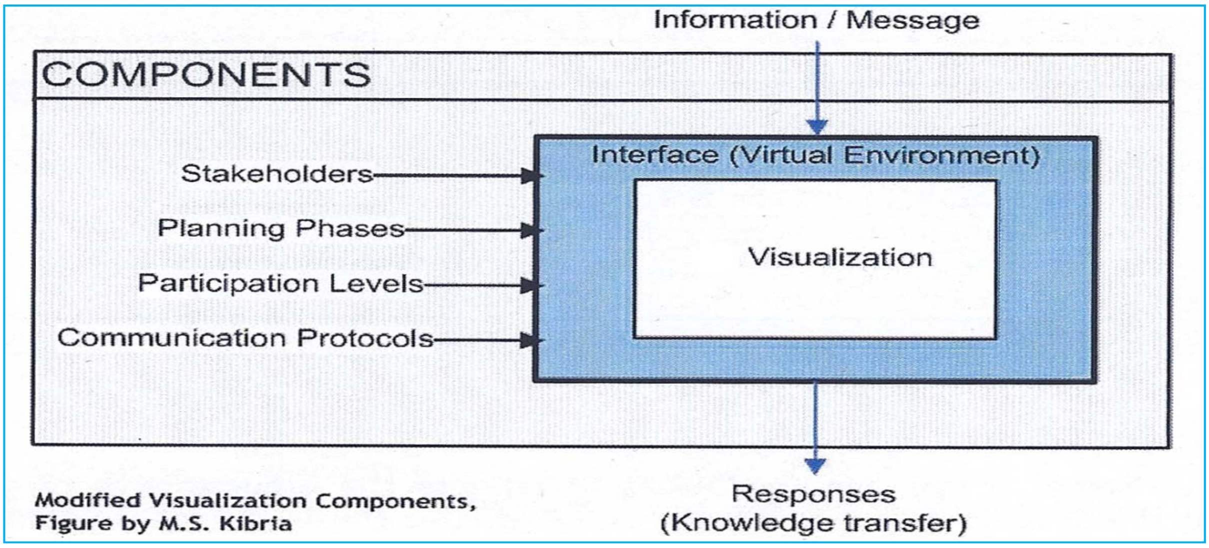


Figure 19: Visualisation Components (Kibria, 2010)

3.3.2 IMGeo

Geonovum developed IMGeo (Information Model Geography): a national standard for 2D and 3D topography containing object definitions for large scale representations of roads, water, land use/land cover, bridges, tunnels etc. IMGeo is a data exchange model but can also be used as a data model for the storage of data. It describes how object-oriented geographic information should be recorded and enables the national exchange of information. In 2007 Version 1.0 of IMGeo established. The information model for the Base Registration of Large Scale Topography (BGT) is a component of the Key Registration and it is the core of the IMGeo model. It was developed in conjunction with IMGeo. In 2012, IMGeo 2.0 is established, in which the information model BGT is completely implemented. Besides BGT, the compulsory component, IMGeo consists of an optional component, namely the plus management and topography. The extension of IMGeo with this extra data will result in standardization and this on its turn will broaden the user group (Brink et al, 2012).

The contents of IMGeo are formed by:
· Abstractions physical topographical objects;
· Virtual objects which have geometry and which are important for showing on a map scale and/or in the management of public space;
· Where the BGT labels the physical appearance a 'landscaping', in IMGeo this is further classified to include park, grass and planting.

However, the administrative management information, such as how often a landscaping: grass "mowed falls outside the scope of IMGeo and is to be incorporated in the management system itself (Brink et al, 2012).

IMGeo 2.0 is based on CityGML, an international standard for 3D geo-information. This allows for an expansion of IMGeo representations of objects in 2.5D and 3D. IMGeo is encoded as an extension of CityGML. This enables 3D IMGeo data to be supported in software that meets the CityGML standard and prepares IMGeo 2.0 optimally for 3D. The IMGeo object types are associated with classes from the CityGML model information and thus have the ability to create 3D geometry in varying degrees of detail.

The deepening and widening impact of BGT for IMGeo is designed for storing and exchanging plus management and topography. Resource holders and customers who wish to share this information can do this using IMGeo 2.0. An information model for plus management and topography is also important for software vendors. IMGeo ensures that those who want the optional information manage and / or exchange, in any event can do as a national standard. As with all the OGC information models, the CityGML ADE IMGeo is modelled in UML (Unified Modelling Language), from which GML application schemas can be derived automatically. In software engineering, a class diagram in Unified Modelling Language (UML) is a type of diagram that describes the structure of a system by showing the system's classes, attributes and the relationships among these classes. Some classes influence other classes and some classes are a part of another class.

3.4 Conclusion

The Dutch models for emergency response are the Geographical Data Infrastructure for Disaster Management (abbreviated in Dutch GDI4DM) and the Information model for safety and security (abbreviated in Dutch IMOOV). The two models are derived from the Dutch emergency response procedures (Kibria et al., 2010). Based on these models, several programmes are used for support during an emergency or disaster. The National Crisis Management System (LCMS) is used in a crisis, major incident or event and provides all the stakeholders involved around the Safety Region with the same up-to-date information. LCMS has tabs with textual information and a LCMS viewer, with a map of the site. It can use a drawn map, air photos or TOP-10 NL files. It also allows layers with other objects and the drawing- and icon functions provide an important supporting role in bringing across data to different sectors. The map also has a zoom function, but the details on the map do not change according to the scale. Upgrading this viewer or another viewer to 3 dimensional data might bring even more clarity. The points of the objects would have three coordinates (x,y,z) on the map instead of two (x,y), thus creating a third dimension allowing users of the model to rotate around an object on the map. CityGML, a program for 3 dimensional visualisations has a new application domain extension (ADE): IMGeo. It is a national standard for 2D and 3D topography containing object definitions for large scale representations. It is this, in UML modelled, ADE that could provide a strong base for a three dimensional emergency response model.

CityGML represents four different aspects of 3D city information models: semantics, geometry, topology and visualisation. . IMGeo 2.0 is a CityGML Application Domain Extension (ADE). This means that the model is a semantic, geometrical and syntactic extension of CityGML. IMGeo contains the same aspects, but it is based on the basis registration BGT (base map of large scale topography) and can be further specified for emergency response. IMGeo 2.0 2D is used to form the basis for the construction of 3D topography

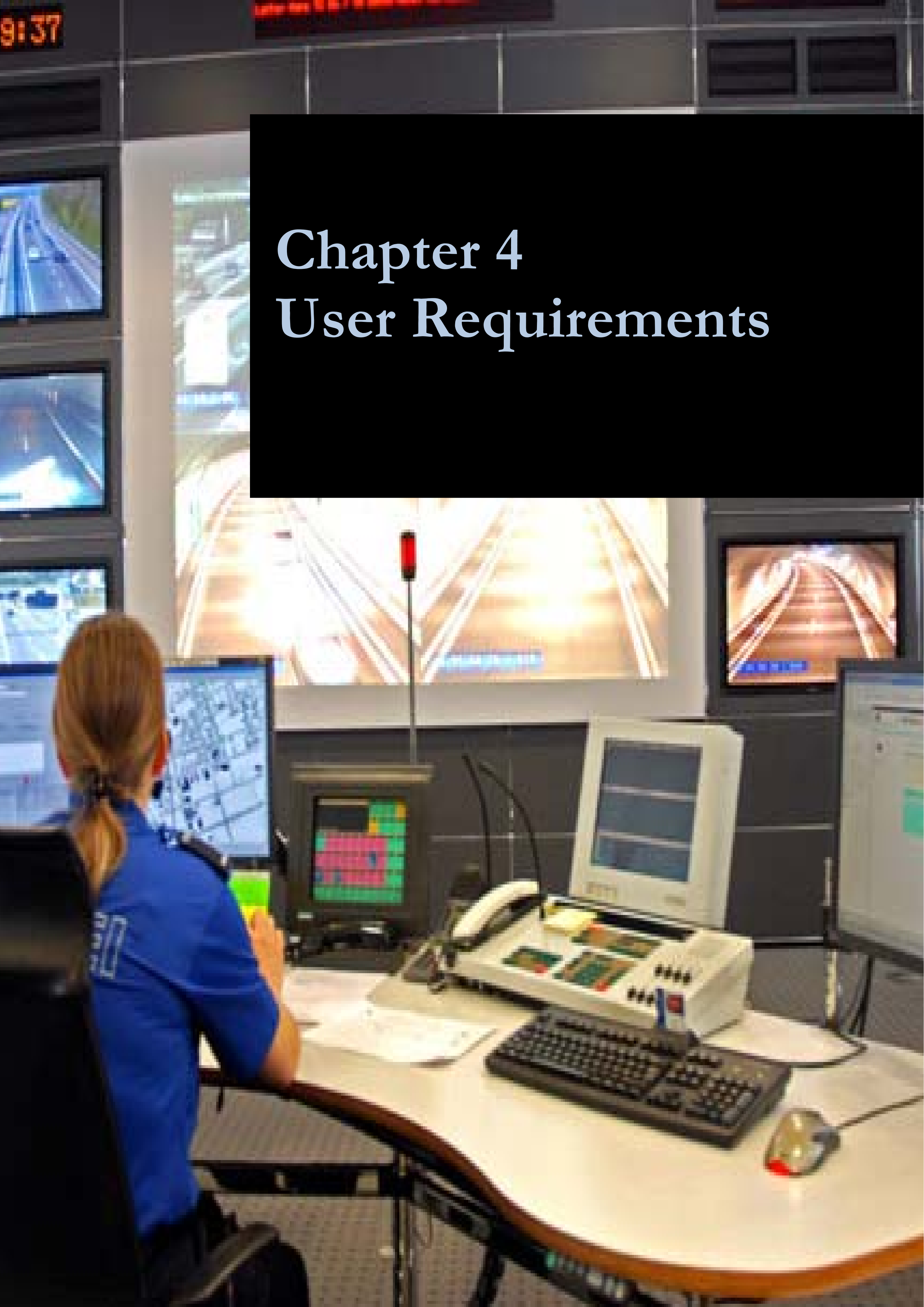
A schematic overview of the models and systems and their comparisons is presented in table 8.

Table 8: Schematic overview ER models and systems

Criteria	**LCMS**	**VeRA**	**CityGML**	**IMGeo**
	Viewer	Architecture	Info. model	Info. model
3D	X	X	✓	✓
Geo information	✓	X	✓	✓
Basic Registrations	X	✓	X	✓
Exchange model	N/A	X	✓	✓
Data storage model	N/A	X	✓	✓
Standards model	N/A	✓	✓	✓

A choice could also have been made to work from 2D topography such as GBKN, GBKX and so on. Geonovum states that the deciding factor was that it was better first to update current 2D topography to 2D IMGeo and then to use this as a foundation for the construction of 3D. Based on the characteristics of IMGeo it is the most suitable to focus on for emergency response modelling in 3D.

Chapter 4
User Requirements



4. User requirements

A model is utilised by users and therefore should satisfy user requirements. The user requirements are about the components of the model, the objects and their settings, functionalities and use. This chapter sheds light on the user requirements of a 3D model for emergency response. The information presented in the chapter is based on an extensive (literature) study and on the opinions of experts. These experts were interviewed with regards to their expertise and experience with 3D models and emergency response. The risk of obtaining data from the experts is that their opinion could be short-sighted by the overwhelming upgrade from 2D to 3D models, regardless of the content. A user who currently makes use of 2D maps (inaccurate or not), will easily be pleased with any form of a 3D model, which provides more information than maps no matter the specification of objects or functionalities. So despite the fact that the experts are important information sources; this forecast also requires additional thorough evaluation of possible needs beyond the obvious stated by experts.

4.1 Methodology

To determine user requirements involves a literature study and more importantly, direct information from the user. This information was gathered by consulting experts during an interview.

4.1.1 Literature study

The first step in this research was a literature study. Before doing field research, it is relevant to know what has already been discovered and thought of, as a base to work form. The search field for literature was based on the (combination of) terms: users, user requirements, 3D models, emergency response, disaster control, disaster management, model, geo objects and software. This resulted in papers by, amongst others: Diehl (2006), Dilo(2010), Kibria (2006), Lee (2008), Snoeren (2007) and Zlatanova (2010).

4.1.2 Interview

15 stakeholders from different specialties have been interviewed, based on their expertise. The specialties of these stakeholders are police, fire department, medics, ministry of defence and government agents at IT. The variety of experts was chosen on purpose in order to get a broader view of emergency response. Each expert received information regarding the subject of the interview before the interview. Then an interview of approximately 60 minutes took place. During this session, questions, placed in a certain category, were asked in either open or closed format. Depending on the data that had to be extracted from the question, an open question will provide extensive and elaborate data but could also become too broad whereas multiple choice questions keep the expert on track. By organising the questions in prearranged subjects, the interviewer can guide the expert through the wanted topics. The topics are: current use of emergency response models, scenarios, 3D objects and functionalities of models.

The interview questions and visuals and the comprehensive results are placed in appendix E and H. The list of experts is stated in appendix F. As stated before, the questions are divided in subjects. Each subject contains an arbitrary number of questions, which mostly have a multiple choice answer. During the interview, the expert will firstly be asked the question without the options, as to not bias the response. The expert will then make a choice which multiple choice answers is, either implicitly or explicitly, discussed by the expert.

In the end, 15 experts' opinions are not a lot to go on, but it does give a fair impression. These experts all use, mostly, the same models and thrive for the same goals, so most of them tend to lean the same way.

4.1.3 Process data

The data has been processed to descriptive statistics. The sample selected from the population is done through snowball sampling. This Snowball sampling, or referral sampling, is a non-probability sampling technique where existing study subjects draft future subjects from among their connections. The snowball sampling was the most effective way to gather experts. As the sample members are not selected from a sampling frame, snowball samples are automatically subject to numerous biases. In this case, the population from which is to be sampled is limited in size and thus are most members connected to each other either way. The population contains merely experts on this subject, although a part of different specialities, informally decreasing the biased risks.

The descriptive statistics derived from the experts will form the framework of the user requirements and provide support for the literature study. The data that was processed is stated in appendix H.

4.2 General requirements emergency response models

An emergency response system, which is a time-critical application, is related to decisions that have to be made by a people during an emergency or disaster. Spatial technology should support that decision maker in getting several rescue strategies derived from the maximum quality and quantity of geo-spatial data. A GIS based decision support system therefore requires data management, efficient data discovery and data integration to allow the decision makers whenever and wherever they need, to make a decision to improve the situation (Zlatanova et al., 2010).

Multiple researches have shown that 3D GIS, compared to conventional 2D GIS, representing the internal structures of high-rise buildings, can considerably improve the overall speed of rescue operations (Lee, 2008). Such a result motivates spatial scientists to develop an intelligent emergency evacuation system of complex buildings using 3D approach (Mayers et al. 2005). In terms of time-critical applications, TCA, the 3D GIS-based emergency response system has to fulfil requirements similar to 2D GIS but and some specific for the 3D domain (Cutter, 2003).

A 3D city model for emergency response would require a multi-dimensional representation of physical and human processes. This allows the model to display the dynamic scenarios of a disaster or crises. The model would integrate essential spatial data represented by both indoor and outdoor data (Lee, 2008). This spatial data will have to be updated with newly collected data from the field for monitoring the disaster events and immediately propagating the information to all the users.

This requires 3D position devices to determine the event locations and standards for integration of existing models. But to be able to integrate different information or data models, there has to be interoperability of data integration. Currently there are troubles regarding compatibility, with integrating external additional applications, such as GASMAL. GASMAL is an application of TNO. Information on the presence of toxic substances in the air, which are measured by the fire brigade, in the field are provided in this application and processed. The result is a toxic cloud on a map. Nieuwland has written an import application that can load data from GASMAL into safety network.

Following all this, the integrated models need analytical and modelling capabilities to facilitate planning and decision making during an emergency (Lee, 2008). The decision making would also require mobile and wireless communication to exchange (on site) information and plans.

The 3D components, the data intensity and the interaction determine which data a user can extract from the information model. 3D components may result in large data files and require wide bands and special treatments (e.g. appropriate selections of data and generalizations). It would be functional if users have the ability to turn of certain 3D aspects, i.e. allow the user to choose which objects are presented in 3D and which remain in 2D.

4.3 Components

An information model for emergency response is made of components that enable specific functionalities as seen in table 9 (Kibria, 2013). Experts specified these components to a part of their emergency response model.

Table 9: Components of 3D model

Entity	Description
Proportionate objects	The 2D/3D objects are in proportion to each other.
Geometries	The 2D/3D objects can be of simple or complex geometries and with or without textures.
Layering	Multiple layers in the model or for an object.
Visual properties	The visual properties are colour, object identifier, shape, lighting, brightness, surface reflectance, scale legend, transparency and occlusion.
Lights	Lighting criteria that may correspond to the time of the day, season or visibility situations.
Shading	3D objects have shades.
Atmosphere	It can project an atmospheric impression.
Visibility	The distance to which is the visual objects in the 3D scene visible.

Referencing	Model contains geo-referenced data.
Controls	There are multiple modes of control. Desktop visualisation environments are mostly keyboard, mouse and joystick based.
Collision and gravity	Dynamic objects in the 3D can collide with each other. Gravity function.
Elaboration	There can be external windows, pointers, and clickable objects leading to extra information for exploration.
Analysis tools	Model can be used for visualisation for analysis of spatial phenomenon.

The objects present in a model need to be in a relative correct size to each other to prevent misinterpretations being made. The objects have a geometry that can either be simple or complex based on the data at hand and the information that is needed. Some object might only have a ground surface and a height, making them an object with geometry of only six surfaces. When objects have more points, a more accurate visualisation of the object can be made, because more surfaces can be made allowing for more detail.

More geometry provides more detail, which could in turn provide more information but also more distraction. The users are visually orientated and when certain (irrelevant) details come into focus which influences the grand picture, it would be best not to visualise such details. So the user states that more information is good, but certainly not always better. It is impractical to display information that is not relevant.

4.3.1 Standard objects

The different types of objects in an emergency response information model are: buildings, bridges, tunnels, vegetations, infrastructures, and water bodies. These objects could be visualised in both 2D and 3D.

In chart 1, experts stated which objects would have added value in 3D.

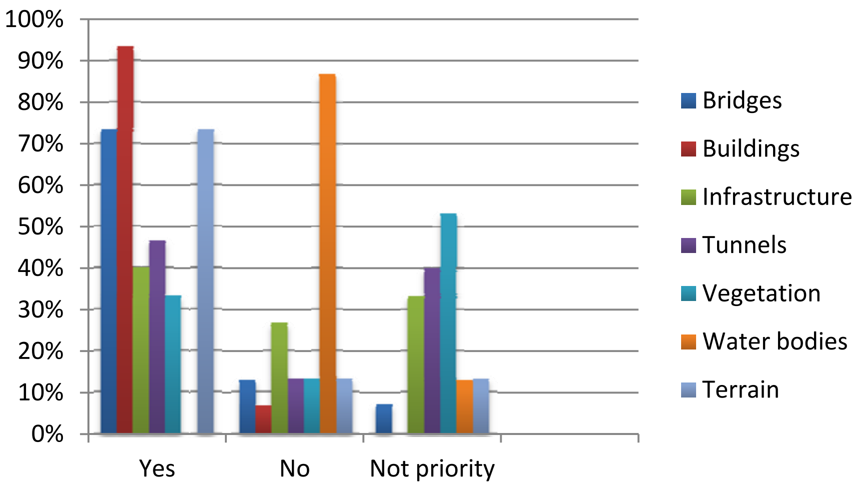


Chart 1: Components of 3D model

Out of the 15 experts that were interviewed, one did not see the necessity of a 3D model in general. Since the user requirements are about a 3D model, the opinion of this expert is stated but it is not used for the requirements, resulting in 14 interviewee opinions. A list of the emergency response experts and software experts is given in appendix G.

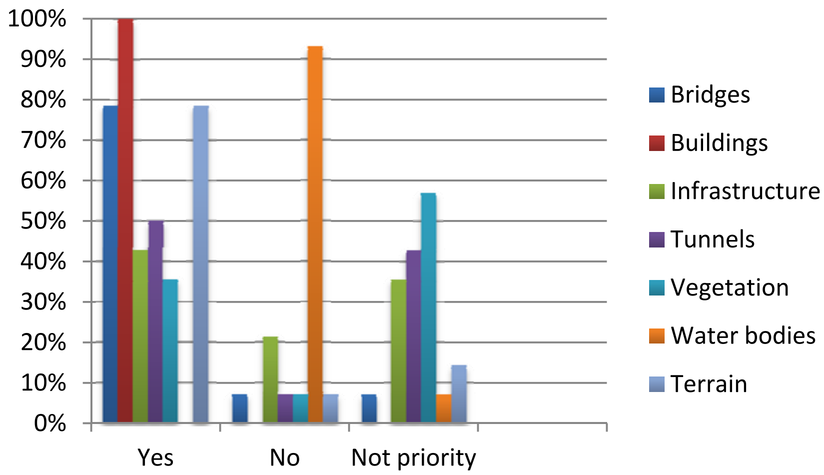


Chart 2: Components of 3D model corrected for expert against 3D

All experts indicated that buildings need to be modelled in three dimensions. Buildings, or cities, that are modelled in 3D give a much clearer overview of a location than a 2D map. The height of a building is an indication of the number of people, potential victims, inside and the type of area a disaster takes place in.
Also, almost all experts stated that bridges and terrain are important to model for emergency response. The terrain is related to flood movements, rail fall runoff, access to sites Objects such as vegetation and water bodies were clearly not a priority to be placed in a 3D model, but were not rejected either. The most rejected object to be modelled in 3D for emergency response was the infrastructure with 21%, even though 43% indicated that it is necessary. The needs for these standard objects are explained by their added value. Currently, the experts and their colleagues use Google Earth to evaluate a location. They said that the visuals Google Earth offered provided a more accurate and extensive overview of a location than the 2D models that they officially use. This indicates that the need for 3D data really there.

As stated in chapter 2, the fire department and police department are responsible for several tasks. The experts with a fire department background indicated that they would like to have an information model with 3D terrain for flood simulations and rain fall runoff calculations. Some areas are more prone to flooding than others, but the ability to determine where exactly the water will go in any area seemed like an important application to them. This could allow for a more local flood fighting and reduce unnecessary evacuations. Another scenario mentioned is smoke distribution during a large fire. Flow computations for the distribution of toxic or smoke clouds through city air can be better estimated with a model that contains 3D buildings that influence the travel path of emissions.

Another application indicated by experts is underground modelling. This would include gas and water pipes but also subway systems. By having a 3D overview of which pipes and tubes run where, experts said that finding a leak or an obstruction would be easier. Also, when an emergency would occur in a subway tunnel, a 3D overview would provide much more information than a regular map, with layers of tunnels, the width of tunnels and possible escape routes.

In order of importance the objects below are to be modelled in 3D in an emergency response model, based on weighted corrected factors (in percentages) ($i = 3 \cdot Y - 2 \cdot N + NP$). The weights imply that wanting objects in 3D (Y) is more relevant than not needing an object in 3D (N), which in return is more relevant than an object having no priority (NP) to be in three dimensions.

Buildings	$i = 3 \cdot 100 - 2 \cdot 0 + 0$	= 300
Terrain	$i = 3 \cdot 79 - 2 \cdot 7 + 14$	= 237
Bridges	$i = 3 \cdot 79 - 2 \cdot 7 + 7$	= 230
Tunnels	$i = 3 \cdot 50 - 2 \cdot 7 + 43$	= 179
Vegetation	$i = 3 \cdot 36 - 2 \cdot 7 + 57$	= 151
Infrastructure	$i = 3 \cdot 43 - 2 \cdot 21 + 36$	= 123
Water body	$i = 3 \cdot 0 - 2 \cdot 93 + 7$	= -179

The object water body has a negative importance ratio, which indicates that water bodies are not needed in 3D emergency response models. It is understood that the third dimension is not of added value to the model. But although the user does not need the water basin to be modelled entirely in 3D, it is practical to know the depth of the water. This information can be delivered through text on the water or as additional information when, for example, clicked upon. The waves are not modelled real-time and not an influencing factor on decision making. Furthermore, the expertise of water (related) bodies does not lie with the emergency responders and external parties are always invited to share their knowledge.

The objects in the model have a wide range of visual properties such as colour, shape, lighting, brightness, surface reflectance and shading. An emergency response situation is a dynamic event and requires a model that can adjust easily to a new or different situation. By adding atmospheric impressions, weather patterns, lighting and shading, the model could become a closer representation of reality and thus provide more insight for decisions.

In order to provide location and routes, geo-referencing is an integrated part of an emergency response model. According to the experts, additional information regarding an object or a situation can be elaborated on in external windows, through points and by clicking on an object. The additional information is preferably presented as text.

4.3.2 Other objects

Besides the objects defined as standard object for a 3D model, there are more objects to be modelled in 3D in an emergency response model. A quick view on such objects presents water related objects, risk related objects and other constructions.

Examples of such objects are:

- Dikes
- Delta works
- Helicopter pads
- Arms depots
- Command centres
- Prisons
- Gas control stations
- Power plants
- Shelters
- Hospitals with quarantine capabilities

These objects are further specified in chapter six where they can be placed into context.

4.4 Information intensity

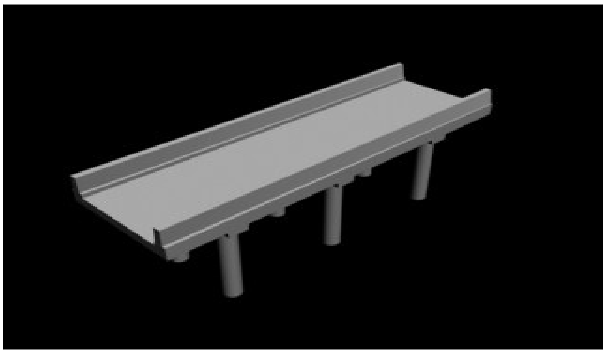
Having the possibility to move between different representations of the same design lets the user get rid of bias to come to a decision. There are various ways to distribute the amount of information. In 3D information models, Levels of detail (LOD) can be used to show different materials and details of the model in different resolution.

4.4.1 Level of detail

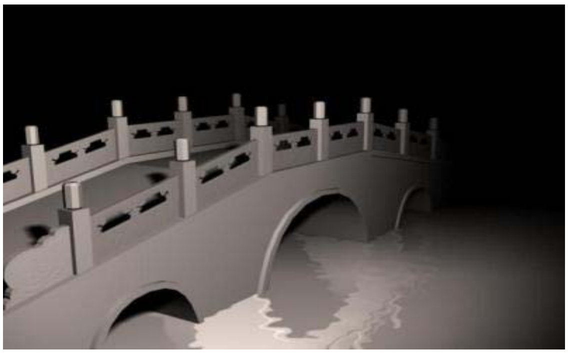
CityGML supports 5 different Levels of Detail (LOD). LODs are required to reflect independent data collection processes with differing application requirements. Although most of the time LOD is applied to geometry detail only, the basic concept can be generalized. "In a CityGML dataset, the same object may be represented in different LOD simultaneously, enabling the analysis and visualisation of the same object with regard to different degrees of resolution. Furthermore, two CityGML data sets containing the same object in different LOD may be combined and integrated" (van Oosterom et al., 2007:304). According to OGC definitions: The coarsest level, LOD0, is essentially a two and a half dimensional Digital Terrain Model, over which an aerial image or a map may be draped. LOD1 is the well-known blocks model comprising prismatic buildings with flat roofs. In contrast, a building in LOD2 has differentiated roof structures and thematically differentiated surfaces. Vegetation objects may also be represented. LOD3 denotes architectural models with detailed wall and roof structures, balconies, bays and projections. High-resolution textures can be mapped onto these structures. In addition, detailed vegetation and transportation objects are components of a LOD3 model. LOD4 completes a LOD3 model by adding interior structures for 3D objects. For example, buildings are composed of rooms, interior doors, stairs, and furniture" (OGC, 2007).

According to experts, there are different LOD needed for different objects and for different situations. The objects assessed for their LOD were: buildings, bridges, tunnels, infrastructure and vegetation which also relates to the LOD for other objects. Diagrams are placed in the next paragraphs and in appendix I. The images in this paragraph are from www.turbosquid.com. The levels of detail needed for any object is completely dependent on what is to be visualised for which case, but generally objects have a minimum or maximum of details needed in any situation. The levels of detail can be interlinked to the scale of the model.

Bridges



LOD1 – Crossing notice



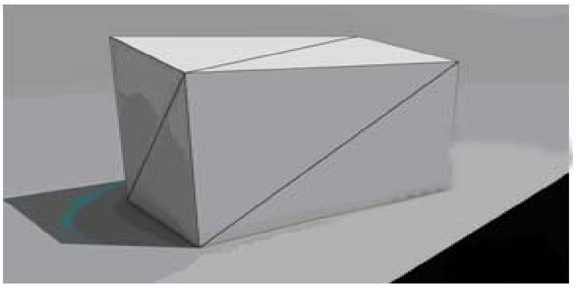
LOD2 – Type of bridge

Figure 20: LOD of Bridges

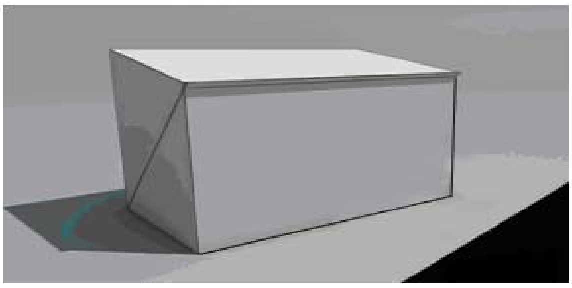
LOD3 – Detailed construction of bridge

14% of the experts indicated that a crossing notice in the model will suffice. The most relevant information of a bridge is its capacity and its size. Emergency response vehicles must know whether they can cross a bridge; this information could also be delivered by text. 79% of the experts would like to have the construction of the bridges modelled in the object. This is very useful during disasters that take place on a bridge. When the bridge object contains the construction, it provides information at first sight.

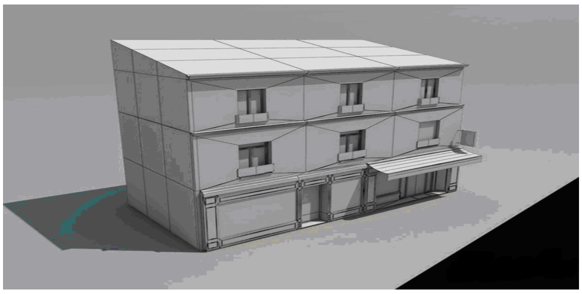
Buildings



LOD1 – Block without rooftype



LOD2 – Block with rooftype



LOD3 – Block with detailed walls and roof

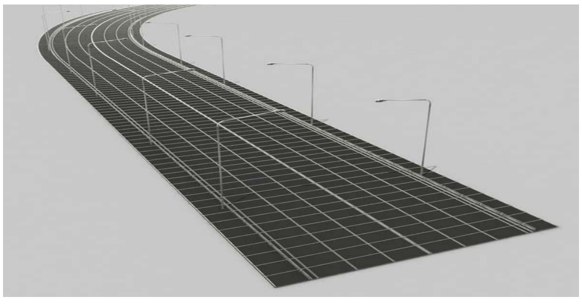
Figure 21: LOD of Bridges

In CityGML, LOD4 completes a LOD3 model by adding interior structures for 3D objects such as rooms, interior doors, stairs, and furniture. All experts stated that interior structures would support decision making enormously and that when the option is feasible, LOD4 would have the preference. Whilst LOD4 is not yet at hand, 29% of the experts stated that a block without a roof type (LOD1) is sufficient in an emergency response. In contrast, the other 71% said that block with full details such as wall and roof structures are necessary. LOD2 did not seem relevant: a user needs details or he does not.

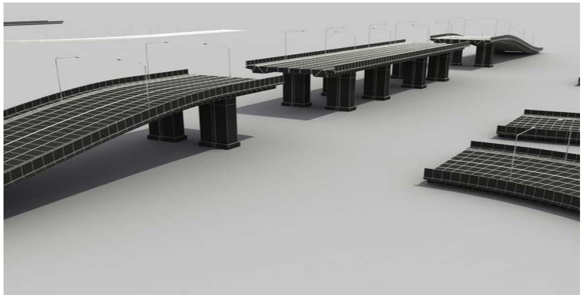
In addition, 93% of the interviewee mentioned that the same LOD can be used for one building, i.e. they do not see an upside to multiple levels of LOD of a building. Whereas the experts did state that it can be helpful to have the building where the emergency takes place in a high LOD while the surrounding buildings remain simple blocks (LOD1).

57% of the experts indicated they would windows en doors on the building block, either in texture or modelled. Priority of windows and doors would go to the first floor, where the doors are used for entrance and exit by the emergency responders.

Infrastructure



LOD1 – Size of infrastructure



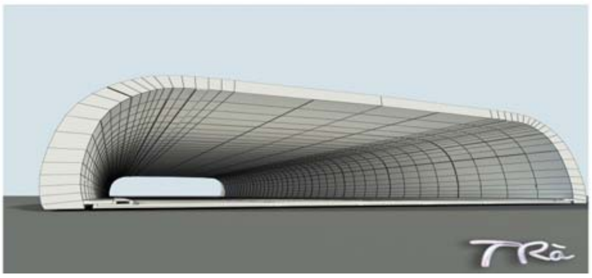
LOD2 – Type of infrastructure

LOD3 – Construction of infrastructure

Figure 22: LOD of Transportation

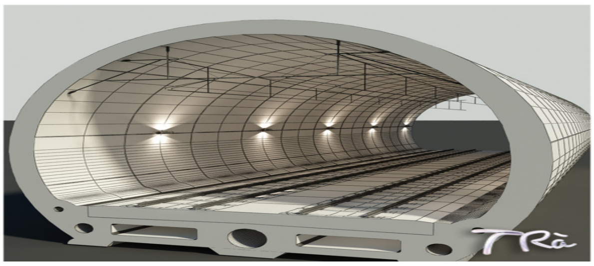
Most experts (92%) need more than just the size of the infrastructure (width and height) (LOD1). LOD2 provides the type of infrastructure: regular road, viaduct etc. LOD3 also provides insight into the construction of the infrastructure. Both could be helpful during an emergency to estimate its strength, its traffic flow capacity and for road signs to determine a specific location.

Tunnels



LOD1 – Size of tunnel

LOD2 – Type of tunnel



LOD3 – Construction of tunnel

Figure 23: LOD of Tunnels

21% of the experts indicated that a 3D view of the tunnel to determine its size is sufficient. On the other hand, 43% would like to have the object illustrate the type of tunnel and 36% would like to have the construction of the tunnel visible in the object. The 21% that only need the size of the tunnel in the 3D model base this on the fact that data on the tunnel is known elsewhere and that the size is just for quick assessments. For details needed in case of a disaster in a tunnel, sensors and cameras inside the tunnel will provide information. The reason for needing a lot of information within tunnels is because when something goes wrong inside the tunnel, the occupants of the tunnel don´t have many places to go or routes to take. The scale of the incident can quickly worsen inside a tunnel.

Vegetation

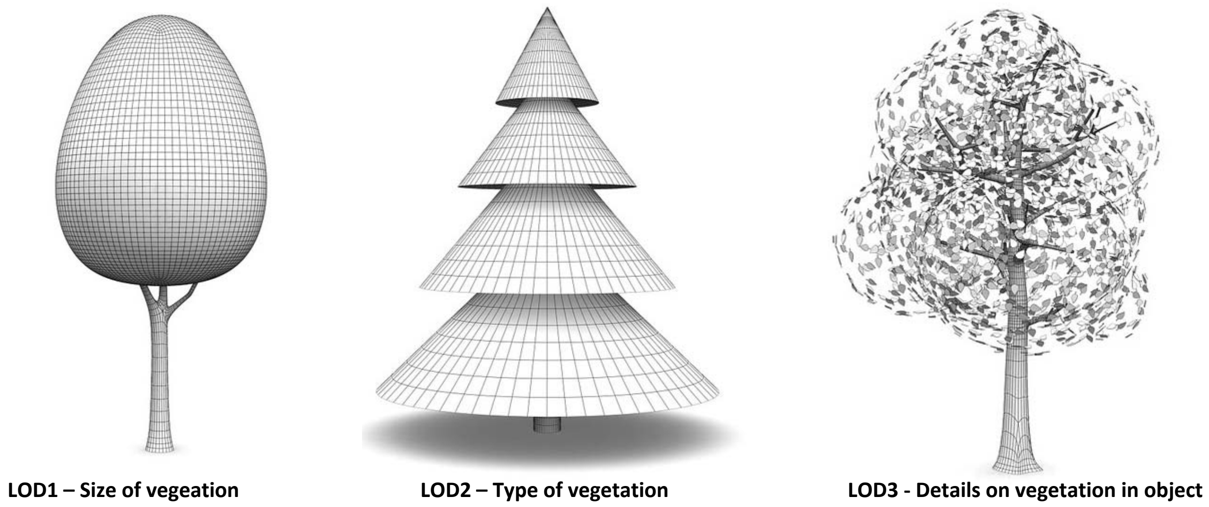


Figure 24: LOD of vegetation

All experts pointed out that vegetation is limitedly relevant in a 3D emergency response model, but with regards to fires it is best to place them there anyway. They agreed on the size of the vegetation, where both the size of the tree and the size of the forest area, to be placed in the model. For fires it is important to know which type of vegetation is in the area. One third of the experts pointed out the size of vegetation is sufficient to model in a 3D emergency response model and show the type by clicking or otherwise. The other two thirds indicated that it is efficient to model the type of vegetation directly in the 3D model.

4.4.2 Scale and view

The technical model is in need of different scales. A user must be able to zoom out to get an overview of the situation and zoom in to get a close up of the emergency. The levels of detail should change according to the scale. The higher the scale the more detail the model should provide.

Because the object has three coordinates (x,y,z) on the map, it will allow users of the model to rotate around an object on the map and support different views. A user can manage top view, aerial side view and street/road view. When an expert states that a certain object needs street view, it is implied that it also needs TOP view, besides the standard aerial side view. The angle of view must adjustable by the user, providing the user with a view upward, downward, sideward or frontal. As in *Phoenix*, touch table software, it is helpful to mark a viewpoint around which can be rotated. By placing a compass on a location, the user can either rotate around the marked point to view the location from all sides, or view the scene 360° all round from the marked location (figures 25a and 25b) .

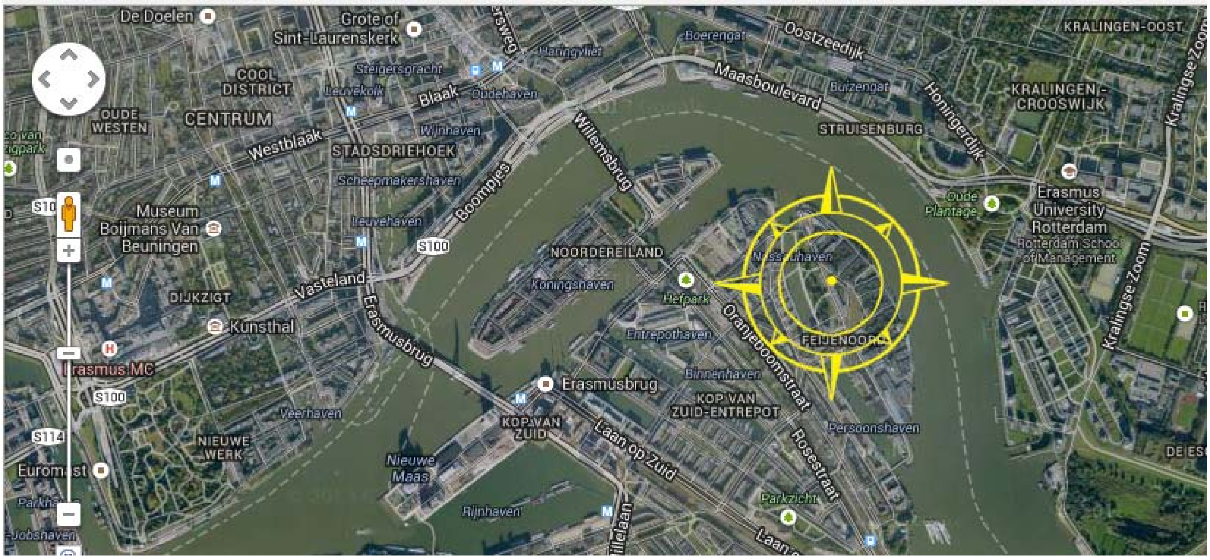
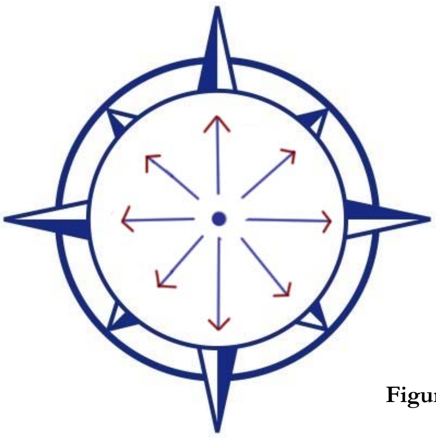


Figure 25a: Map with compass



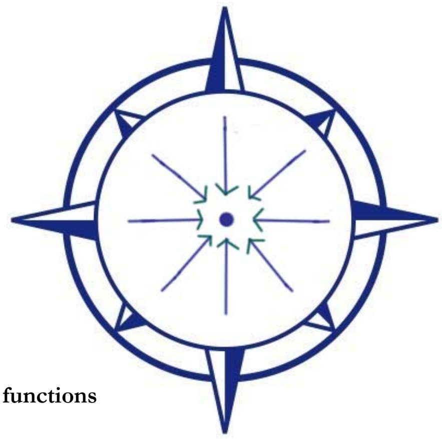


Figure 25b: Compass functions

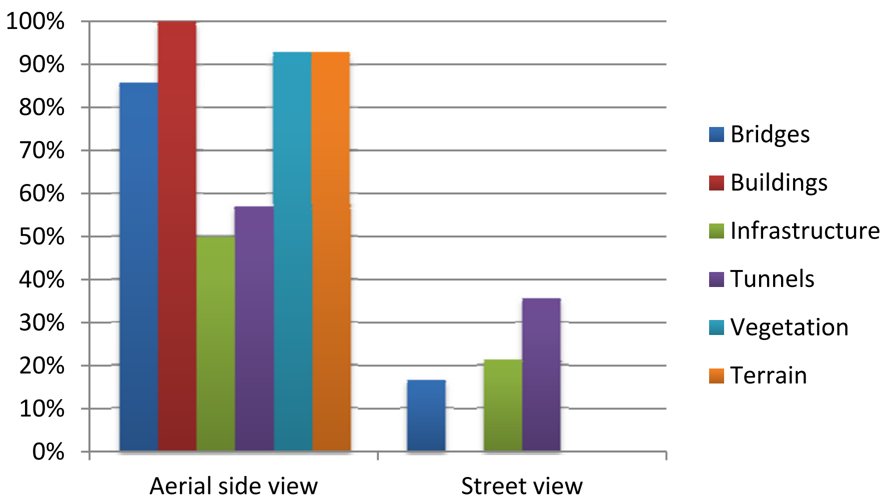


Chart 3: Expert opinion - Type of view

4.4.3 Additional information

In order to not overflow the model with information regarding the objects, additional information can be placed in a separate menu. Experts indicated that additional information of an object is to be presented when a user clicks on an object with their cursor. A textbox with information about the object which is not obvious through visual means will appear, can be edited, stored and clicked away. It is also possible to display different pictures or images of an object by clicking on it. By allowing users to click on an object for additional information, information will only be presented when specifically demanded for the selected object. This keeps the model from overflowing with redundant information.

4.4.4 Representation

Representation is about the obvious visual matters of objects in a model. It comprises the geometry, colour, shape, texture, lighting, shading, object identifier etc. There are different types of representation of objects with regards to construction of the object (Kibria, 2008):

Table 10 Representation of objects

1	Wireframe mesh models	Only the frames of the objects are visible. No sides of the 3D objects are visible.
2	Transparent mesh models	The mesh frame of the model is very visible and the polygonal walls of the 3D objects are semi-transparent
3	Hidden-line models	The frame of the object is hidden but the side-walls of the polygons are highlighted
4	Flat models	The frame is visible in lines and polygonal sides visible in opacity.
5	Shaded models	The frame is visible in lines and the polygonal sides visible in various opacities with shade and shadow.
6	Textured models	The frame and polygonal sides of the 2D objects are visible and is textured like the real world.

A model can be shown in various representations while keeping its geometry. Experts have indicated that different types of representation are needed. Not all the objects in a 3D model require texture, where some never require texture and others do not require texture some or most of the time. Also, it is important for users to be able to see the construction of the objects, such as buildings. By allowing buildings to be displayed as a transparent mesh model, a flat model and a texture model it can provide the user with the both the inside and the outside details of an object. “The way the 3D models are rendered have impact on the human cognition how one perceives information” (Kibria, 2008).

A texture on an object can deliver additional information but it can also be misleading. Figure 27 demonstrates how a texture can create assumptions. Figure 27b shows rust on outside wall on the first floor, by which users could assume there is a steel construction behind that piece of wall. On the other hand, the building might have been completely renovated since the object was uploaded into the database. Regarding the objects for an emergency response model, the following suggestions were made:

Bridges

93% of the experts indicated that they do not need a texture on bridges in an emergency response model. Of the 7% that indicated that they would like the texture to have an on and off function, all wanted the texture to be based on an image of the bridge.

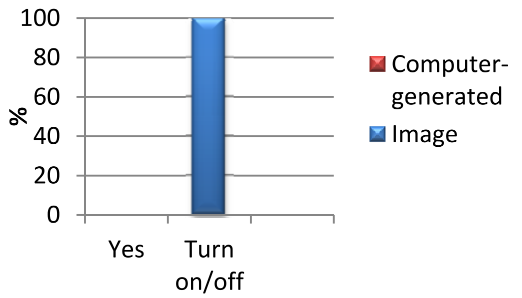


Chart 4: Experts opinion – texture bridges

Figure 26a Bridge without texture

Figure 26b Bridge with texture

Buildings

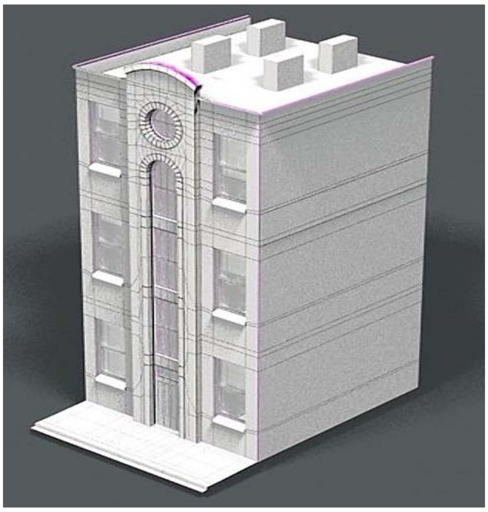
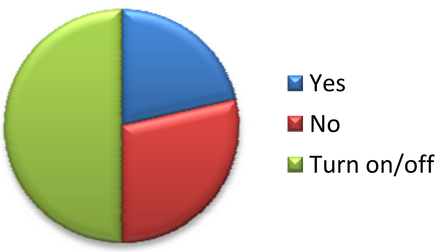


Figure 27a Building without texture

Figure 27b Building with texture

71% of the experts indicated that they need a texture on buildings in an emergency response model and 29% said they do not need texture. Of the 71%, 50% indicated that they would like the texture to have an on and off function and all wanted the texture to be based on an image of the building. This also applies for the experts that require 3D buildings with texture at all times. All experts agreed on that, besides texture, a building would also have to be able to become transparent and show the building structure, in accordance with a transparent mesh model. The structure of a building provides information about its stability, materials and capacity. This property is very important to fire fighters and the police with regards to choosing whether to enter a building or not. The fire department has a new regulation which states that a fire fighter may not enter a building unless it is known to be safe. In the past too many fire fighters jeopardised and lost their lives in order to save another. The construction of the object will provide insight in the collapse risk of a building and could support the new regulation.



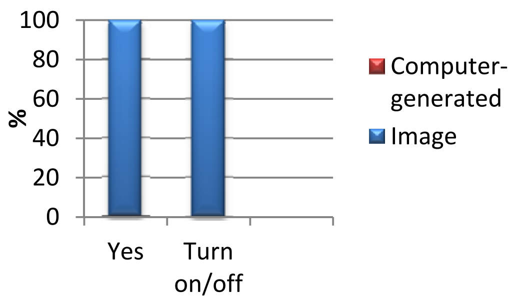


Chart 5: Experts opinion – texture building

Infrastructure

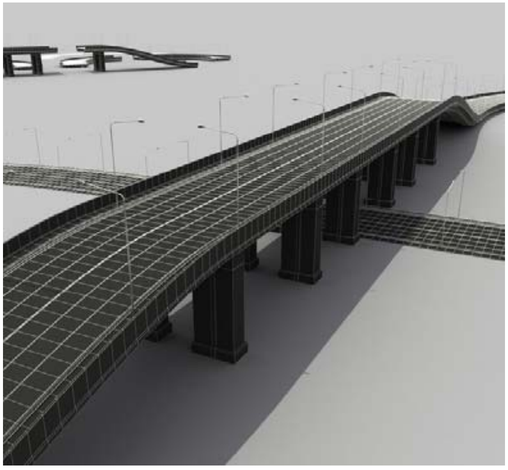


Figure 28a Infrastructure without texture

Figure 28b Infrastructure with texture

53% of the experts indicated that they do not need a texture on infrastructure in an emergency response model. Of the 40% that indicated that they would like the texture to have an on and off function, all wanted the texture to be based on an image of the infrastructure. Texture of infrastructure includes the material of the infrastructures which visualises what kind of infrastructure the object is. It also includes the number of lanes, sign details and other visual additions.

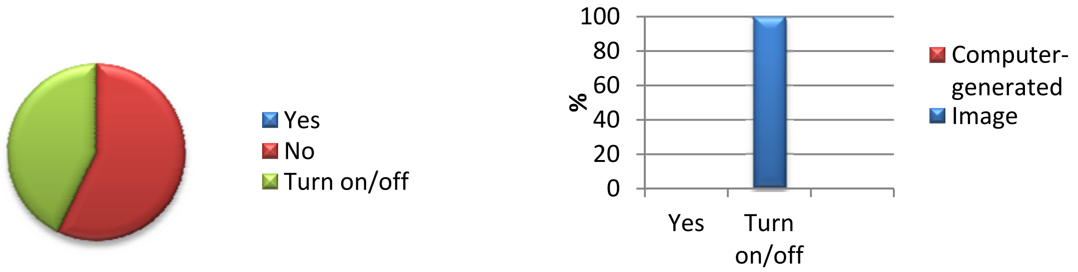


Chart 6: Experts opinion – texture transportation

Tunnel

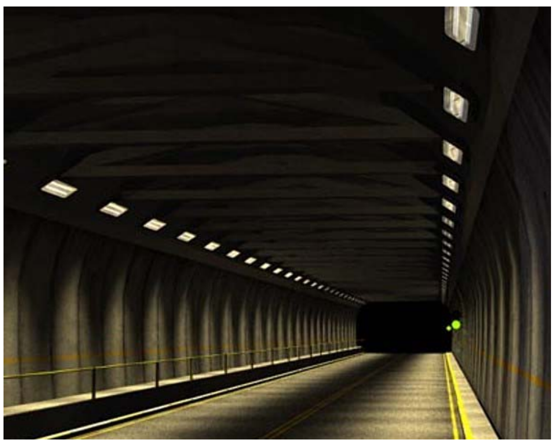
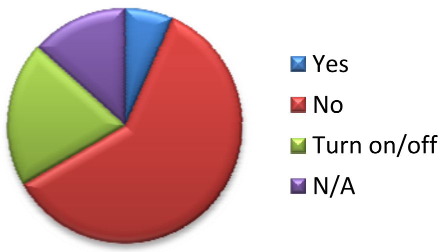


Figure 29a Tunnel without texture **Figure 29b Tunnel with texture**

60% of the experts indicated that they do not need a texture on tunnels in an emergency response model. Of the 20% that indicated that they would like the texture to have an on and off function, all wanted the texture to be based on an image of the tunnel. This also applies for the experts that require 3D tunnels with texture at all times. The texture of the tunnel shows the material with which the tunnel is coated from the inside. It does not shows how the tunnel is constructed and the material on the surface does not tell information about the material below the surface. The 13% that has N/A indicated that a tunnel does not have to be modelled in 3D and therefore does not require a texture.



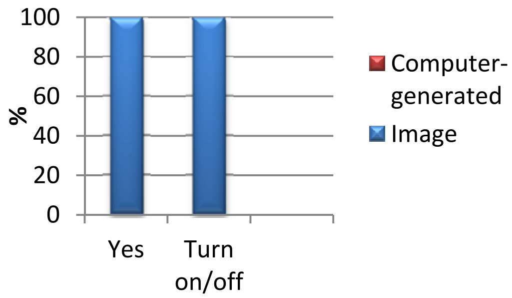


Chart 7: Experts opinion – texture tunnels

Vegetation

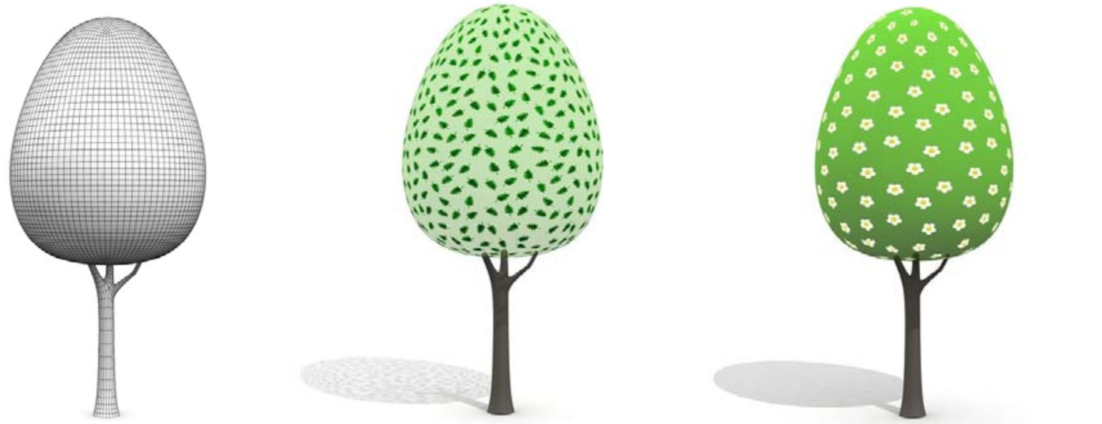


Figure 30a Vegetation without texture **Figures 30b and 30c Terrain with (seasonal) texture**

All the experts indicated that they do not need a specific texture on vegetation in an emergency response model. The only information required about vegetation is the size and the type of vegetation (grass, deciduous trees or needle-leaved trees). This information could easily be provided by applying a texture, but it could also be provided by text or the shape of the object. Since vegetation is generally not important for emergency response, except for large fires in natural environments, the experts believe that text or certain shapes will suffice. Also, it must be said that to place a green coat on all vegetation allows for faster visualisation of the model. So in summary, vegetation does not need texture to elaborate on the tree details, but it does need a green texture that can be turned on and off to show vegetation in a fast way.

Water bodies

100% of the experts indicated that they do not need a texture on water bodies in an emergency response model (2D or 3D). The most relevant properties of a water bodies are its volume; with height, width and depth, and its salinity. During an emergency response where much water is involved, an external (water) expert is called in to share knowledge and assist in decision making. The local fire department is dependent on water resources and has the basic information regarding the water bodies in the area.

Terrain

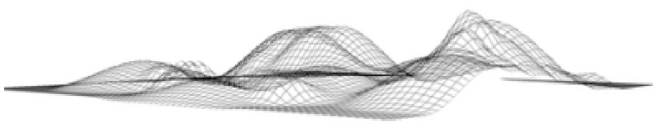


Figure 31a Terrain without texture

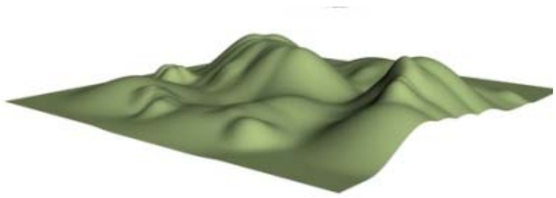


Figure 31b Terrain with texture

79% of the experts indicated that they need a texture on terrain in an emergency response model and 21% said they do not need texture. Of the 79%, 15% indicated that they would like the texture to have an on and off function and all wanted the texture to be based on an image of the terrain. The 7% that has N/A indicated that a bridge does not have to be modelled in 3D and therefore does not require a texture.

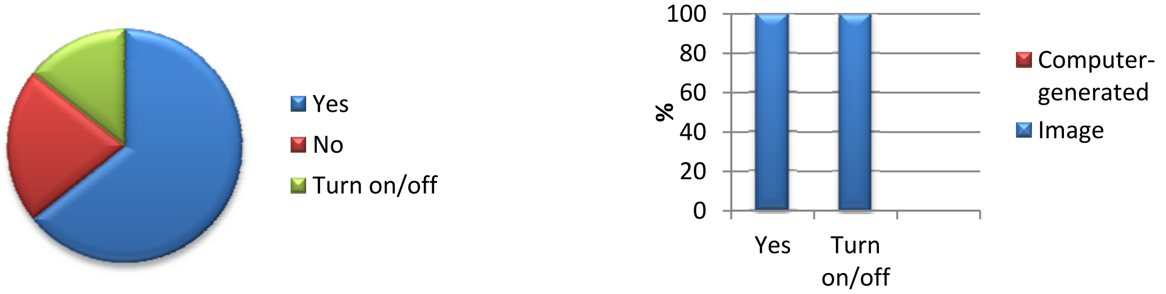


Chart 8: Experts opinion – texture terrain

4.4.5 Layering

To prevent too much information to be presented at once, while still allowing the model to contain all the information that might be needed, a requirement is that the model is multi-layered. Currently in LCMS, there are layers where different type of information can be stored. Examples are the COPI threatened area, COPI roadblocks, ER information, COPI information, ROT information and subject related information. Most of these layers contain icons or could additionally contain a picture to sketch the scene.

Further type of layers can be differentiated specifically for 3D emergency response models:

1. Layering for different objects
Placing buildings in a different layer than e.g. vegetation allows users to visualise only the objects that are relevant for that case.

2. Layering for texture of objects
If there is a separate layer for texture, users can choose whether to visualise the texture or not. Figure 31 shows an example of such a situation.

3. Layering with the inner structure of objects
Experts indicated that the construction of a building very important is with regards to emergency response. By adding a layer where the inner structure of an object can be visualised, the user can turn to that information when it is needed without it always being visible.

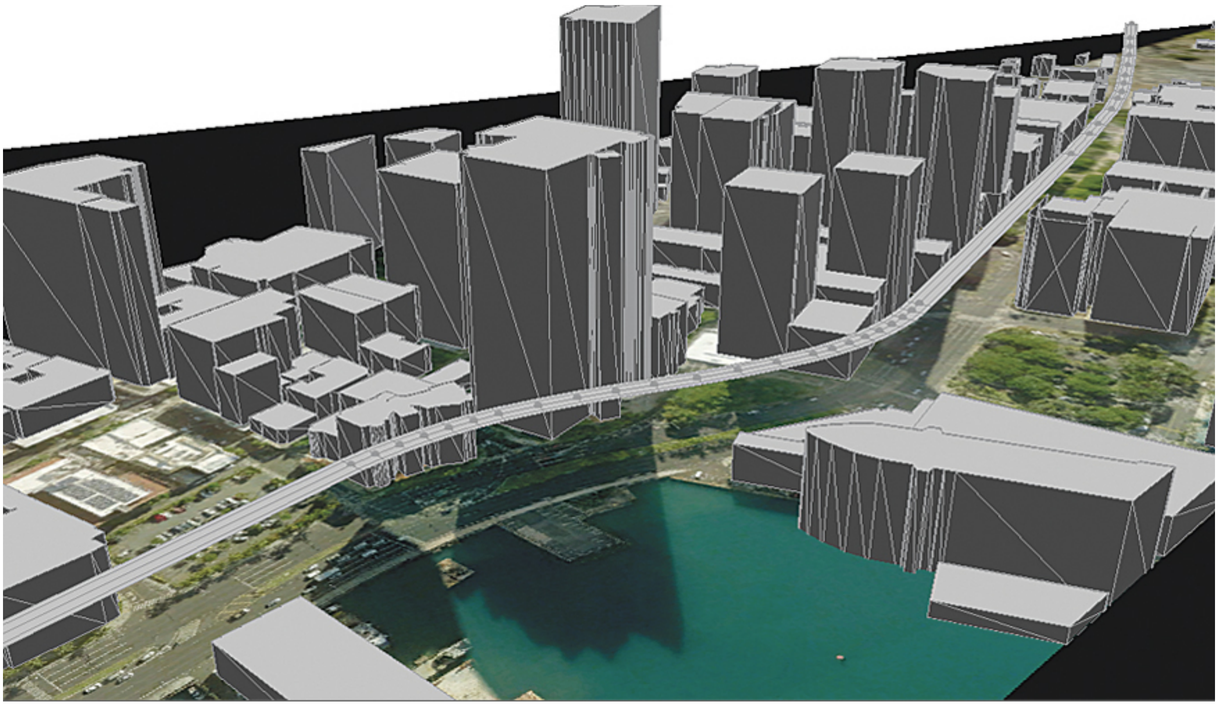


Figure 32: A 3D model shot with 2D textured terrain and untextured 3D buildings

4.5 Capabilities

The construction of a 3D scene is inseparable to the scale and resolution of 3D data (Kibria, 2008). The construction is related to the control, experience, exploration and interactive tools, object preparation, data sources and database types. The capabilities of a model are related to the construction of the system. The basic capabilities of a model are interfacing, data integration, representation and multi-dimensionality.

4.5.1 Interface

The interface of a (3D) model determines how the user can interact with the virtual environment. The viewer can be equipped with functionalities to support the user to interact and with visual options to illustrate the contents of the model. Currently, LCMS has a plot to see the maps and text boxes with written details on the situation. This set up is found to be valued by the users. Short text descriptions are quicker for understanding a situation then to decipher a map with alterations.

4.5.2 Data integration

The 3D model consists of various datasets and servers. These datasets are geo-referenced and can be in 2D, 2.5D or 3D. These different types of data are integrated into a requested 3D scene, through a process called data-integration. This data integration allows newly designed objects to be inserted into the model and merge the data with the existing model (Kibria, 2008). The most important aspect of the data in any model is its accuracy and therefore how up to date the data is. Every expert who was asked which the most important aspect of the model is answered accuracy. If the data is out of date, visuals can be misleading and mistakes will be made based on the out-of-date data. The capability of a model to perform data integration will determine its usability. A user will not use an out of date database for real-time important decisions.

4.5.3 Analysis tools

There are numerous analysis tools that can be used in a (3D) model. Prominent analysis tools are:

- Buffer, an analysis tool used in calculating proximity.
- Distance, an analysis tool used to determine the distance between two reference points.
- Intersection, an analysis tool used to perform overlay analysis on feature classes.
- Volume, an analysis tool used to determine the volume of an object.
- Area, an analysis tool used to calculate the area of a specified region.
- Sight of view, an analysis tool used to determine the sight of view from a certain point.
- Flow computation, an analysis tool to determine toxic or smoke cloud travel passages.
- Flood computations, an analysis tool to measure water runoff patterns and volumes.
- Numerical computations to count objects.

4.6 Use and interaction

The user should be able to be aware of the entire 3D environment through effective overview of the situation.

Interactivity

According to Heim, known as "the philosopher of cyberspace", interactivity is defined as the functionality that describes the user's ability to change the viewpoint and manipulate data. This means that an interactive environment would let the user change the objects physical characteristics. Table 11 shows the basic forms of interaction.

Table 11 Forms of interaction (Kibria, 2008)

	Functionality	Description
1	Object entity change	Interaction with object through deleting, adding, copying and pasting.
2	Object position change	Interaction with object by picking up and moving the objects.
3	Object attribute change	Interaction with object by changing colour, texture, shade, shape and thematic attributes.
4	Object query	Interactions with objects to derive qualitative and quantitative information about the objects.
5	Object editing	Interaction can be enhanced if the users have the option of editing designs real-time.

These interactivities enable the user to change their viewpoint, to change the relative position to that of others objects and to change the object itself. By enabling this interactivity, users can alter their 3D environment to the situation at hand and their requirements.

Additional application domain extensions

Specific "hooks" in the CityGML schema allow defining application specific extensions, for example for rainfall runoff simulation. Application domain extensions (ADE) can be used for analysis of spatial phenomena. Multiple application domain extensions can be integrated into a model or connected at request. Relevant ADE's inquired through the experts are rainfall run-off models, flood modelling, Gasmal in 3D, underground modelling, fire modelling, explosion simulation and evacuation modelling. The ADE that were raised, reflect the conclusion that Buildings, Terrain, Bridges, Tunnels, Vegetation and Infrastructure are all to be modelled in three dimensions in order to support the decision making during emergency response.

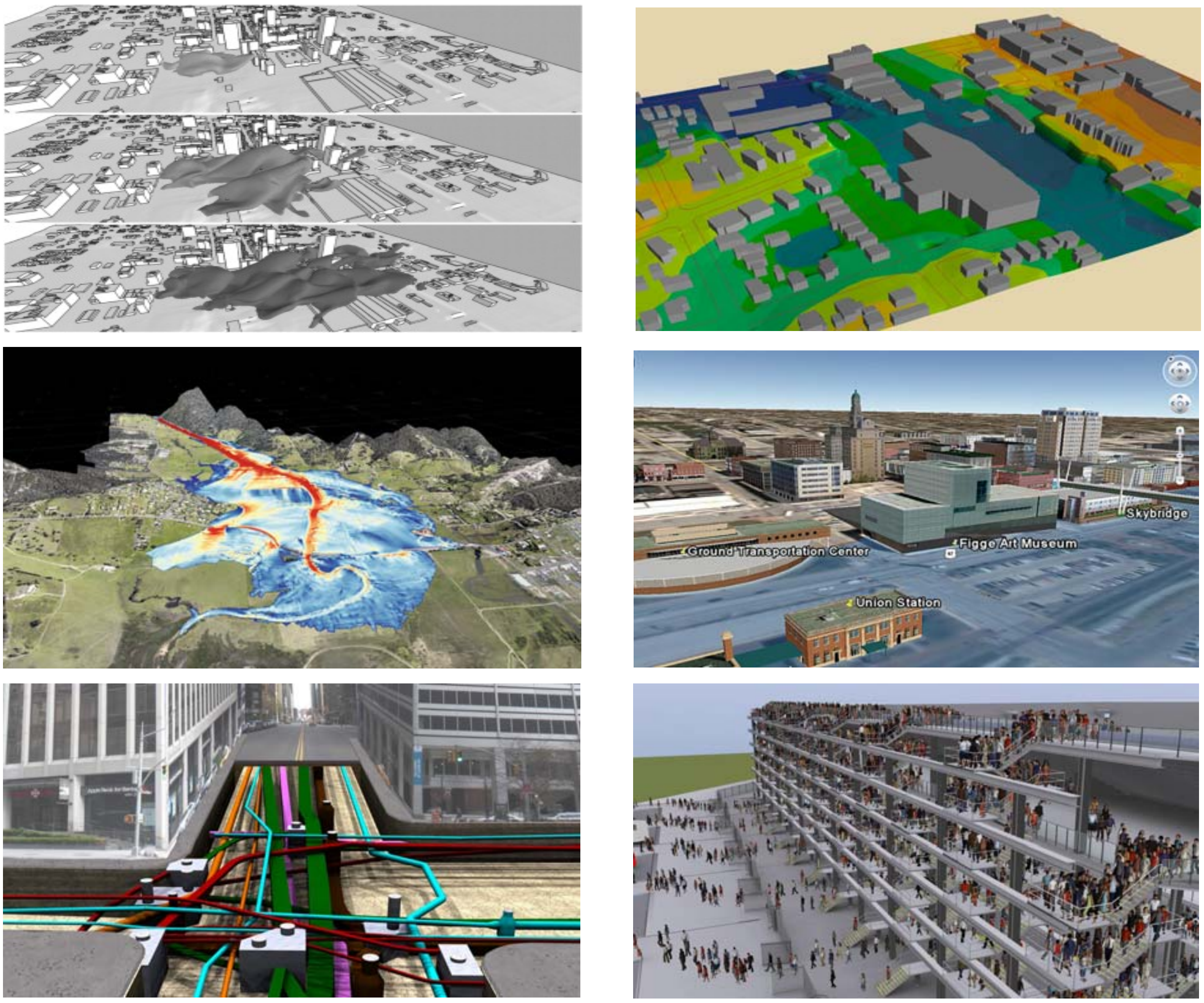


Figure 33: ADE

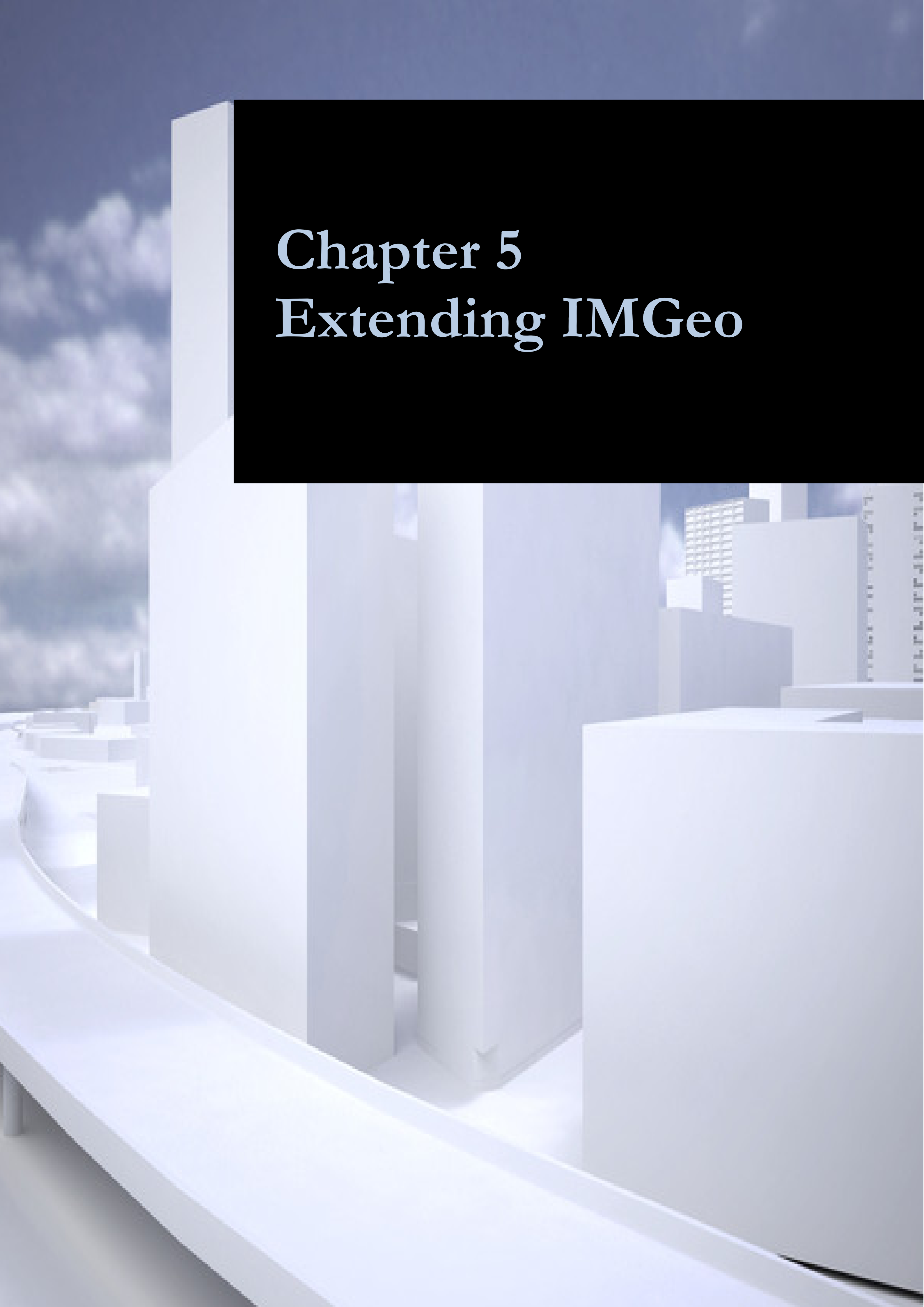
4.7 Conclusion

To determine user requirements involves a literature study and more importantly, direct information from the user. This information was gathered by consulting experts during an interview. The different types of objects in the emergency response model are: buildings, bridges, tunnels, vegetations, infrastructures, and water bodies. These objects could be visualised in both 2D and 3D. The object water body has a negative importance ratio, which indicates that water bodies are not needed in 3D emergency response technical models. It is understood that the third dimension for water is not of added value to the model, but the depth of the water body should be stated somewhere. Beside the standard objects of a 3D model, additional emergency response related objects are also of need. These objects are derived from the different categories of disasters, as stated by the government. They are numerous and in most cases relevant to a specific type of emergency. Examples of such objects are helicopter pads, dikes and gas pipes. The experts indicated that by modelling objects in 3D, their tasks could be carried out more effective and more efficient.

A technical model is in need of different scales. A user must be able to zoom out to get an overview of the situation and zoom in to get a close up of the emergency. The levels of detail should change according to the scale. The higher the scale the more detail the model should provide, but it should also be possible to retain a low LOD at a high scale to reduce information using manual adjustments in the visualisation software. With regards to texture, buildings and terrain are in most need of texture to visualise the objects. The texture should preferably not be based on computer generations but on images, which can be automatically extracted from oblique aerial images. All experts agreed on that, besides texture, a building would also have to be able to become transparent and show the building structure, in accordance with a transparent mesh model.

To prevent too much information to be presented at once, while still allowing the model to contain all the information that might be needed, a requirement is that the model is multi-layered. Different types of layers can be differentiated specifically for 3D emergency response models: Layers for different objects, layers for texture of objects and layers with the inner structure of objects

Chapter 5
Extending IMGeo



5. Extending IMGeo

The user requirements for an emergency response models 3D have been established. These can be implemented for use with IMGeo. This chapter will elaborate on how IMGeo is modelled as a CityGML ADE and support achieving the goal of this thesis: To development a conceptual extension for IMGeo for 3D emergency response, containing user requirements. The first paragraph will elaborate shortly on what data is obtained and how IMGeo classes are connected to CityGML classes. And then, based on the current IMGeo, extension suggestions will be made for emergency response purposes.

5.1 Data sources

5.1.1 BGT

The BGT is the mandatory part of IMGeo as mentioned in chapter 2. It consists of 15 types of object, the majority of which have an area geometry. The other objects have poly-line geometries. With the exception of label locations, the BGT does not contain point geometries.

- Road
- Road support
- Railway
- Bridge
- Tunnel
- Bare terrain
- Plant covered terrain
- Water
- Water support
- Building
- Other structure
- Other construction
- Separator
- Unclassified object
- Functional area

All proprietors of public information are mandated by law to deliver a complete and correct dataset of their objects to the government (van Winden, 2012). The process of delivering this information is usually in multiple steps.

5.1.2 IMGeo

The IMGeo models allows for the storage of detailed objects. There is no minimum size requirements on objects and similar adjacent objects do not have to be aggregated. Quite recently, IMGeo was extended with city furniture, other objects (bridges and trees) and further specification of certain BGT objects types. An example of this is that now a plant covered terrain can be specified with a type of vegetation.

5.1.3 AHN2

The Current Dutch Height File (AHN2) is the second version of the National Elevation Data set. Measured by aerial flights using LiDAR, AHN2 provides height data for The Netherlands. It is not only used for information on elevation, but also used for 3D-mapping; A solid basis for the use of height in other national geometric base registrations. Supposedly the data set should cover the land, but it can contain gaps in certain locations caused by an irregular point distribution (Alkemade, 2013) . The products of AHN2 include a point cloud of the terrain, point cloud of the buildings and vegetation included and grids of terrain of 0,5 m. to 5 m. (like AHN1). The applications of AHN2 involve (Alkemade, 2013):

By Water authorities and Rijkswaterstaat:

- Quality and safety check barriers;
- Drainage maps;
- Hydrological models;
- Monitoring of coastal erosion / subsidence;
- Scheduling of major infrastructural work;
- Ordinances relating to water levels;
- Planning buffers between ground water levels and location of pumping stations.

By third parties:

- 3D visualization and modelling;
- Archaeology assets;
- 3D geo-information facility (Cadastre);
- insurance companies (type and volume determination of buildings);
- Route studies (for infrastructure);
- urban drainage models;
- location research for radar or windmill installations;
- Solar Potential; so-called Solar Cadastre.

Currently, the next generation of AHN is on its way. Water authorities need an update for watermanagement (i.e. safety check dikes; Water Act), so AHN3, the new updated and improved version of AHN2, will be released in 2014. The further improvements of AHN3 will consist of (Alkemade, 2013):

- Further classification: terrain, building, infastructures + the rest;
- RGB coding and laser intensity value per point;
- Echo count for automatic classification (by business)(e.g. vegetation); full wave optional;
- Pointclouds in LAZ format;
- Griddata: INSPIRE-proof.

5.2 IMGeo

This paragraph will elaborate on the current classes and subclasses of CityGML and IMGeo from which possible extensions can be derived for emergency response modelling.

5.2.1 Connecting IMGeo to CityGML

In order to connect IMGeo to CityGML, the classes of IMGeo are modelled as subclasses of CityGML. The following text will shortly explain the basics of this, to better understand how the UML diagram is put together. Since CityGML is only available as xml schema, the first step is to recreate the UML model. In the next step all IMGeo classes are modelled as subclasses of CityGML classes. Using the selected modelling approach, these subclasses get the same class name as the CityGML class they are extending. The stereotype <<ADEElement>> is assigned to these subclasses. This marks these classes as subtypes that only add properties to the CityGML class, and accordingly no XML component for these classes will be created in the XML Schema. In addition, the specialization relation with the CityGML class is marked with a stereotype <<ADE>>. Since IMGeo is in Dutch, a Dutch translation of the subclass name is added as an alias for documentation purposes (Geonovum, 2013).

For all CityGML classes which are relevant for IMGeo, a subclass is created, adding at least a 2D geometry property to all classes. Figure 34 shows an example of the IMGeo ADE of a subclass *Bridgepart* which contains additional properties compared to the equivalent CityGML class (2D geometry and LOD0 geometry properties). The yellow classes are classes from the CityGML Tunnel package. The *<<ADEElement>> Bridgepart* is a class defined in the IMGeo ADE package as a subclass of CityGML *Bridgeconstructionpart* class. The ADE Element is a part of IMGeo and more specifically a part of the BGT basic registration, the mandatory content of IMGeo. The orange classes are classes or code lists of IMGeo's so called plus management, the non-mandatory content.

According to Brink et al (2012) in paragraph 2.5.2, the integration of IMGeo and CityGML 2.0 uses modelling principles. Some are relevant for a proper extension of IMGeo and stated as follows:

1. There is maximum use of CityGML classes, attributes and attribute values. The IMGeo classes are modelled as specializations of CityGML-classes. The specialization relationship with CityGML is realized for all objects.

2. Not every IMGeo class has a 1-to-1 mapping equivalent CityGML class. For these classes, two solutions are optional.

a. IMGeo classes that, conceptually and in terms of the properties, match CityGML classes. This indicates that the CityGML class is being used and IMGeo can only add properties. This is preferred and therefore applied as much as achievable. It remodels the IMGeo concept so that an equivalent CityGML class can be found. For IMGeo this is for example done for *Vegetation* that models any vegetation-related concept and *AuxiliaryTrafficArea* meant for road segments which are not used for traffic, such as verges (in IMGeo modelled under the classes Road or Land Use). b. IMGeo classes that are a further specialization of a CityGML-class. They are modelled as a subclass.

3. For structures that are not equal to specific buildings, CityGML has no equivalent class. A class is added, namely "Other Construction". The class '*OverigeConstructie*' (OtherConstruction) is a class to represent man-made constructions other than buildings, bridges and tunnels. Examples are water management constructs such as pumping plants, locks, and weirs but also wharfs, fences, loose-standing walls, high-tension line towers and wind turbines. It is modelled as a <<featureType>> subclass of the CityGML class _Site (with a Dutch class name) which is not suppressed from the XML Schema. The class has its own properties which are modelled similar to CityGML classes, such as implicit geometry on different LODs as well as 2D and 3D geometry up to LOD3" (OGC, 2008:10).

4. For most attributes, CityGML has an equivalent. When that is the case, the CityGML attribute is used. Where no CityGML attribute is available, an attribute is added.

5. Because CityGML has no definitions for the domain values, the Dutch domain value lists (lists of codes) 1:1 are maintained.

6. CityGML defines the different classes depending on the different LODs level of detail.

7. In CityGML, not all classes have a LOD0 (2.5D) representation, some classes start at LOD1. These are Vegetation and City Furniture. For these classes LOD0 representations were added to IMGeo.

8. The 2.5D topology is consistent with the 2D topology of IMGeo: all objects have a LOD0 representation (= 2.5D surface) which together form a 2.5D topological structure.

The IMGeo UML can be converted into a XML schema with Java. The Java tool ShapeChange is used to create an XML Schema (GML application schema) from IMGeo defined in UML (Portele, 2008). ShapeChange implements the UML to GML encoding rules described in ISO 19136, ISO 10118, and ISO 19109. ShapeChange was modified to add a custom encoding rule for classes with the <<ADEElement>> stereotype. These classes are hidden from the GML Application schema, while their properties are added to the ADE namespace as substitutes for the CityGML <Featuretypename> as described in CityGML 10.13.1 (OGC, 2008).

5.2.2 Code lists

CityGML provides code lists to allow predefined values for the CityGML attributes. However, the CityGML-IMGeo ADE makes use of national classification code lists instead of the CityGML code lists. These national lists are specifically suited to the Dutch context and contain a definition for each concept, approved but the involved Dutch organisations themselves. There is no need to map the Dutch code lists to the CityGML code lists, because they are non-normative and software does not check on code list values nor process them in a specific way (OGC, 2012). The code lists are maintained in the UML model and XML code lists can be derived from this UML using the ShapeChange module of Java.

The code lists in IMGeo are a part of the standard and allowed only to change when a new IMGeo version is published.

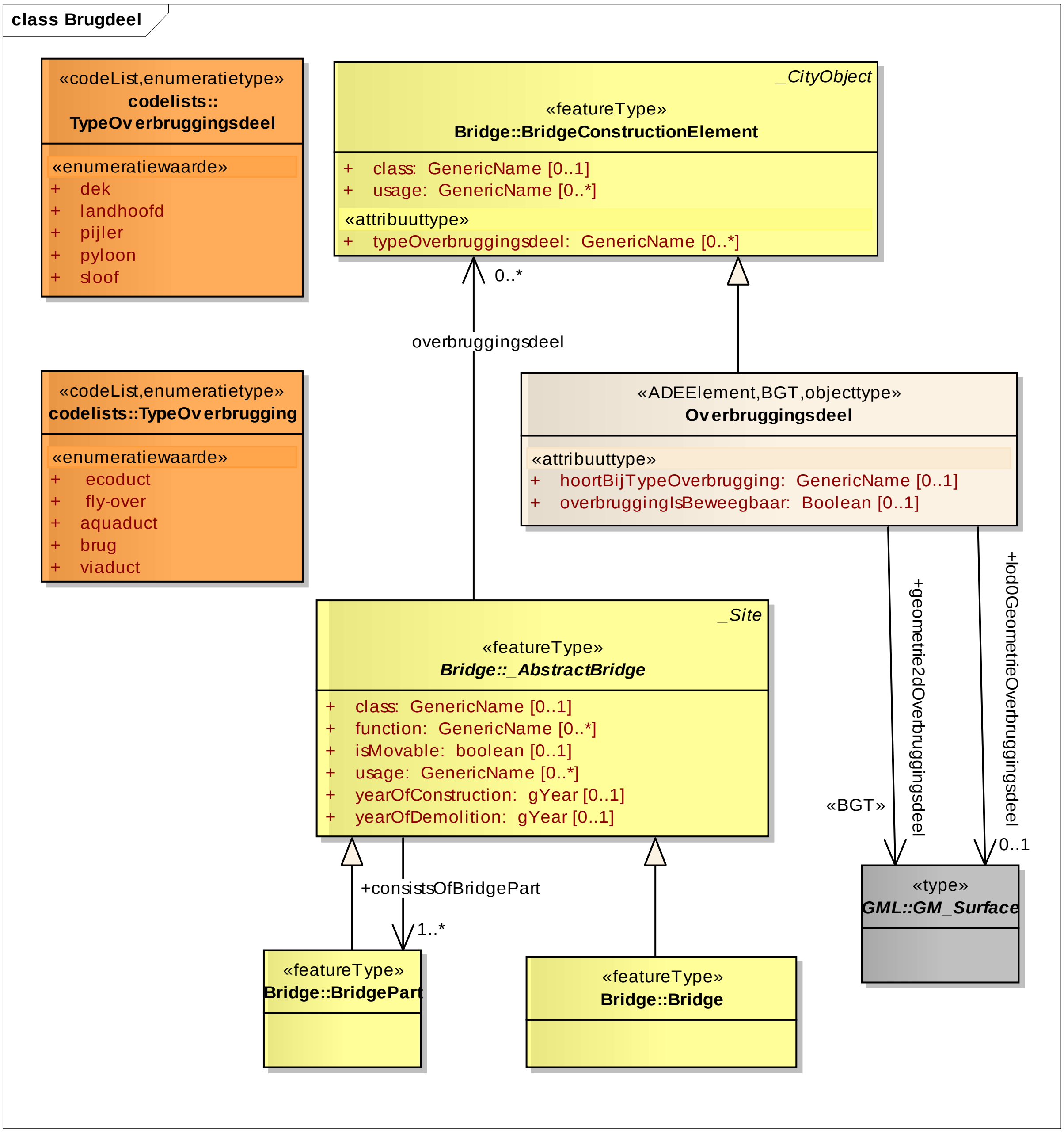


Figure 34: Bridgepart IMGeo

5.2.3 IMGeo sub model classes

Currently, IMGeo consists of approximately 13 sub models that are separated for structure due to their size. The sub models and classes in the application scheme of CityGML and IMGeo are stated in table 12. Each of these sub models can be displayed as .ear .xml and .xsd files.

Table 12 Sub model classes

CityGML	→	Application schema IMGeo
Bridge		Bridge section
City furniture		Interior elements
CityGML core		Building
		Unclassified objects
		Other construction
Land use		Functional area
		Registration area
Relief		Bare terrain
Transportation		Road section
		Railway
Tunnel		Tunnel section
Vegetation		Vegetation
Water body		Water section
		Void

5.2.4 Bridges

Bridges can be modelled from LOD1 up to and including LOD4. When extending 2D IMGeo to 3D, the different parts of a bridge defined in IMGeo (BridgeConstructionElements) can be used. These have a surface geometry in 2D. Both moveable and fixed bridges can be modelled by the CityGML class Bridge. Representing every part of a bridge as a closed volume is not possible. In situations such as these, a 'multisurface' can be used (*LOD1MultiSurface* to *LOD4MultiSurface*). The BridgeConstructionElements is a part of the AbstractBridge. This class contains information regarding usage, year of construction etc. Currently IMGeo provides a code list for *TypeBridge (*eco-duct, fly-over, aqua duct, bridge and viaduct*)* and *TypeBridgeParts* (deck, land abutment, pillar, pylon and apron).

5.2.5 City furniture

IMGeo recognises the following City Furniture objects:

- Container
- Sign

- Installation
- Casing
- Mast
- Pole
- Sensor
- Street Furniture
- Water city furniture
- Road city furniture

Each of these objects has their own code list in IMGeo, not from BGT, that provides the type of those specific objects by means of enumerative codes. These City Furniture objects can be described in 3D with a limited number of base variants. This is in essence also the case for 2D. The visualisation in 2D IMGeo consists of pictograms.

5.2.6 Buildings

The information model is capable of presenting a multi scale model with 5 well-defined consecutive Levels of Detail: LOD0 describes a 2.5D terrain model where each object is represented as a poly-line, point or surface. On LOD1 a selection of objects is included as block models, where block means that each roof surface is exactly horizontal. LOD2 allows texture and the inclusion of sloped or specified roofs. LOD3 includes more complex models describing outside features of houses such as doors and windows. Finally, LOD4 may contain full house models describing even the interior. Figure 35 shows a schematic overview of the components of each LOD. Each of these LOD can be specified per object or per object or applied to the entire visualisation of the buildings of the model.

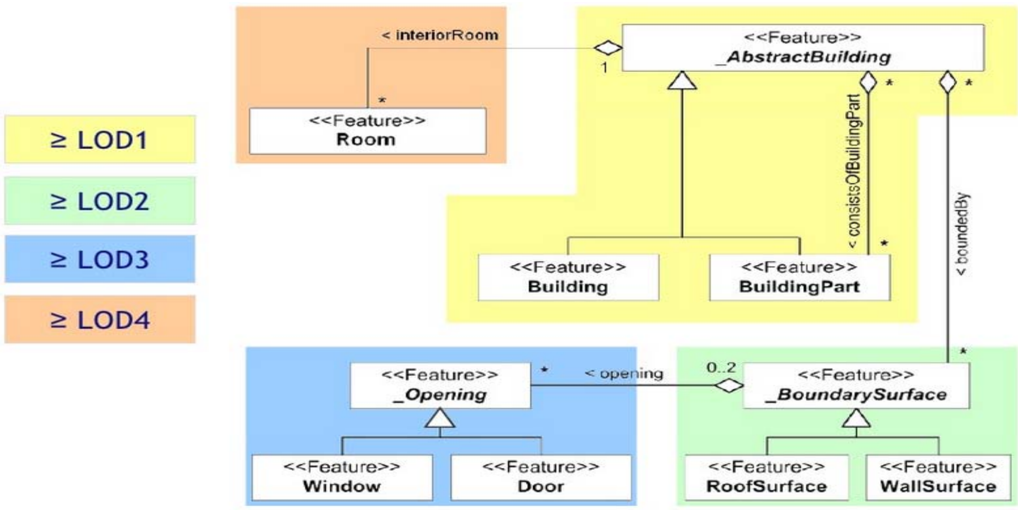


Figure 35: Schematic overview LOD components

5.2.7 Terrain and areas

CityGML is equipped with terrain modelling. A 2.5D terrain can be modelled if sufficient height information is available (from AHN2, own surveying or image matching in stereo-aerial photos). The

LOD0 terrain is formed by a collection of adjacent triangles (TIN), with recognisable object boundaries (constrained TIN). As a result of this only flat surfaces and straight lines are allowed and no bent surfaces or arcs.

5.2.8 Transport

Transportation can also be modelled from LOD1 up to LOD4. When extending 2D IMGeo to 3D, the different parts of the transport defined in IMGeo as ADE element of the BGT (RoadPart and SupportiveRoadPart) can be used. These have a surface geometry in 2D.
CityGML specifies Transportation objects as city objects. The three main classes that form transportation objects are *TrafficArea*, *AuxilliaryTrafficArea* and *TransportationComplex*. Classes already documented in IMGeo are the function of the road, its physical characteristics, materials and road furniture. In IMGeo, roads and railway are modelled separately.

5.2.9 Tunnels

The Tunnel class includes representations from LOD1 up to LOD4. *TunnelPart* is the IMGeo class which is used for this extension, which is modelled in 2D by a surface. When extending to 3D this surface becomes the footprint of the volume object. Just as with building objects, LOD1-3 only defines the outside of the tunnel and consists of the boundary surfaces with the earth, water or air which is situated beside it. The inside of the tunnel is only modelled in LOD4. If a tunnel consists of two parts, for e.g. for trains and cars or two adjacent tunnels for a two way road, which have different geometry and/or attributes than each other, then the tunnel can consist of two *TunnelParts* (Geonovum, 2013).

5.2.10 Vegetation

Green objects (for example trees) can be modelled if point topography is available. This point topography can be obtained from outdoor maintenance systems or from analyses based on, for example, the AHN2. In IMGeo only the coordinates are recorded as attribute. Geonovum states that if so desired, a model with trees represented according to the width of their crown and their height, can be more closely specified by adding a growth model of each tree species. This requires, however, the clear definition in advance of 3D models for each tree species which, so far known, are not currently available. In this way each tree would be portrayed by a unique 3D model. These models would be constructed automatically using a restricted number of basic properties and corresponding parameters, which would enable the demands on IT resources to remain limited, while concurrently delivering a more realistic portrayal of each tree.

5.2.11 IMGeo Input and output data

The IMGeo model has multiple data sources for its queries. These are the most important, most suitable or most often used source data taken directly from existing processes:
1. GBKN of BGT, where the BGT forms the base of IMGeo;

2. BAG;
3. TOP10NL;
4. AHN2;
5. DTB;
6. Stereo Aerial Photos and derived Orthophotos.

In order to fit the IMGeo data into CityGML output, a conversion has to be made. The output of the IMGeo workflow is an ObjTopo file and an Object Point file. The steps taken to create output in CityGML are as follows:

1. Read files from 3D IMGeo tools output (always a pair of *.top and *.objpts)
1.1 Merge these files
1.2 Create geometry
1.3 Join original gml:id
2. Read 2D CityGML IMGeo file
3. Merge data from 1. and 2.
4. Assign CityGML-relevant geometry properties
5. Add colouring following 'IMGeo_BGT_standaardvisualisatie'
6. Write CityGML

There is a schematic overview of the output by Geonovum in appendix J.

5.3 IMGeo extension for emergency response

Based on the emergency response model user requirements stated in table 13 extensions can be formulated.

Table 13: Emergency response object for 3D information model

	Emergency response object for 3D information model
1	**Standard objects**
2	**Emergency response objects for**
	Large fires
	Traffic incidents (land, aviation, water)
	Terroristic attack
	Epidemic
	Nuclear disaster
	Flood
	Collapse risk
	Extreme weather

	Public disturbance
	Hazardous goods (explosion, emission)
	Failure of power, gas or water
3	**Extra classes building**
4	**Extra classes tunnels**
5	**Extra classes bridges**

The next paragraphs will provide suggestions for an extension of IMGeo with regards to emergency response situations. The suggestions will be made based on the current IMGeo model as presented in paragraph 5.2. The extensions can be added as a class, preferably added as a subclass or added as an alteration to a current code list. The type of extension in the UML depends on the extension of the alteration that has to be made. The boxes in the UML that are a part of the UML extension will be marked green. The type of extension is mentioned in the box itself as with the other classes currently modelled in IMGeo.

5.3.1 Buildings

For the visualisation of buildings for emergency response, two suggestions stand out. The first extension is that the structure of the building should be in the model.

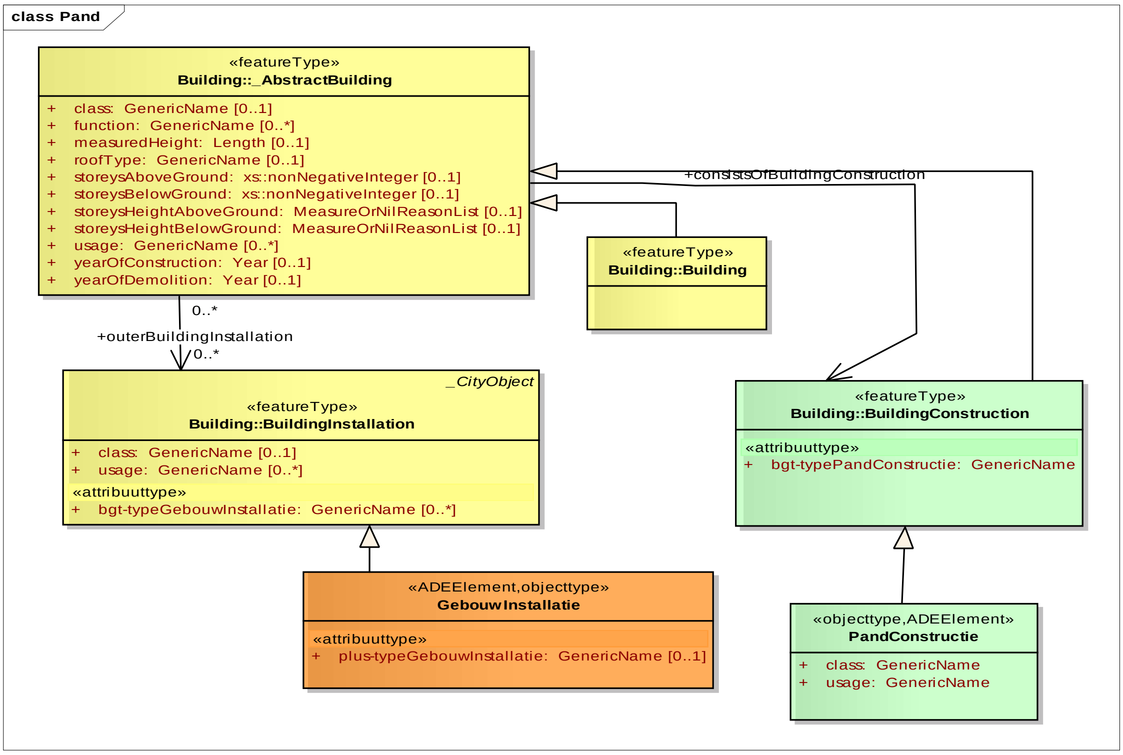


Figure 36: Extension of building UML

In CityGML a class with *BuildingConstruction* should be a part of the generalisation to the AbstractBuilding. This *BuildingConstruction* class should also have an IMGeo subclass with *PandConstructie* ("i"), so the two can be related by means of a generalisation relationship. Abstract building has a 'consists of' relation with building construction. *Pand constructie*, building construction in IMGeo, is associated with a GML surface. The construction will have a 3D geometry through CityGML (the 3D aspect of the UML is not mentioned explicitly but inherited through the properties of higher classes and their attributes in CityGML). The construction can be an integral part starting at LOD1. Figure 37 shows a schematic overview of the components of each LOD, including building construction. By having building constructions in an information model, emergency responders can make better estimations of collapse risks and routes through a building.

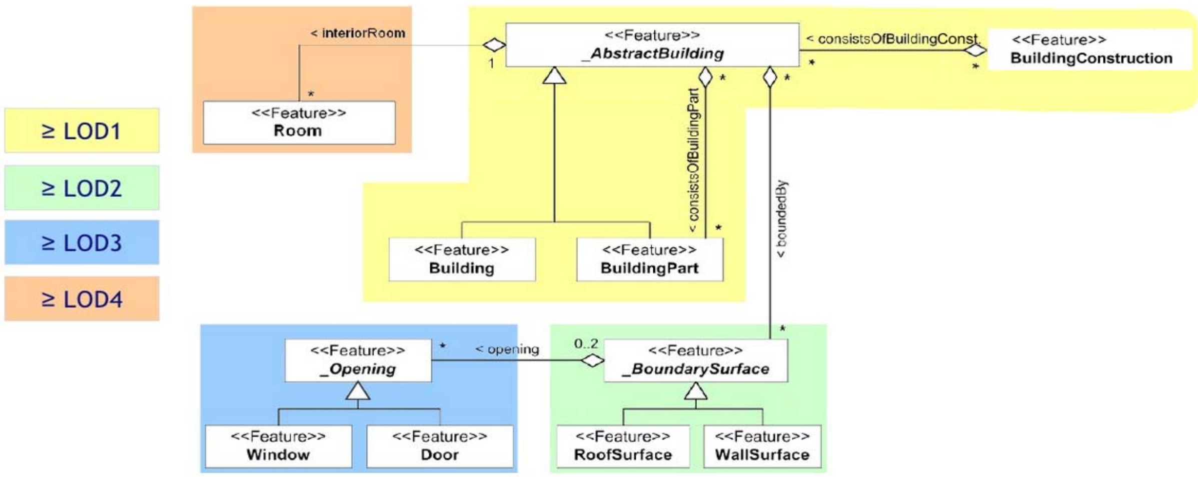


Figure 37: Schematic overview LOD components

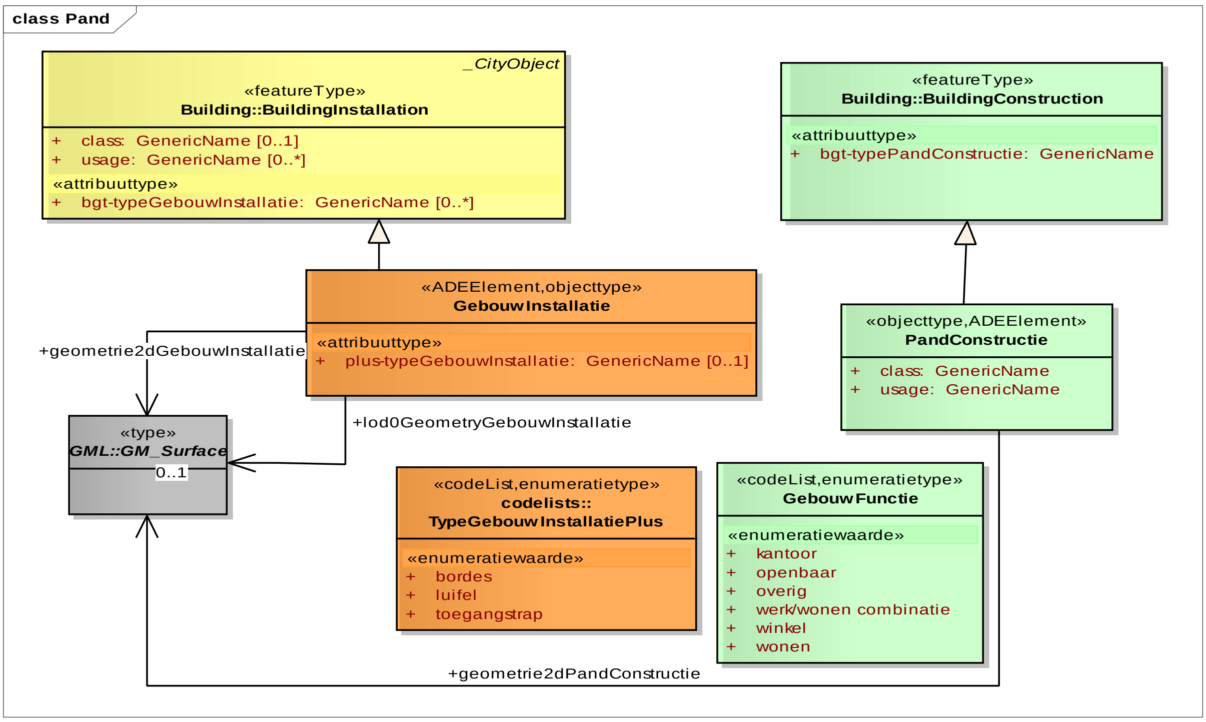


Figure 38: UML extension building

The other suggestion for extension embraces that the function of buildings should be able to be visible.

The information for building functionalities is additional. It is important for emergency responders to know what kind of building they are engaging with. Enumerative values for the function of the building code list could be: office, public, other, work/home, home and shop. A fire in large office that is closed during the night requires a different approach than a building where people live. I.e. the function of a building co determines the approach by emergency responders.

5.3.2 Tunnels

A complement that could give important information is the ventilation of a tunnel. When a disaster or emergency takes place in a tunnel, the police and fire department need a lot of information to get everybody into safety. Besides visual and audio support during a tunnel crisis, the technical aspects of a tunnel are also relevant. The type of ventilation in a tunnel co determines the risk of fires escalating, evacuations possibilities and influences situations that involve hazardous substances.

The Tunnel ventilation systems can be categorized into five main types or any combination of these five and are all stated in the complement code list *TunnelVentilation* (US Department of Traffic, 2013). By adding a code list to IMGeo with the tunnel ventilations, more information can be provided on the tunnel. Data regarding this information will have to be placed in a data base and added to IMGeo.

The tunnel sub model, *Tunnelpart*, should also be extended with an IMGeo code list *FunctionTunnel*, either as an integrated part of BGT or not. To know the function of the tunnel (for pedestrians, public transport or motor vehicles) could speed up risk assessment and the course of action. It gives insight in the facilities of the tunnel and who or what is at risk. Experts indicated that the local emergency responders usually know this kind of information, but that it could benefit task forces from other areas when they are called in to assist.

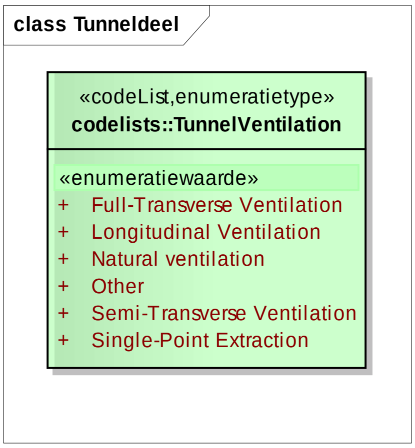


Figure 39: class TunnelDeel

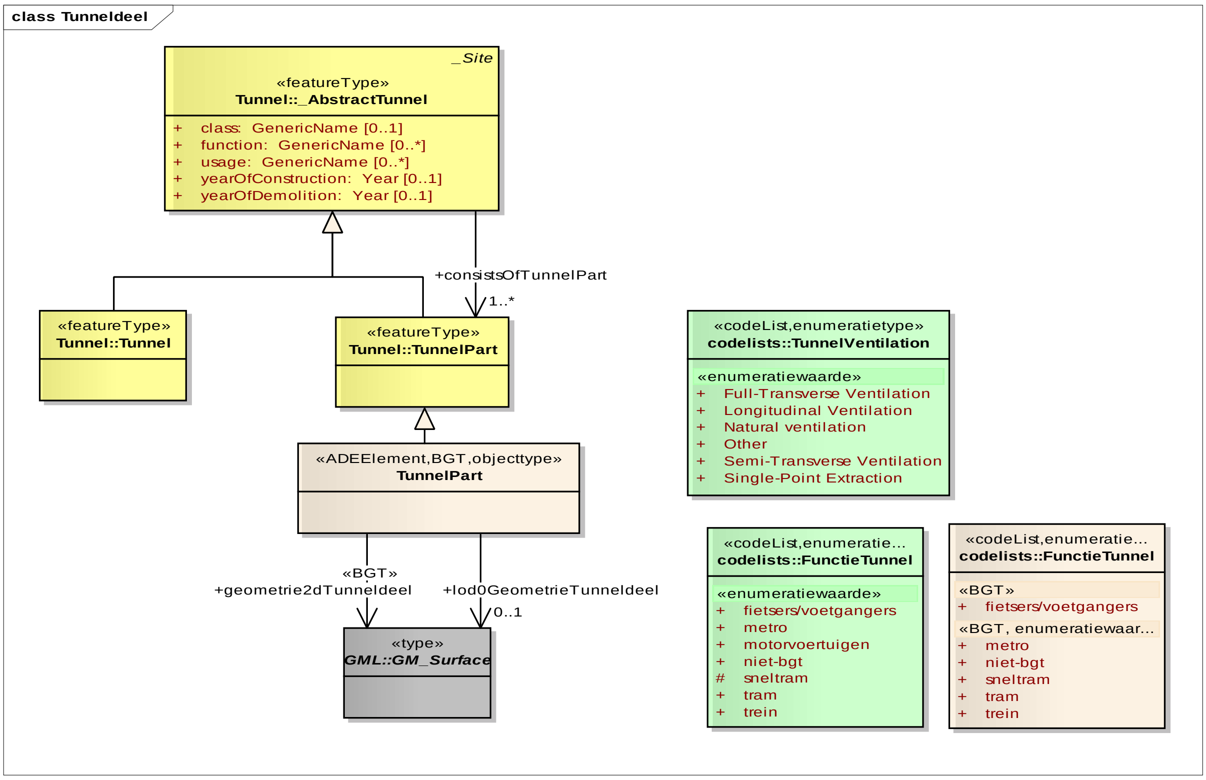


Figure 40: Expansion UML Tunnel

5.3.3 Bridges

The class *TypeBridge* should be supplemented with specific types of bridges. The code *bridge* is replaced with six other codes that specify the bridge construction. The most common types of bridge are: arch bridge, cable-stayed bridge, continuous span girder bridge, moveable bridge, suspension bridge and transporter bridge. The code *other* is also added in case the crossover (overbrugging) type is not stated in the code list, making space for other options instead of having to choose the closest option.

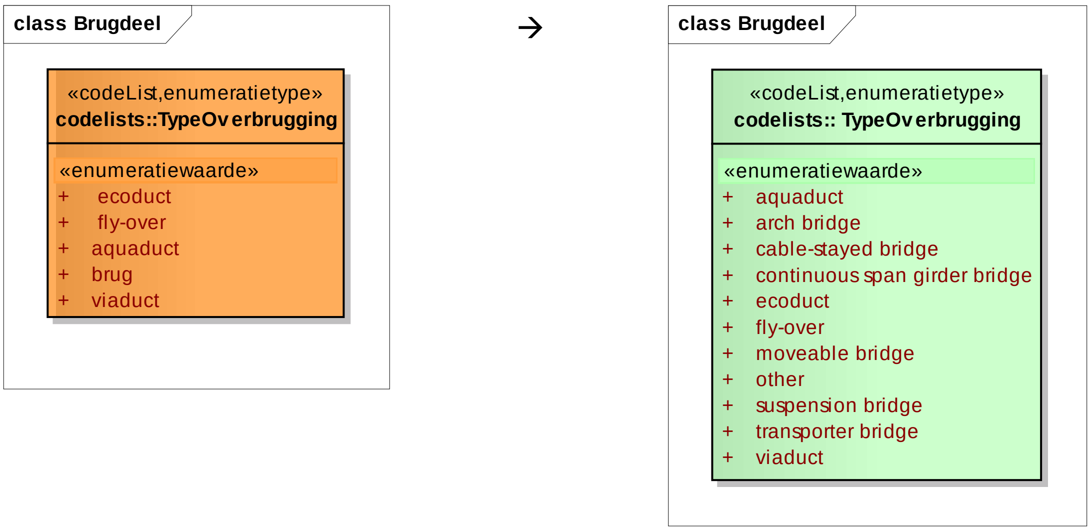


Figure 41a: Bridge expansion a

Beside the actual type of Road Bridge, the construction material of the bridge is seemingly relevant for emergency responders to know. This demand leads to an additional code list named *BridgeMaterial*.

The combination of having knowledge about the specific type of crossover (in case other is not selected) and its material provides information to emergency responders about for example the weight capacity of a bridge or the force it can withstand in certain situations (e.g. extreme weather, flood and explosion).

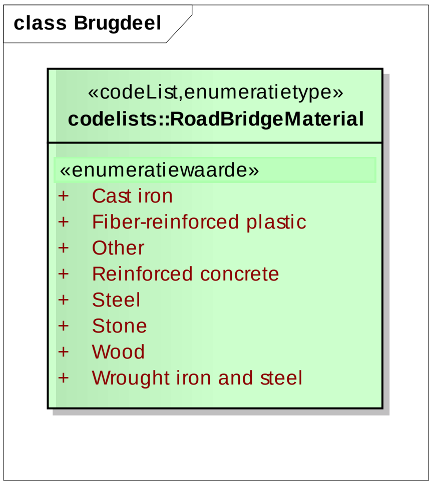


Figure 41b: Bridge expansion b

5.3.4 Transport

All the user requirements indicated can be satisfied with the competencies of CityGML and IMGeo. For railway, there were no specific requirements discussed with the experts and none of them mentioned any. It would be helpful if the BGT *FunctionRailway* code list would be expanded with a code subway (metro) considering the Netherlands has multiple cities that have subway systems.

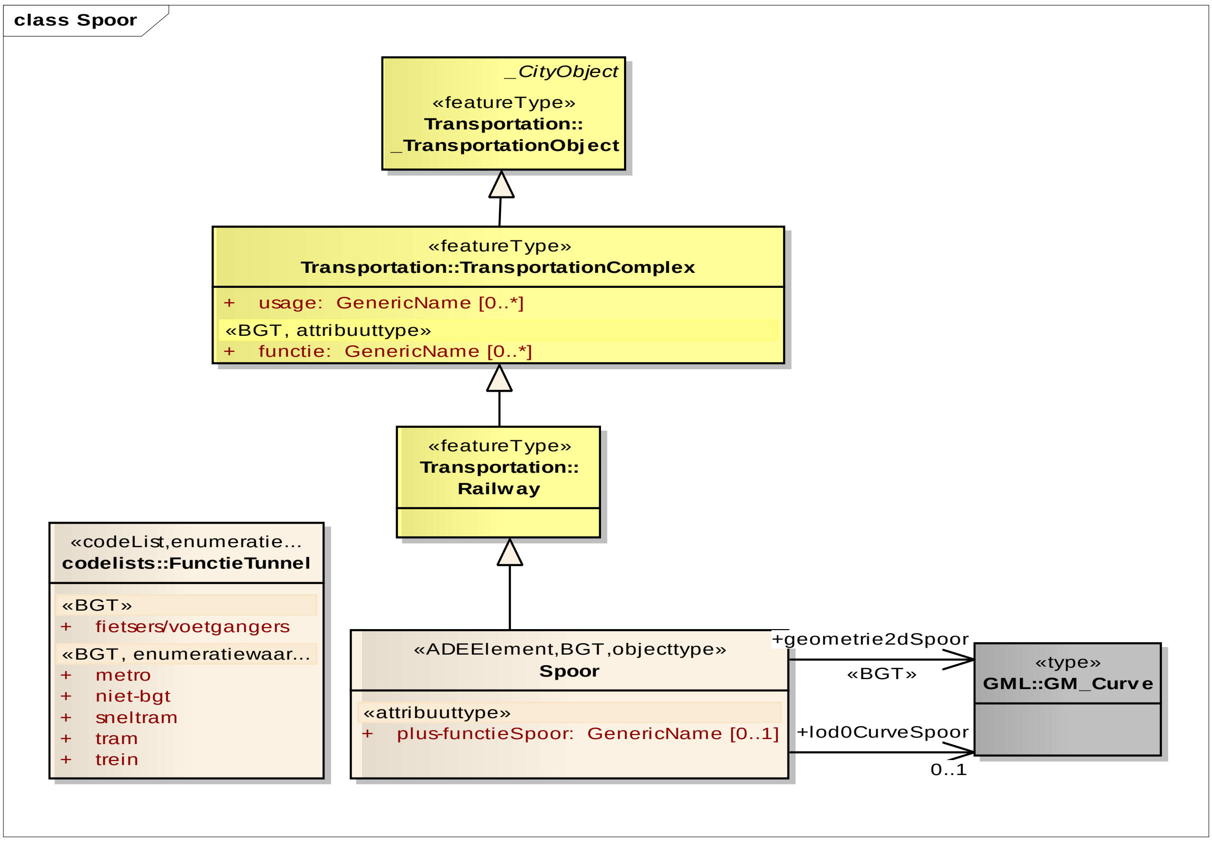


Figure 42: UML railway

5.3.5 Other objects

Emergency response modelling requires more than the standard objects of a 3D model. The objects were derived based on the literature and the insight derived from interaction with the experts. The objects, related to emergencies or consequences to those, have been divided over multiple categories. The government has divided disaster and emergencies into different categories: Traffic and transport, dangerous material, public health, infrastructure, population, nature and on distance. These categories form the base of the scenario based modelling for the extension of IMGeo for emergency response in chapter six. The objects related to emergency response can be incorporated in IMGeo by adding them as new (sub)classes, attributes, code lists or as additional UML diagrams.

5.3.6 Texture of specified objects

Emergency response will in some situations require texture on objects. The objects that are not within the emergency area do not require texture. Note that the model will run much faster without textures and that speed is often more of the essence with emergency response than detail. Emergency responders need to be able to turn off and on textures per building. This enables the model to run faster and still provides the users with texture. It requires the extension of IMGeo to be flexible in visualising texture. There is a need for data base connections between texture and every object and for every building floor.

5.3.7 (Risk) objects

For emergencies, there are always certain risk objects that need to monitored, cleared or isolated. Examples of such risk objects are silos with explosive, flammable and/or combustible substances, power plants and gas stations. These risk objects are divided amongst the various classes of IMGeo. The data base of IMGeo should be structured in a way that relations between risk objects and objects are fixed. The visualisation of the emergency model should be able to immediately show the risk objects in a certain area.

5.3.8 Levels of detail

It is important that not too much detail is given, but in some cases much detail can be useful. Not all objects require the same LOD, not even in the same object types. When an emergency occurs in a building, this building might need LOD3 while the bridge behind the block and the surrounding buildings only require LOD1. It is important to recognize that combinations of LOD can simultaneously be obtained from the model. Which LOD is viewed depends on the data that is available and of which LOD the user has set the visualisation programme to.

Emergency responders have indicated that a high LOD is much more important on the ground floor than a high LOD on the upper floors of buildings. The bottom floor of a building in LOD 3 models entrances and exits and windows. It also visualises the architectural fundament of the building. The upper floors are less important for information in terms of details on the outside of the building. What is of importance is the indoor aspect. Even though the data is not yet available to model such interiors, users have indicated that it could be of much help. One of the occupational hazards in emergency response is entering a building that is unfamiliar to the team. In order to go through a building efficient and safer, data on floor designs are necessary. This would be data that includes how a floor is divided into rooms, where the staircases and exits are, the location of fire extinguishers, additional information per floor etc. The exact location and type of office furniture is less relevant, which also counts for texture of indoor modelling. Whether an inside wall is white or grey or has paintings is not of much added value. The inner structure of the building is of the greatest importance because it visualises (potential) routes for operational teams.

5.3.9 Symbolic representations

As stated in the user requirements, pictograms/symbols help to easily screen a specific area and allow for a quick observation of objects other than building in a certain area. A prominent symbol in an emergency model is the Incident location. Other symbolic representations that should be optional in the model are: COPI location, source of fire marking, water extraction points, hospital locations, road blocks, set up shelter locations, prohibition areas of landing helicopter, treatment centres. In 2D models certain symbolic representations are already used. These symbols can also be placed in a 3D model. For emergency response it is emphasized that such symbols are also placed in a 3D model.

Figure 43: 3D symbolic

But in order to achieve the same overview effect as in a 2D model, the symbols will have to be adjusted. The 3D symbol would have a top view with the standard symbol and a pointer shape to enable sight at street view. This way, the symbol can be seen from a distance and close by in any type of view.

The user should be able to choose whether the symbols can be scaled along with the view (i.e. they become larger when the user zooms out and the other way around) or that they stay the same size. The use of pictograms should be considered with due reference to the standards, such as EN ISO9241 or ISO/IEC Guide 71. Some pictograms, like the ROT location notification can be extracted from LCMS.

5.3.10 Functionalities

There are multiple functionalities relevant to emergency response models. These functionalities are not related to a model, but to the use of a model. Functionalities are determined by the structure and relations of the data base of a model.

Scenario based modelling

To assist the user more, the concept of scenario based modelling can be applied. The objects and relations related to a type of emergency/disaster are grouped in categories that can be selected by the user. For example: a dike breach, resulting in a flood. The data base and the software should enable the disaster categories and their specified objects to display all at once. The user simply checks the box "flood" and automatically the objects related to floods, as stated in chapter 4, are visible. This pre-programmed scenario based modelling saves time and effort for the user, is complete in its basics and provides only the relevant objects for that time. By showing only what is relevant for the situation at hand, the model will not be slowed down by unnecessary objects and the user is less overwhelmed by the large amounts of information that the model contains. It is a structured manner to dose highly useful information. Chapter 6 will further specify on this matter, since it is considered the most valuable aspect of the emergency response variant of IMGeo.

Position change

Objects should be able to change locations at the hand of users, allowing the model to stay slightly dynamic. This could be applicable for all objects, although it does not seem necessary for permanently placed objects. Position change might concern objects such as water extraction points, vegetation, incident location etc.

Queries

Queries are important because they derive qualitative and quantitative information about the objects. These queries require certain relationships between classes in a data base for them to arrive at inquired information. Examples of queries relevant for emergency response models are:

A. How many <u>water extraction points</u> lie within **street x**?
B. How many <u>cameras</u> are mounted within **street x**?
C. What is the **distance** to the nearest <u>hospital</u>?
D. Give **coordinates** of an open area of min. <u>size x</u>**?**
E. Determine closest <u>risk object</u> to **incident location**?

Each of these queries relies on a relationship between <u>variable a</u> en **variable b** and perhaps other variables. In order to determine the water extraction points on street x, the data base needs data that states where each water extraction point is located and link those locations, or coordinates, to the street that covers that location. The same goes for the other queries. The distance between the nearest hospital and the current location is derived from the difference in coordinates and selecting the shortest distance.

Object editing

Interaction can be enhanced if the users have the option of editing designs real-time. By allowing the user to change the object, a model can stay more up to date, include information that relevant for a specific scenario and more importantly, exclude information that is irrelevant at that moment.

View

A model can be viewed from different angles, at different scales and static or dynamic. Functionalities regarding view for an emergency response model involve a zoom function (zoom in and out) and a fly over. Furthermore, the user should be able to rotate around a certain point viewing the location or view the 360^{o} around the location.

Additional information

The additional information should be presentable in an extra box and can be adjusted by the user by editing the text in the extra box. Such as text box could state information on the latest renovations, alterations, potential hazards etc.

5.3.11 Underground modelling

The three dimensions of 3D consist of Earth surface (DTM), above ground (e.g. building models) and below ground (e.g. utility assets, underground structures). The underground modelling is also important in multiple emergency scenarios. Underground contains, besides tunnels, also the subway system, cables and pipes. A so called 'KLIC map', Cables and Pipes Information Center (in Dutch abbreviated to KLIC), indicates interferences and malfunctions of electricity cables and gas pipes. In 2008, KLIC was added to the cadastre. By allowing additional geometry types, e.g. constructive solid geometry and sweep geometry, the interoperability with the Industry Foundation Classes (BIM, US BIMS) would significantly increase. With the addition of sweep geometries, 3D representation of pipes can be more easily modelled. It would be useful if KLIC were to be connected to IMGeo as the BGT is.

5.4 Validation

Since the model is a static model and doesn't actually run, an input and output verification is of limited use. Beside the fact that the technical coupling of the complementary classes lies beyond the scope of this thesis, the verification did entail the connection between the classes of IMGeo and CityGML. All IMGeo classes are indeed a part of a CityGML class. Some IMGeo classes are additional and connected to a CityGML class that is the most closely related. The output of the scheme runs through CityGML, of which many competences are not clearly visible in the UML. They are an integrated part of CityGML and therefore remain the same as before.

In system (and software) development validation means that the built system meets the expectations of the user and the desired user functionality. The context of the IMGeo "extension" was presented to a random selection of experts to validate the user requirements implemented in the UML. The experts all indeed concurred with the following general user requirements:

Table 14: Emergency response user requirements for 3D models

	Emergency response user requirements for 3D models	Concurrence
1	Terrain in 3D	✓
2	Building in 3D	✓
3	Tunnels in 3D	✓
4	Bridges in 3D	✓
5	Vegetation	✓
6	Transport in 3D	✓
7	Other 3D objects	✓
8	Symbolics, icons	✓
9	Construction of buildings	✓
10	Details on Bridges	✓
11	Function of buildings	✓
12	Texture of specified objects	✓
13	Queries	✓
14	Scenario based modelling	✓
15	Additional information in text per click	✓
16	Layering of objects and texture	✓
17	Levels of detail according to scale	✓
18	Other objects than the standard city objects	✓
19	Interactivity regarding view and data manipulation	✓
20	Underground modelling	✓

The website of Geonovum provides an IMGeo GML validator. The IMGeo GML validator checks if a file is compiled (XSD validation) according to the IMGeo GML schema of a particular version. It also validates 2D geometries in compliance with ISO19107. It does not, however, validate correct domain values and topological correctness. The GML validator is beyond the scope of this thesis and will be more useful after the actual construction of the IMGeo expansion.

The code lists are external and therefore not included in the IMGeo XSDs. This means that the XSD validation cannot be used. In particular, for BGT exchange, it is important that it is validated whether a file recorded in a SLS value is listed in the associated code list. This requires a validation to be performed where for each field that must contain a value from the code list according to the information model, it is checked whether the value is found in the corresponding Concept Scheme. Every feature that has a domain value must contain the following checks:

- The URI in the code space attribute must match the domain value list according to the information model associated with the attribute.

- The value of the element must exist as a concept associated with the domain value list.
- The CodeSpace attribute must be filled
- There must be a valid combination with a parent BGT domain values

The extension of the IMGeo consists of multiple code lists. Each was assessed based on the criteria mentioned above.
RoadBridgeMaterial can be linked to the IMGeo class Type of Bridge part. This way each of constructive part of the bridge is assigned a material. The CodeSpace is filled with specified materials. The parent BGT is *BridgePart* ("Overbruggingsdeel" in Dutch).
TypeRoadBridge is a subclass of *TypeBridge* and will copy its links. The CodeSpace is filled with common types of bridges. The parent BGT domain is again *BridgePart.*
TunnelVentilation is a code list of Abstractunnel and as CodeSpace it states the various tunnel ventilation types. The same goes for the other code lists: *TunnelFunction, BuildingFunction and BuildingConstruction.*

5.5 IMGeo meets VeRA

As mentioned in chapter 3, VeRA gives the Safety Regions a guideline for the direction of the integral information management on an administrative organisation's level, the preparation to set in emergency responder en for up scaling an emergency within a Safety Region. It also provides a guideline on national level to ensure optimal information exchange. The main goal of VeRA is to name the general elements in the information management of Safety Regions. In addition to the areas in which business functions are identified, there is also a specific domain data. It goes without saying that a business function makes use of data. Cooperation between most business functions is largely influenced by exchange of data. In one of the domains of the application landscape, data groups of safety region's are appointed, and divided into:

- Basic registrations
- External data sources
- Own core records
- Internal data sources.

There are thirteen basis registrations, one of which is the BGT (Basic registration Large Scale Topography). The BGT is the core (compulsory part) of the information model geography IMGeo. The deepening impact of the BGT in IMGeo is defined as the optional part and is designed for storing and exchanging management and plus topography.

In 2014, a new version of VeRA will be released. A part of this new VeRA is focused on risk control and management of geographic information. These will make use of their own core records for objects and risk maps and the BGT. Related data models are risk maps, Fire department data book, INSPIRE, NEN 3610, NEN 1414. The data exchange standards for the management of geographic information are WMS WFS GML, IMGeo2, INSPIRE and CityGML.

VeRA is being expanded to also contain a data landscape, basic registrations, semantics and standards. A recommendation to the expansion of VeRA would be to impose that all basic registrations are available in the same format, preferably the UML format. This would allow for a greater inoperability and a possible connection to IMGeo. For instance, when both the BGT and the GBA would be in IMGeo, and a fire breaks out the software could determine which people are immobilised and need to be evacuated by others. VeRA 2.0, which is currently being modelled, will most likely state that it uses geo-information based on the standards of Geonovum. Stating that large scale topography will be described in IMGeo and fire department specific objects which are not in IMGeo are described as an extension of IMGeo in document "X", to be defined. This way, VeRA 2.0 will incorporate IMGeo.

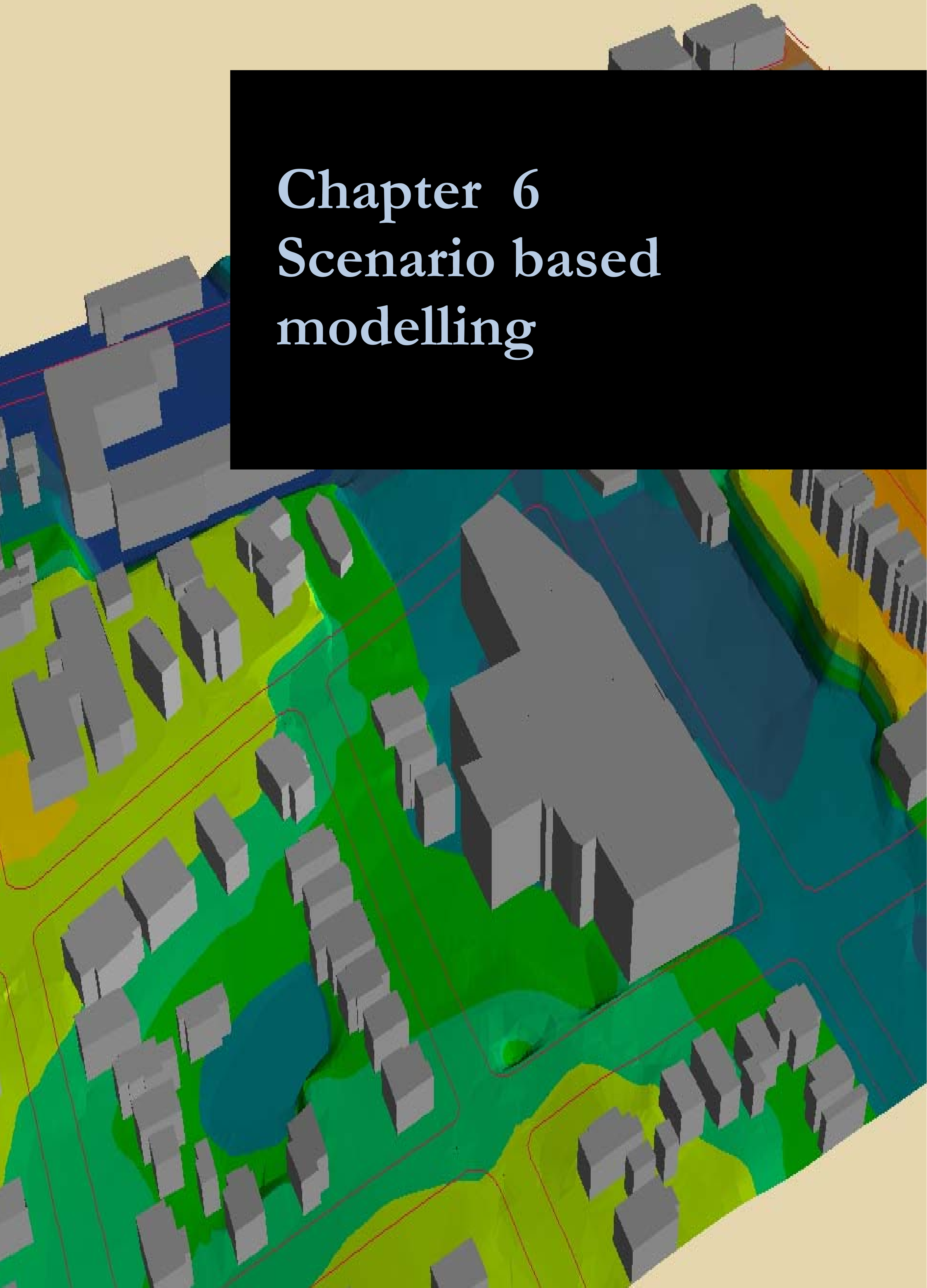
5.6 Conclusion

Most of the indicated user requirements are already within reach with the use of CityGML and IMGeo. Some additional requirements were set up. For the visualisation of buildings for emergency response, two suggestions are made. The function of the building should be indicated with a code list: *Functiegebouw*, and the construction of buildings should be visible in an extra class: *BuildingConstruction*. For tunnels, a class *TunnelVentilation* is to be added. Also the function of the tunnel should be an additional code list in order to view the type of tunnel at first sight or click.

Two complements to the bridge would be to extend the *Type of crossing* code list with popular types of bridges, which would emphasize the actual bridge construction and code for *other* to allow users to select other in case the specific construction of a bridge is not in the code list. Beside *Typecrossing*, *BridgeMaterial* is seemingly relevant. The knowledge of both type of crossing and the material of the bridge, emergency responders can estimate the strength and the traffic flow capacity of a bridge. This could come in handy during extreme weather or a large evacuation of an area.
Based on the current capabilities of CityGML and IMGeo, it would seem that Vegetation does not need an expansion for emergency response. It would be helpful however, if the BGT FunctionRailway would be expanded with subway. For City Furniture there seems no complement necessary.

In CityGML, buildings can have multiple representations in different LODs simultaneously and allows generalisation relations between objects in different LODs. Which LOD is viewed depends on the data that is available and of which LOD the user has set the visualisation programme to. Beside the standard objects of IMGeo and CityGML, other, emergency response related, objects are to be implemented in the model. Examples of such objects are: dikes, gas control stations, helicopter pads and power masts.
The first important functionality the model should have is queries. By allowing users to search for a combination of objects or relations in the model, through queries, information can be found more easily. An example is to search for placed cameras on street x. The other, perhaps more important, functionality is scenario based modelling. This allows users to select a disaster/emergency at hand, which will automatically load the relevant objects. This function will make the model more efficient and makes certain decisions for the user. This will be elaborated on in chapter 6.
In short, the existing model steers the user requirements but at the same time the user requirements are steering the development of the model. The users are content with the model because they are not entirely aware of all the options, but the model also already contains a lot of data.
Despite the fact that the application of the data is the starting point, the available source data also often determines how ambitious the model is.

Chapter 6
Scenario based modelling



6. Scenario based modelling

Scenario based modelling is effective when systems are being built with the requirements known at the outset. Users are involved from the start, to build prototypes evolving towards the final product. The users are also involved with the testing of the prototypes which is essential for the validation of requirements and help the users to gain an initial experience of the final system during the development itself. This chapter will elaborate on the build suggestions of a prototype which contains IMGeo extensions for emergency response modelling. This scenario based modelling enables users to utilise pre set scenarios with their objects and data.

6.1 Scenarios

The figure 45 shows the possible disasters that could that place in The Netherlands (or elsewhere). The x-axis states (L-R) a low chance of something happening to a high change of something happening. The y-axis illustrates how catastrophic a disaster would be.

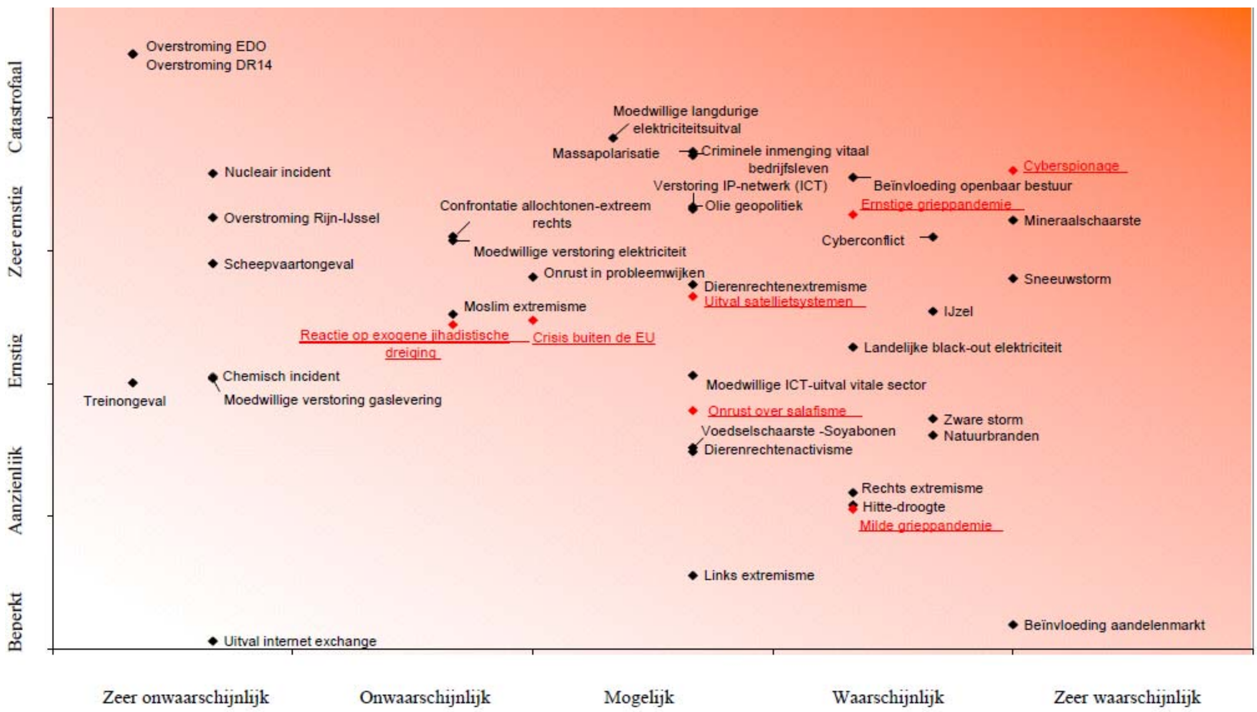


Figure 44: Diasters (Ministerie van binnenlandse zaken en koninkrijksrelaties, 2012)

As stated in chapter 2, the government has specified the following 18 types of disasters:

- Disaster in relation to traffic and transport
    1. Aviation accident
    2. Accident on water
    3. Traffic accident on land

- Disaster with dangerous material
    4. Accident with inflammable/ explosive material (in open air)
    5. Accident with toxic gasses (in open air)
    6. Nuclear accident
- Disaster in relation to public health
    7. Treat to public health
    8. Dispersal of disease
- Disaster in relation to infrastructure
    9. Accidents in tunnels
    10. Fire in big buildings
    11. Collapse of big buildings
    12. Disruption of utility
- Disaster in relation to population
    13. Panic in large groups
    14. Large-scale disturbance of public peace
- Nature disaster
    15. Flood
    16. Nature Fire
    17. Extreme weather conditions
- Disaster on distance
    18. Incident out of city boundaries, in which citizens of that city are involved

Other disasters, such as volcanic eruptions, tsunamis, drought and tornados were not included in this list because of their very low change of happening or because they do not exist in The Netherlands. Additional to the government categories, certain fields of expertise might require separate "scenarios" to support other scenarios:

- Law enforcement and military
- Failure of gas network
- Failure of power network
- Failure of telecom network

All of these scenarios require different information, which in return is related to different data sets and different objects related to a scenario. The three examples of scenarios on page 106-107, illustrate the different types of objects required.

Failure of gas network

- Sources — Production fields
  National border crossing stations
  Harbour jetties
  LNG storage
  Coastal transition locations of North Sea gas to land based network
  Drillings rigs
- Network — Piping network
  Major block valves
  Check valves
  Safety relief valves
  Letdown stations
  Pressure and flow sensors
  Control stations
  Bypass routes
  Boost compressor stations
- Users — Gas fired power stations
  Heavy industry power generation
  Green houses
  Tie-ins with chemical plants
  Households low pressure network connections
  Export connections

Flood

- Failure of power network scenario

- Sources — Primary and secondary dikes
  Delta works
  Sluices
  Water reservoirs

- Network — Piping network
  Pumping stations
  Waterways
  Canals
  Harbour infrastructures
  Buoys
  Waste water piping network

- Users — Household network connections
  Industrial network connections

- Additional — Power grid structures and contingency options
  Still dry (higher) long strip aerodromes for international aid
  Location military emergency pontoons
  Civil and military helicopter locations

Accident with toxic gasses

- Traffic on land scenario
- Public health scenario
- Failure of gas network scenario

- Shelters
- Hospitals

The other scenarios and their specified objects are stated in appendix K. The scenarios described there can exist of specifically suggested objects for that situation or it can be based on other scenarios. For example, public disturbance mostly requires the same information as "large traffic incidents" because of possible mass movements and "medical back up" to provide potential additional care for the public. These scenarios are just a sketch of possible data and objects. It is important to remember that similar scenarios can play out very differently. A more severe variant is imaginable, but also a less severe. Also variants with other properties, a different course, in other circumstances, or a different context are possible. The pre set scenarios are a supportive function and not a smart model where the computers takes over the thinking and decision process of the user. It is important that the user does not take an automatic pilot state, but the scenario based modelling will make the model more efficient and more pleasant for the user.
For variants of scenarios and their probabilities, the reader is referred to the document `National Risk Assessment (NRA) findings report` by the Dutch Government.

6.2 Scenario modelling

In order to model the different scenarios for IMGeo, new UML diagrams are needed. In this thesis, one scenario will be elaborated on and set up in an additional UML diagram. The flood scenario will be set up in this paragraph. For a flood the following systems/products are also relevant (Altan, 2013):

- Inundation Map
- Damage Assessment Map
- Risk Map
- Flood Risk Monitoring System
- Recovery Process Map

6.2.1 UML diagram concept

Figure 45 describes the concept of the UML diagram for a flood scenario. The UML contains main classes relating to sources of floods, the network of water(pipes), the users of that water and other flood and disaster related objects. This other category could also include other scenarios that can also relevant during a flood. An example of such another disaster would be a power failure. This scenario would, in the model, contain objects related to electricity production, distribution and use. Since electricity and water do not

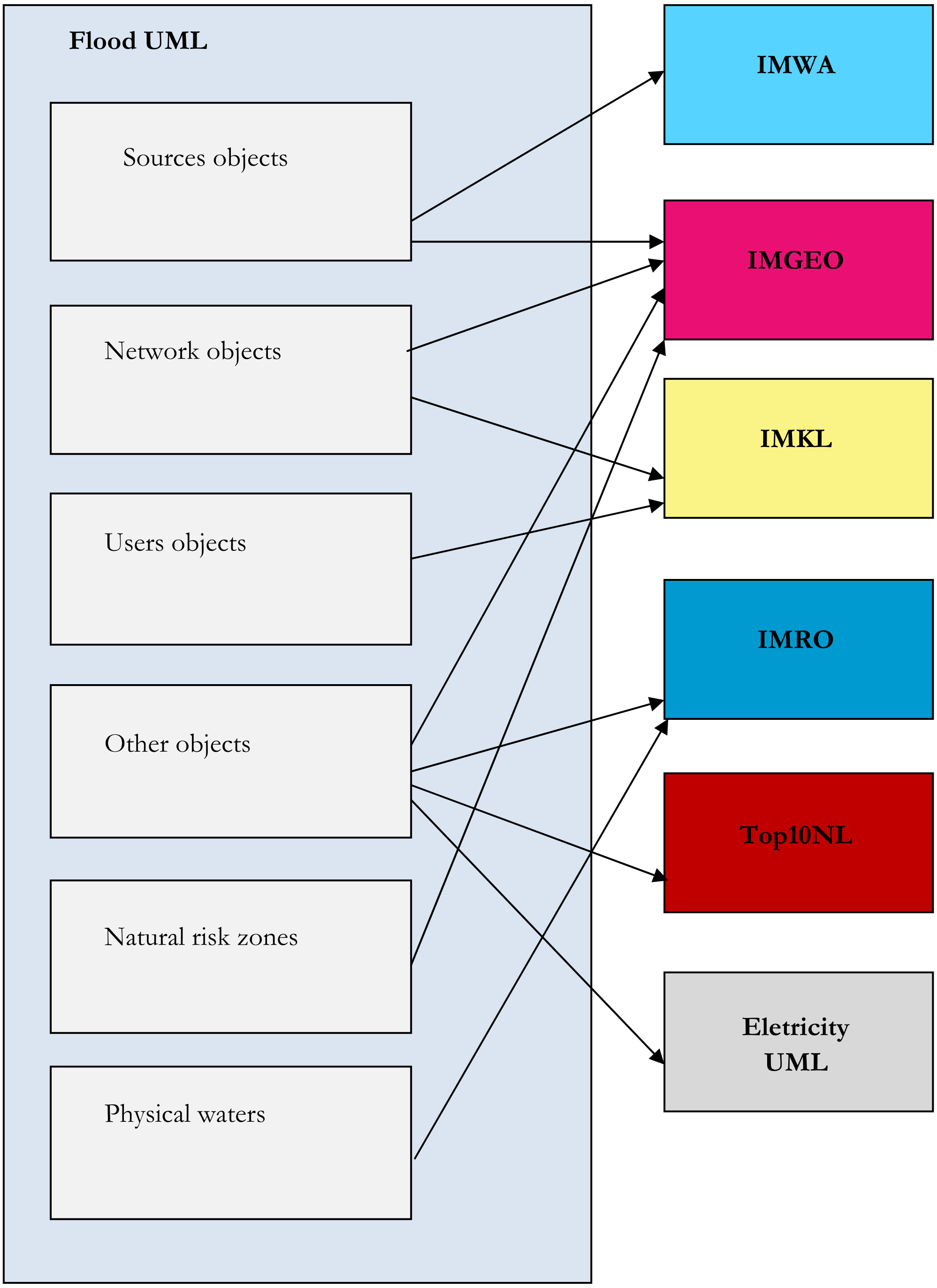
work well together, it can be a wise decision to include the electricity/power related objects in a flood model.
The data that the model of this UML requires can be placed in IMGeo or it can be derived from other existing data bases and then linked to IMGeo. The data bases mentioned in figure 45 are optional for the data required for a flood scenario.

IMKL, the information model Cables and Pipelines (IMKL), provides a common conceptual framework for data exchange for excavation work. The IMKL is linked to the Information Exchange Underground Networks (WION) Act (Geonovum, 2014).

IMRO, the Information Model of (Spatial) Planning (ruimtelijke ordening in Dutch), is used to digitally set spatial imaginations and plans according to the Spatial Planning Act and exchange at national, provincial and municipal levels. With the onset of Wro, the Act of (spatial) planning, all spatial plans should be handed in IMRO-coded (Geonovum, 2014).

Top10NL is a digital topographic base file from the Land Registry. This is the most detailed product within the Register of Topography (BRT). The Land Registry provides TOP10NL in Shape files and in GML. TOP10NL originated from aerial photographs, field recordings and information from external files. The Land Registry keeps the file up to date by interpretation of digital imagery and data from external sources. (Kadaster, 2014).

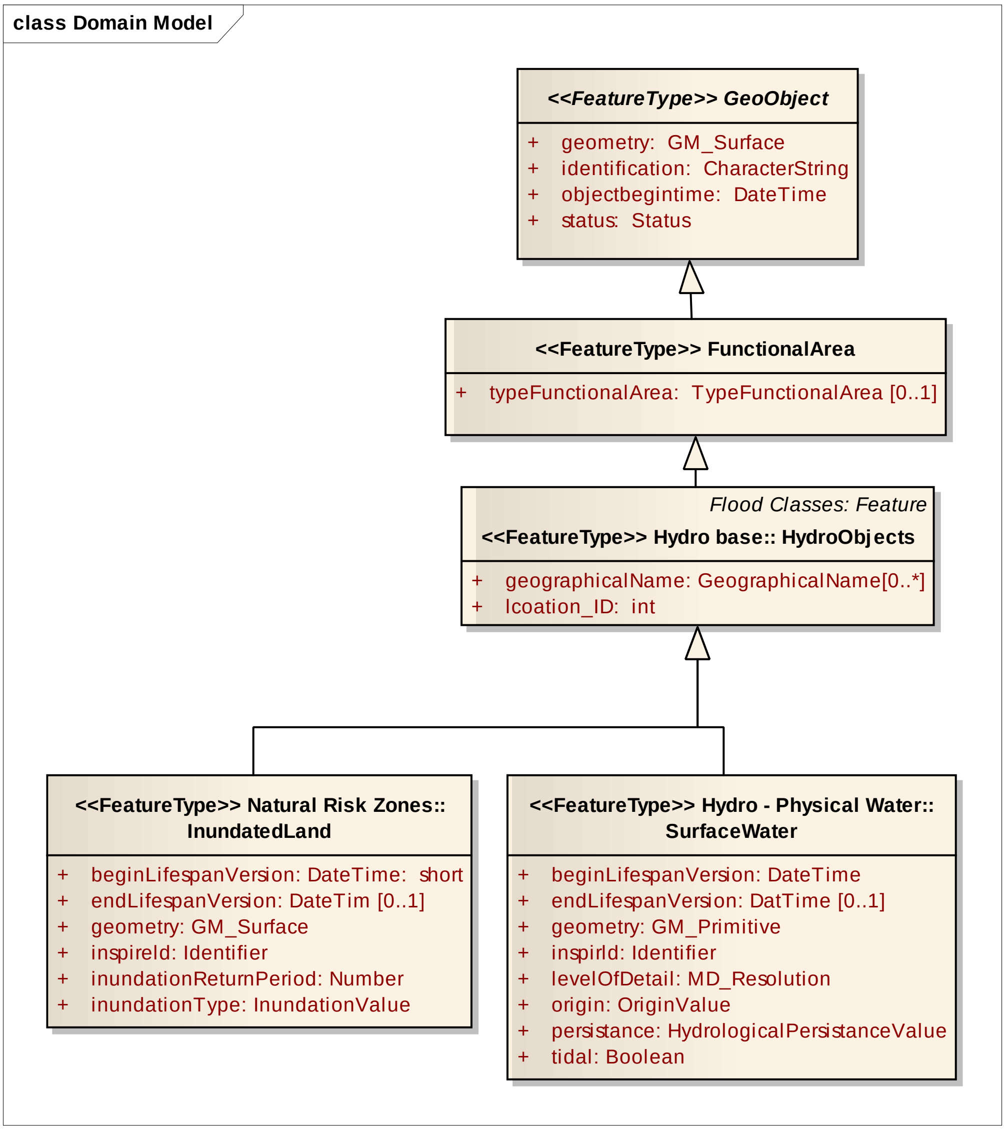
IMWA, Information Model Water, is the Dutch standard for the exchange of geographic information in the water. IMWA is included in the NEN3610 as a model for water sector, in addition to other industry models, such as the Town and Country Planning (IMRO), Cables and Pipelines (IMKL) and Top10NL.
With the advent of the Basic Scale Topography (BGT) and - to a lesser extent - the European framework directive 'Infrastructure for Spatial Information in Europe (INSPIRE), information is widely shared and reused for various water management processes. IMWA will therefore be modified to be able to share detail in (inter)national information flows. This ensures that their water management information can be shared for various purposes. The starting point is that IMWA is used for the Dutch Registration Large Scale Topography basis. Water management is often in need of more detailed data, which is then incorporated into IMWA. This will make IMWA a sector-specific extension of the BGT.

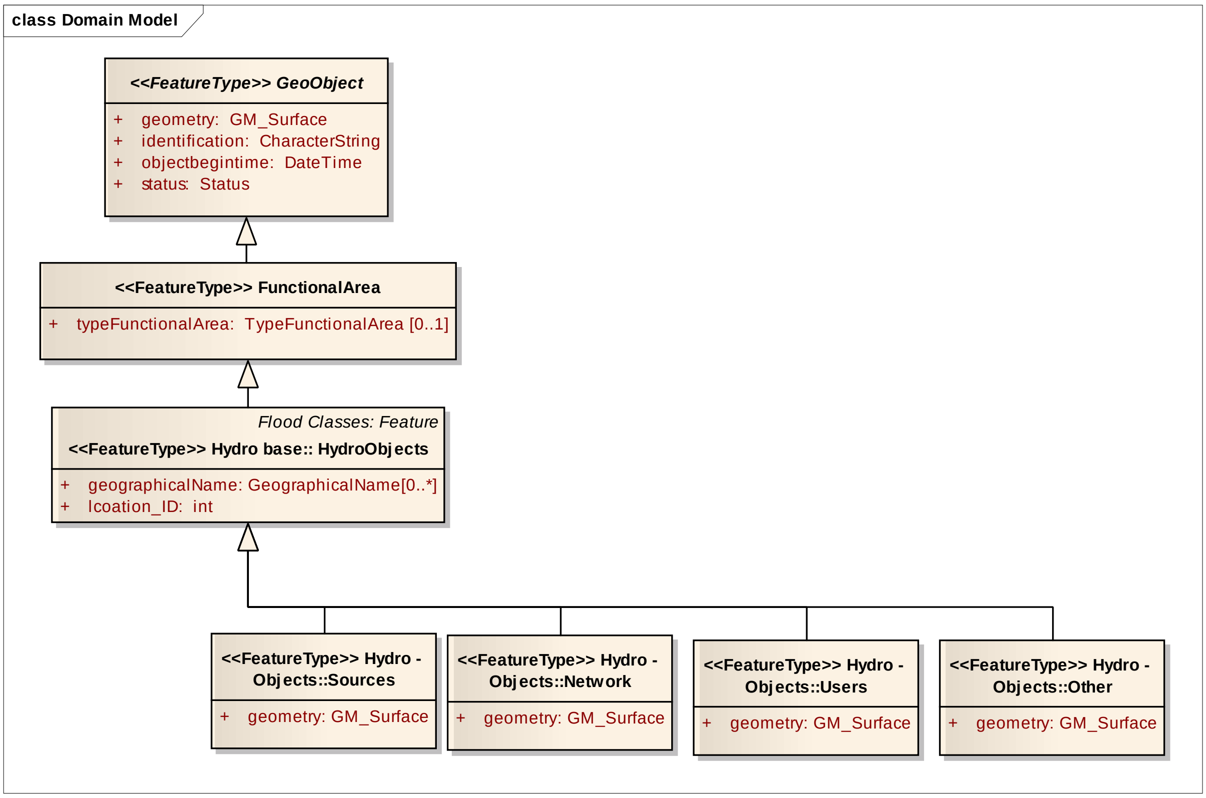


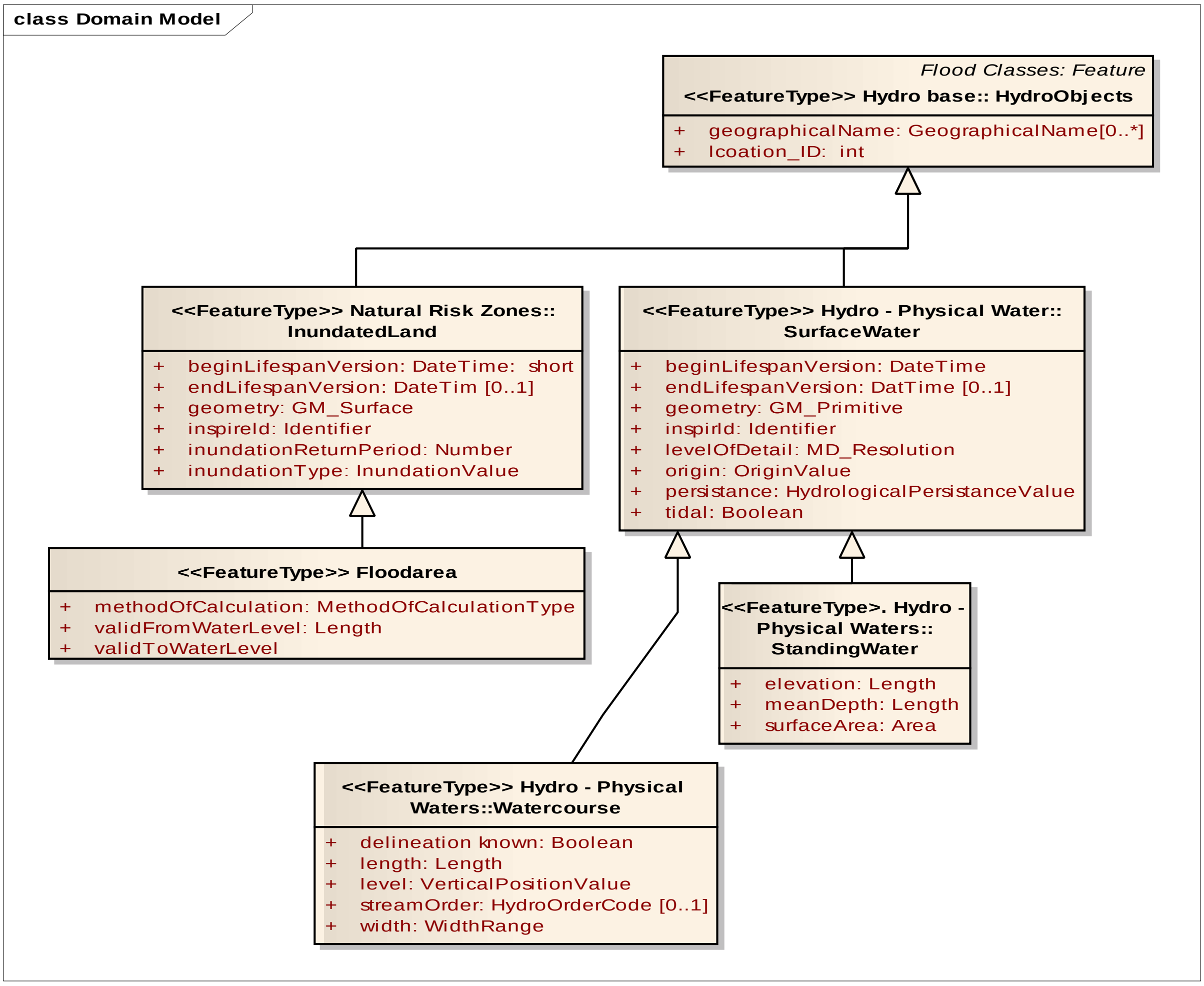
Figuur 45: UML concept Flood

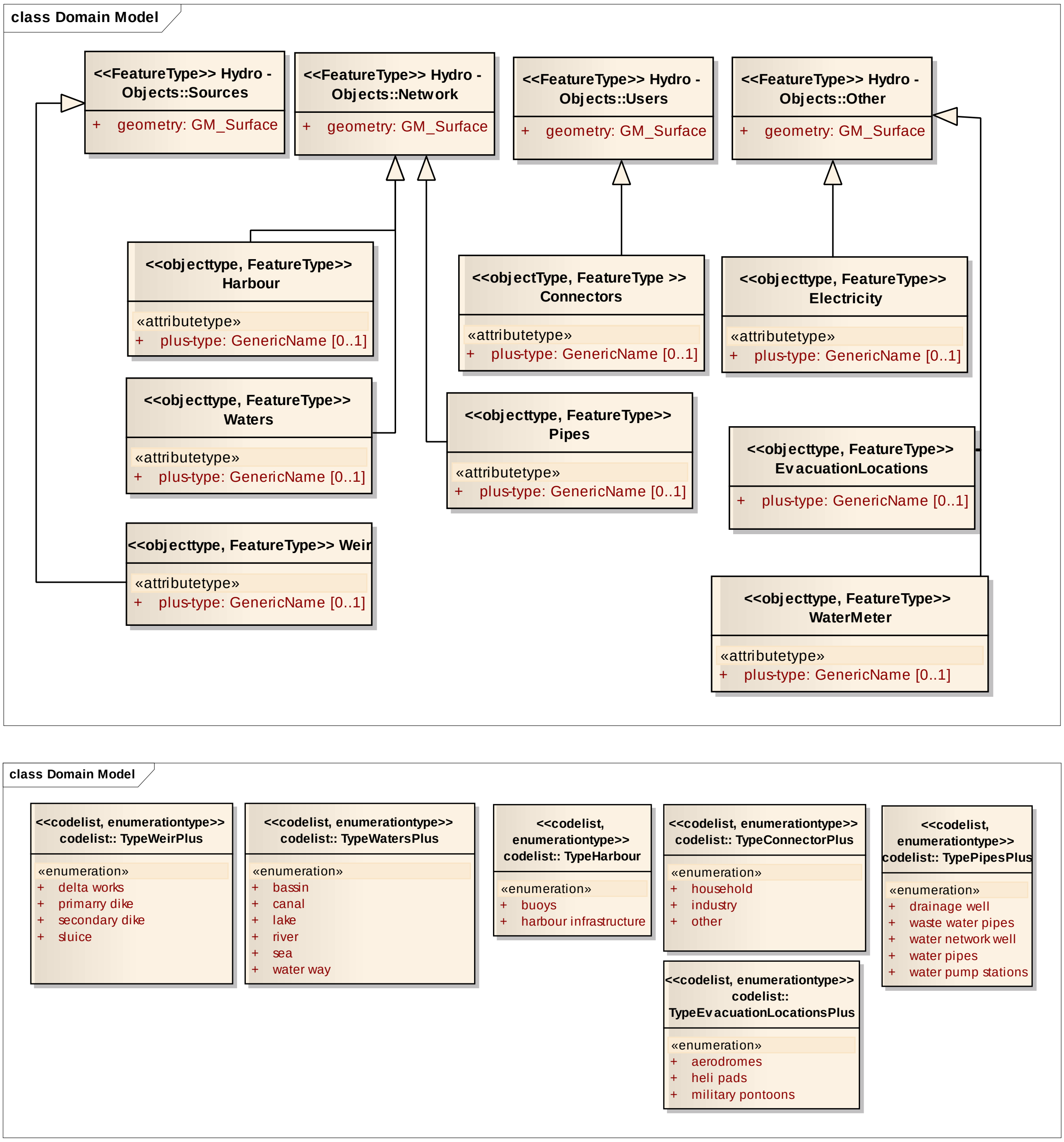
6.2.2 UML diagram

Figure 46 shows a UML with the classes and objects of a flood scenario which is partially based on the Subset of the ERiskA common data model by Humboldt (Schäffler et al., 2010). The top of the UML diagram shows a feature type Geo object and a feature type Functional Area. These are the main classes of any spatial model. They refer to all the objects in the diagram below the main class as a geo object with a functional area. A class inherits the attributes of any classes linked to it that is further up in the UML diagram (bottom up). By labelling the classes, and thus objects, as a geo object is give the object a geographical description and with that spatial properties. As these geo objects are linked to CityGML further up in the larger diagram, they inherit the 3D attributes given to geo objects, which allows for three dimensional visualisation and data storage.




class Domain Model
<<FeatureType>> GeoObject
+ geometry: GM_Surface
+ identification: CharacterString
+ objectbegintime: DateTime
+ status: Status
<<FeatureType>> FunctionalArea
+ typeFunctionalArea: TypeFunctionalArea [0..1]
Flood Classes: Feature
<<FeatureType>> Hydro base:: HydroObjects
+ geographicalName: GeographicalName[0..*]
+ lcoation_ID: int
<<FeatureType>> Hydro - Objects::Sources
+ geometry: GM_Surface
<<FeatureType>> Hydro - Objects::Network
+ geometry: GM_Surface
<<FeatureType>> Hydro - Objects::Users
+ geometry: GM_Surface
<<FeatureType>> Hydro - Objects::Other
+ geometry: GM_Surface


class Domain Model
Flood Classes: Feature
<<FeatureType>> Hydro base:: HydroObjects
+ geographicalName: GeographicalName[0..*]
+ lcoation_ID: int
<<FeatureType>> Natural Risk Zones:: InundatedLand
+ beginLifespanVersion: DateTime: short
+ endLifespanVersion: DateTim [0..1]
+ geometry: GM_Surface
+ inspireld: Identifier
+ inundationReturnPeriod: Number
+ inundationType: InundationValue
<<FeatureType>> Hydro - Physical Water:: SurfaceWater
+ beginLifespanVersion: DateTime
+ endLifespanVersion: DatTime [0..1]
+ geometry: GM_Primitive
+ inspirId: Identifier
+ levelOfDetail: MD_Resolution
+ origin: OriginValue
+ persistance: HydrologicalPersistanceValue
+ tidal: Boolean
<<FeatureType>> Floodarea
+ methodOfCalculation: MethodOfCalculationType
+ validFromWaterLevel: Length
+ validToWaterLevel
<<FeatureType>. Hydro - Physical Waters:: StandingWater
+ elevation: Length
+ meanDepth: Length
+ surfaceArea: Area
<<FeatureType>> Hydro - Physical Waters::Watercourse
+ delineation known: Boolean
+ length: Length
+ level: VerticalPositionValue
+ streamOrder: HydroOrderCode [0..1]
+ width: WidthRange



Figures 46: UML Flood Objects in parts due to the size

A class can also have a code list where the type of that class is further specified by options, codes, in that code list. For example, the weir class indicates weir objects and can be further specified as delta works, sluices and types of dikes.

6.2.3 Object catalogue

Prominent objects required in a model when a flood takes place are stated in the previous paragraph, where a distinguishment is made between sources, network, users and additional objects. The flood UML includes these as four classes that represent objects in the real world. Three form the core of the model:

• An object class *Sources*;

• An object class *Network*;

• An object class *Users*.

In addition, the following class was included:

• An object class *Other*

With each object class, a table with the definition and other class information is given.
The data table has the following format:

Table 15: Class table format

Class	Class name	
Definition	Definition of the class	
Origin definition	The origin, source, of the definition	
Gathering line		
Generalisation	Of which class is this class a generalisation	
Specialisation	Of which class is this class a specialisation	
Attributes	The attributes that are defined for this class	
Attribute name	Explanation An explanation for the goal and use of this attribute	Is the attribute: required conditional optional
Associations	With which class is this class associated	
Explanation	Explanation for the use of this class	

The object classes shown in the diagram are described in the tables in appendix L. Two examples, Geo Object and Functional Area are stated below.

.

Table 16: GeoObject class

Class	GeoObject
Definition	A geo object is an abstract of a phenomena in reality, that is directly or indirectly associated with a location relative to the Earth's surface.
Origin definition	ISO19101
Gathering line	
Generalisation	This class is the main class of the flood model. With

	this it is the generalisation class of the other classes in the model.	
Specialisation	n/a	
Attributes:		
Identification objectBeginTime status Geometry	A unique id for a geo object System time when geo object was made Status linked to lifecycle of geo object Surface geometry	Required Required Optional Required
Associations		
Explanation	For this class, those attributes that are defined for all subclasses apply. This class is not used for naming existing geo-objects. If an object is not known, or not of interest, to which base class the object belongs to, than a subclass is to be made.	

The classes *GeoObject* and *FunctionalArea* originate from the Basic model Geo-model Information (NEN 3610) by which the connection with other models is guaranteed. Below (figure 47) is the NEN36010 pyramid for standards in The Netherlands.

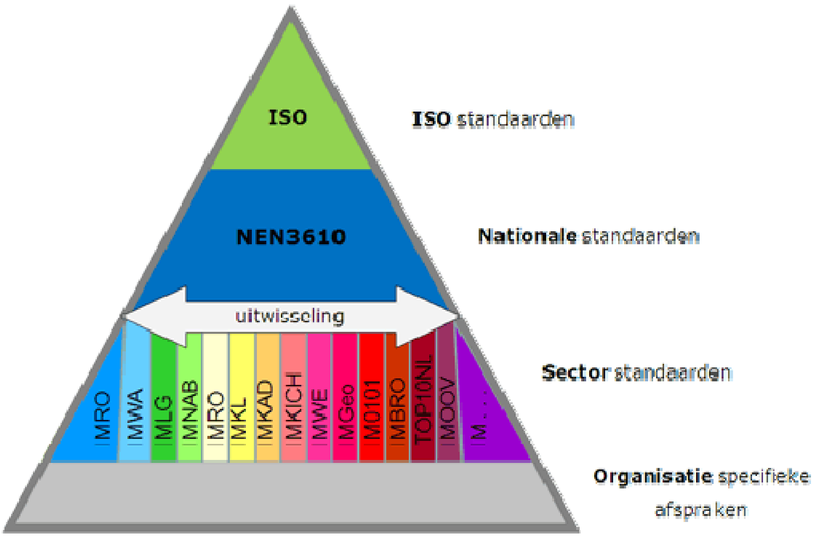


Figure 47: Standards

6.2.4 Code lists

All these classes have an attribute *plus-type* with a generic name. With this plus-type comes a code list that allows the class to give details on the type of object within that class. These code lists are stated in table 17.

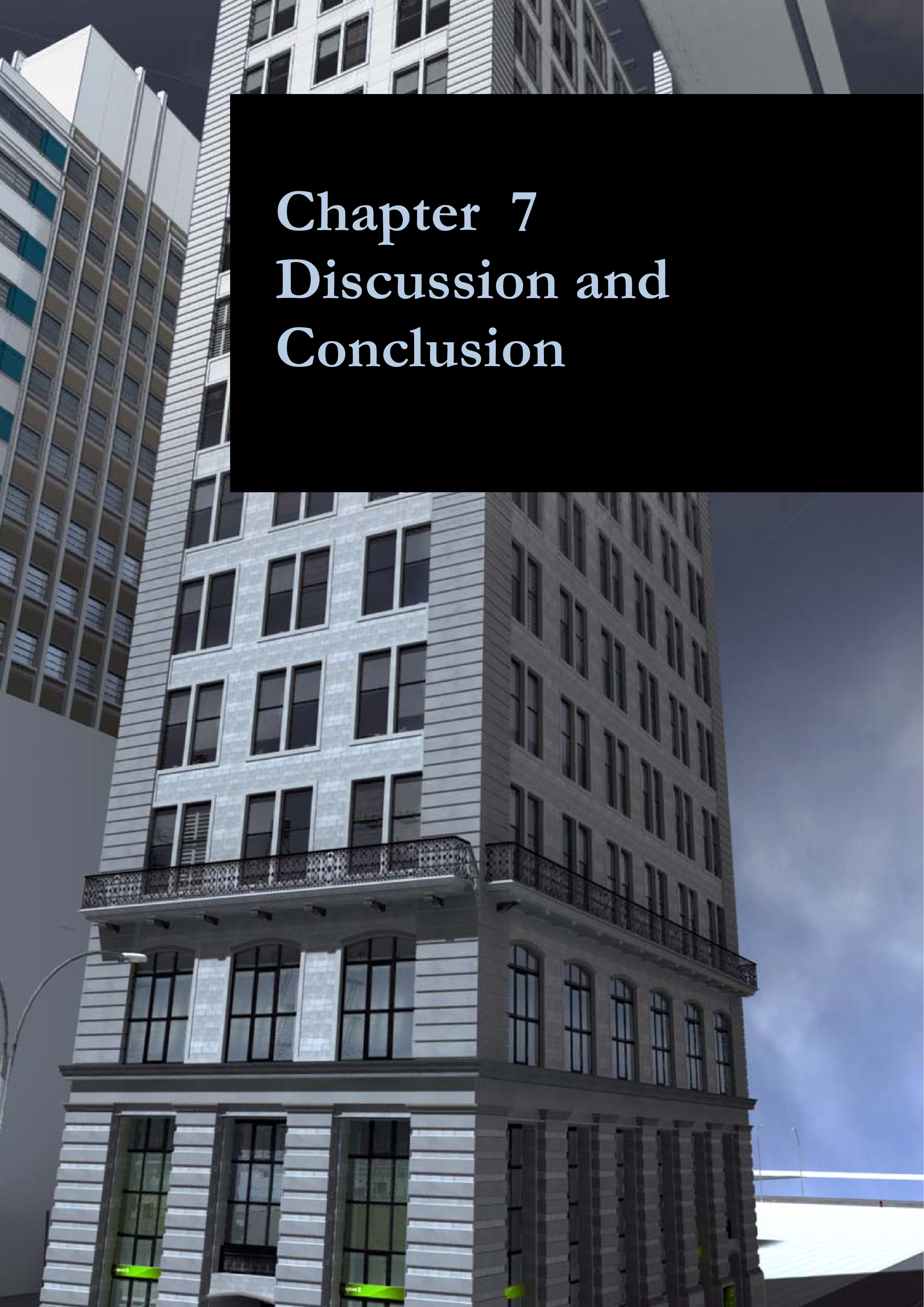
Table 17: code lists

Code list	Weir	Waters	Harbour	Pipes	Connectors	EvacLocat.
	Primary dike Secondary dike Delta works Sluice	Canal Water way River Lake Basin Sea	Harbour infrastructure Buoys	Drainage well Waste water pipes Water network well Water pipes Water pump stations	Household Industry Other	Heli pads Aerodromes Military pontoons

6.3 Conclusion

The government has divided disaster and emergencies into different categories: Large fires, Large traffic incident, Terrorist attack, Epidemic, Collapse risk, Extreme weather, Public disturbance, Flood, Nuclear disaster, Earthquakes and Hazardous goods (explosion and emission). These categories form the base of the scenario based modelling for the extension of IMGeo for emergency response. In addition to these categories: law enforcement and military, failure of power network, failure of gas network and failure of telecom network were suggested as additional scenarios to support situations. These categories can be selected and the pre set objects will be visualised. This way of modelling will be efficient for the user and will only provide the relevant information in this mass model of data. The example scenario described in this chapter, flooding, illustrates the UML diagram that it could have and the data bases related to that UML diagram to obtain proper data and therefore objects. The additional UML diagram for floods contains the classes: sources, network, users and other. These classes and their subclasses can be placed in IMGeo or connected to existing classes in IMGeo and to the IMWA, Top10NL, IMRO, IMKL and IMLB data bases and extract the information from there.

Chapter 7
Discussion and Conclusion



7. Discussion and Conclusion

The discussion reflects on the choices and interpretations made in this thesis. In the end, conclusions can be drawn and recommendations can be made based on this research and its discussion.

7.1 Discussion

The thesis is about a user requirement analysis of a 3D emergency response information model. It has explored how the users of such a model would like it to be equipped and set up concepts to adapt a current 3D model application, IMGeo, to fit these needs. The discussion will focus on the results, the methodology and the impact on the results. While doing so the thesis defends what is done and why, what knowledge is obtained and what else could have been done in the whole process, leading to new research topics.

7.1.1 Discussion on the methodology

The user requirements that were obtained were derived from a small selected group of experts with regards to emergency response. One could argue that because not many experts were approached, the research of the thesis is limited. More expert opinions would have provided with a stronger fundament for user requirements, but it would most probably not have lead to different user requirements. Experts in any same field are most likely to indicate the same important factors, requirements and pointers regarding their field of expertise. The interview through which the requirements were obtained from the experts was free with an underlying structure of questions and options. This method of conducting an interview allowed the interviewer to remain between the boundaries of the topic at hand but gives the interviewee the space to answers and elaborates on their opinion. A consequence was that some of the answers had to be placed within preset answers (multiple choice) by the interviewer without losing its context or intention. Reflecting on the questions asked and scenarios discussed, more task-oriented scenarios should have been talked about. Future studies should focus even more on the tasks of the experts and data related to their actual experiences. Furthermore, follow up studies should use a larger group of experts to make sure that the user requirements are universal for their line of work.

The expert opinion was also used as a validation for the obtained results of user requirements, which were also based on literature study and the information gathered at the emergency responder's scene. In the end, the methodology was mostly based on text and behavioural analysis and not on numerical analyses which might be unusual in Geomatics. Nevertheless, this qualitative study was conducted with care and with an academic approach.

7.1.2 Discussion on the results

As predicted, most of the user requirements stated by the experts are already an integrated part of the current model. By already being pleased with the expansion of the model with a z-coordinate, they easily overlook the greater possibilities that lie within a 3D model. Through the insights obtained from the experts and their hospitality to demonstrate and guide around, it allowed other important objects to come to light. The findings on the standard objects were mostly derived from contact with the experts. The so-called other objects were deduced from categories of disasters stated by the government and the experience of the experts. Because the categories used in this thesis are adopted from the government, it provides a familiar structure to the user making an information model easier to use.

Findings on buildings

Modelling buildings in 3D could provide more information regarding for example the collapse risk of that structure and the damage that it could inflict. A higher building will cause more damage to its surroundings than a smaller one. So at the same time, if the buildings near a building on fire are modelled in 3D it can give additional information on possible casualties and damage. This could be calculated with a 3D buffer zone or distance computations and help out the tasks of the fire department regarding rescue operations, technical assistance and alerting the right population. The height of the buildings and structures around a fire can also have an effect on smoke distribution, so to see the buildings in 3D can provide additional information on where smoke will travel. I.e. allow for a 3D flow computation of smoke or toxic clouds. This would give a more accurate estimation and allow for better emission fighting and observing and measuring. For the visualisation of buildings for emergency response, two suggestions are made for extension. The function of the building should be indicated with an extra class: *Functiegebouw (BuildingFunction)*. *Functiegebouw (BuildingFunction)* will allow the user to quickly obtain information about the potential population within that building, and their potential presence outside office hours. A fire in large office that is closed during the night requires a different approach than a building where people live. Furthermore, the construction of buildings should be visible in an extra class: *BuildingConstruction*. CityGML already provides much detail and thus information regarding buildings. The construction of the building is a category that most experts emphasized on. The building is only as strong as its construction and it will determine for instance, the amount of time inside a building considered to be safe. Buildings are indicated as the most important object in the 3D model.

Findings on tunnels

Tunnels should also consist of a class *TunnelVentilation* and a class *TunnelFunction*. When a disaster or emergency takes place in a tunnel, the police and fire department need a lot of information to get everybody into safety. Besides visual and audio support during a tunnel crisis, the technical aspects of a tunnel are also relevant. The type of ventilation in a tunnel co determines the risk of fires escalating, evacuations possibilities and influence situations that involve hazardous substances. Tunnel ventilation is a good example of a code list that is not necessary in standard city models but can be very useful for an emergency response model.

The information about the function of the tunnel provides additional information for what kind of construction the tunnel has and what (technical) help might be needed inside the tunnel. The Tunnel ventilation systems can be categorized into five main types that can added to a code list.

To know the function of a tunnel (pedestrians, public transport or motor vehicles) could speed up risk assessment and the course of action. It gives insight in the facilities of a tunnel and who or what is at risk. Experts indicated that the local emergency responders usually know this kind of information, but that it could benefit task forces from other areas when they are called in to assist.

Findings on bridges

For emergency response, the construction of the bridge is the most important. All experts indicated that there needs to be a crossing notice and most stated that the construction is extremely relevant. The construction determines the weaknesses and strengths of a bridge and its characteristics. This resulted in a new code list: *BridgeMaterial* and additional codes in the code list *TypeCrossing*. In the code list of *TypeCrossing*, bridge was replaced with multiple specific types of bridges. It would define the type of bridge (e.g. suspension bridge) and the maximum loading (individual vehicles and convoy loading) and *BridgeMaterial* the main materials the bridge is constructed with (e.g. cast iron with steel, concrete). The combination of knowledge about the specific type of crossover (in case other is not selected) and its material provides information to emergency responders about for example the weight capacity of a bridge or the force it can withstand in certain situations (e.g. extreme weather, flood and explosion).

Findings on vegetation

Emergency response regarding large fires, require information about vegetation. Bush fires, park fires and meadow fires are not common, but not uncommon either. A 3D model for emergency response should therefore contain visualisations of vegetation. The size and type of trees is relevant and the vegetation area is important to know. Based on the current capabilities of CityGML and IMGeo, it would seem that the size and type of vegetation do not need an expansion for emergency response since this is already possible.

Findings on water

Experts indicated that they do not need the 3D model of a water body (e.g. the shape of the basin). The emergency responders require the help of external parties when a large water body is involved, which sets them free of information for all water bodies. One aspect of a water body should be clear though, the depth of the water body in relation to mean sea level (“NAP”)and in relation to the terrain. The depth of a water body can also be relevant to first responders on sight. It determines work procedure for divers, vehicle and water sourcing. Basic information is available at the Safety Regions, but usually RWS is called in to assist and provide additional expertise.

Findings on transportation

Transportation is already excellent modelled in CityGML and IMGeo, where there has been a two cast of transportation (roads) and transportation complex (railway). This railway entails trams, train, speed trams and other kinds not specified. It would be helpful however, if the BGT FunctionRailway would be expanded with subway. The larger make use of subway and since these railways continue underground in tunnels, the specification of subway could be of added value.

Findings on terrain

In CityGML, terrain can be modelled in 3D and with different types of land use. A terrain that is modelled in 3D can give a much quicker overview of a site than a map with height markings. The height of terrain could co determine where to access or exit a site and where safer places are with respect to hazardous places. Also to know how the water flows in case of flooding or rain fall runoff. The demand on terrain for emergency responders is congruent with the competences of CityGML and therefore does not require complementary classes.

Findings on LOD

Emergency response requires different LODs per scenario, per object, per time frame. The model should be able to depict multiple LOD at the same for different objects. This is very important because some objects require more detail than others, and even this differs per scenario. The flexibility of the model requires the data base to contain various LOD in relation to an object. All experts stated that interior structures would support decision making enormously and that when the option is feasible, LOD4 would have the preference. For outside visuals, LOD2 does not seem relevant and LOD3 has the preference.

Most experts mentioned that the same LOD can be used for an entire building, i.e. they do not see an upside to multiple levels of LOD of a building. Whereas the experts did state that it can be helpful to have the building where the emergency takes place in a high LOD while the surrounding buildings remain simple blocks (LOD1). More than half of the experts indicated they would windows en doors on the building block, either in texture or modelled. This would provide additional information on possible entrances and exits.

Findings on other objects

The hypothesis that the experts might not come up with many new objects due to the overwhelming upgrade to 3D mentioned in chapter 5 was accepted. This risk was evident from starting point due to the fact that by suggesting a model in 3D, their information at hand will be (more and) better no matter which objects are modelled.

But emergency response modelling indeed requires more than the standard objects of a 3D IMGeo model. These objects were derived based on the literature and the insight derived from interaction with the experts. The objects, related to emergencies or consequences to those, have been divided over multiple categories. The government has divided disaster and emergencies into different categories: Large fires, Large traffic incident, Terrorist attack, Epidemic, Collapse risk, Extreme weather, Violation of public disturbance, Failure of power, gas or water, Flood, Nuclear disaster, Earthquakes and Hazardous goods. These categories form the base of the scenario based modelling for the extension of IMGeo for emergency response.

Findings on functionalities

The main functionality of the emergency IMGeo should be scenario based modelling. The pre set scenarios are a supportive function and not a smart model where the computers takes over the thinking and decision process of the user. It is important that the user does not take an automatic pilot state, but the scenario based modelling will make the model more efficient and more pleasant for the user. Scenario based modelling uses the categories handled by government. In addition to these categories, a medical back up, law enforcement and military were suggested as additional scenarios to support situations. These categories can be selected in the software and the pre set objects will be visualised. This way of modelling will be efficient for the user and will only provide the relevant information in this mass model of data. The scenario described in this chapter, flooding, illustrates the UML diagram that it could have and the data bases related to that UML diagram to obtain proper data and therefore objects. The additional UML diagram for floods contains the classes: sources, network, users and other. These classes and their subclasses were connected to existing classes in IMGeo and to the IMWA, Top10NL, IMRO, IMKL and IMLB data bases.

Other functionalities that are required for the emergency response model include position change of objects, queries, object editing, computations and view functions. These functionalities provide for a dynamic model and allow qualitative and quantitative information to be obtained from the model. This is important and highly relevant for emergency response. The environment within emergencies can occur are highly dynamic, which results in a model that needs constant updating and additional information. The queries allow for relevant information to be obtained in a very efficient and reliable manner, provided that the data is accurate. Each of these queries relies on a relationship between variable a en variable b and perhaps other variables. If the data or the relations are inaccurate or out of data, than automatically the query becomes unreliable, proves wrong or gives an error. Relevant computations are Buffer, Distance, Intersection, Volume, Area, Line of sight, Flow estimations, Flood simulations and Numerical computations.

Pictograms/symbols help to easily screen a specific area and allow for a quick observation of objects other than buildings in a certain area. The symbols in the currently used 2D model are assessed as very useful so it concluded that these are also to be modelled in the 3D model for emergency response. By placing (3D) symbols in the model at certain locations and objects, it could save time and frustration in a large data model. These symbols will have to be modelled in three dimensional shapes with a side view, as to make them visible in a 3D model with street view.

Other findings

Despite the fact that the application of the data is the starting point, the available source data also often determines how ambitious the model is. Even if source data were available easily, the construction of such a model is very expensive. If use can be made of data which an organisation already possesses or of data which can be acquired at relatively low cost, than the cost of constructing the 3D model will also be low. Otherwise, the constructing of 3D models for emergency response is further away than we would like to think.

7.1.4 Discussion on impact of the results

Considering that there are multiple additional UMLs needed for IMGeo to comply with the user requirements for emergency response models, the results have some impact. Although the adjustments have not been technically implemented, the requirements are so clear that future implementation will not be a difficult task for someone who's expertise and skills lie in that domain. Despite the fact that different emergency responders need different information, and perhaps more or less than others, a 3D model accustomed specifically for emergency response will provide better insight in emergency scenarios for all users. This combined with the functionality of scenario based modelling allows the user to dose the needed information. Information that is pre set to support the user in a specific scenario. The ability of visualisation software should allow users to turn on or off certain information, which determines a part of the usability of the model. It cannot be emphasized enough that more information is often better, but too much information can spoil an overview and cause indirect damage.

A recommendation to the expansion of VeRA would be to impose that all basic registrations are available in the same format, if possible the UML format. This would allow for a greater synergy and a possible connection to IMGeo, allowing more analyses to be possible and more information to be called in.

7.2 Conclusion

In the beginning of the analysis a research question was stated:

To what extent do IMGeo and CityGML comply with the user needs in a 3D emergency response model, and what is missing?

And three secondary research questions were mentioned:

Who are involved in emergency response?

How can CityGML contribute to the emergency response procedure?

What are the user requirements for a 3D emergency response model?

Related to the first secondary research question at least five actors can be identified for direct emergency response. They are the police, the fire department, the medics, the emergency room and the safety region. Based on the type of emergency, external organisations like RWS are called in to assist and provide additional information and expertise. Each organisation has its own tasks that are guided by information and law. Providing these organisations with 3D information could benefit the decisions and their results. By modelling the buildings in 3D emergency responders obtain more information regarding the buildings and structures they have to work around and use a model that can make realistic computations, provide more information regarding for example the collapse risk of a structure and the damage that it could inflict using 3D buffer zone or distance computations and help out with rescue operations, technical assistance and alerting the right population. A terrain that is modelled in 3D can give a much quicker overview of a site than a map with height markings. Considering the tasks of the emergency responders, 3D information could really benefit both disaster prevention and disaster control.

Regarding to the second secondary research question CityGML can contribute to the emergency response procedure by adding the third dimension. All the current emergency response models and software are in 2D, with exception of users using Google Earth for a 3D model to inspect locations. The fact that they engage in Google Earth for 3D model and situations shows there is a demand for three dimensional models. CityGML is available as a data model is expected to encourage data providers to organise their 3D city information models according to the CityGML standard, i.e. containing a rich variety of semantic, geometric and appearance properties. The database storage will further facilitate the seamless, consistent and robust management of large data sets. The third dimension will mostly contribute to the higher buildings and objects, where a third dimension comes to stage. CityGML in combination with the Dutch ADE IMGeo supply the structure and content for a three dimensional model that can be used for emergency response. CityGML is equipped with data structures to model 3D environments and cities in particular, making it very suitable to use for emergency response modelling. Furthermore, IMGeo already contains a lot of geo referenced objects that can be visualised in 3D providing a realistic and up to date overview of any location chosen within the Netherlands.

Regarding the 3rd secondary research question the thesis has defined several user requirements for a 3D emergency response model. In short, the requirements that come forward from the literature study, the information gathered at the emergency responder's scene and the opinion of the experts entailed the following:

- Expansion of the code list *TypeCrossing* with specific types of bridges
- A new code list with materials of a bridge
- Class with Construction of buildings to visualise the underlying architecture;
- A new code list with the function of buildings (e.g. home, office and industry);
- A new code list with the ventilation of tunnels;

- Additional information of an object per click;
- Multiple LOD visible during visualisation, where more detail is required on the ground floors than the upper floors;
- Interactivity regarding view and data manipulation, such as queries;
- New objects with regards to underground modelling, such as pipes and subway systems.
- Scenario based modelling, where objects are stored as a package to allow for pre set scenarios in the model to be visualised.

These pre set scenarios are based on the division made by the government and consist of the following scenarios:

- Disaster in relation to traffic and transport
    1. Aviation accident
    2. Accident on water
    3. Traffic accident on land
- Disaster with dangerous material
    4. Accident with inflammable/ explosive material (in open air)
    5. Accident with toxic gasses (in open air)
    6. Nuclear accident
- Disaster in relation to public health
    7. Treat to public health
    8. Dispersal of disease
- Disaster in relation to infrastructure
    9. Accidents in tunnels
    10. Fire in big buildings
    11. Collapse of big buildings
    12. Disruption of utility
- Disaster in relation to population
    13. Panic in large groups
    14. Large-scale disturbance of public peace
- Nature disaster
    15. Flood
    16. Nature Fire
    17. Extreme weather conditions
- Disaster on distance
    18. Incident out of city boundaries, in which citizens of that city are involved

Each scenario has its own relevant objects and possible other scenarios that are relevant at the same time (e.g. power failure scenario with electricity related objects during a flood). These identified objects are to be referenced in the database to be a part of a certain, or multiple, scenarios in order to help out the emergency responder when he needs specific information with crucial timing.

The requirements that were found in this research are additional to the standard 3D representations in the current IMGeo. This thesis shows that IMGeo and CityGML already comply with the basic user needs in a 3D response model, but that emergency response requires more objects and a way of dosing the information. The specific emergency response objects are divided into scenarios to build up relevant data and information. It is important for users to be able to dose the information that is modelled, which is enables by scenario based modelling. One of these scenarios was worked out into a UML to demonstrate how the scenarios are to be modelled. By doing so, the goal of thesis: To development a conceptual extension for IMGeo for 3D emergency response, containing user requirements, was accomplished.

7.3 Concluding remarks and future approaches

There are new frontiers that have been disclosed while conducting this thesis. It is important that follow up research will include a larger group of experts and will subsequently test the technical model with a large group to verify that the model does indeed comply with the user requirements of the emergency responders.

Because the technical integration of the complementary classes are beyond the scope of this thesis, a future follow up would be to explore the options of how to connect the classes and make them best usable for emergency response. The UML diagram that was designed to illustrate the scenario based modelling has not yet been validated. The validation of the new classes and UML models would be an important part of the follow up research.

Epilogue

We learn by experiences that allow us to (Wertenbroch & Nabeth, 2000):

- Absorb (read, hear, feel)
- Do (activity)
- Interact (socialize)

In addition, we learn by reflecting on such experiences (Dewey 1933). Reflection is thinking for an extended period by linking recent experiences to earlier ones in order to promote a more complex and interrelated mental schema. The thinking involves looking for commonalities, differences, and interrelations beyond their superficial elements. During this research I learned many things which, afterwards, allowed me to reflect on the context of the research and the curriculum of Geomatics.

Reflection on Geomatics

Geomatics (also known as spatial technology or Geomatics engineering) is the discipline of gathering, storing, processing, and delivering geographic information, or spatially referenced information. The curriculum of this master, as set up when I began my masters in 2010, reflects this definition. The Master's programme in Geomatics provides you with the necessary knowledge and expertise to develop better solutions for solving real-world problems in an innovative way. The master of Geomatics that is offered at the TU Delft today is not the Master of Geomatics I enrolled for back in 2010. The master programme back than was mostly divided over the faculty of Aerospace engineering and Civil engineering, providing subjects from both those faculties as well as subjects that are an integrated part of Geomatics. I really enjoyed most of the subjects given at Geomatics, even though I realised that my talents may only partially lie within this domain. I am now suited to solve challenges which are industrial, governmental and research sectors related and to the use and production of spatial information. I learned how to analyse information, perform the required processing and analysis steps, produce a visualisation of the solutions and through that acquire data. My Geomatics thesis, a part of the Geomatics master programme, should also reflect on the contents of the master. It contained the elements specified above and more.

Reflection on thesis

The research that was conducted for this thesis has taken a really long time. Due to multiple circumstances, there was much delay during the past two years, which asked a lot of patience from my supervisors and a lot of motivation from me to stay on track. I am grateful that they provided me with enough time, space and spirit to deliver this thesis.

The documentation of this thesis is an aspect that is not fully related to Geomatics, but nevertheless important. This aspect is what I found the most rewarding, because it gave structure to the research I conducted. By writing down everything that was in my head and what came forward from my enquiries, the thesis finally got some shape.

The thesis contains a literature study and expert consultations which gave me a lot of information. The information was processed into a clear overview and further analysed for requirements. This method of conduct is perhaps not standard for a Geomatics thesis, considering most studies are solely quantitative or about programming. In the years that I began Geomatics it was a combination of three faculties: Aerospace engineering, Civil engineering and Technology, Policy & Management. The latter is where I also obtained my bachelor degree and it was for this reason that I choose their path for conducting a research. This was an uncommon choice, but nonetheless an acceptable one.

The requirements from the analysis were, in theory, implemented in a conceptual model which would allow for visualisations of the solution/final product. These visualisations will provide data for the user.

This framework for three dimensional objects based on geo-information is a set up that can support emergency responders by making the right information available. It makes this research about the use of geo-information and its context, which is very much in the vein of Geomatics.

Reflecting on the steps taken in this thesis, it shows that the research contains all the elements for today's needs. What the future of 3D imaging for emergency response will bring is likely to be much larger than we can fathom today.

May the contribution of 3D visualisations to emergency response save many lives.

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Appendices

Appendix A – Emergency response processes

Table 18: Emergency response processes (Snoeren, 2006)

Cluster A: Source- and Effect Control Responsible for processes: Fire department
Fighting fire and emission of hazardous substances Saving and technical assistance Decontaminate humans and animals Decontaminate vehicles and infrastructure Observe and measure Alarm population Make accessible and clean up

Cluster B: Medical assistance Responsible for processes: GHOR
Medical assistance-somatic Preventive public health Medical assistance-psychosocial

Cluster C: Law and Order and Traffic Responsible for processes: Fire department
Clear and evacuate Quarantine and portion off Traffic control Maintain public order Identify victims Guide Criminal investigation

Cluster D: Population care Responsible for processes: Fire department

Educate and inform
Take in and care for
Funeral
Registration of victims
Provide primary necessaries
Registration damage and handling
Environmental care
Care afterwards

General supporting processes
Alarming
Caring/logistics disaster management
Connect/Communicate
Registration, reporting and archiving
Evaluatie

Appendix B – Disciplines

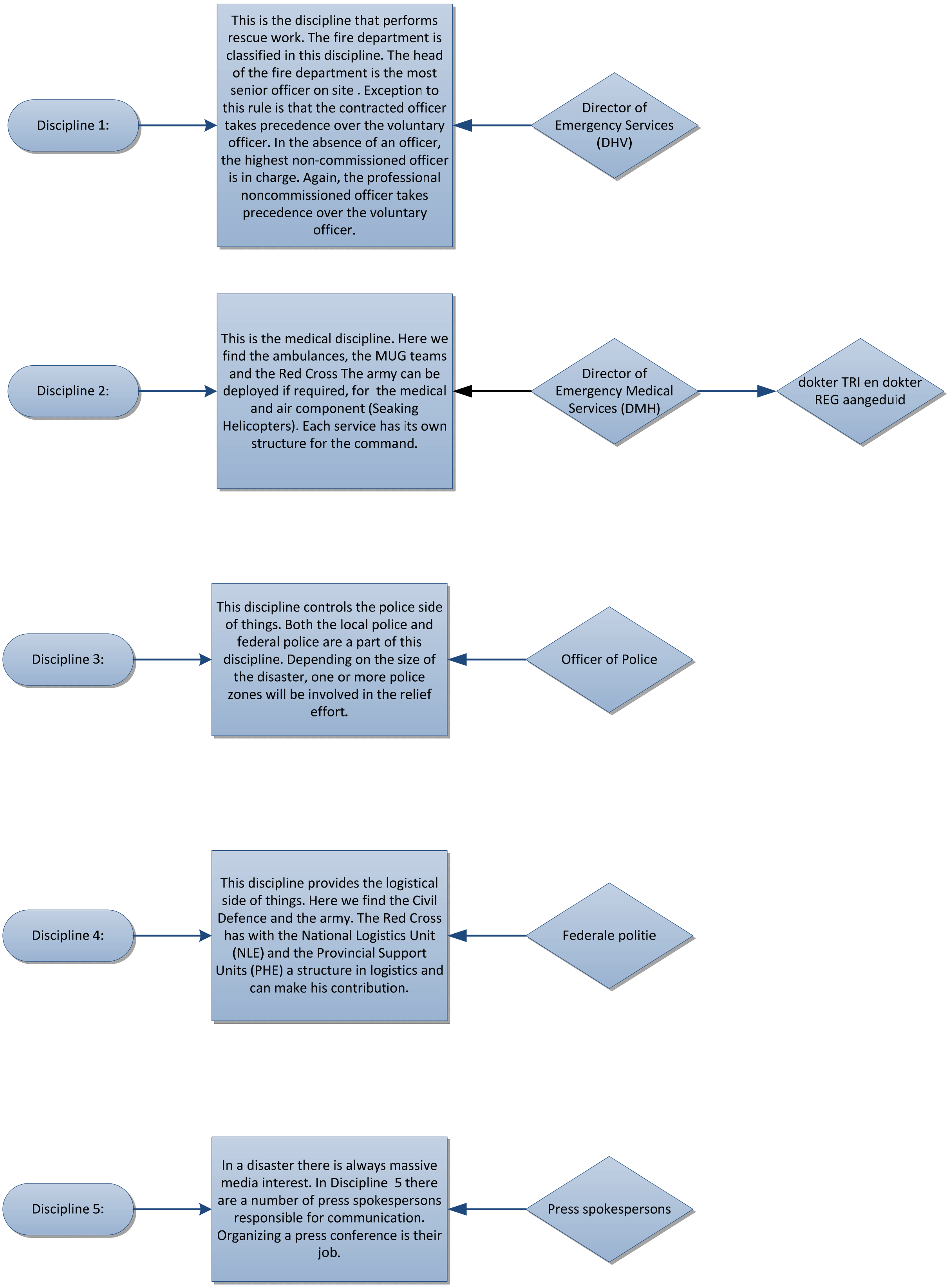


Figure 48: Disciplines

Appendix C – Stakeholders

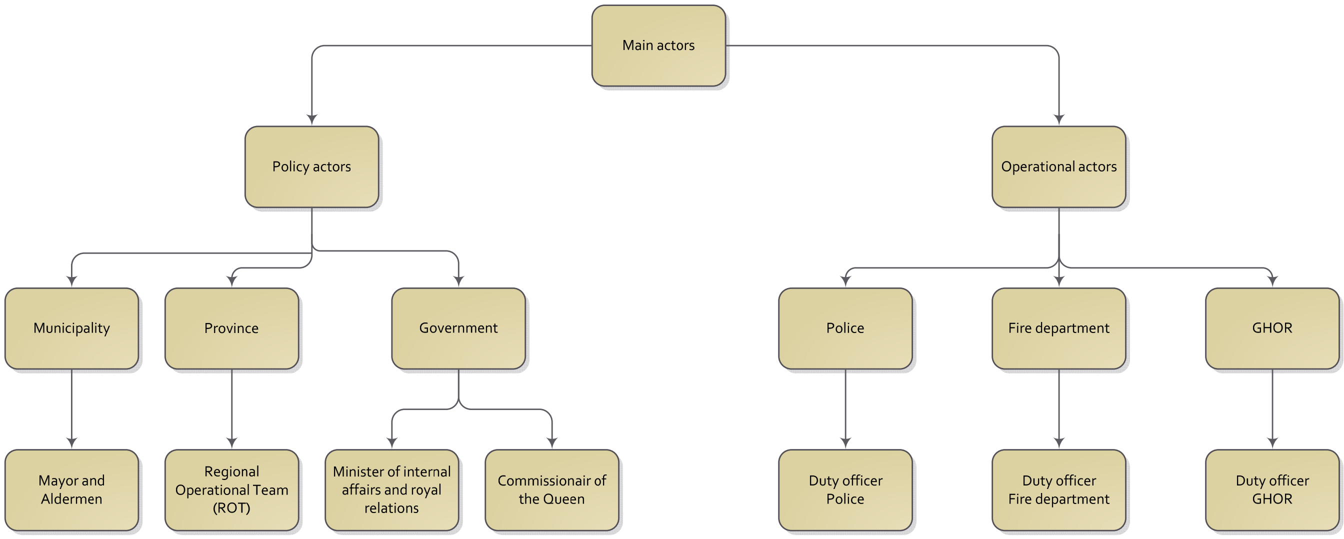


Figure 49: Diagram of stakeholders involved in emergency response

Appendix D – Breakdown of 3D model

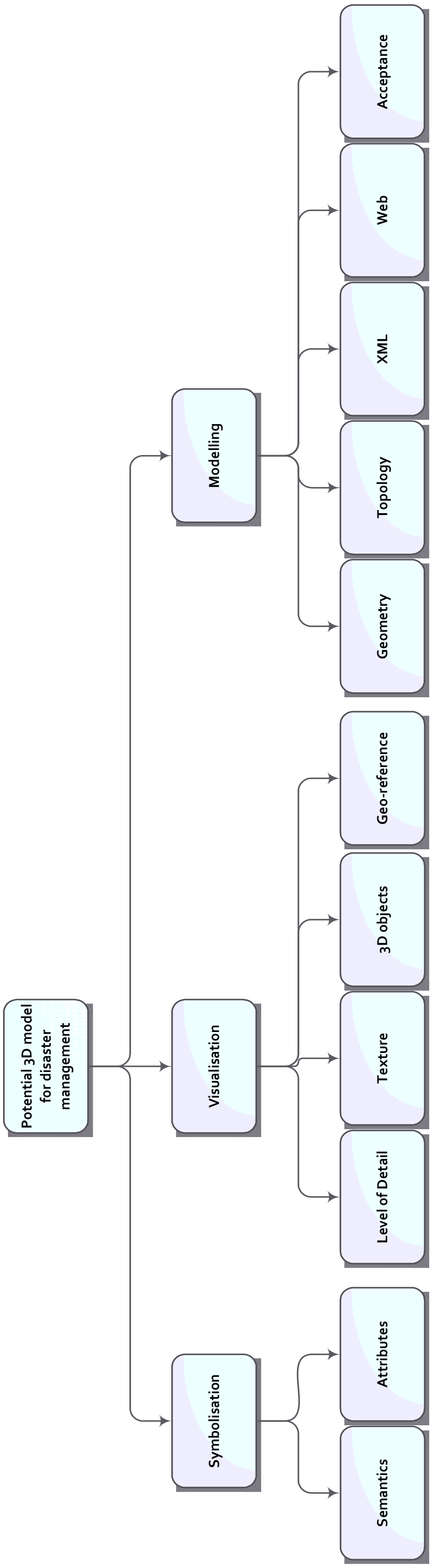


Figure 50: Diagram of specifics in a 3D model

van Campen et al. states on page 12 :

Semantics indicates the possibility to assign thematic meaning to an object or a group of objects. CityGML is one of the first 3D file formats that have introduced unique meaning of topographic objects.

Attributes estimates the possibility to attach text properties to objects. CityGML allows a very basic set of attributes (such as name, type, year, etc.) for each object. It does not have the range of possibilities offered by SHAPE file for example, but at least they are standardised.

Levels of Detail (LOD*)* is an indication for support of several geometries per one object. As mentioned above, CityGML uses LOD to indicate the resolution of an object (a bit like a scale), in contrast to LOD of VRML or X3D which use LOD for fast visualisation. At the same time some first attempts are already made to use the LOD also for speeding up the visualisation.

Texture evaluates the support of texturing with real photos. CityGML supports texture mapping (synthetic and real photo images), which although not that elaborated as in typical visualisation formats as X3D and COLLADA. However, it is sufficient for creation of very realistic models.

3D Objects estimates the possibility to distinguish between different objects in terms of geometry. CityGML is clearly an object-oriented file format.

A **Geo- reference** estimates the possibility to use geographical coordinates. CityGML is clearly geo-standard, since it is built up on GML

Geometry*:* estimates the support of 3D geometries. CityGML supports only the simple features (point, line, surface and eventually polyhedron) and therefore it is classified as standard functionality.

Topology evaluates the existence of relationships between the geometries in the model. CityGML theoretically supports a topological data structure as specified by OGC, however, no model so far has been created using this topology.

The criterion **XML** indicates whether the standard is XML-based.

Web gives an indication which standards are designed and optimised for web use. CityGML is classified here as average too, because it is not really intended and thus not optimised for web use. However, many viewers have been developed and some of them are plug-ins to web browsers.

Acceptance indicates the support of the standard by software vendors. CityGML is a relatively new standard but clearly the interest to it is large. Software vendors, municipalities and other institutions are investigating options for use.

Appendix E – The interview

D.1 Standard Objects

D.1.1 Bridges

1. Do you need bridges in 3D?

A. Yes B. No C. It's not a priority

3. Which level of detail do you need in bridges?

A. Crossing notice B. Type C. Construction

D. Materials E N/A

10. Which view is necessary for bridges?

A. Side view B. Street view C N/A

Do you need texture on bridges?

A. Yes B. No C. Sometimes; turn off/on function would be of value

D N/A.

Would the texture be an image on the surfaces or computer generated?

A. Image B. Computer generated C N/A

D.1.2 Buildings

1. Do you need buildings in 3D?

A. Yes B. No C. It's not a priority

2. Which level of detail do you need in Buildings?

A. Block without roof type B. Model with roof

C. Materials/Texture D. Interior E N/A

3. Do you need windows and doors?

A. Yes B. No C. Occasionally D N/A

On all floors or only on the first?

4. The same LOD for all floors?

A. Yes B. No C N/A

5. Which view is necessary for Buildings?

A. Side view B. Street view C. Top view D N/A

6 Do you need texture on buildings?

A. Yes B. No C. Sometimes; turn off/on function would be of value.
D N/A

7 The same texture for all floors?

A. Yes B. No C. Depends on the appearance of the building
D N/A

8 Would the texture be an image on the surfaces or computer generated?

A. Image/photo B. Computer generated C N/A

D.1.3 Transportation

1. Do you need transportation in 3D?

A. Yes B. No C. It's not a priority

2. Which level of detail do you need in transportation?

A. Size B. Type C. Construction D. Materials
E. N/A

3. Which view is necessary for transportation?

A. Side view B. Street view C. N/A

4. Do you need texture on transportation?

A. Yes B. No C. Sometimes; turn off/on function would be of value.
D. N/A

5. Would the texture be an image on the surfaces or computer generated?

A. Image B. Computer generated C. N/A

D.1.4 Tunnels

1. Do you need tunnels in 3D?

A. Yes B. No C. It's not a priority

6. Which level of detail do you need in tunnels?

A. Size B. Type C. Construction D. Materials
E. N/A

13. Which view is necessary for tunnels?

A. Side view B. Street view C. N/A

Do you need texture on tunnels?

A. Yes B. No C. Sometimes; turn off/on function would be of value.
D. N/A

Would the texture be an image on the surfaces or computer generated?

A. Image B. Computer generated C. N/A

D.1.5 Vegetation

1. Do you need vegetation in 3D?

A. Yes B. No C. It's not a priority

2. Which level of detail do you need in vegetation?

A. Size B. Materials C. Details

3. Do you need the exact type of vegetation, tree name etc?

A. Yes B. No C. Sometimes

4. Which view is necessary for vegetation?

A. Side view B. Street view C. N/A

5. Do you need texture on vegetation?

A. Yes B. No C. Sometimes; turn off/on function would be of value.

6. Would the texture be an image on the surfaces or computer generated?

A. Image B. Computer generated C. N/A

D.1.6 Water bodies

1. Do you need Water bodies in 3D?

A. Yes B. No C. It's not a priority

2. Which level of detail do you need in water bodies?

A. Size B. Boundaries C. N/A

3 . Which view is necessary for water bodies?

A. Side view B. Street view C. N/A

4 Do you need texture on water bodies?

A. Yes B. No C. Sometimes; turn off/on function would be of value.
D. N/A

5 Would the texture be an image on the surfaces or computer generated?

A. Image B. Computer generated C. N/A

D.1.7 Terrain

1. Do you need terrain in 3D?

A. Yes B. No C. It's not a priority

2. Which view is necessary for terrain?

A. Side view B. Street view C. N/A

3. Which level of detail do you need in terrain?

A. Elevation B. Texture C. N/A

4 Do you need texture on terrain?

A. Yes B. No C. Sometimes; turn off/on function would be of value.

D. N/A

5 Would the texture be an image on the surfaces or computer generated?

A. Image B. Computer generated C. N/A

D. 2 Priorities

20. When using a 3D model, what would be more important to you?

A. Level of detail B. Accuracy C. Attributes

21. When using a 3D model, what is the order of importance of the following?

A. Level of detail B. Accuracy C. Attributes

23. Could you give an examples of situations/scenarios you encountered where a 3D model would have been more useful? Why? What objects were relevant?

D.3 Functionalities

1 Do you need resizing?

A. Yes B. No

2 Do you need rotation?

A. Yes B. No

3 Do you need to be able to move through the model?

Discuss views further.

A. Yes B. No

4 Do you need to be able to turn 3D off for certain objects?

Discuss layering further.

A. Yes B. No

5 Do you need to be able to add or remove crisis data?

A. Yes B. No

6 Do you need an object browser?

A. Yes B. No

7 Do you need an object editor?

A. Yes B. No

8 How do you want your information on objects?

A. Click on B. Put cursor on C. In separate menu

9 Which way to present additional object information?

A. Text B. Image C. More maps D. Video

10 What kind of operations do you need?

A. Buffer B. Distance C. Intersection D. Height E. Volume
F. Area G. Sight of view

11 Do you need the export of data?

A. Yes B. No

D. 5 Other objects in specified scenarios

12 Do you need gas modelling? Objects?

13 Do you need flood modelling? Objects?

14 Do you need water runoff modelling? Objects?

15 Do you need fire modelling? Objects?

16 Do you need evacuation modelling? Objects?

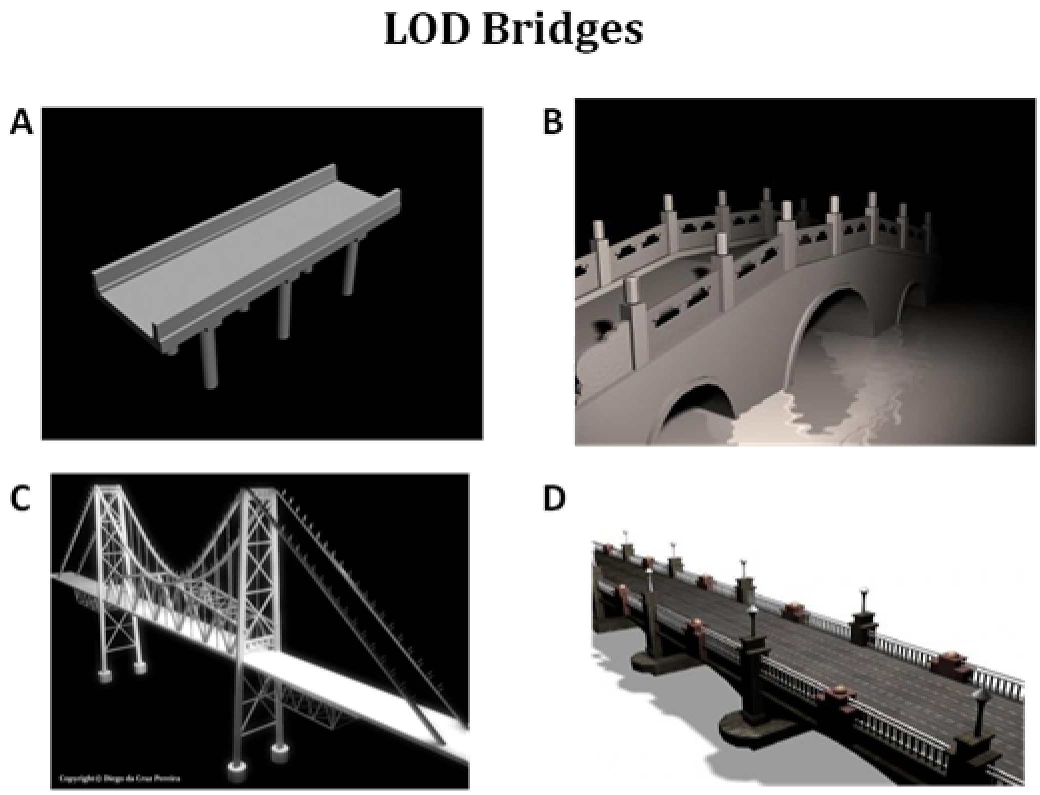
17 Do you need Underground modelling Objects?

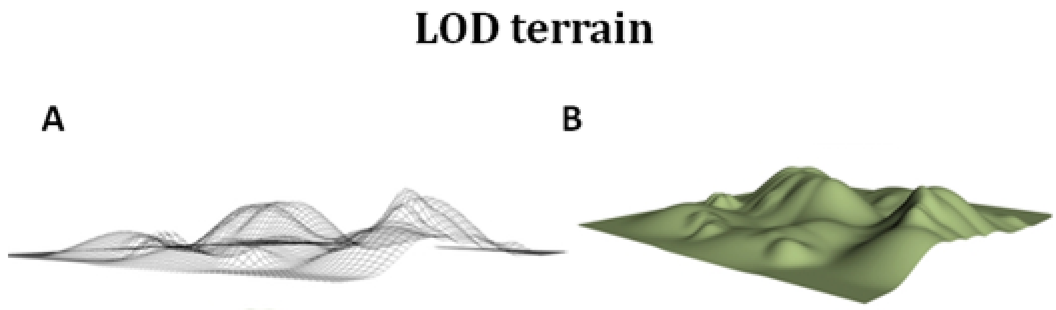
18 Could you recall more situations where 3D data might have been more useful? Objects?

19 Dosing of information

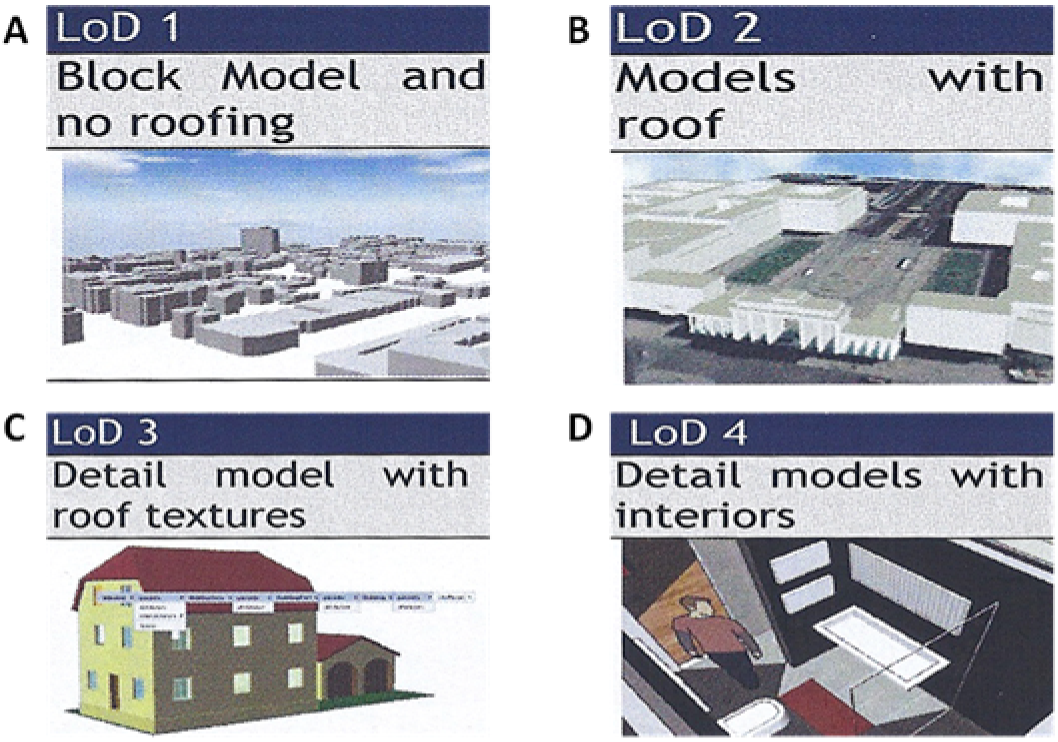
Main interview visuals for support

Figure 51: Interview visuals

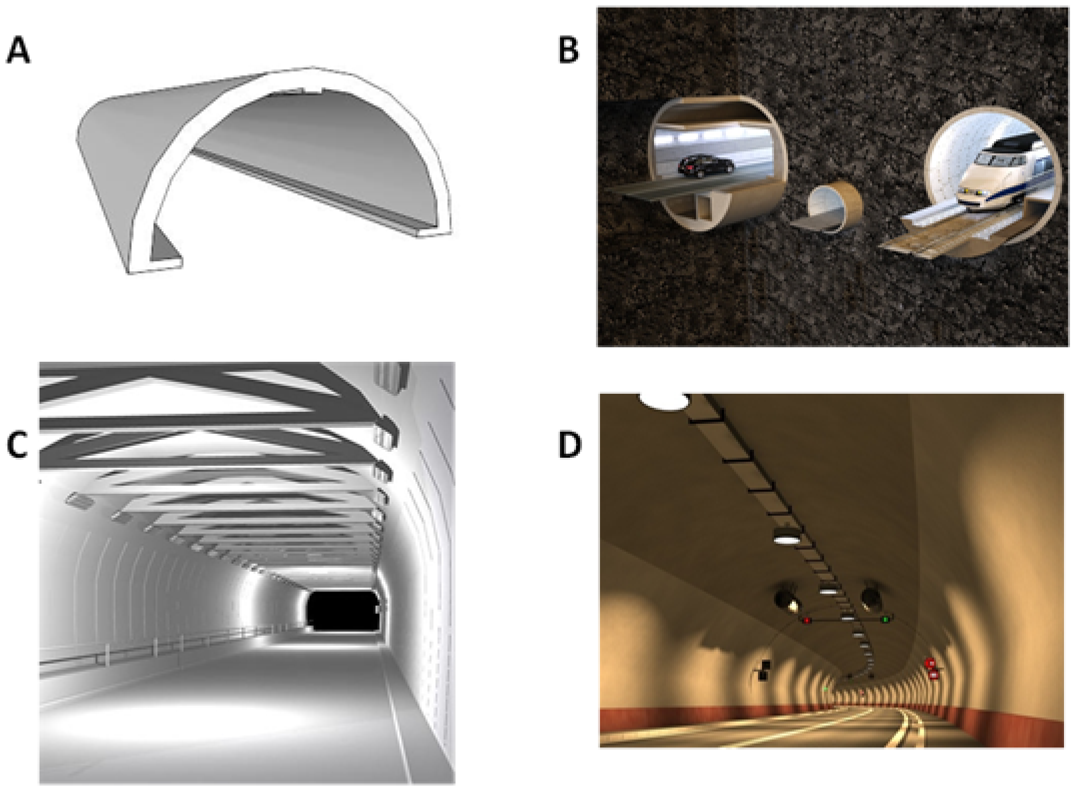




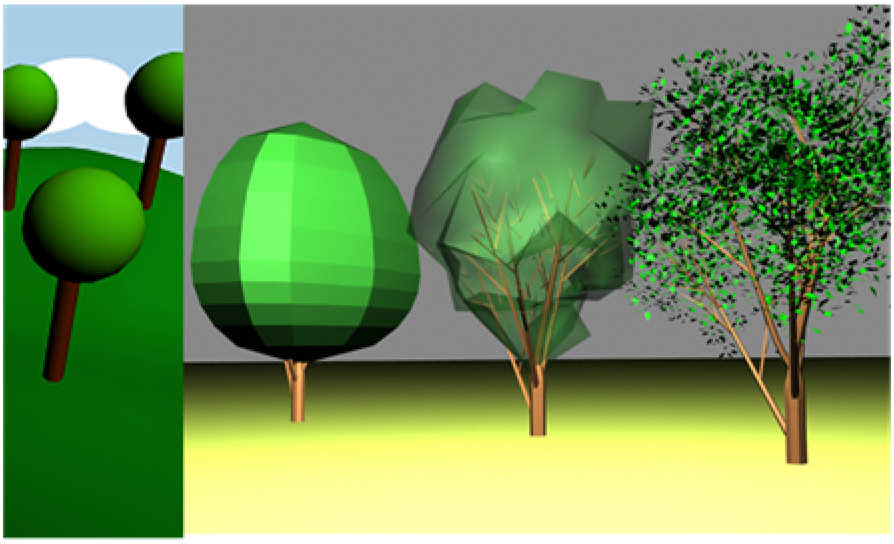
LOD Buildings



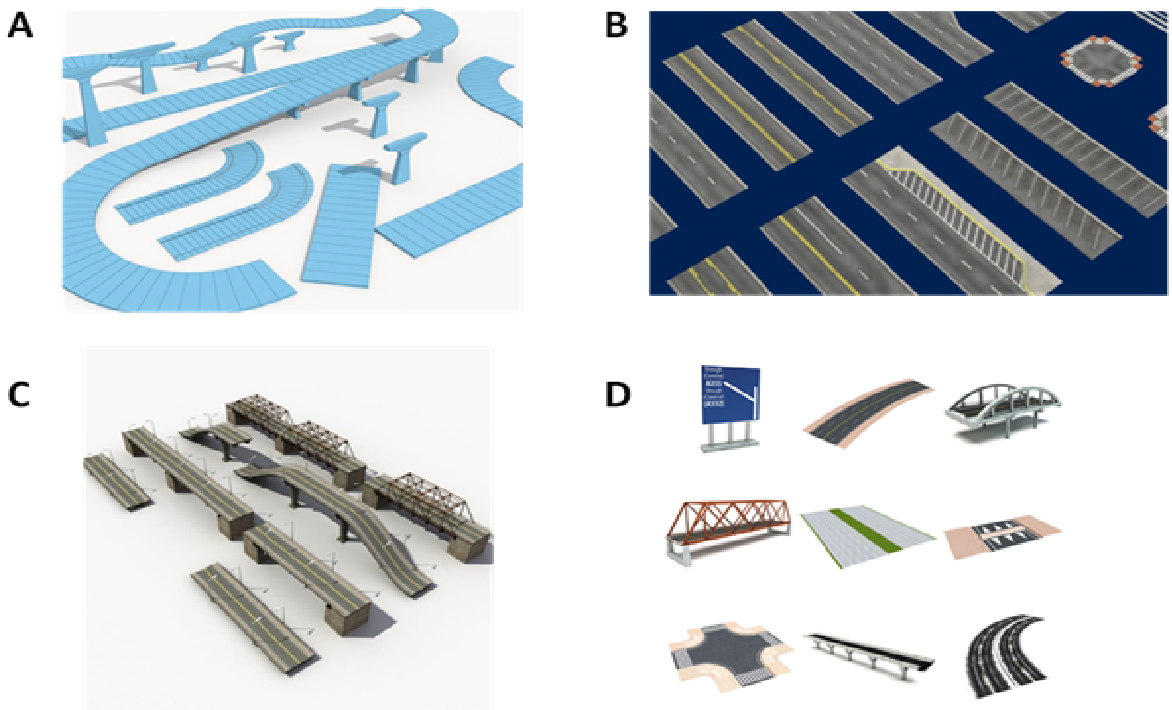
LOD Tunnel



LOD vegetation



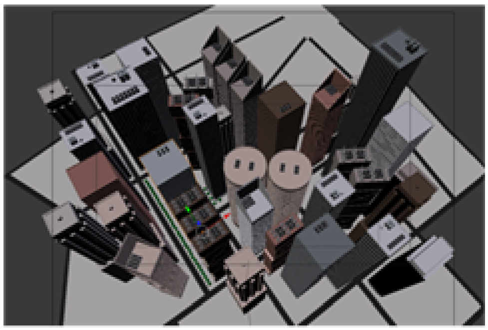
LOD Transportation



Scale and view

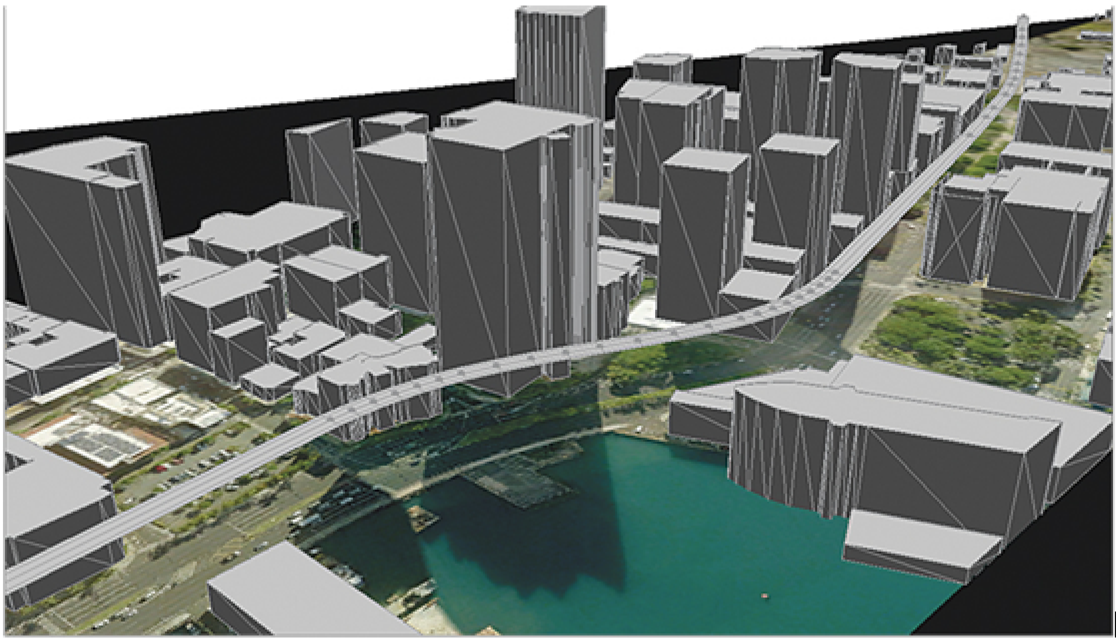
A

C



B

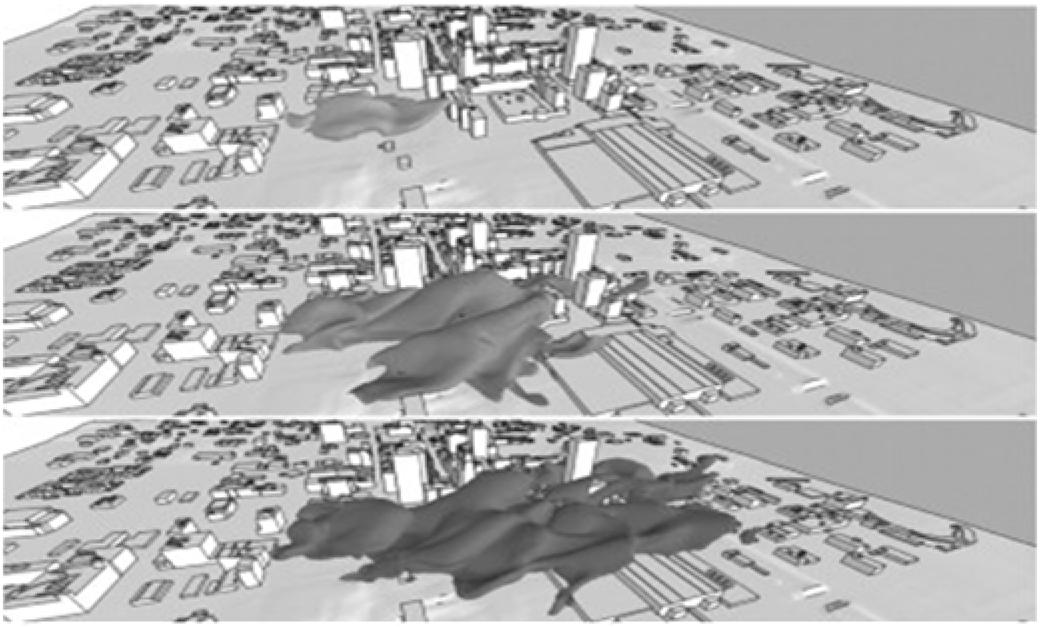
Geometry and texture



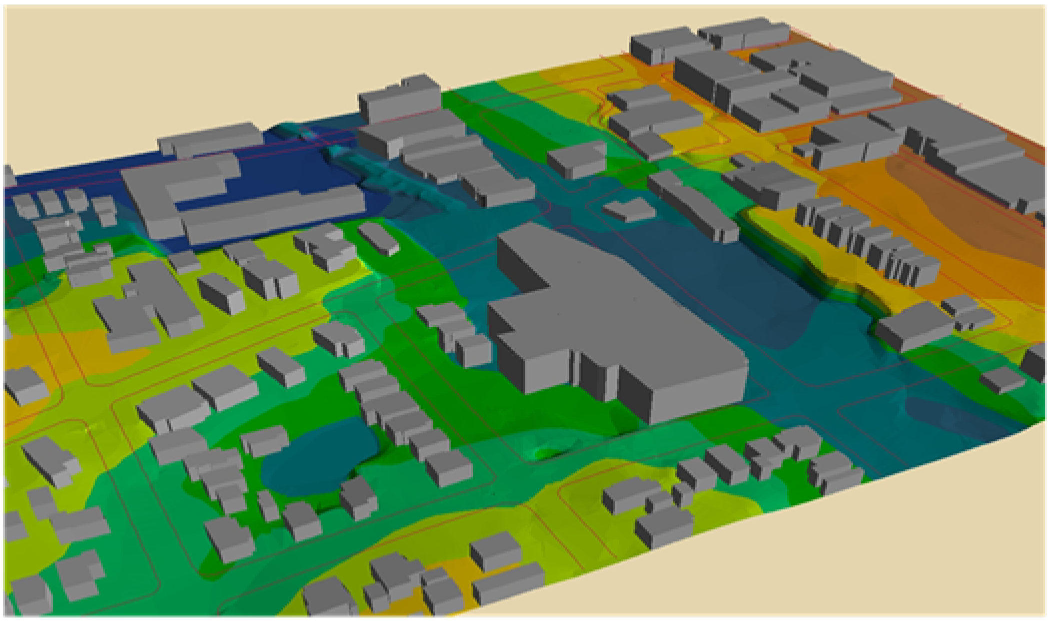
Resolution

Application Domain Extensions

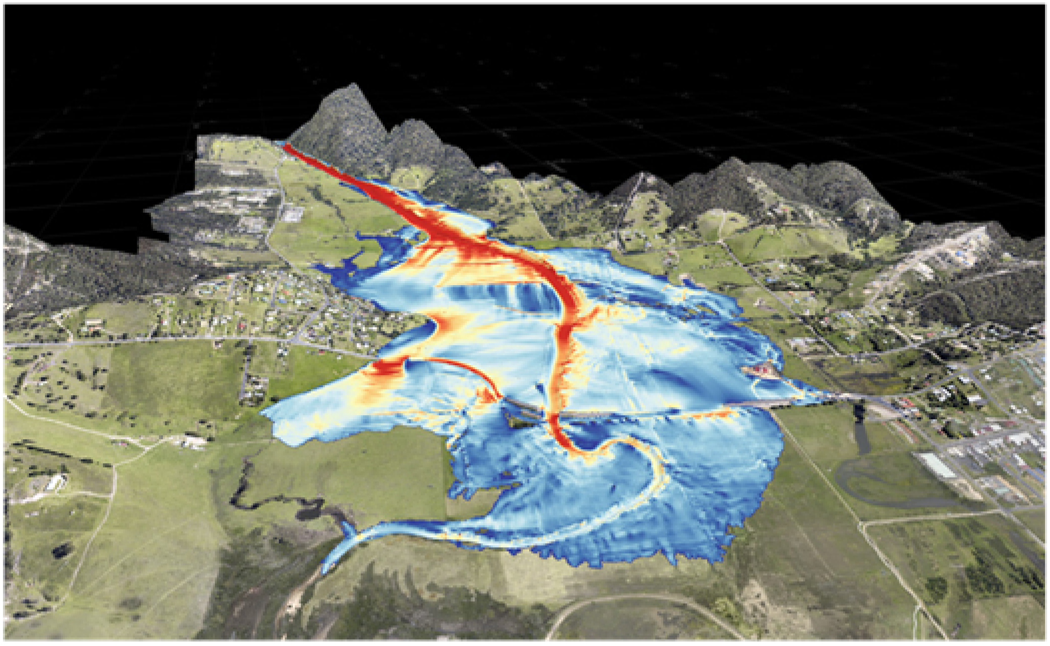
Gasmal



Flood

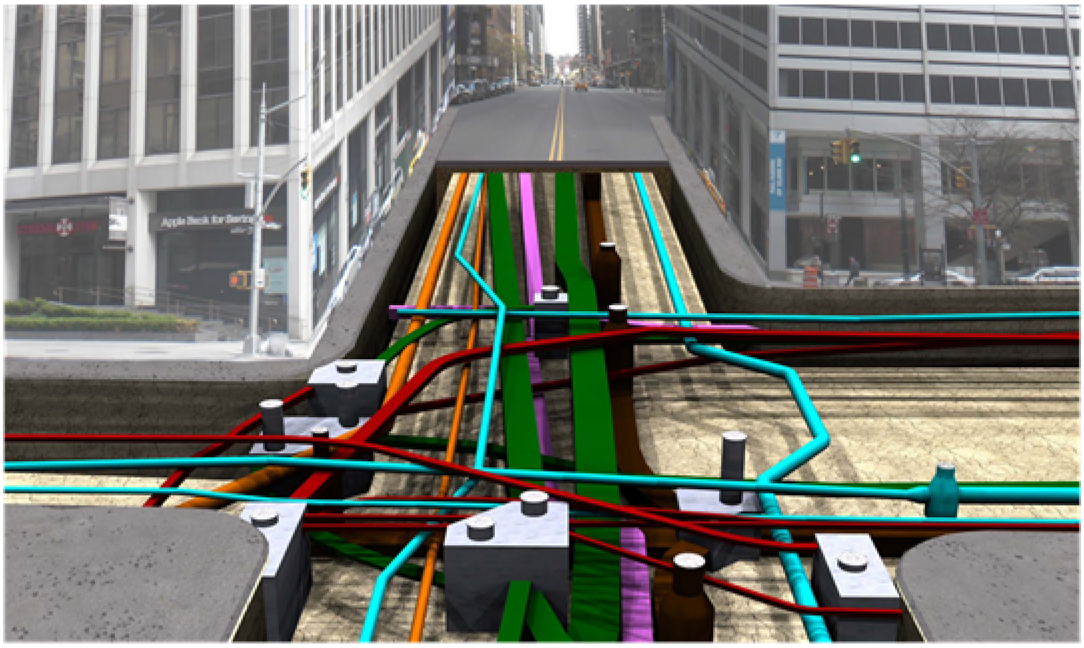


Water runoff



Rainfall runoff

Underground modelling



Evacuations

Appendix F – Example IMGeo UML

Building (in Dutch)

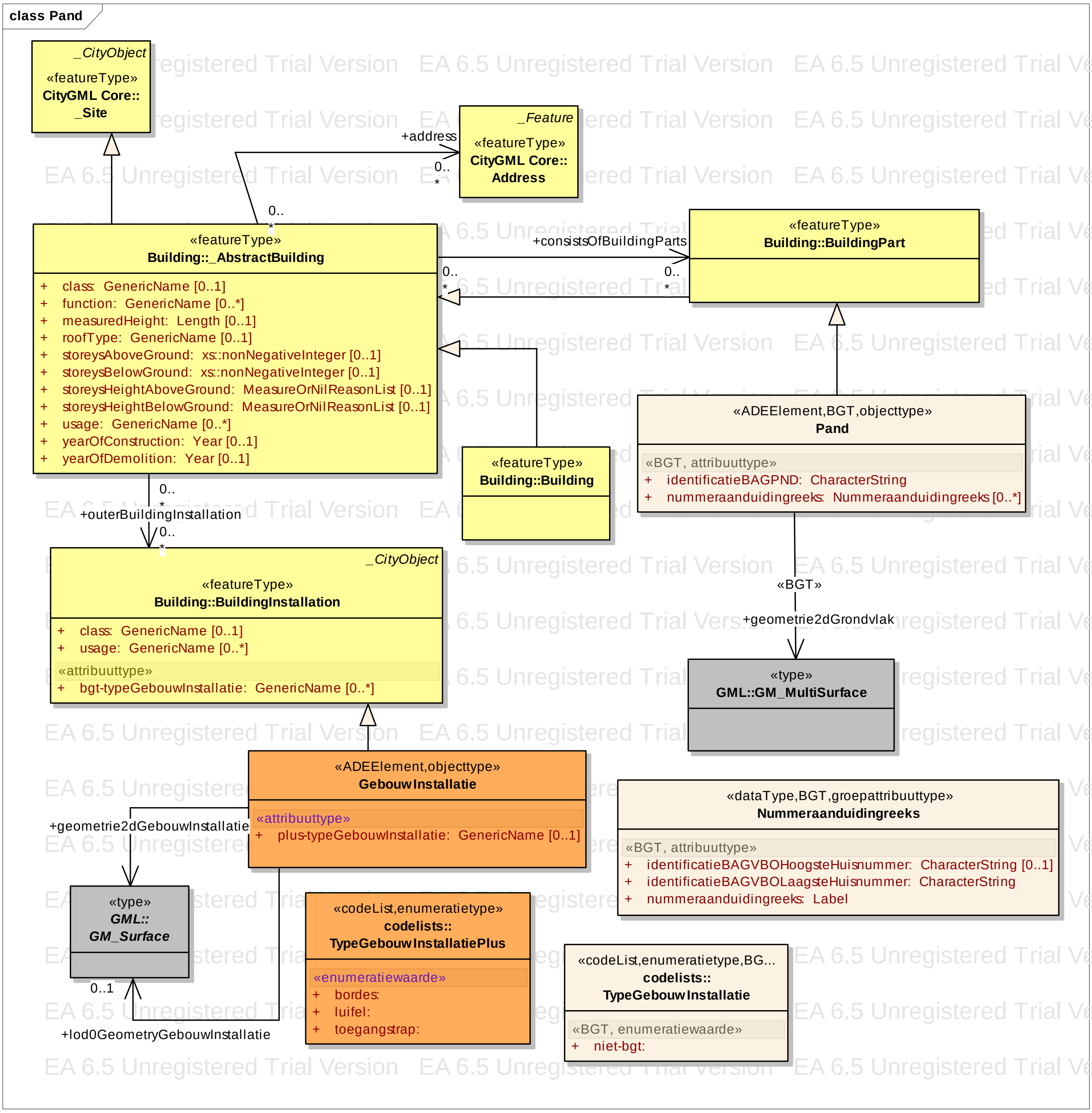


Figure 52: UML example building

Appendix G - List of experts

Interview

1. Rob Peters, Informationmanager (CIO) & Infocoordinator operationa crisisstaff, Safety Rgion Kennemerland

2. Erik Spronk, I-Bridge IVENT | Technischal integration Operations | Advice & Applications | Defense Materieel Organisatie

3. Patrick Brooijmans, I-Bridge - Functional integration Operations | Advice & Applications | Defense Materieel Organisatie

(4.) Jack Ruibing, Projectdirecteur, ambassadeur, serial innovator |Adviser fire department at fire department academy.

5. Hans Broekhuizen, Events advising | Team leader ROT | Leader Copi

6. Schelte Egbers, Risk control| Safety region | Fire department |

7. Jan Keuning, Manager bedrijfsbureau | Officer van GHOR IJsselland

8. Felix van der Meijden, Team Green, Noise, Air en External Safety | Department Testing and Permits Environment |Omgevingsdienst Haaglanden

9. Hans Peijen, General policy employee ACGZ GHOR-GGD Kennemerland

10. Jonh Vredenbregt, Head officer of fire department- Leader COPI | Compagnie commandant |Regional officer hazardous goods

11. Edith Langerak, Senior policy manager Crisis control at Safety region Rotterdam Rijnmond

12. Ingrid van der Kooij, Senior Policy employee Crisiscontrol at Safety region Rotterdam Rijnmond

13. Ellen Oude Kotte, Safety region Kennemerland I Account Schiphol/ Tata Steel I Brandweer district Oost

14. Richard Kamphuis, Information manager Safety Region IJsselland | Crisis control IM ROT

15. Anton Tanesha, employee Stafdirection Risico- en Crisisbeheersing at Safety Region Rotterdam-Rijnmond

Background information

Frans Copini, Dutch Institute technology Safety and Security | Copini Innovation Mediation | Police academy

Panayiotis Sophronides, Dipl.-Ing. Rural & Surveyor Engineer, MSc & DIC Hydrologist, Spatial Planner. Employee Geodan.

Azarakhsh Rafiee, Developer bij Geodan. University of Tehran Master of Science (MSc), Remote Sensing.

Appendix H – Interview results

Table 19: Interview results

	Rob Peters	Eric Spronk	Patrick Brooijmans	Jack Ruibing
A1	Informatiemanager (CIO) & Infocoordinator operationele crisisstaf Veiligheidsregio Kennemerland	I-Bridge IVENT | Technische integratie Operations | Advies & Applicaties | Defensie Materieel Organisatie	I-Bridge - Functionele integratie Operations | Advies & Applicaties | Defensie Materieel Organisatie	Projectdirecteur, ambassadeur, serial innovator Adviseur lectoraat Brandweerkunde bij de Brandweer academie
D111	A	A	A	B
D112	C	C	C	E
D113	A	A	A	C
D114	C	B	B	D
D115	A	A	A	C
D121	A	A	A	C
D122	C	C	C	C
D123	C	C	C	C
D124	B	A	A	A
D125	A	A	A	A
D126	C	C	C	B
D127	A	C	C	D
D128	A	A	A	C
D131	C	C	C	B
D132	B	C	C	E
D133	B	A	A	C
D134	C	B	B	D
D135	A	C	C	C
D141	A	A	A	B
D142	C	C	B	E
1D43	B	A	A	C
1D44	A	B	B	D
1D45	A	C	C	C
1D51	C	C	C	C
D152	A	B	B	B
D153	C	C	C	B
D154	A	A	A	A
D155	B	B	B	B
D156	C	C	C	C
D161	B	B	B	B

D162	C	C	C	C
D163	C	C	C	C
D164	B	B	B	D
D165	C	C	C	C
D171	A	A	B	B
D172	A	A	C	C
D173	B	B	C	C
D174	A	A	B	D
D175	A	A	C	C
D19				
D20	B	B	B	B
D21	BCA	BCA	BCA	BCA
D22	BDAGCEF	BDEGACF	BDEACGF	BEGACDF
D31	A	A	A	A
D32	A	A	A	A
D33	A	A	A	B
D34	A	A	A	A
D35	A	A	A	B
D36	A	A	A	B
D37	A	B	B	B
D38	A	A	A	A
D39	A	A	A	A
D310	ABCDFG	ABCDFG	ABCDFG	ABDEF
D311	A	A	A	B
D312	A	A	A	A
D313	A	A	B	B
D314	A	A	B	A
D315	A	A	B	A
D316	A	B	B	B
D317	A	A	A	B
D318	Rookverspreiding modelling	B	B	B

	Hans Broekhuizen	**Schelte Egbers**	**Jan Keuning**	**Felix van der Meijden**
A1	Evenementen Advisering | Leider ROT | Leider Copi	Risico beheersing | Veiligheids regio | Brandweer |	Manager bedrijfsbureau | Officier van Dienst GHOR Ijsselland	Team Groen, Geluid, Lucht en Externe Veiligheid Afdeling Toetsing & Vergunningverlening Milieu Omgevingsdienst Haaglanden
D111	A	A	B	C
D112	C	C	A	B

D113	A	A	A	A
D114	B	B	B	B
D115	A	C	C	C
D121	A	A	A	A
D122	C	C	A	C
D123	A	A	B	A
D124	A	A	A	A
D125	A	A	A	A
D126	C	A	B	A
D127	C	C	D	C
D128	A	A	C	A
D131	A	B	B	B
D132	C	C	A	E
D133	A	A	A	C
D134	B	B	B	B
D135	C	C	C	C
D141	A	A	B	C
D142	B	C	E	B
1D43	A	A	C	A
1D44	B	B	D	B
1D45	C	C	C	C
1D51	A	C	C	B
D152	A	B	B	A
D153	C	C	B	B
D154	A	A	A	C
D155	B	B	B	B
D156	C	C	C	C
D161	C	B	C	B
D162	B	C	B	A
D163	A	C	A	A
D164	B	D	B	B
D165	C	C	C	C
D171	A	A	C	A
D172	A	A	A	A
D173	A	B	A	A
D174	B	C	B	C
D175	C	A	C	A
D19				
D20	B	B	B	B
D21	BCA	BCA	BCA	BCA
D22	BDAGCEF	BDEAGCF	BFGECAD	BDAGCEF
D31	A	A	A	A
D32	A	A	A	A
D33	B	B	B	B
D34	A	A	A	A

D35	A	A	A	A
D36	A	A	B	A
D37	A	A	B	A
D38	A	A	A	A
D39	AB	A	A	A
D310	ABCDFG	ABDEF	BEF	
D311	A	A	A	A
D312	A	A	A	A
D313	A	A	A	A
D314	A	A	A	A
D315	A	A	A	A
D316	A	A	A	A
D317	A	A	A	A
D318	B	Rookverspreiding modelling	B	B

	Hans Peijen	**John Vredenbregt**	**Edith Langerak**	**Ingrid van der Kooij**
A1	Algemeen Beleidsmedewerker/ ACGZ GHOR-GGD Kennemerland	Hoofd officier van dienst Brandweer-Leider COPI | Compagnie commandant |Regionaal officier gevaarlijke stoffen	Afdelingshoofd Informatiemanagement | Veiligheidsregio Rotterdam-Rijnmond | Risico- en Crisisbeheersing | Informatiemanagement |	Functioneel Beheerder GEO
D111	C	A	A	A
D112	A	C	C	C
D113	A	A	A	A
D114	B	B	B	B
D115	C	C	C	C
D121	A	A	A	A
D122	A	A	C	C
D123	A	A	A	A
D124	A	A	A	A
D125	A	A	A	A
D126	B	C	C	C
D127	D	C	A	A
D128	C	A	A	A
D131	C	B	A	A
D132	B	E	B	B
D133	C	C	B	B
D134	B	B	C	C
D135	C	C	A	A
D141	C	C	C	C

D142	B	B	A	A
1D43	A	A	B	B
1D44	B	B	C	C
1D45	C	C	A	A
1D51	B	C	A	A
D152	A	A	B	B
D153	B	B	A	A
D154	C	A	A	A
D155	B	B	B	B
D156	C	C	C	C
D161	B	B	B	B
D162	C	C	C	C
D163	C	C	C	C
D164	D	D	D	D
D165	C	C	C	C
D171	A	C	A	A
D172	A	A	A	A
D173	B	B	B	B
D174	A	A	A	A
D175	A	A	A	A
D19				
D20	B	B	B	B
D21	BCA	BCA	BAC	BAC
D22	BGCDAFE	BADCEF	BADCEF	BDGACEF
D31	A	A	A	A
D32	A	A	A	A
D33	B	B	A	A
D34	A	A	A	A
D35	A	A	A	A
D36	A	A	A	A
D37	A	A	A	A
D38	A	A	A	A
D39	A	A	A	A
D310	ABCDEFG	ABCDEFG	ABCDEFG	ABCDEFG
D311	A	A	A	A
D312	A	A	A	A
D313	A	A	A	A
D314	A	A	A	A
D315	A	A	A	A
D316	A	A	A	A
D317	A	A	A	A
D318	B	B	B	B

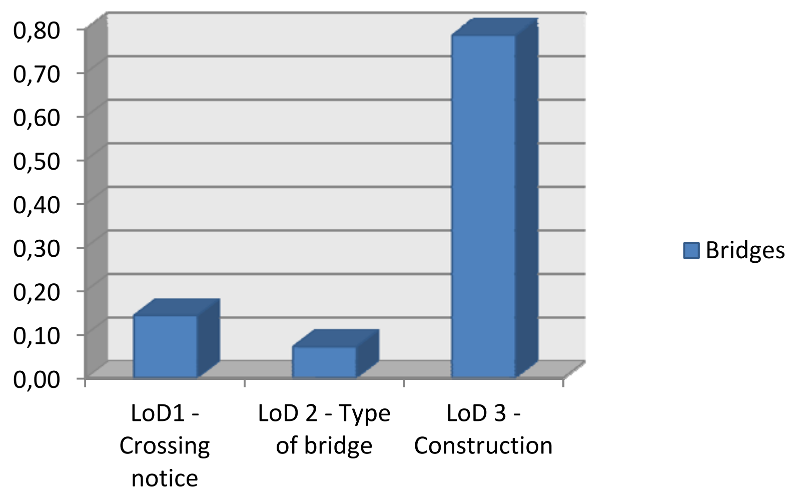
	Ellen Oude Kotte	**Richard Kamphuis**	**Anton Tanesha**
A1	Veiligheidsregio Kennemerland I Account Schiphol/ Tata Steel I Brandweer district Oost	ROT	Crisis beheersing - RR
D111	A	A	A
D112	C	C	C
D113	A	A	A
D114	B	B	B
D115	C	C	C
D121	A	A	A
D122	A	C	C
D123	C	C	A
D124	A	A	A
D125	A	A	A
D126	B	A	C
D127	D	A	A
D128	C	A	A
D131	C	A	A
D132	B	C	B
D133	A	A	B
D134	C	C	C
D135	A	A	A
D141	A	A	C
D142	B	C	A
1D43	B	A	B
1D44	B	B	C
1D45	C	C	A
1D51	C	A	A
D152	B	B	B
D153	B	C	A
D154	A	A	A
D155	B	B	B
D156	C	C	C
D161	B	B	B
D162	C	C	C
D163	C	C	C
D164	D	D	D
D165	C	C	C
D171	A	A	A
D172	A	A	A
D173	B	B	B
D174	A	A	A

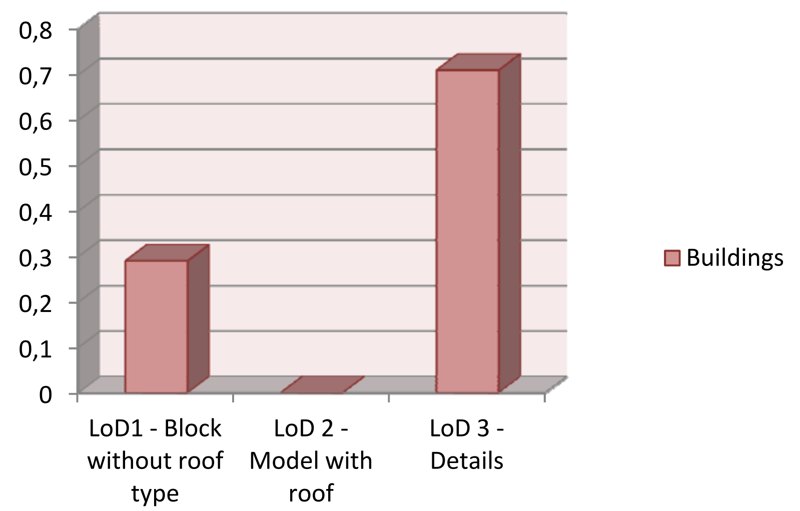
D175	A	A	A
D19			
D20	B	B	B
D21	BAC	BAC	BAC
D22	BDAGCEF	BGACDEF	BDGACEF
D31	A	A	A
D32	A	A	A
D33	A	A	A
D34	A	A	A
D35	A	A	A
D36	A	A	A
D37	A	A	A
D38	A	A	A
D39	A	A	A
D310	ABDEF	ABCDEFG	ABCDEFG
D311	A	A	A
D312	A	A	A
D313	A	A	A
D314	A	A	A
D315	A	A	A
D316	A	A	A
D317	A	A	A
D318	Pipes modelling	B	B

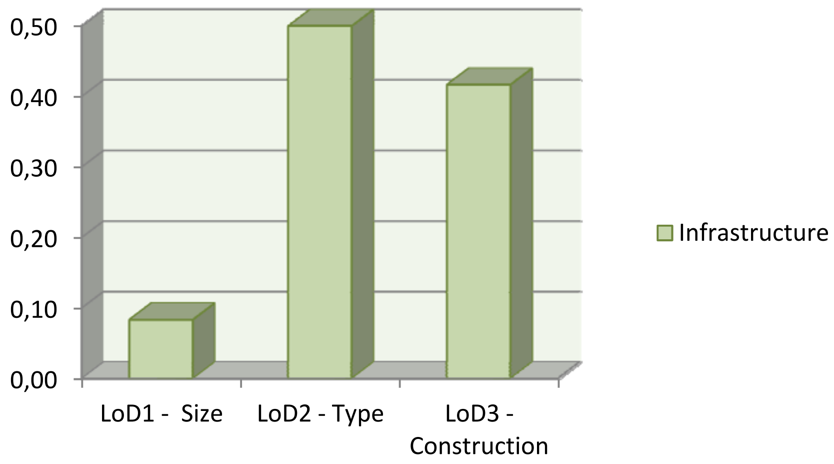
Appendix I - Diagrams user requirements

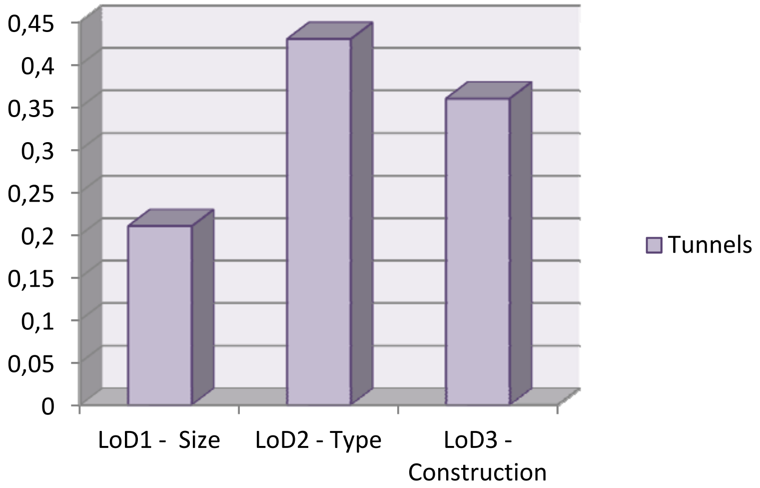
Chart 8: Diagrams user requirements

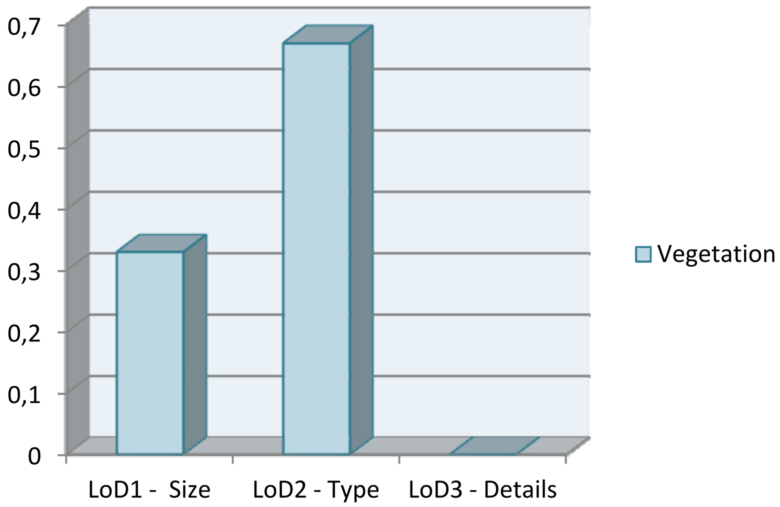
Levels of detail

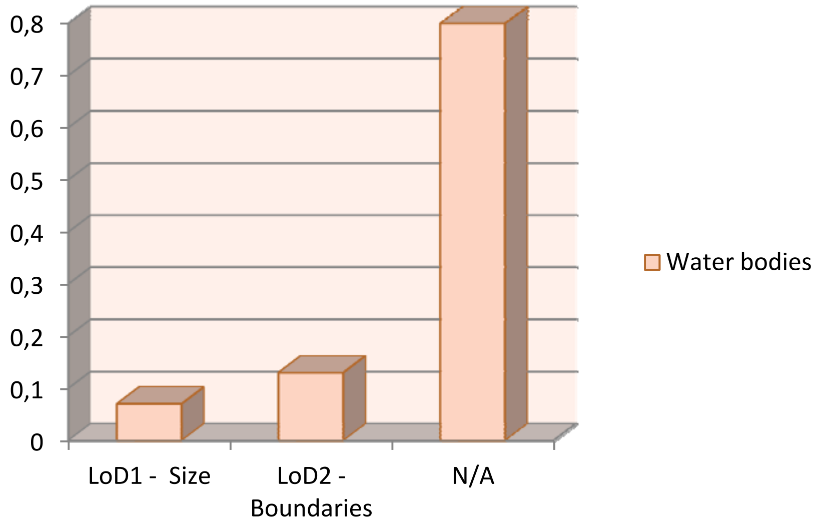


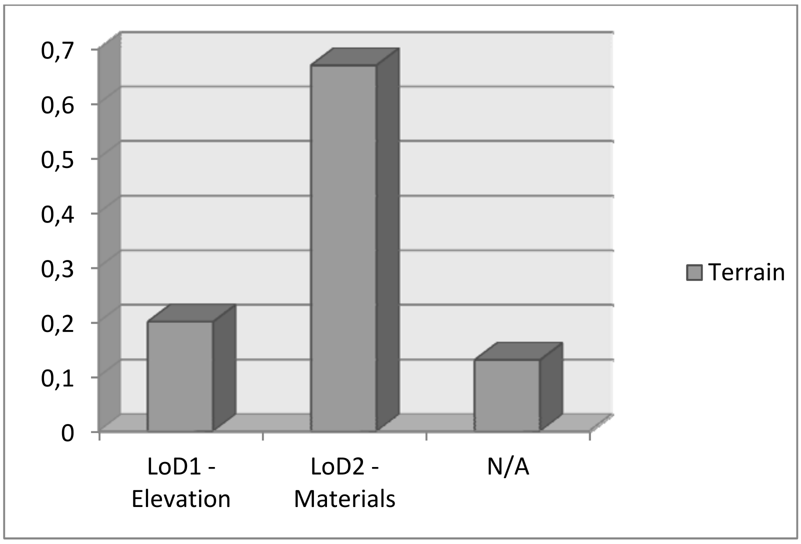



0,50
0,40
0,30
0,20
0,10
0,00
LoD1 - Size
LoD2 - Type
LoD3 - Construction
Infrastructure


0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
LoD1 - Size
LoD2 - Type
LoD3 - Construction
Tunnels

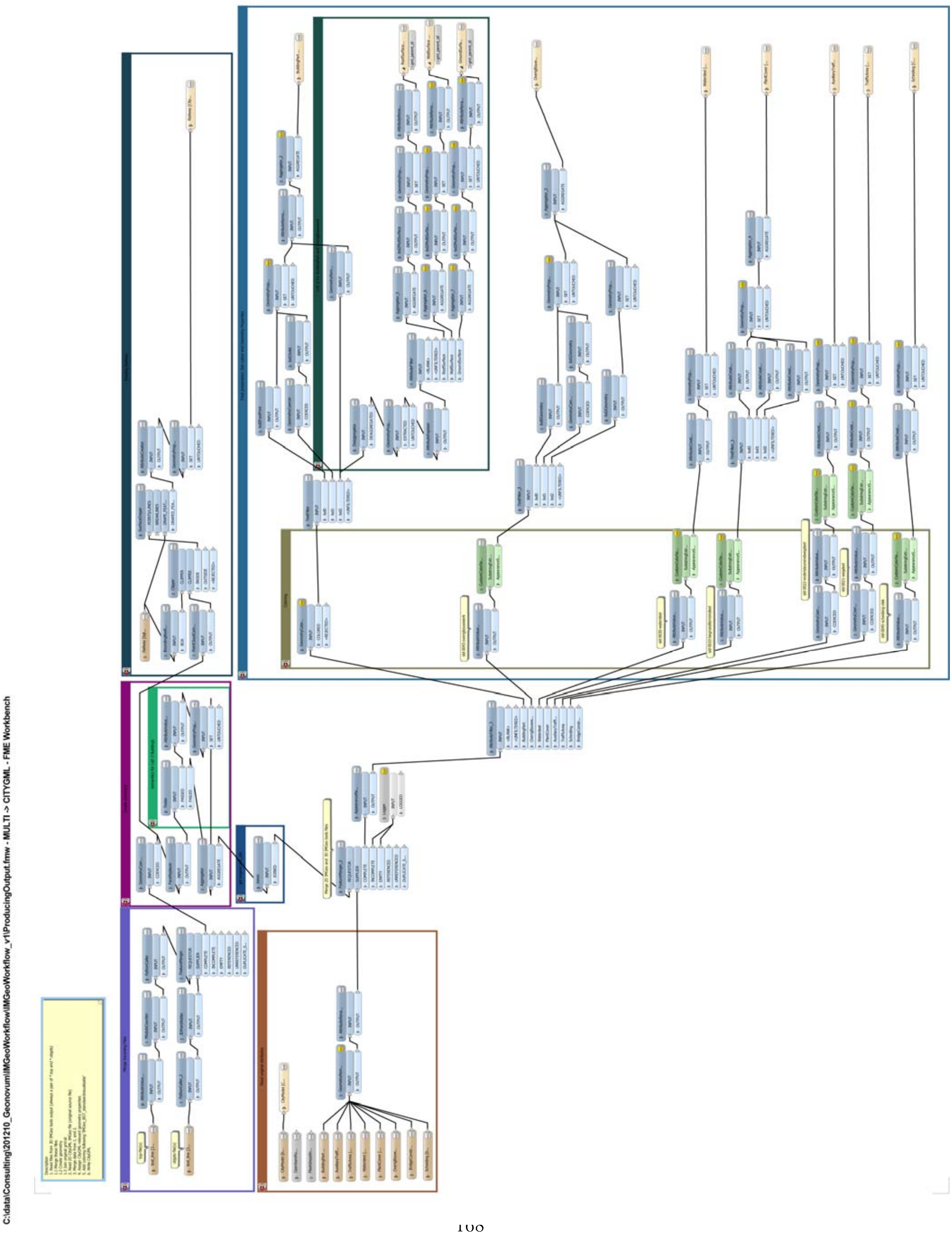

0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
LoD1 - Size
LoD2 - Type
LoD3 - Details
Vegetation


0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
LoD1 - Size
LoD2 - Boundaries
N/A
Water bodies


0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
LoD1 - Elevation
LoD2 - Materials
N/A
Terrain

Appendix J – Schematic overview of output IMGeo to CityGML

Figure 53: Schematic overview of output IMGeo to CityGML



Appendix K – Scenarios

Appendix K represent a list of the disasters, scenarios, in the Netherlands as stated by the Dutch government and some additional scenario that might not be directly related to a disaster but are grouped for efficiency purposes anyway. Some scenario groups has subgroups to make a further distinguish between the types of scenarios. For each scenario or its subgroups, objects are stated that are to be modelled in 3D as a package when a user clicks that scenario. Some scenarios require objects that are already preset in another scenario (e.g. flood with failure of power network) to make the model even more efficient.

Scenarios in relation to traffic and transport

1. Aviation accident

- Network: High ways
  Motor roads
  Provincial roads
  Urban roads
  Airports
- Additional: Road signs
  Cameras
  Hospitals

2. Accident on water

- Network: High ways
  Motor roads
  Provincial roads
  Urban roads
  Harbour
  Buoys
- Additional: Road signs
  Harbour signs
  Cameras
  Hospitals
- Coast guard

3. Traffic accident on land

- Network: High ways
  Motor roads

	Provincial roads
	Urban roads
	Railroads
	Metro stations
	Metro tunnels
	Tram lines
	Train stations
	Remises
▪ Additional	Road signs
	Cameras

- Scenarios with dangerous material

4. Accident with inflammable/ explosive material (in open air)

- Traffic on land scenario
- Failure of gas network scenario

- Public health scenario
- Industry — Risk sites; Storage facilities hazardous goods

- Shelters
- Hospitals

5. Accident with toxic gasses (in open air)

- Traffic on land scenario

- Public health scenario
- Failure of gas network scenario

- Shelters
- Hospitals

6. Nuclear accident

- Public health scenario

▪ Sources	Nuclear power plants
▪ Network	Waste storage
	Access routes
▪ Additional	Nuclear shelters
	Decontamination sites

Equipment inventory locations
Pharmaceutical wholesale depots
Riot and panic mob control (police stations, mil. barracks)
Evacuation routes
Quarantine locations
Civil and military helicopter locations

Scenarios in relation to public health

7. Threat to public health

- Hospitals — Specialised hospitals
  - Hospitals with quarantine capabilities
- Pharmacies — Import depots
  - Pharmacies
  - Vaccine depots
- Medical equipments supplies
  - Producers
  - Importers with stock
- Med.evac. — Ambulance locations
  - Secondary ambulance locations
  - Helicopter first aid teams
- Veterinarians
- Morgues
- Research & expertise centres
- Private clinics
- Revalidation centres
- Dentists with surgical specialisation
- Public shelters

8. Dispersal of disease

- Hospitals — Specialised hospitals
  - Hospitals with quarantine capabilities
- Pharmacies — Import depots
  - Pharmacies
  - Vaccine depots
- Medical equipments supplies
  - Producers

Importers with stock

- Medical evacuation
  - Ambulance locations
  - Secondary ambulance locations
  - Helicopter first aid teams
- Veterinarians
- Morgues
- Research & expertise centres
- Private clinics
- Revalidation centres
- Dentists with surgical specialisation

Scenarios in relation to infrastructure

9. Accidents in tunnels

- Network
  - High ways
  - Motor roads
  - Provincial roads
  - Urban roads
  - Railroads
  - Metro stations
  - Metro tunnels
  - Tram lines
  - Train stations
  - Remises
- Additional
  - Road signs
  - Cameras
  - Tunnel ventilation

10. Fire in big buildings

- Public health scenario
- Sources
  - Buildings
  - Other constructions
- Traffic accident on land scenario

11. Collapse of big buildings

- Public health scenario

- Sources — Buildings
  Other constructions
  Bridges
- Additional — Construction of buildings
  Function of buildings

12. Disruption of utility

- Traffic accident on land scenario

Scenarios in relation to population

13. Panic in large groups

- Traffic accident on land scenario
- Public health scenario

14. Large-scale disturbance of public peace

- Traffic accident on land scenario
- Public health scenario

Nature disaster

15. Flood

- Scenario of failure electricity network
- Sources — Primary and secondary dikes
  Delta works
  Sluices
  Water reservoirs
- Network — Piping network
  Pumping stations
  Waterways
  Canals
- Harbour infrastructures
- Buoys
- Waste water piping network
- Water meters
- Drainage well
- Water network well

- Users — Household network connections
  Industrial network connections

- Additional — Power grid structures and contingency options
  Still dry (higher) long strip aerodromes for international aid
  Location military emergency pontoons
  Civil and military helicopter locations

16. Nature Fire

- Sources — Vegetation
  Housing
  Industry
- Extinquish — Water basins
  Water taps
  Ground water
  Fire stations
  Airport fire teams
- Control — Function buildings

17. Extreme weather conditions

- Flood scenario
- Nuclear disaster scenario

Scenarios on distance

18. Incident out of city boundaries, in which citizens of that city are involved

- Traffic accident on land scenario

Additional scenarios

19. Terrorist attack

- Nuclear disaster scenario
- Public health scenario
- Toxic gasses scenario
- Law enforcement/Military scenario

20. Failure of gas network

- Sources
  - Production fields
  - National border crossing stations
  - Harbour jetties
  - LNG storage
  - Coastal transition locations of North Sea gas to land based network
  - Drillings rigs
- Network
  - Piping network
  - Major block valves
  - Check valves
  - Safety relief valves
  - Letdown stations
  - Pressure and flow sensors
  - Control stations
  - Bypass routes
  - Boost compressor stations
- Users
  - Gas fired power stations
  - Heavy industry power generation
  - Green houses
  - Tie-ins with chemical plants
  - Households low pressure network connections
  - Export connections

21. Failure of electrical network

- Sources
  - Coal fired power stations
  - Electrical fired power stations
  - Nuclear power stations
  - Waste-to-energy incinerators
  - Bui fermentation power
  - Solar power fields
  - On shore windmill units
  - Off shore windmill parks
  - Industrial supply sources
- Subsea network
  - 450kV marine grid
- High voltage network
  - 380 kV backbone grid
  - 150 kV network

50 kV network

- Medium voltage network

  10 kV

- Low voltage network

  650 V Industry power

  380/400 V "krachtstroom"

  220/230 V Household power

- Transformer stations
- Major grid interconnect stations
- Masts
- Cross border grid connections
- Surge protection switches
- Separation switches
- Control stations

23. Failure of telecom network

- Data centres
- Relay masts
- Fibre networks
- Satellite reception stations

24. Law enforcement and military

- Police Police stations

  Patrol car locations

  Heavy equipment locations

  Arms depot

  Shooting ranges

  Precinct jails

  Harbour police locations

  Fleet

  Helicopter and small fixed wing aircraft locations

- Royal marshalls

  Schiphol airport section

  Mational reguinal command centres

  Heavy equipment locations

  Patrol ships

- Central security services
  - AIVD Headquarters
- Coast guard
  - Command center
  - Helicopter units
  - Berths
- Prisons
- Army
  - National command center
  - Barracks
  - Depots
  - Training camps
  - Heavy equipment
  - Medical regiment
- Navy
  - National command center
  - Harbours
  - Helicopter bases
  - Marines
- Air force
  - National command center
  - Airfields
  - Helicopter fields
  - Missile units

Appendix L – Tables of UML flood classes

Table 20: Functional area class and Hydro object class

Class	FunctionalArea	
Definition	Limited and appointed area that is a functional unit described.	
Origin definition	NEN3610	
Gathering line		
Generalisation	This class is a main class of the flood model. With this it is the generalisation class of the other classes in the model.	
Specialisation	GeoObject	
Attributes:		
typeFunctionalArea	Further indication of the type of functional area.	Optional
Associations		
Explanation	Use / examples: industrial, bungalow, gardening, cemetery, marina, wind farm, recreation, nature.	

Class	Hydrobase	
Definition	Limited and appointed area that is a functional unit described.	
Origin definition	NEN3610	
Gathering line		
Generalisation	This class is a main class of the flood model. With this it is the generalisation class of the other classes in the model.	
Specialisation	FunctionalArea	
Attributes:		
Location_ID		Required
GeographicalName		Optional
Associations		

Table 21: Weir class

Class	Weir	
Definition	Weirs	
Origin definition	IMWA	
Gathering line		
Generalisation	This class is a sub class of sources.	
Specialisation	Sources	
Attributes:		
plus-type: Generic Name	Generic name and the possibility to define further through a code list	Required
Associations		
Explanation	Weir failure can cause a flood.	

Table 22: Waters class

Class	Waters	
Definition	Waters that were created by man and naturally formed	
Origin definition	IMGeo	
Gathering line		
Generalisation	This class is a sub class of network.	
Specialisation	Network	
Attributes:		
plus-type: Generic Name	Generic name and the possibility to define further through a code list	Required
Associations		
Explanation	These waters can overflow or take in water.	

Table 23: Harbour class

Class	Harbour
Definition	A harbour (see spelling differences), or haven, is a body of water where ships, boats, and barges can seek shelter
Origin definition	IMGeo
Gathering line	
Generalisation	This class is a sub class of network.
Specialisation	Network

Attributes:		
plus-type: Generic Name	Generic name and the possibility to define further through a code list	Required
Associations		
Explanation	These waters can overflow or take in water.	

Table 24: Pipes class

Class	**Pipes**	
Definition	A harbour (see spelling differences), or haven, is a body of water where ships, boats, and barges can seek shelter	
Origin definition	IMKL, IMWA, IMGeo	
Gathering line		
Generalisation	This class is a sub class of network.	
Specialisation	Network	
Attributes:		
plus-type: Generic Name	Generic name and the possibility to define further through a code list	Required
Associations		
Explanation		

Table 25: Connectors class

Class	**Connectors**	
Definition	A connector to a house hold or an industry from the water network	
Origin definition	IMKL	
Gathering line		
Generalisation	This class is a sub class of users.	
Specialisation	Users	
Attributes:		
plus-type: Generic Name	Generic name and the possibility to define further through a code list	Required
Associations		
Explanation	Connectors provide information of which pipes go to which users.	

Table 26: Electricity class

Class	Electricity	
Definition	A connector to a house hold or an industry from the water network	
Origin definition	IMKL	
Gathering line		
Generalisation	This class is a sub class of other.	
Specialisation	Other	
Attributes:		
plus-type: Generic Name	Generic name and the possibility to define further through a code list	Required
Associations		
Explanation	Flooding can be extra risky near electricity structures.	

Table 27: WaterMeter class

Class	WaterMeter	
Definition	A connector to a house hold or an industry from the water network	
Origin definition	IMGeo	
Gathering line		
Generalisation	This class is a sub class of other.	
Specialisation	Other	
Attributes:		
plus-type: Generic Name	Generic name and the possibility to define further through a code list	Required
Associations		
Explanation	Water meters are relevant for monitoring a flood.	

Table 28: Evacuation locations class

Class	EvacuationLocations
Definition	A connector to a house hold or an industry from the water network
Origin definition	Top10NL, IMRO
Gathering line	
Generalisation	This class is a sub class of other.
Specialisation	Other

Attributes:		
plus-type: Generic Name	Generic name and the possibility to define further through a code list	Required
Associations		
Explanation	Evacuation locations provide information for emergency evacuation.	