Formal modelling of tasks to support search of geo-information in emergency response

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Abstract
Many Command& Control or Early warning systems have been developed providing access to large amounts of data (and metadata) via geo-portals, or by accessing predefined data sets relying on Spatial Data Infrastructure. However, the users involved in emergency response are usually not geo-information specialists and they lack the deep understanding about the spatial data structures and corresponding terminology. Formal modelling, semantic web and knowledge engineering approaches applied to geo-data can bring significant improvements in these directions. This paper presents a formal modelling of the tasks of the emergency responders in the Netherlands. Having the tasks of the actors well specified, it is possible to define the geo-information needed for completing the task.

1 Introduction

Emergency response procedures may significantly differ per country because they reflect the vulnerability and preparedness for disasters, which is specific for each country. Some countries are exposed to earthquakes, others to flood and fires; fire brigade and police might be the primarily responders in some countries, while in others civil protection centres or other governmental institutions may take the lead. However, all governments have legislations that prescribe work-flows and procedure for emergency response. A plenty of procedures for emergency response are also available on the Web, such as in the Netherlands (www.minbzk.nl/english/subjects/public-safety), for school safety in Australia (www.crisis.sa.edu.au/), and FEMA (www.fema.gov/plan/ehp/response.shtm), OSHA (http://www.osha.gov/SLTC/emergencypreparedness/) in USA. Using these documents and analyzing the work of the emergency responders, it is possible to specify what kind of data might be of primarily interest when performing a certain task. This approach is expected to help in reducing the information flows to only those portions of data needed for the specific task. This is especially critical for geo-information, since the emergency responders are not geo-specialist and may need more time in reading and perceiving maps. The geo-information used in emergencies is quite diverse ranging from topographic maps to specialized cadastre, soil, utility, road, etc. maps. All these data sets may use terminology, presentation and symbology, which are very specific for a particular domain.

A conceptualisation is required to make the knowledge (or to establish the relations) between the tasks of the actors and the data (and information) explicit and usable. Different conceptualization approaches can be used to formally express this knowledge, e.g. description logics, ontology, object-oriented modelling (Baader et al 2005, Dolbear and Hart, 2008, Harmelen 2008, Zlatanova et al 2006, Xu and Zlatanova 2007, Pund 2008). Thought all of them have advantages and disadvantages (e.g. Xu et al 2008). In this paper, a formal object-oriented modelling is applied and more specifically the Unified Modelling Language (UML) is used. UML is used to represent application structures, behaviours, architecture, business process and data structures (www.uml.org). There are nine types of UML diagrams, but for the scope of this paper only the class diagram (Bell 2004) is used. A class diagram gives an overview of a system by showing its classes and the relations among them and as such it is static.

This paper presents our approach for formal modelling of emergency response processes and tasks in Netherlands in order to define the data (information) needs per task. The study is concentrated on geo-information, but some non-geographical data are considered as well. Next section explains the emergency response management in the Netherlands. Section 3 presents briefly the conceptualisation of the emergency response processes. Section 4 discusses in detail the formal modelling of actors, tasks and information in two processes and analyzes the results. Section 5 addresses next steps and future developments.

2 Emergency response in the Netherlands

The Netherlands has well-defined procedures for emergency response that have been presented in various papers (Borkulo et al 2005, Diehl et al 2006, Neuvel and Zlatanova 2006, Snoeren et al 2007, Xu and Zlatanova 2007, Dilo and Zlatanova 2008). The overall legislation and manner of work will only briefly presented here.

Emergency response processes in the Netherlands are legally arranged within the Law for Disasters and Large Accidents (WRZO, http://wetten.overheid.nl/). The document provides definitions, describes responsibilities, manner of working, levels of emergencies, and provides classification of disasters. The organization of emergency response in the Netherlands is divided into a local level (at the site of an incident), a regional level (involving several municipalities), a provincial level and a national level. Most emergency incidents of a minor nature are responded at the local level. Within this operational structure, the local fire chief has the primary operational responsibility for the on-site coordination of local disaster response. The Mayor of the municipality the incident is taking place has the overall responsibility. If the magnitude of an incident increases, then a regional coordination team will be formed in liaison with the operational coordination team at site. The regional coordination team is often situated in a regional office remote from the incident (e.g. a joint office of the regional emergency services). If a regional coordination team is formed, then the mayor of the municipality in which the incident is taking place takes the administrative lead. On municipality level, a policy team is formed to support the Mayor.

Several more structures can be involved when the disaster incident transcends administrative borders e.g. a municipal, provincial or national border. If the effects of an incident transcend provincial borders (e.g. a toxic cloud after a nuclear incident) the Ministry of Internal Affairs may take the administrative lead. They will work together with coordination teams at national, provincial, regional and local level to manage and mitigate the disaster. For example, in an imminent flood, experts from the Water Board, the Ministry of Transport, Public Works, and Water Management will be heavily involved. In case of major flood, a cooperation up to the international level may be established, e.g. during floods from the river Rhine or Meuse, the Belgium and Germany emergency authorities are consulted (Rosenthal et al 1998).

Response and short-term recovery can be categorized into four different clusters, namely *containment and control of the disaster and its effects*, *public order and traffic management*, *medical assistance*, and *taking care of the population*. A cluster is made of several processes (in total 25) that are responsibility of mainly one of the emergency response sectors (police, fire brigade, municipality, medical care). The fire brigade units have a leading role in the containment and control of a disaster and its effects. In the Netherlands, the fire brigade is usually organized at a municipal level and has equipment not only for fighting fire, but also for performing various measurements related to release of dangerous substances in the air, water or in the soil. The fire brigade is also responsible for alarming the citizens is case of emergency using the net of stationary sirens. Generally the fire brigade is obliged to maintain a fire brigade call centre, but the tendency of the last years is to maintain a common call centre (together with the police and medical care). Several other organizations may also take a part in the containment and control, if the operational organizations (i.e. first responders) need support. For example, in case of flood (a major threat in the Netherlands) Directorate-General for Public Works and Water Management (Rijkwaterstaat, http://www.rws.nl/), the Dutch National Reserve (http://www.natres.nl/), the Royal Dutch Water Life Saving Association (KNDRD, http://www.rednet.nl), the Royal Netherlands Sea Rescue Institution (KNRM, http://www.knrm.nl) and Search and Rescue (SAR, http://www.werkenbijdemarine.nl/) can be involved. Some of these institutions, e.g. KNRM, SAR follow emergency scaling, which differs from the ones described in WRZO.

The police forces are responsible for processes from the second cluster, which are related to evacuation of citizens from affected areas, clear threatened areas, protect shelters and commando centers, controlling traffic, etc. In most cases the police are working under the authority of the mayor. In some special cases (e.g. criminal cases), the High Officer of Justice is taking the lead (together with the mayor and the regional police chief).

The third large cluster comprises processes related to medical assistance. Key actors are the Ambulance Central Point (CPA), ambulances, hospitals, and Communal Health organization (responsible for general health issues such as prophylactic medical inspections, vaccinations, etc.). Compared to the fire brigade and police, the medical help is quite independently organized and does not directly depend on any local administrations. In case of emergency, however, a regional medical official is appointed who takes the lead within the medical help (similar to the regional officers in fire brigade and police structures). The medical teams during emergencies operate under the abbreviation GHOR, Medical Assistance in case of Accidents and Disasters. One hospital is dedicated to the victims of large disasters. The SIGMA teams of the Netherlands Red Cross (NRD, http://www.rodekruis.nl/) and special ambulance teams can be formed and included in the medical help operations. NRD is usually involved only in large disasters, requiring help and evacuation of many people, such as floods.

Besides the overall responsibility for disaster management (under the authority of the mayor), the municipal structures are responsible for processes related to taking care of the population such as informing citizens, accommodating non-injured people from affected areas, registering casualties, etc. Generally the municipalities have to take care of good preparation of response sectors as well as citizens. Therefore, the municipality has to prepare (and update every 4 years) the disaster management plan. The disaster management plan describes the most important types of disasters at the territory of the municipality and the way of dealing with a particular emergency. Responsibilities, tasks and all required medicaments, shelters, reserves of food and clothes, etc. are also part of the disaster management plan.

The complexity of incident is measured by the impact and the area it covers. More actors are getting involved in a process if the incident affects the territory of more than one municipality. In this case a special Regional Operational Team (ROT) will be formed, which will take the lead for managing the emergency. The complexity of the incidents is reflected in the GRIP levels (Coordinated Regional Incident Suppression Procedure, MBZ, 2003), which are discussed in (Borkulo et al, 2005). Level 1 (GRIP 1) is coordinated by the Operational team on the place of incident (COPI), GRIP-2 requires involvement of the Mayor and formation of ROT. GRIP3 and GRIP 4 requite establishment of several more managing teams at provincial or national coordination centres (for GRIP4).

3 Formalising the processes in emergency response

Xu et al, 2008 have presented the *process*, *tasks*, *sector*, *actor* and *information* (data) as the most important concepts in the emergency process in the Netherlands (Figure 1). The conceptualisation is done with respect to development of a system that will serve management and sharing of information during emergency response (Scholten et al 2008).

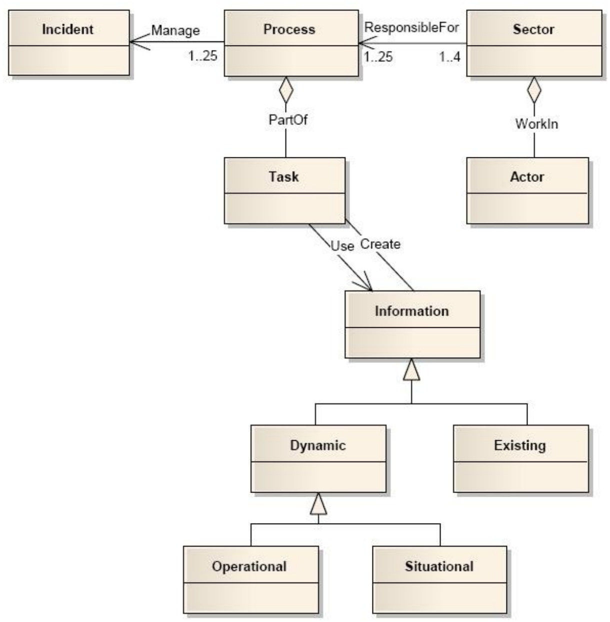

Figure 1: Top-level classes representing the relationships between process, sectors, task, actor and information, which are needed to manage an incident.

The disaster (called also *Incident*) in the Netherlands is managed by connected activities, which are indicated as *Process*. As mentioned above, there are 25 types of processes defined in the Netherlands (Diehl et al 2006). The four primarily emergency response *Sectors* are municipality, fire brigade, police and medical care (GHOR). Each sector is responsible for a group of processes. For instance, the fire brigade is responsible for seven processes such as fire fighting, rescuing and technical assistance, decontaminating people and animals, measurements and observations and so on. *Actors* are all the users that work with the system and they can play different roles and perform different operations. These operations are considered as *Task*. Every process consists of a set of tasks, which are performed by actors (individuals or teams). The team reacts as one unit as the team leader performs the communication to the other actors in the process or with other actors. Therefore a team is also referred as to an actor. Each actor needs data to complete the task and can deliver data (measurements, number injured people, number damaged infrastructure, etc.) to the system. The data that are therefore either *used* or *created* by an actor is indicated as *Information*. The information could be existing information and dynamic information (operational and situational). *Process*, *Sector*, *Actor*, *Task*, *Information (Existing and Dynamic)* and *Incident* constitute the top-level classes in the model (see Figure 1).

To be able to identify the information that is needed, a two step approach is followed. First, the data needed for/created by a process are specified and, second, the information needed for an actor/task in a process is identified. While identifying the manner of working and the needed information, it is very important to cooperate closely with the emergency responders by organising interviews, filling out questionnaires, conducting open discussions, participating in training, studying organisational instructions, etc. Many of these activities have been reported elsewhere (Neuvel and Zlatanova 2006, Snoeren et al 2007, Zlatanova 2008). It should be noticed that the obtained results may vary per administrative region (safety region, municipality or province). Some regions may have better organisation, more advanced software systems or may have more elaborated preparation plans. As result, particular emergency responders could have better (worse) knowledge on understanding and using geo-spatial data. This can affect the scope of geo-information that they consider important.

The information flows in Netherlands were investigated in one safety region (consisting of several municipalities). The 25 processes (Figure 2) were studied in detail and formally modelled in UML, using use case and activity diagrams. This effort resulted in the specification of actors, the communication between those actors and the required (existing/static and newly created/dynamic) data sets per process (Snoeren, 2006). The dynamic information required for all processes was further organised in dynamic data model (Dilo and Zlatanova 2008) to be used for an emergency response system (Scholten et al 2008). Next section will demonstrate the modelling of information required for the tasks in two processes.

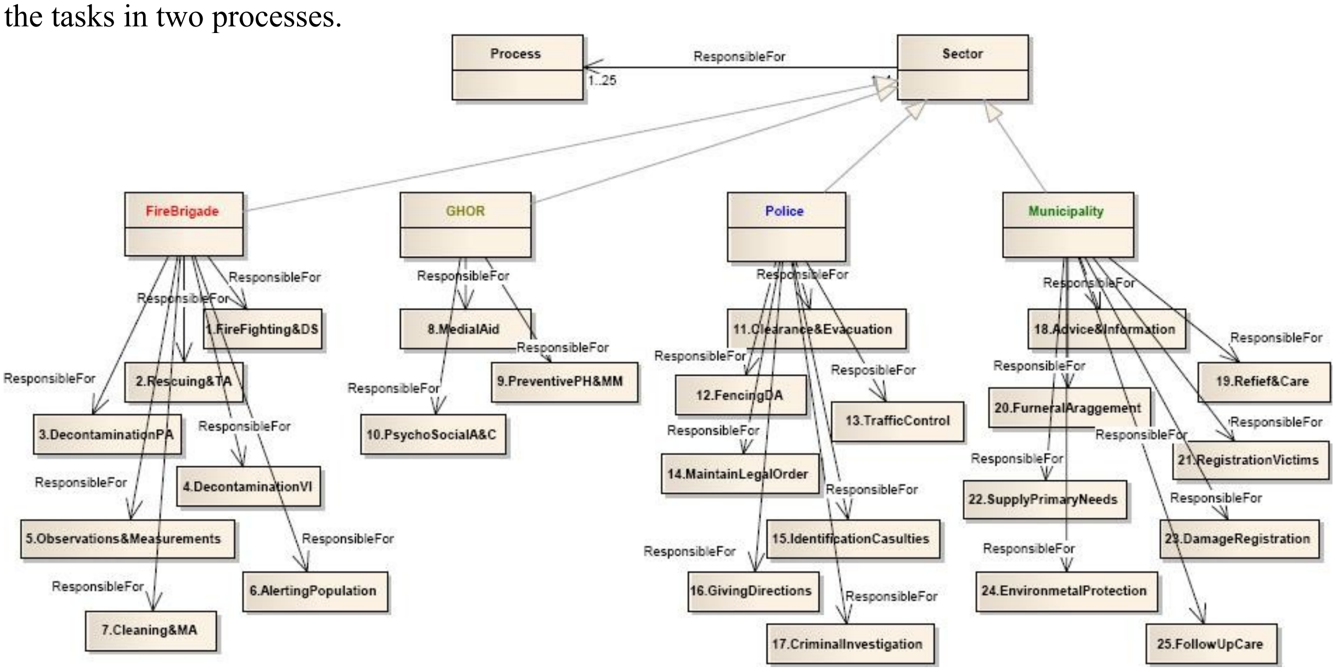

Figure 2: Processes and major emergency response sectors in the Netherlands

4 Modelling of tasks

The actors and tasks within a process depend on goal of the process but also on the complexity of the incident. So far, the modelling of dynamic information and actors has considered only the GRIP 1-2, i.e. only COPI and ROT emergency management teams are considered.

4.1 Process 1: Fire fighting

This process belongs to the group of processes of the fire brigade sector. It is one of the primarily processes, activated immediately with the reporting of an incident. The goal of the process is to fight a fire, prevent further damages on property and limit emission of dangerous substances in the air. This process aims to serve all types of fires such as natural (e.g. forest fire), industrial (chemical based), fires on ship, airplanes, trains and in houses. The workflow does not change much in the different cases: a call for fire initiates the process; the call centre registers the incident and informs the responsive fire brigade unit (in particular, the officer on duty and the fire brigade trucks leader). The officer in duty and the FB-leader move to the area of the fire. On the way to the fire they request various pieces of information: different topographic maps, locations of water resources (open water and hydrants), the optimal route to the area, vulnerable objects in the area (available on risk maps), information about citizens, etc. If the size of the fire is relatively big and cannot be localised fast, ROT might need to be formed and take over the coordination. If this happens, several other processes most probably will be started such as process 11 'clearance and evacuation' (performed by the police) and process 5 'measurements and observations' (performed by the fire brigade).

The actors in this process 1 are specified as *CallCentre, FBleader, OfficerDuty* and *ROT*. The tasks that have been identified as important for providing/recording information are *RegisterInsident, FightFire, Report, OperationalLead and TacticalLead* (Figure 3). The task of the call centre is to register the incident and inform the fire brigade sector. FB-leader has to fight the fire and take case of the consequences. The officer on duty performs the overall operational lead on the filed. The two actors report to the ROT.

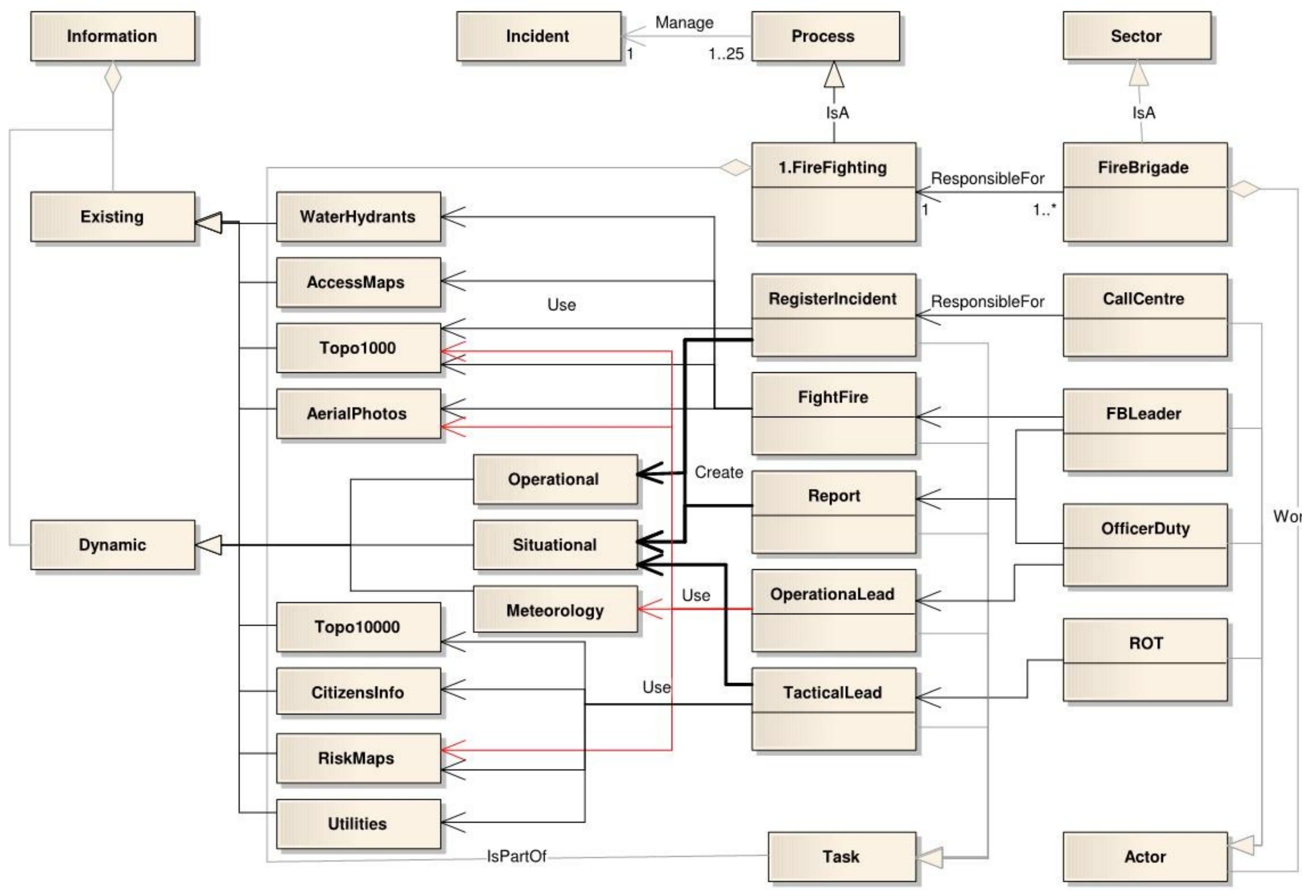

Figure 3: Task, actor and information in the process Fire Fighting.

The information that is needed at first instance for this process slightly differs with respect to the actors. The registration of the incident and the actors that are on the field (FB-leader&teams and the officer in duty) need large scale topographic maps (i.e. Topo1000, scale 1:1000). ROT (positioned in the command centre in the safety region or municipality) requires small-scale map (Topo10000, scale 1:10000) and information about citizens, vulnerable objects (available through Risk Maps) and often utility maps (e.g. gas-pipe lines). Essential for the FB-lead is the information in the access maps (representing entrances of public buildings and industrial establishments). Some of the actors have more than one task, for example FB-leader and officer of duty have to report about the situation in addition their major responsibilities. The reports are recorded in the spatio-temporal data model (Dilo and Zlatanova 2008).

4.2 Process 11: Clearance and evacuation

This process is responsibility of the sector Police and it is a very good example of a secondary process, i.e. it is activated after an incident is registered. It concerns all the activities that are required to clear (or evacuate) certain area. There is no clear border between clearance and evacuation. A certain area might be declared a limited-access area to facilitate the work of the emergency responders (usually referred as clearance). In other cases the citizens are requested to leave the area due to some treats (flood, dyke break, etc.), which is regarded as evacuation. Large evacuations are managed by another process, which is responsibility of the municipality and the police has a supporting role only. In this process 11, the police units are leading and have two major tasks: 1) to prepare a plan for transportation providing directions and capacity of roads and 2) to guard the cleared area. This process is likely to be initiated after the process 1 as explained above.

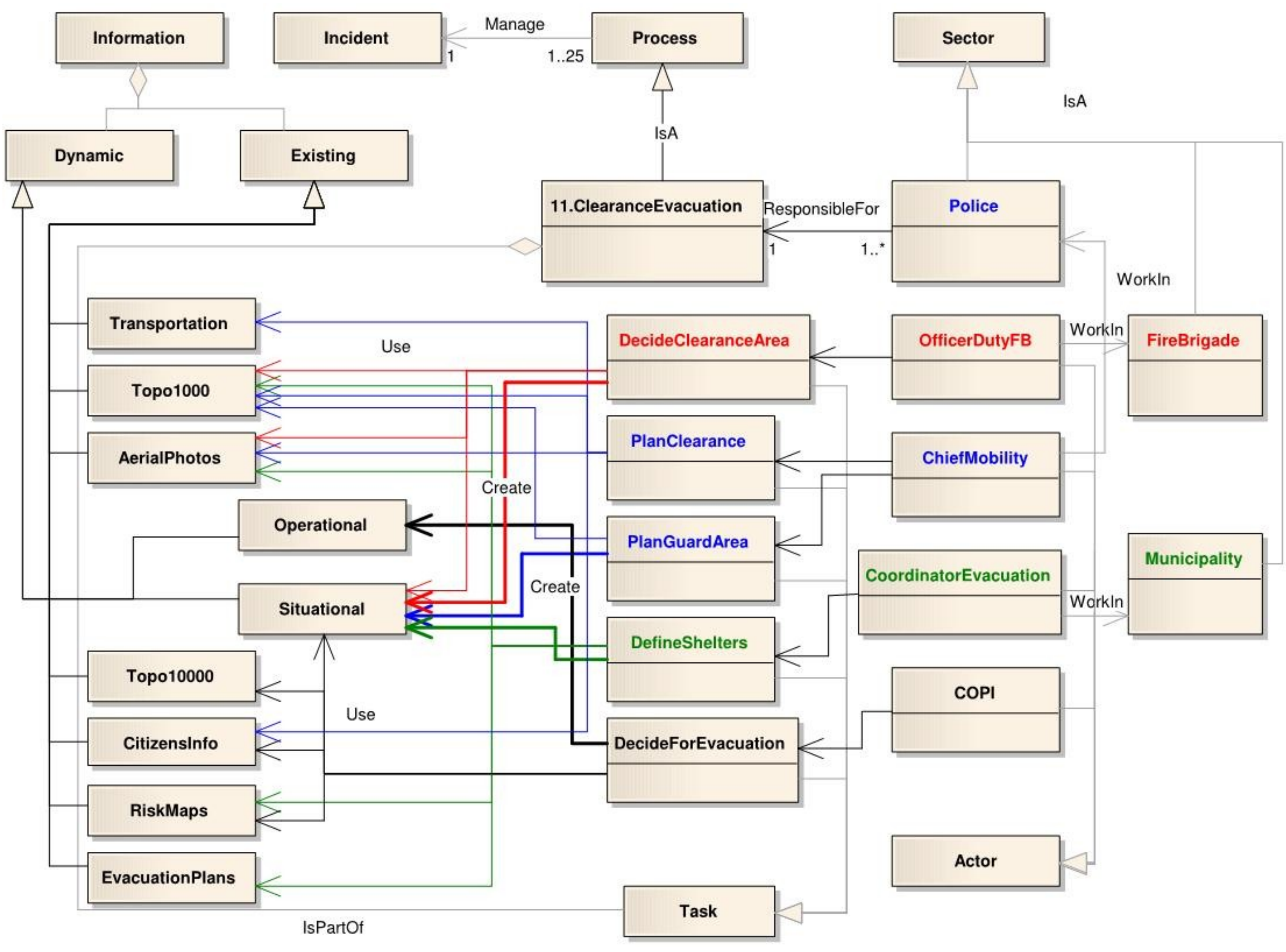

Figure 4: Tasks, actor and information in the process Clearance and Evacuation.

Although the process is coordinated by the police the municipality and the fire brigade are also involved. The tasks and the actors of different sectors are therefore given with different colours in the UML diagram (Figure 4). The relationships with tick line between task and data indicate that the task create information. The major actors in this process are the *OfficerDutyFB, ChiefMobility, CoordinatorEvacuation and COPI.* COPI is usually composed by representatives of all the sectors that are present at the filed. COPI takes a decision whether an evacuation of citizens is required. COPI takes this decision using all the situational information (available for the moment) and several existing sources most essential of which are topographic maps (usually small scale), information about citizens and risk maps. COPI might also decided whether the evacuation should be leaded by the municipality (which will introduce changes in the dynamic operational information). The officer of duty from the FB defines the area that has to be kept clear (or evacuated) and indicates it in the situational section of the dynamic information. The municipality coordinator decided which shelters/intake locations (available in the evacuation plan) have to be used in the current incident and locates them in the spatio-temporal data model (class *EventObject,* Dilo and Zlatanova, 2008). The chief mobility has to deliver a plan for the evacuation and guarding of the area. These plans are based on the situational information, information about citizens and transportation models (software available at the office of the police). Similar to the previous process some of the tasks use information (e.g. *PlanClearance*), others create information.

Compared with the first example, the information flow is much more complex. The tasks are dependent on each other, i.e. some of the tasks have to wait for certain information to be created (e.g. clearance area). The importance of order of tasks is observed also in other processes, e.g. process 5 'measurements and observations' (Xu et al 2008).

4.3 Discussion

This modelling of tasks revealed that the information can be further specialised with respect to the actors. For example, most of the tasks require use of topographic maps and aerial images as background information to get a better orientation. However, the scale of the maps differs per task/actor. Actors on the place of incident (as officer duty FB, FB Leader, chief mobility) perform their work on large scale maps, while members of ROT prefer small-scale, more generalised maps, which give better overview on a larger area. This was not obvious from the first step, i.e. the information modelling per process. In contrary, it looked as most of the processes require the same set of data.

As can be easily realised, the actors and the tasks could result in a quite large (but finite) number, which might be difficult to handle. Furthermore, many of the relationships between tasks and actor are 1:1, which raises the question whether the modelling of the tasks can be avoided. Theoretically relationships could be established between the actors and the information they need. Currently, we prefer to keep this separation since some tasks can be repeated in the processes (e.g. *Report*) and some actors can have several roles in different processes (e.g. *OfficerDutyFB* and *CoordinatorEvacuation*), which may require different information. As soon as all the tasks are modelled, it will be investigated whether they can be further aggregated to a smaller generic set of tasks. The actors and the generic tasks can be then used to specify the needed information (by creating rules). For example, several actors could make a decision about the area to be evacuated (e.g. *OfficerDutyFB*, *CoordinatorEvacuation*, *ROT* or even GHOR actors). The task then will be only *DecideClearanceArea,* but it will be performed by the different actors.

Such modelling of actors, tasks and corresponding information allows for providing the most relevant data sets as soon as the actor logs-in in a system to perform a certain task. The data sets can be readily available on the server of the corresponding safety region or accessed remotely via services (Scholten et al 2008). In this respect, the data must be seen as a default data set that will be immediately available for use, which is expected to safe time and efforts. As soon as an actor needs further information, it can be obtained by browsing geo-portals or predefined data sets. The data sets considered in this model are as general as possible, and are applicable for the most common experienced incidents. Specific disaster will definitely require additional information. For example fire in on a ship (tanker, cruiser) will require information about the cargo or the number of people on board. This information can be further requested by the actors.

It should be noticed that this approach is still insufficient in resolving vocabulary problems and lack of knowledge about content of different data sets. The emergency responders still have to learn how to read and interpreted utility or cadastral maps, i.e. to understand their semantics (meaning). Furthermore, the data sets may still contain too much information which is not required for completing a specific task. For example, a FB-leader needs generally buildings, roads and fire hydrants to fight a fire. Looking at the digital Dutch large-scale topographic map, one will notice two problems: first there is much more information than needed and second the buildings and roads are spread over several different layers (having distinct names). In this case, a mechanism will be needed to map the terms 'building' and 'road' used by the firemen to the much richer classification of buildings and roads available in the data set.

To resolve semantic interoperability and especially to apply reasoning (i.e. search according to a rule), description logics (ontology) approaches are needed. After the ontologies for data sets and the actors are built, it will be possible to access/search information with respect to the specific terminology used by the actors. Search of additional information will be facilitated as well. Some initial ideas about use of ontology in emergency response are presented in Xu and Zlatanova, 2007, Xu et al 2008 and Fan and Zlatanova 2010. The modelling of tasks completed so far can be further extended and linked with the ontologies developed for actors and information.

5 Conclusions

This paper presented an approach for formalising emergency response tasks and actors in the Netherlands. The approach relies heavily on the legislation for emergency response in the Netherlands. The procedures are derived from the daily routines of the primarily responders and their need to cooperate and communicate in any kind of incident (and middle-scale disasters). The modelling, however, can be applied for other counties and even for specific types of disasters. The top-classes in our model are very generic as well as many of the actors and the specified tasks. Naturally new tasks and data sets would be identified. Future work will concentrate completing the identification of generic tasks and performing tests with several processes. Special attention will be given on ontologies approaches and semantic technologies to represent the knowledge regarding tasks and needed data. The formal modelling is expected to facilitate machine processing (search and query) of data and therefore speed-up the supply of data.

UML is quite appropriate for modelling tasks and actors, since it gives a good overview of the classes (actors and tasks) and their relationships. It is also well-suited for describing attributes of the classes (not shown here) and their mapping to logical models (i.e. spatial schemas in database management systems). However, the language provides insufficient tools for reasoning, which would be needed to establish rules between general tasks and actors in different processes. For instance, if one wants to derive the relation between the actor and the information, he/she needs to specify a rule like 'use (*Task*, *Information*) Λ responsible (*Actor*, *Task*) => use (*Actor*, *Information*). Similar rules can ensure the correct order of tasks is a process as well. This inference can be accomplished only through ontology modelling and reasoners, which is yet another topic to be address in near future.

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