

# Utilization and Exchange of Geospatial Data in Swedish Emergency Management

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**Abstract.** In this paper, research investigating the current situation with respect to geospatial data (GSD) access and integration at the inter-organizational level in Swedish local and regional emergency management (EM) is presented. The performed analysis resulted in a range of conceptual, organizational, administrative and ontological problems, recognized by the international research community and also identified among the studied Swedish EM organizations. Additionally, close interconnection between particular problems or groups of problems was observed in several cases. The documented findings can be seen as hindering the sharing of GSD. Moreover, development of useful GIS-based analytical and decision-support applications for day-to-day use in EM is becoming difficult without effectively sharing GSD. It is suggested to promote further research in an integrated way to understand the full complexity of the problems. Moreover, involving both the research and EM communities is seen as essential.

## 1 Introduction<sup>1</sup>

Many authors, for example [2], [3], [23], [28], claim that information and communication technology (ICT) support is needed to achieve sophisticated emergency management (EM) and to facilitate more effective response to day-to-day emergencies as well as disasters. As EM becomes more and more multi-disciplinary, multi-institutional, and multi-jurisdictional with joint planning and sharing resources [1], [23] the demand on ICT to integrate data exchanged with other users – also in real-time – into advanced, but easy-to-use, powerful information systems constantly increases. By combining technologies, such as the communications, space-based sensors, geographical information systems (GIS), simulation models and integrated databases, it will be possible to design tools for improved risk analysis and other prevention and preparedness activities as well as to obtain a fast and correct situation assessment when emergency or disaster occur, according to these authors.

Focusing on GIS, most of the initiatives to implement and use GIS in EM organizations have arisen in the last ten – fifteen years [6], [29]. GIS is recognized as clearly contributing to all the phases of the EM cycle [26]. Together with other ICT,

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GIS can improve the possibilities to design interactive systems facilitating comprehensive EM, where the scalability of GIS is an invaluable feature in coordinating efforts [12]. Further, GIS can also help to utilize diverse heterogeneous digital data from various sources [15], [16] providing a common scalable organizational framework through georeferencing the data [9], [12]. However, this utilization of diverse data into coherent geospatial data (GSD) sets is not always done without difficulties, involving technical, organizational, conceptual, ontological and other problems.

In this paper, research investigating the current situation with respect to GSD access and integration at the inter-organizational level in Swedish local and regional EM is presented. The research aim is formulated as to explore the present GSD access and integration problems at the inter-organizational level and to gain knowledge of these problems in a broad range of possible considerations. Moreover, a combination of three research methods within an embedded case study framework is used to identify the challenges, weakness, and threats connected to the access and integration of GSD.

## **2 Research Issues**

GIS because of their spatial basis, will always retain some degree of separateness from mainstream ICT in their management [7], although they become increasingly compatible and integrated with other ICT. As GIS are in many cases tailored systems even if standardized software and open systems are diffused, these are likely to differ between particular organizations [24]. Taking into account present EM involving multiple organizations with different jurisdictions, individual missions and priorities, the EM organizations have also likely different GSD needs. Moreover, considering the public sector setting of most EM organizations, these organizations often pose monopoly to collect and store official GSD, which sometimes results in separate closed systems preventing effective exchange of GSD [25]. As a result, delivering the appropriate GSD to the proper party at the appropriate place and time in a consistent, comprehensive, accurate and logical form [22] still remains a significant challenge.

One of the greatest difficulties is identifying whether GSD of a specific nature exist and from where they can be acquired [20]. Legal and administrative issues may also restrict access to GSD and additionally complicate GSD acquisition and exchange. The lack of plans for integrating GSD, formal mechanisms for obtaining data, pre-existing formal and informal relationships [13], [26] or GSD access agreements [18] are some of the reported constraints by international research. Data confidentiality, liability, pricing, and varying information access policies, even differing between organizations under the same laws, are further documented obstacles [16], [18], [20].

Furthermore, integration of GSD is challenged by incompatible data formats, different data definitions, varying scales of data, duplicated and incomplete data, and conflicts over accuracy, precision, and specifications of the exchanged GSD [5], [14], [18], [20], [24]. GSD integration can additionally be obstructed by data quality and quantity issues [5], redundant disjoint databases with lack of linkage between various

data [14], [17] as well as unfamiliarity of data specifications, formats and standards among the EM personnel [14].

### **3 Methodological Overview**

To investigate issues related to GSD access and integration in-depth within their real-life institutional and social context, an embedded case study was chosen as an overall framework [8], [27]. Additionally, three research methods were used within this framework – interview, explorative case study and observation.

Standardized open-ended interviews were performed. The sampling was driven by searching information-rich units of analysis within a selected region – Swedish local and regional EM organizations in two neighboring counties. From the known sampling techniques, purposeful sampling, in particular a combination of critical case, criterion, and maximum variation sampling was applied. These techniques were combined to select and document variations that have emerged in adapting – in this case GIS and GSD – to different conditions [19]. Totally, thirteen organizations with EM tasks were selected – three fire and rescue services, five municipal administrations, two county administrations, two county health boards and one county police authority. Consequently, nineteen face-to-face and telephone interviews were made with representatives from these organizations – ICT, GIS and GSD infrastructure responsible. In the interviews, areas of GSD collection and exchange, inter-organizational cooperation, and present and future management of ICT, GIS and GSD were addressed.

To document the studied phenomenon – in this case the process of accessing and acquiring GSD and furthermore integration of these GSD – as completely as possible, an explorative case study technique [27] was employed. Eighteen possible sources of relevant GSD were approached if they pose any suitable GSD for risk analysis in a selected area – one municipality. This was done together for one municipal administration, fire and rescue service, and county administration with jurisdiction in this area. The available GSD and other non-geospatial data from ten national, regional and local organizations were collected, reformatted, georeferenced and compiled to the form of a single-view data set.

Additionally, these two techniques were completed with free unsystematic observations. These observations were carried out in an in-house and unobtrusive informal style.

## **4 Results and Discussion**

### **4.1 Present GIS and GSD Infrastructure**

At present, all the studied EM organizations have utilized ICT as a key part of central administrative systems to most operations, implementing various network and database services and other technologies to day-to-day work. Concerning GIS, with

the exception of two all the studied organizations have in some form implemented GIS. ICT and GIS were both often highlighted as of a strategic importance, becoming a standard tool in government and EM.

With regard to the present GSD infrastructure, base data, such as road network, land use and administrative boundary, are in place in most of the studied EM organizations. Additionally, available socio-economic data, such as population and social structure, are accessible in formats allowing integration with existing GSD. From the present available GSD, most of these data are stored in geo-databases or individual files following open-GIS or well-recognized industry formats. This was also the case of GSD obtained in the explorative case study, delivered in industry recognized formats. Central government organizations together with municipal administrations were identified as the main sources for these types of GSD. Furthermore, private companies and corporations managing infrastructure were also listed as GSD sources. However, only two of the studied organizations were using services of consulting companies to obtain GSD.

In the case of EM, thematic GSD, such as risk objects, hazard maps and incident statistics, are however just in their beginning. Large amounts of EM related data are still kept in non-geospatial formats, such as reports, schemes, notes or as hard-copy documents. These data have to be additionally processed in order to transform them to suitable forms for use in GIS. This includes manual re-typing, scanning, digitizing, etc., which is demanding, regarding the time, resources, as well as the relevant methods and knowledge. Additionally, certain data, due to the way they are collected, cannot be transformed into GSD formats at all, as experienced in this research. Furthermore, some potentially useful data for GIS applications are not collected at all. This is particularly the case of EM organizations with national jurisdiction, such as various government agencies and bureaus that collect data without using any geographical references, such as key-code areas and local administrative boundaries. Taking into account the existing EM thematic and other GSD, these reside at the regional and in particular at the local level. This is in contrast to other parts of existing data infrastructure, such as various centralized registers and databases, managed at national and regional level. Consequently, GSD sources differ greatly in number and variety compared to other digital data sources relevant for EM.

#### **4.2 Access and Acquisition of External GSD**

The studied EM organizations identified allocation and access of EM thematic GSD outside their own organizations as one of the most problematic issues. This was also experienced during the explorative case study in this work. Time consuming “snowball sampling” [19] through a number of persons had to be utilized to uncover if and where particular GSD are located. Similar phenomenon was also documented during the interviews when the studied organizations were asked if they possess any GSD suitable for EM. Three organizations mentioned their interventions towards their own organization in order to identify this type of GSD. These pointed out that practically no GSD suitable for EM have been identified. These results are in contrast to the comments obtained from other EM organizations describing these same GSD as potentially essential for their decisions. This situation is influenced by the fact that

utilization of GIS may change the structure of the information sets. It also points to underdeveloped capabilities to allocate and access GSD on neither push nor pull bases as well as to limited knowledge of GSD needs by the data sources and the potential users. This is supported by the fact that in most cases the own organization was the main and only source of EM thematic GSD. The unavailable and missing EM thematic GSD lead into GIS, which are unable to support organizational tasks as initially intended by some of the studied EM organizations. One EM organization even highlighted that limited access to the GSD from other organizations makes utilization of GIS in its work very limited and hardly meaningful. This also corresponds to our findings, where many of the studied organizations use GIS only for visualization of available, often only single set, GSD.

Even if appropriate GSD exist and their locations are known, diverse cost recovery and revenue policies for GSD and high GSD costs are still causing difficulties and remain as a major problem in exchange and acquisition of GSD. These policies differ greatly among the studied EM organizations. Organizations at the regional level and with emergency response tasks do not require any payments for their own GSD in general. At the local level, the situation is different - the policies vary greatly and even between organizations of the same type. In particular, the municipal administrations implement various economical models, such as open access, various types of fees, several levels of cost recovery, or “buy & sell” principles for the exchanged GSD. The different cost recovery models were implemented in the municipalities independently of their size. From this perspective, the studied organizations identified the cost recovery and revenue policies, and in particular the disarray of these policies as negatively affecting the GSD exchange and consequently limiting GIS utilization. Besides, with the increased role of the private sector in critical infrastructure management one EM organization pointed out that increasing amount of GSD is additionally moving from free access towards full cost recovery policies.

As a result, EM organizations may stay away from acquiring and exchanging relevant data, considering GSD as extra challenging, if the legislative, administrative and technical aspects would become too difficult, or if the economical demands would be too high, as documented in the study of nineteen Swedish EM organizations in 1999 [11]. This is coherent with our findings that most of the organizations access and exchange GSD on rather informal bases using individual relationships between the organizations applying the “data for data” mechanism without any cost recovery demands, but still following present legislative, ethical and administrative norms. Moreover, most of the GSD obtained within the explorative case study were also received in this way. Written agreements are normally connected to GSD acquisition if cost recovery is required, or if the GSD are exchanged with private companies, corporations, or national government organizations. In other cases, the informally exchanged GSD are often missing written formal agreements, regulating the exchange and use, either metadata<sup>2</sup>, as documented in this research. Above all, it was particularly difficult to collect any documentation concerning EM thematic GSD.

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<sup>2</sup> Metadata are GSD documentation developed for the purposes of GSD identification and quality management, carrying information about authors, content, scale, date of collection, updates and validity [14], [15].

Moreover, in some cases documentation does not exist at all. At present only one studied EM organization has all its GSD documented via metadata. Some organizations stated that they will reach a situation with full GSD documentation soon without specifying further. However most of the organizations identified themselves somewhere in the documentation process with two being in the beginning of the documenting. Even so we did not register any concerns regarding the unofficial GSD exchange and related missing agreements and metadata as a problem, which may point to low awareness of these issues and their potential consequences.

### 4.3 Ontological and Conceptual Aspects of GSD Integration

In situations when organizations exchange for own use collected GSD with others, ontological and conceptual problems occur then as observed in the study. Every EM organization has different preferences concerning GSD collection and management with respect to data quality and resolution needs, available resources, and available time frame for data collection, due to the nature of its tasks. Considering these different preferences the way GSD are collected in terms of describing geographical and temporal features differs greatly. It is additionally accompanied by limited understanding of these features and mapping of their state and topology resulting in limited geographical reference, as observed in this research.

Moreover, this different perception and limited understanding by various users, individual organizations or groups of organizations may result in very different, even conflicting, descriptions and representations of the same GSD [4] due to the insufficient means to assess the ontological<sup>3</sup> and conceptual bases of the data and their collection. From the obtained GSD in the explorative case study, these bases were in most cases unknown or unavailable to the authors. This problem is, however, not solvable by intensified standardization of common symbols, terminologies, or graphical representations, etc. Instead these ontological and conceptual bases in data collection and management need to be studied by particular organizations and their cultures as well as in the entire EM process. GIS and GSD include ontologies and are ontologically more demanding than ordinary administrative information systems [10]. With this in mind, clarification of the ontological and conceptual bases is ever more important, particularly with the number and volume of GSD sources, which will be increasing. Even so, the ontological and conceptual bases in EM have obtained, to the knowledge of the authors, a rather low attention so far.

Additionally, the problem of ontological and conceptual bases in GSD integration is further accelerated by the fact that these GSD are often collected without following any standards concerning quality, data portability and transfer, etc., such as ISO, Stanli (a set of Swedish standards for GSD). In our research, we have found a broad variation of approaches to standards. From this perspective, it has to be considered that a part of the EM thematic GSD does not follow any standards at all. Instead, most of the EM organizations follow only various recommendations and general praxis.

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<sup>3</sup> Ontologies are basic cognitive assumptions on and knowledge based descriptions of various phenomena [10].

#### 4.4 Using Integrated External GSD

A number of conceptual and ontological problems were mainly identified during the GSD integration, such as different definitions and scales but also lack of geographical features necessary for linking the data, and especially critically missing data and quality descriptions. It turned out to be very difficult to keep track of all these issues (e.g. different data quality, scale, content, etc.) even when a relatively small amount of GSD were integrated. Due to the minimal use of common geographic references, e.g., standardized addresses and units of property, in present EM thematic GSD, data cannot be cross validated to reduce the uncertainties coming from the integration of data. Considering these ontological and conceptual problems as well as the missing standards an unaware GSD integration may lead to GSD sets of doubtful quality, introducing additional uncertainties to these compiled data. Moreover, it can be assumed that there are certain risks for making decisions on incorrect interpretation of the integrated GSD, as the assessment of their reliability could be difficult to carry out. This delimits the usability of the integrated GSD sets. Additionally, there is a risk that some GSD may never be integrated due to these problems, as experienced by the authors in the explorative case study.

#### 4.5 Summary of main findings

The performed analysis resulted in a range of conceptual, organizational, administrative and ontological problems, recognized by the international research community and also identified among the studied Swedish EM organizations. Additionally, close interconnection between particular problems or groups of problems was observed in several cases. From the range of findings made in this research, several can be emphasized as essential:

1. Compared to other digital data infrastructures, GSD suitable for EM are particularly resided among the organizations at local levels.
2. Identification and access of EM thematic GSD are problematic and demanding, limiting utilization of GIS in EM organizations.
3. Official continuous inter-organizational collaboration in terms of GSD management and exchange preparation among the studied organizations does not exist in most cases (only sister organizations exceptions).
4. A part of the existing GSD is exchanged on informal bases without any proper documentation. The actual structure and the volume of the flow are in most part unknown.
5. Different ontologies and other conceptual problems make GSD integration particularly challenging.
6. Limited use of standards, missing metadata and unknown ontological bases result in doubtful quality of integrated GSD sets.
7. Utilization of GSD to support tasks and activities in post-event phases of larger emergencies and disasters without previous collaboration and preparation can be seen as very challenging.

## 5 Conclusions

The research presented in this paper is focusing on aspects of GSD access and integration in Swedish EM, i.e., mapping its complexities. The documented findings can be seen as hindering the sharing of GSD. Moreover, development of useful GIS-based analytical and decision-support applications for day-to-day use in EM is becoming difficult without effectively sharing GSD. Taking into account the increasing volumes of EM thematic GSD compared to other EM related data, more data will have an impact on the discussed problems. Eliminating or at least minimizing these problems is a basic necessity when introducing mature GIS to EM.

Inter-organizational issues in EM are more challenging compared to other sectors due to its additional complexity, uncertainty, number of organizations involved, as well as the space and time segment [28]. The enduring research question is therefore how to manage and distribute GSD to make it available throughout the EM organizations. Moreover, with the intentions to shift from traditional organizational structures in EM towards more network centric oriented frameworks, addressing of the GSD related problems will be even more essential. The capacity to access, exchange and utilize remote shared GSD will be an important factor for the involved EM organizations in these frameworks. Thus, it is important that the dimensions of the inter-organizational GIS and GSD in EM are analyzed in an integrated way to understand the full complexity of the problems, and to discover the points of vulnerability as well as to make an adequate effort to address these problems. Furthermore, it is also essential to evaluate the solutions, proposed by the R&D community, their impacts as well as their implementations within and between the EM organizations. From this perspective, new collaboration forms will be necessary, such as (dynamic) coalition systems, federations of resources, and service concepts.

Finally, it is suggested to promote research in a way the EM and R&D communities are actively engaged and cooperating. This is necessary in order to combine the concerned multiple research disciplines and professional EM fields as well as to integrate the results from the involved participants [6], [21], [28].

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