

Simulation of Accessibility in Crisis Management

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Abstract

To route the rescue service, the police and the ambulance during an emergency event, the command and control units need information about accessibility. When two countries are involved in the rescue work there is also a possibility to send rescue help from either country, which complicates the situation but of course gives a great opportunity. Good predictions for when rescue service are to appear at the scene of the emergency and from where to send them are of great importance. Different actions are to be taken due to the waiting time. Accessibility is a complex term which is further elaborated and conceptualized in the paper. The paper also presents tentative results for how to conceptualize and simulate accessibility in this crisis management setting. The results are based on empirical data from the region involved in the GSS project.

Keywords: accessibility, crisis management, simulation, geographical information, collaboration

1. Introduction

In large scale crisis in the region close to the border between two countries, there is a need to be able to collaborate between the countries. Inter-organizational cooperation and collaboration between emergency authorities is challenging and even more so if the emergency authorities are located in different countries. Even if the emergency authorities work in the same geographical area and under the same jurisdiction, cooperation and collaboration can be extremely challenging. Different organizations, as well as individuals within organizations, understand the situation differently depending on their task, position, information, knowledge, organizational culture and preparedness for action (Dubois et al, 2012).

Earlier research indicates that the final outcome of a disaster is highly dependent on early preparations and training made before the crisis outbreak (Sundelius et al., 2001, Asproth et al., 2010). Boin and 't Hart (2007) claim that earlier emergencies provide a good learning source for feasible planning and preparations for future emergencies. Despite those somewhat contradictory results, Asproth et al. (2010) argue that training for emergency situations can make people better prepared for the management of emerging situations.

In any crisis situation it is necessary that all resources involved in a crisis management are used optimally. In less populated areas the resources available are limited and may be far away. Often the nearest needed resource is located in the neighboring country.

To route the rescue service, the police and the ambulance during an emergency event, the command and control units need information about accessibility. When two countries are involved in the rescue work there is also a possibility to send rescue help from either country, which complicates the situation but of course gives a great opportunity. In extended emergency situations there also is, besides from immediate need for ambulances, police and/or fire brigades, a need for different kinds of equipment that needs to be transported.

Good predictions for when rescue service are to appear at the scene of the emergency and from where to send them are of great importance. To anticipate and take different actions due to expected waiting time is of great importance. In training situations there is also a need to be as realistic as possible and that includes realistic simulations of accessibility.

Accessibility is a complex term which is further elaborated and conceptualized in the paper. The paper also presents tentative results for how to conceptualize and simulate accessibility in this crisis management setting

The results are based on literature studies and empirical data from the region involved in the GSS project.

2. Research Setting

The work in this paper has been carried out in the project Gaining Security Symbiosis (GSS) which is funded by Interreg / European Regional Development Fund (ERDF). The project is a joint research project between Sweden and Norway, coordinated by the Mid Sweden University and Nord-Trøndelag University College, and includes external supporting partners in the local police, fire and ambulance emergency organizations. The aim of the project is to develop a computer and net based integrated environment for mutual preparation and training for complex emergency situations.

The project is responsible for arranging one large training exercise each year during three years. The overall goal of GSS is to contribute to increased security and thereby also increased quality of life for both the resident population and visitors to the border region.

3. Accessibility

Accessibility is a widely used concept, and occurs in different contexts. The meaning of the term varies depending on the topic and context it is used in. The word is cognate with the word access, where one of the general definitions according to the Oxford English Dictionary (1996) is: "The action of going or coming to or into; coming into the presence of, or into contact with; approach, entrance". If the word access is viewed from a geographic context, the concept is described as: "Access in a geographical context is the quality of having interaction with, or passage to, a particular good, service, facility, or other phenomenon that exists in the spatiotemporal world" (Talen, 2011). In the definition not only geographic space is included, but also time. There is also a

specialized definition of access to health care where the definition is: "Access refers to the capacity of people to obtain healthcare at the right place and right time regardless of location, socioeconomic factors, or cultural background" (Humphreys and Smith, 2009). In healthcare perspective access is composed of five sub-concepts, where availability and accessibility are two of them. Availability refers to the relationship of resources and needs, e.g. number of hospital beds. "Accessibility is the relationship between the location of supply and the location of clients" (Humphreys and Smith, 2009; Penchansky and Thomas, 1981). The division of the two concepts is argued to be merged into the concept of spatial accessibility (Guagliardo, 2004). Moreover, an early definition of the term and in the context of urban studies is "accessibility is defined as the potential of opportunities for interaction" (Hansen, 1959). The definition relates to a concept about relationships between something, but not including time and space. Furthermore relative and integral accessibility were introduced in the 1970:s, as an attempt for a more useful definition of accessibility. Relative accessibility is "the degree to which two places (or points), on the same surface are connected" (Ingram, 1971). Further, "Integral accessibility is defined for a given point as the degree of interconnexion with all other points on the same surface" (Ingram, 1971). The latter two definitions imply the extension of the concept of the geographical space but the time factor is less pronounced from the definition. In context of transportation the distinction of accessibility is. "denotes the ease with which any land-use activity can be reached from a particular location, using a particular transport system" (Koenig, 1980; O'Sullivan et al., 2000) with source in a paper of Dalvi (1978). This definition focuses on the transportation system, and land-use activity which makes the definition less universal, depending on how land-use activity and transportation system are defined.

Accessibility is defined in a number of ways common that the definitions give a hint of measurement but that the way of, and context of measurement differ. The words, *potential*, *ease*, *degree*, or *relation* from the examples above give a hint of measurement. In a geographic focus and in the context of crisis in rural areas, accessibility is the measure of access where access is defined according to definition in the International Encyclopedia of the Social & Behavioral Sciences (Talen, 2001). The definition does not indicate the inclusion of availability similar as in the definition of access and for health studies. The word *obtain* is not included in the definition but *interaction* and *passage to* does. The use of the concept of accessibility for future studies will include availability in the definition. But instead of a rewrite of the definition of access, the definition will be interpreted to meet the inclusion availability. The degree to how any service or resource exists in a geographic space and can meet needs, derived from (Penchansky and Thomas, 1981). For example, if an event occurs on a geographic location at a given time and emergency services resources need to be used, question arises as to what resources are available and who can reach the site within a reasonable time. A fire station may have three vehicles, all of whom are admitted to another assignment at time of the alarm, the vehicles are not available. Another fire station with its vehicles is available and can reach the site within a specified period, instead. One aspect of the concept with its definition in a specific context is that the same words, but in another context may be needed simultaneously

and thus in the double context. Access to information about accessibility involves a dual context of the concept of accessibility. Access to information has another meaning than access with respect to a geographic perspective.

3.1 Measurement of Accessibility

There are exists many different ways that of how accessibility can be measured. Two big groups of approaches is place based accessibility and individual based accessibility. The scale of measurement can be local, regional or global. The purpose and aim of accessibility studies vary but differences between social groups or individuals are an important element (Kwan et al., 2003).

- *Place based accessibility* A Cumulative model of place based accessibility can be designed to sum the number of facilities that is of a distance from a location in combination with weight for travel cost or time (Koenig, 1980). Further gravity models of place based accessibility include factors for friction that travel distance case and this together with other factors. It can be used in models that sum the number of opportunities to healthcare service locations from a population zone or point, and by the inclusion of distance and factor of difficultness to travel that an increased travel distance leads to. There exist simple or more developed models (Guagliardo, 2004). Depend on how attractive a geographic area is it will generate a level of accessibility from a location. Depending on how attractive activities are on the geographic area, people will have different level of motivation to travel thru distance to it (Hansen, 1959). Further this willingness of people to travel thru distance depend on different variables of facilities in an area, variables which are weighted compared to the travel distance (Hansen, 1959).
- *Individually based accessibility*
- *Space-time accessibility framework* is an individual approach to movement or communication in space and time. Instead of being based on an aggregate approach in which human behavior is aggregated into clusters, space-time is based on the behavior of individuals and its representation in time and space (Hägerstrand, 1970). Movement or communication that takes place mainly affected by three different constraints, where the first constraint concerns the capability that affect the movement of an individual. Capability can be seen from both the immediate area around an individual, which can be reached at arm's length. Furthermore, from the area that can be accessed with voice or by sight. Tools may affect the ability to reach an area, such as communication aids and other equipment. Another approach to capability is the starting point for an individual and its home and how far an individual can reach within a period of

time with regard to reach back to home location, for example at the end of a workday. An individual has a limited time budget that can be illustrated in a space-time prism in a coordinate system where one axis is time and the other axes is space. The second constraint named coupling, involves the collaboration / cooperation, which affects the movement pattern. Coupling constraints is about for example meetings that can be performed by communication aid or on-site. It can also be interactions such as train and bus schedules and waiting at bus stops. The third involves different rules and requirements from authority. Authority constraints include things such as ownership of land and rights or restrictions to reside there. This may include private land, nature reserves and various countries. It can affect certain groups, organizations or activities.

Furthermore, the idea of space-time approach is also to study interactions between the constraints in aggregate form, based on individual space-time paths. Several studies have been built on space-time accessibility framework. Analytical definitions for measurements based on collected data with errors and uncertainties have been studied (Miller, 2005). 3D GIS has been used to visualize behavior in space-time by human mobility patterns, based on collected data (Kwan, 2000b). To study interactions between multiple space-time paths a hybrid environment of CAD / GIS have proved to be an alternative to pure GIS environments (Neutens et al., 2007). Aggregated mobility patterns of social groups involved, how been studied included a gender perspective (Kwan, 2000a).

3.2 Accessibility and Crisis

According to Oxford English Dictionary one of the definitions of crisis is "A vitally important or decisive stage in the progress of anything; a turning-point; also, a state of affairs in which a decisive change for better or worse is imminent; now applied esp. to times of difficulty, insecurity, and suspense in politics or commerce".

In a societal context a crisis occurs when vital functions in the society are not working or liable to risk for not working (MSB, 2011). Important functions are for example rescue service, police, health care, water supply, and electricity. Access to these functions can be viewed from the individual level, i.e. the individuals' possibility to reach a certain function, or on societal level, i.e. how can the society in a geographical area supply the service to the individuals.

There are different kinds of means of transport to be able to move the resources to locations where they are needed. Vehicles and persons can use the road network and if that is not possible snowmobiles or other off-road vehicles, boats and helicopters can be used. Water is normally supplied by water pipes and electricity in electric cables. When these functions are not at hand other transportation means must be used.

Different vital functions in society are dependent on each other. Roads need to be passable for ambulances and fire brigades. Health care is dependent on electricity and water supply.

Even if there is no big emergency present, but all resources are occupied with several minor accidents, there is a risk for a crisis due to shortage of resources. In sparsely populated areas with limited resources this can be a fact, particularly as weather, with snowstorms, can cause trouble both with traffic and electricity supply.

3.3 The Picture of Accessibility During Crisis

A crisis scenario can engage several organizations needing to exchange information within the organization as well as with other organizations. In border areas information and communication also must come about between organizations on different sides of the country border (see figure 1). Information about closed roads on the other side of the border is an example of essential information. It is of great importance that everybody has a common picture of what is going on to be able to effectively manage the emergency.

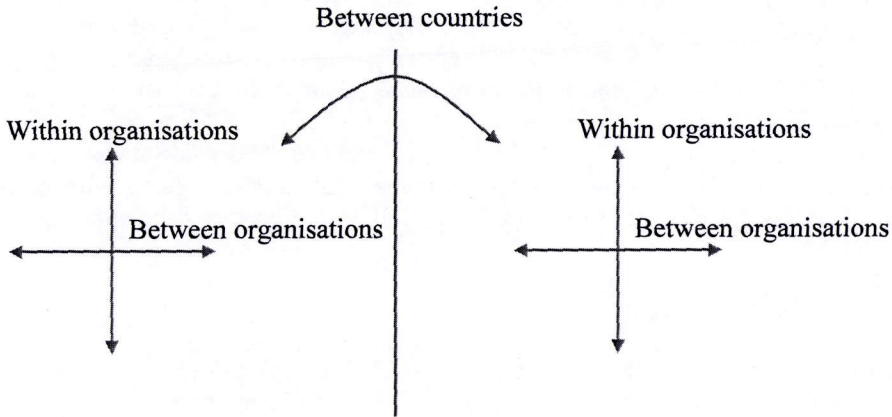


Figure 1: Information exchange in an emergency situation.

4 Test of Accessibility in a Training System

To test how accessibility can be implemented in a training system for emergency management a prototype has been developed. The case that the prototype is built upon is an invented accident in the mountain region, on the Swedish side but close to the border of Norway. There is only one way and a long distance to any crossroads. In the scenario it is also winter and heavy snowfall. The road is blocked by snow. There are injured people in need of immediate help. There are different options to reach the people in distress.

4.1 Factors of Measurement

To be able to anticipate the different alternatives there are some factors or variables that needs to be accounted for. For each alternative you have to know the *locations of origin* and the *locations of destination*. It might seem easy to determine the locations of destination, but in some cases as for a helicopter the scene of the accident might not be able to reach. In that case you have to find a safe landing place.

The next factor is the *relations between origin and destination*. An ambulance has to follow a road from the origin to the destination. There are several alternative routes and it is not always the shortest way that is the best. In this snowstorm there might be difficulties along the road. A helicopter can normally go in a straight line from origin to destination, but there might be mountains that it has to make way for. In bad weather helicopters most often follow the roads for safety reasons.

The last two factors concerns *attributes of origin* and *attributes of destination*. There can be a wide range of attributes to consider and they are in many cases connected to the circumstances. Examples of attributes of destination are snow or other hindrance, the accidents location in relation to the road, and as earlier mentioned a safe landing place. At the location of origin a question can be if necessary equipment is in place. Last winter there was an accident with a snowmobile going through the ice on a lake. When the rescue service arrived to the place they realized that they would have needed a boat.

4.2 Visualization of Measurement

Many emergency authorities have area based maps showing the general time to arrival at the scene of an accident. These maps are based on census statistics with home locations and travel time to destinations. These measurements can of course change over time due to number and location of resources and road conditions (i.e. new or better roads, new speed limitations, etc.) The usefulness of such area based maps is that you get a fast glimpse of the predicted time of arrival. Such maps are also used for a dialogue with residents and politicians. An example of such an area based map can be seen in figure 2.

The prototype visualizes what we can call an individual or situation based map. The measurements here are space-time paths and space-time constraints. In the system you can put in the location of the accident and the attributes of the destination. Available resources are at hand in the system, but conditions of the route from origin to destination must be obtained. As the system is to work in the GSS setting information is gathered through communication within the organization at hand, from other organizations in the own country or from the other country as indicated in figure 1.

In the prototype the different options and their accessibility gradually visualizes (see figure 3). Delays or faster access change the picture. This tool for calculation and visualization of situation based accessibility serves as a help for making decisions about emergency management.

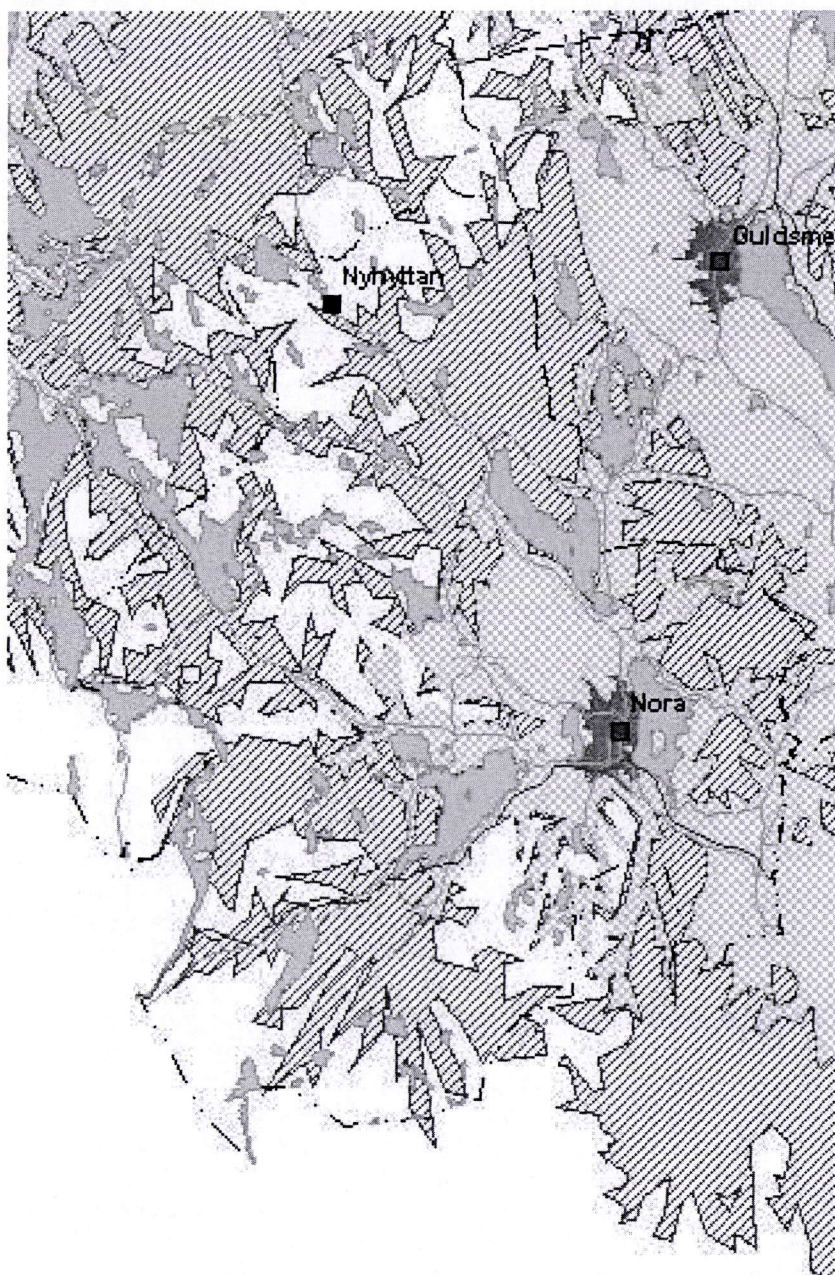


Figure 2: Time zones for rescue service to arrive to an accident

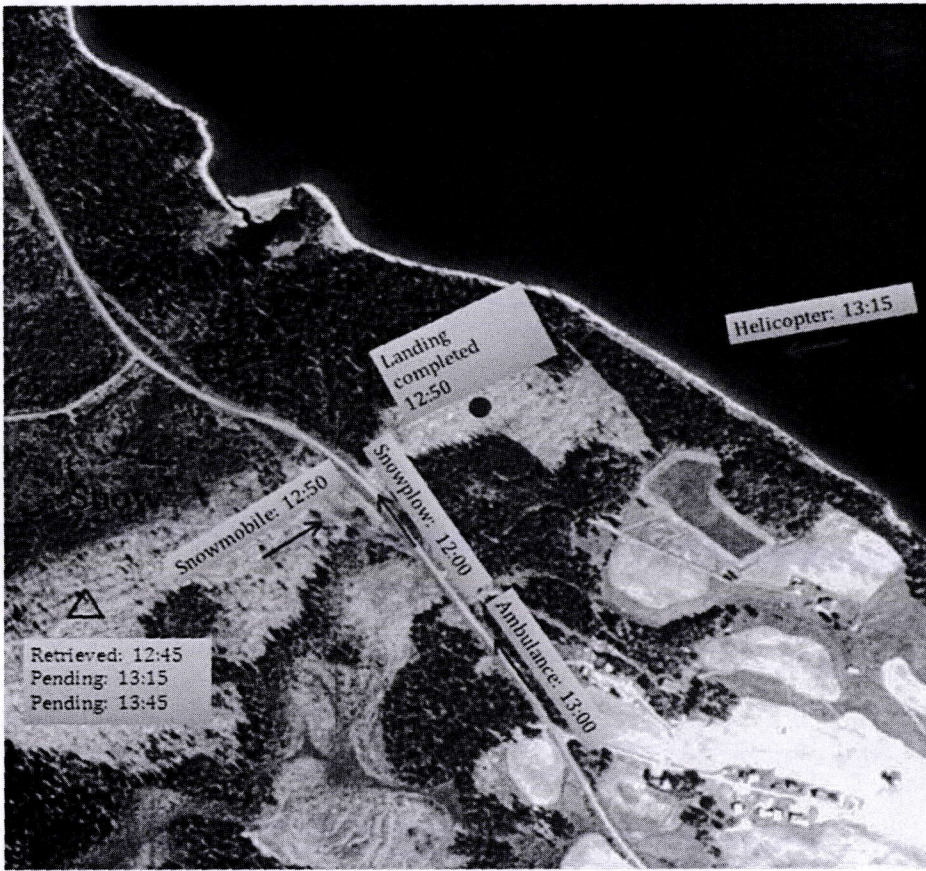


Figure 3: Screen from the prototype.

5 Conclusions

The first conclusion that can be drawn is that the question of accessibility is essential in crisis situations. This paper gives an overview of the concept accessibility and an example of how this can be applied in emergency situations.

As have been stated by earlier research the final outcome of emergencies is highly dependent on early preparations and training before the outbreak of the crisis. The conclusion we make is that training for emergencies is necessary.

There are different considerations to make when constructing a training exercise. One important consideration is to make the training as realistic as possible. Even though the emergencies simulated in the training session can be complex and maybe include something that very seldom happen or even never have happened, the circumstances

around must be realistic. A realistic simulation of accessibility contributes to the realistic scenario in the training situation.

This paper describes a first attempt to calculate and visualize accessibility in emergency situations. There still remains work to do to implement simulation models of accessibility in information systems with capabilities to support exercises in crisis management. More research on how different types of geographic information can be used to simulate accessibility of basic features of society during different crisis scenarios must be performed.

Furthermore, to make the most use of measurement of accessibility it would be of great interest to apply an anticipation model to the case.

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