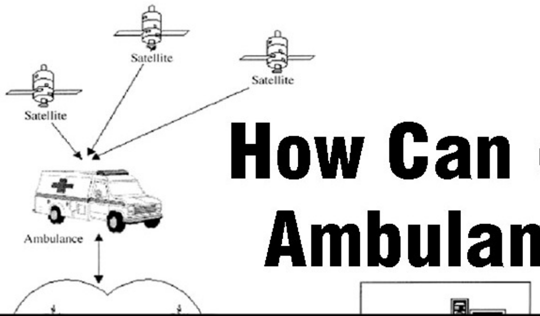
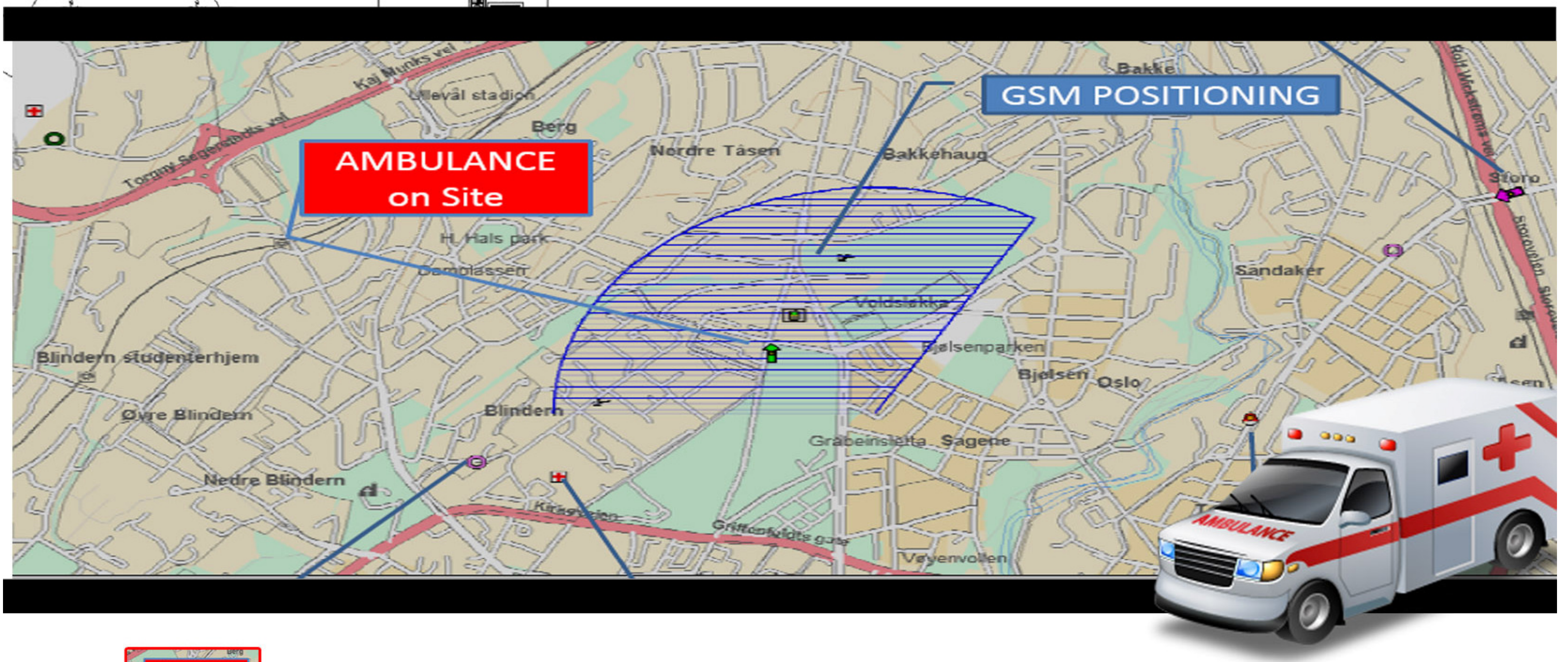
King Fahd University of Petroleum & Minerals
College of Environmental Design
Architectural Engineering Department

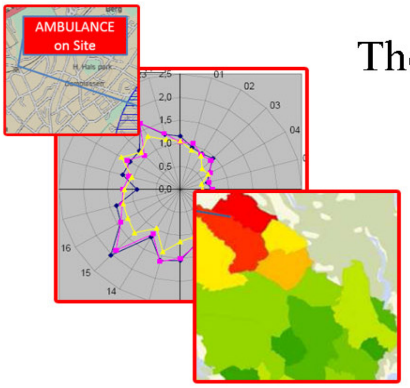
**CRP 514: Introduction to GIS**

**Term Paper**

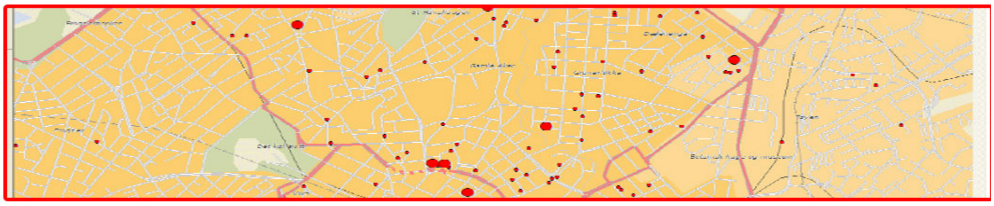



# How Can (GPS)and (GIS) Improve Ambulance Performance Levels




The supervisor: Dr. Baqer AL-Ramadan
Done by: Saleh Bahartha
ID - 200804320



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## Introduction:

Emergency medical services are very important components of health care. Patients need to be rapidly transported to the hospital. This can be accomplished by the efficient management of ambulance and reduce ambulances response time. Unavailability of ambulance at the center closest to a call response time can make response time becomes a random variable causing considerable variation in response time performance. In urgent call situations, it is important to deploy a limited number of vehicles in any way to that response time standards are met. Assessing ambulance performance can be affected by many variables such as ambulance travel time and ambulance availability. Understanding why an ambulance service has not met performance standards in a particular area is essential to inform better deployment decisions.

GIS (geographic information system) has the ability to communicate with other programs such as web-browsers, spreadsheet database systems .It also provides us a lot of information about people and accidents in the past.

## Research Objectives:

The objective of this paper is to explain the role of GIS(geographic information system) and GPS(global positioning system) in improving and assessing the ambulance service performance.

## Research methodology :

The research methodology of this paper will focus on acquiring the knowledge through an extensive literature review about improving and assessing ambulance performance levels . In addition , I will include a case study on Funen Danish island in how to allocate ambulances in the best location .

## Using a GPS system for effective management of ambulance:

This system is based on the integration of geographic information system (GIS), global positioning system (GPS) and global system for mobile communication (GSM) ( G. Derekenaris, 2001).

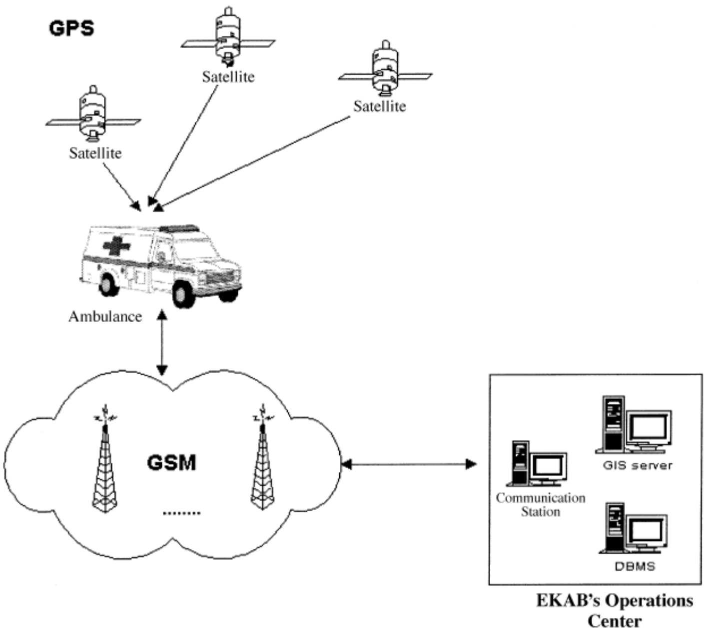


**Fig. 1**. The overall integrated GPS,GIS,GSM system.

The GPS and GSM technologies will be used to transmit the exact positions of ambulances to the GIS operating in EKAB's Operations Center. This can offer us a better management of vehicles such as company trucks, patrol cars and ambulances.

The exact position of ambulances will be determined based on the signal transmitted by satellites by equipping each ambulance with a GPS receiver . In addition, it will have a GSM modem in order to transmit its position to the base station in the Operations Center. This will be achieved through the GSM network. Furthermore, through the GSM network other useful data, as well as voice messages, can be transmitted. Each ambulance may also be equipped with a computer or a mobile data terminal to display the route computed by the GIS operating in the Operations Center.

EKAB's Operations Center will exchange data with the ambulances through the GSM network.. The optimal route calculated for a specific ambulance will be transmitted to it. In the Operations Center there will be a computer dedicated to communication with the ambulances and another one for the operation of the GIS. In addition, there will be one or more computers for the operation of the database management system (DBMS) containing data used by the GIS.

## The primary functions for GPS subsystem:

1- Depiction on a map of ambulance positions and hospital locations:
   all the information about the ambulance will be displayed, as well as hospital chosen from the map. All ambulances that are closer to a hospital, will be located also. Different symbols will be used for displaying ambulances.
2- Ambulance districting:
   GIS will take into consideration the data concerning the road network, population distribution, hospital locations, locations of gas stations and traffic conditions and will propose efficient distributions of ambulances.
   For example, areas where many incidents take place should be allocated more ambulances. A densely populated area entails a higher probability of an incident occurring. Areas close to major streets facilitate ambulance access to whereas areas with narrow streets inhibit it.
3- Finding the site of the incident:
   Based on the address given by the person calling EKAB's Operations Center for help, the GIS can use address geocoding functions to find the incident's coordinates on the map. When the person lose some words and were not able to give precise information, the DBMS will link telephone numbers with addresses will facilitate this matching.
4- Choosing the appropriate ambulance to handle an emergency incident:
   There are many factors will affect choosing the appropriate ambulance such as:
   - The ambulance position.
   - The traffic conditions.
   - The type and location of the incident.

   According to these factors, GIS will chose the ambulance requiring the least time to reach the site of the incident. The type of the incident will affect the choose of the ambulance because some ambulances are equipped to handle special emergency cases.

5- Routing an ambulance to the incident site and from there to the closest
6- appropriate hospital:
According to the distance as well as traffic data, the GIS will find the optimal routes corresponding to minimum required transportation time. Through the GSM network, the personnel in the Operations Center will communicate with the ambulance personnel and the appropriate hospital will be chosen according to the type of incident. The GIS can also present the driver with directions corresponding to the routes generated and then transmit these directions to the ambulance.
7- Generation of statistics regarding incidents:
The statistical analysis of incidents containing incident records will be established by the GIS in cooperation with the DBMS. Lastly, important conclusions supporting the ambulance districting can be obtained.

## Ambulance Allocation:

### A case study (Funen Danish island):

Solving location-allocation problems is not a new discipline (Christian, 2002) . Actually, it has a long history and it was used to find a good place to settle near resources such as wood, food and water. Despite this long history , many are still difficult to solve to optimality if not impossible.

In this paper, we will focus on finding placing ambulances on the Danish islands of Funen, Tasinge, Thuro, Sio and Langeland.

The ambulance access to these islands is easy, because they are connected by bridges.

We will talk basically about Funen, because ambulances rarely move off it to assist other regions in Denmark.

Flack Company (the leading provider of ambulance services in Denmark) has provides data of these islands.

The role of information system (GIS) and global positioning system (GPS) is to identify the positions of current available ambulances and to dispatch the ambulances so that they will reach the locations of accidents as quickly as possible.

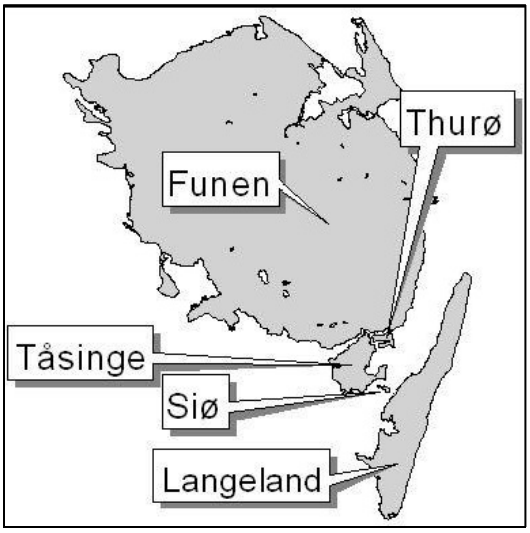


**Figure 2**. The island investigated in this paper

GIS data include: a road network, demographic data, ambulance duties, accidents and Falck-resources (number of vehicles, garages etc.).

## Working with Data:

Features such as road network, accidents and the outline of Funen Island are collected in themes (layers).

We can gather features in a stack. This means that the features in the top theme will cover the themes beneath.

An example of Falck garages on top, then the road network with speed limits above 70 km/h and at the bottom the theme representing outline of Funen.This can be seen in figure 3.

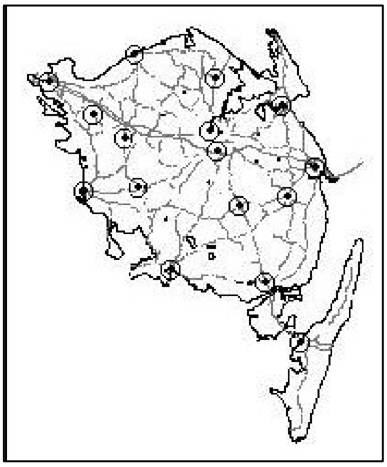

**Figure 3**. Geograhic data from Funen.

We can switch on and off themes. We Can also determining all accidents within **ten** kilometers of a Falck garage or locating all the highway approaches close-by .I addition we have the ability to snap one feature to another feature.
To calculate the distance between two points on a road, the points actually have to be on the road.

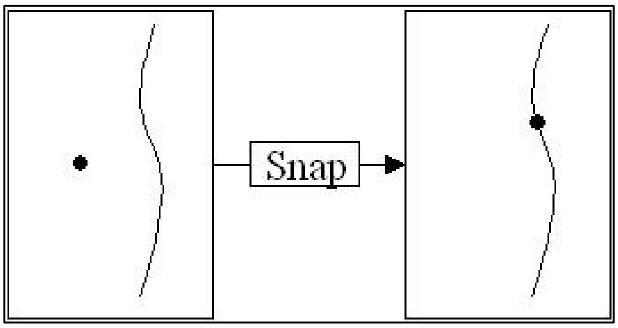


**Figure 4.** Snapping a point to a line using "snap to boundary"-rule.

## Using GIS for determining the suitable placement of ambulances :

GIS has the ability to communicate with other programs such as web-browsers, spreadsheet database systems .It also provides us a lot of information about people and accidents in the past. This will make it very powerful tool in any environment that deals with data that has a geographic dimension.
Ambulances should be placed at a kind of static placement Falck stations, by using allocation ambulances so that a certain response time can be met for 95% of the accidents.

## Data:

The main elements of data include the following:

- **Accidents:** They are placed on the network using a process called geocoding. The following time information are available: the time of the call, the time that the ambulance reaches the accident and the time when the ambulance is available again.
- **Road Network**: It contains information about one way street speed limits, travel time, and information about which addresses belong to which road.

## Accident Analysis:

In order to to handle 60,000 accidents at a time, It is necessary to understand the data. Furthermore, if the accidents were just numbers in a table, it will be difficult to comment on solutions to the ambulance allocation, and to get ideas on how to improve the allocation.

Accidents are deal with the following items:

1) Accidents in general.
   a. Where do accidents happen and when.
2) Dividing data into time periods.
   c. Do the accidents differ as to where they happen and when?

## Geography:

Accidents mostly happen in towns, where people live and work (Christian, 2002)as shown in Figure 5 and Figure 6.

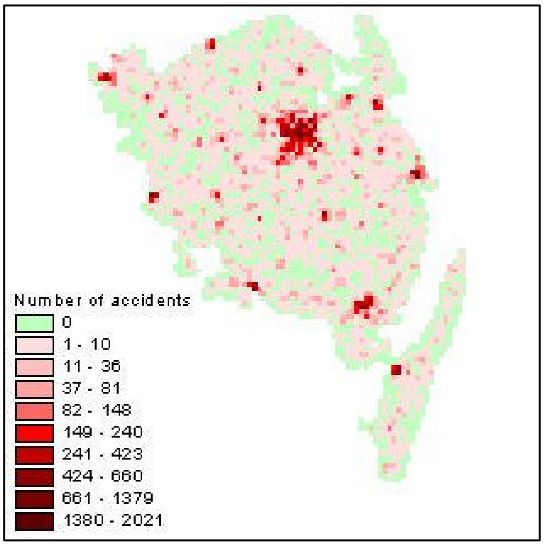


**Figure 5**. Accidents per km2 over the period.

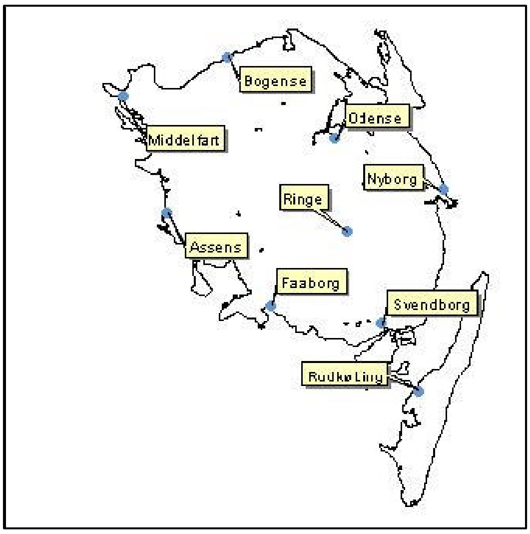


**Figure 6**. Positions of major towns on Funen.

Figure 5 and Figure 6 identifies the positions of towns on Funen in a grid cells. Each cell is one by one kilometer.
Areas where there are no roads such as lakes and sea will not be considered.

**Time:**

The number of accidents over year is represented in **Figure 7** .

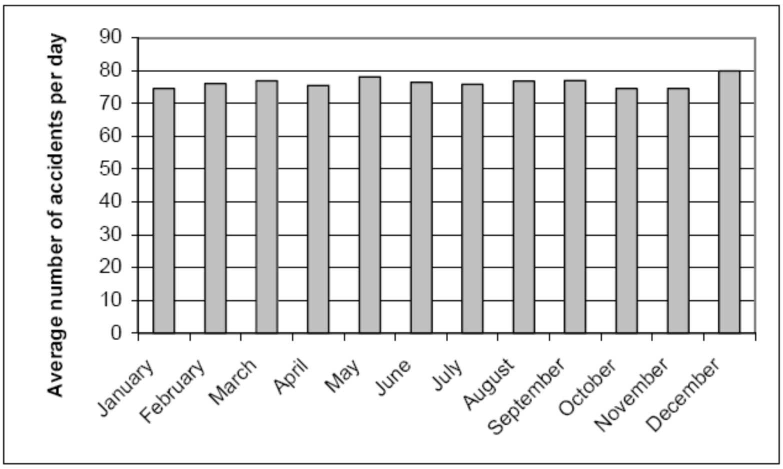


**Figure 7**. Average number of accidents per day in a standard month.

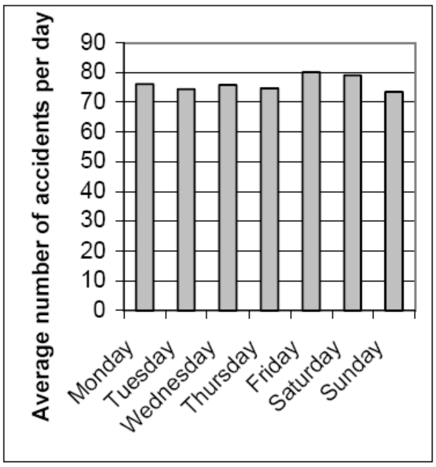


**Figure 8**. Average number of accidents per day.

We can interpret from **Figure 7** that there is no considerable difference in the number of accidents over the year. December has the largest number of accidents (76,3 accidents per day) .
**Figure 8** show us that there is a considerable deviation when looking at days.
Friday has the most average of accidents and Sunday has the lowest number of accidents.

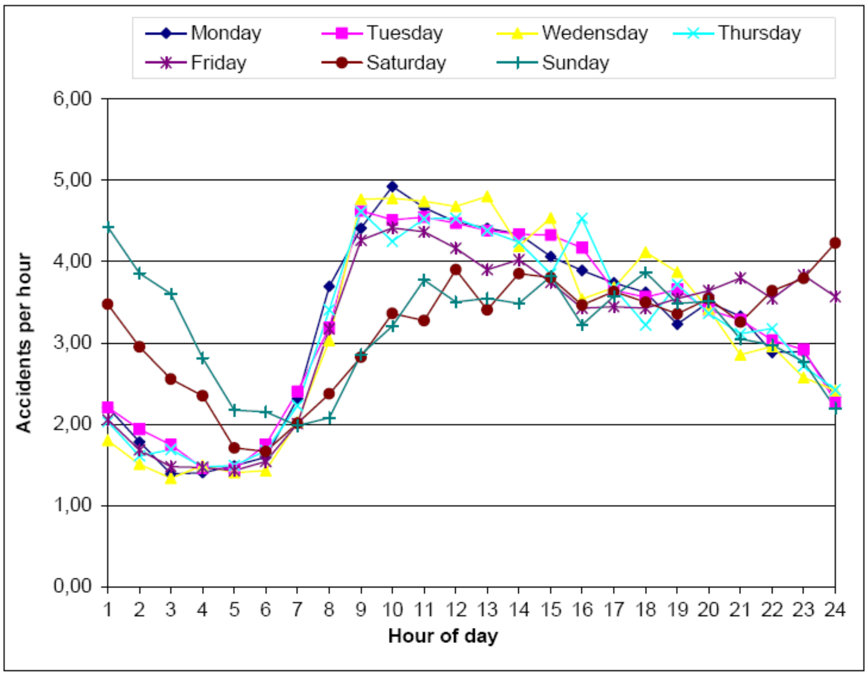


**Figure 9**. Average number of accidents per hour over a mean day.
Hour of day 1 if from 0 am to 1 am..

If we took the number of accidents over the week on an hourly basis, rather than on a daily basis, the variation will be more different as shown in **figure 8**.

- The lowest number of accidents happen when people are at sleep(Christian, 2002).
- The highest number of accidents happen between **9 am** and **2 pm** in the weekdays when people are at work.

## Visual Inspection of Accidents:

The visual inspection is carried out using the grid features of spatial analysis. Each grid is a square of one by one km, i.e. one km2(Christian, 2002). Areas where there are no roads such as lakes and sea will not be considered. Accidents in accidents in "summer weekends" are difference from accidents in "winter weekends "as shown in **Figure 9**. In addition, accidents in "fall at work". are different from accidents in "summer weekends" as shown in **Figure 10**.

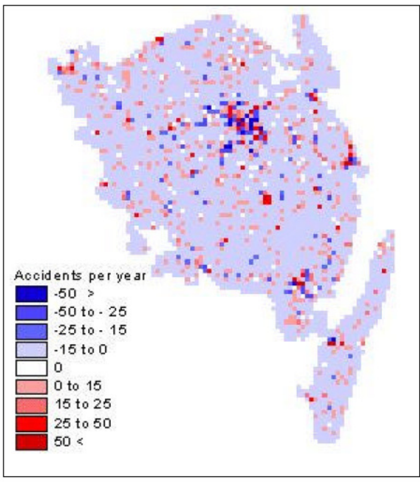


**Figure 10**. Accidents per km2: "summer weekends" minus "winter weekends".

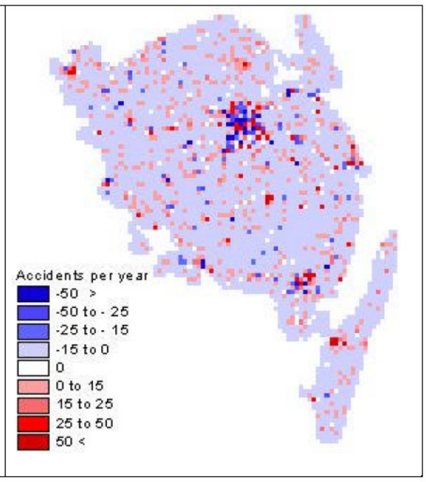


**Figure 11**. Accidents per km2: "summer weekends" minus "fall at work".

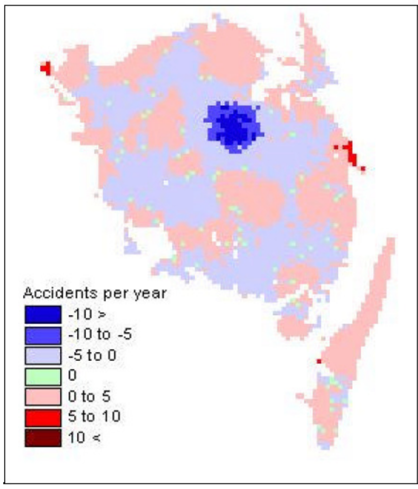


**Figure 12**. Accidents per km2 (mean within five km radius): "summer weekends" minus "winter weekends".

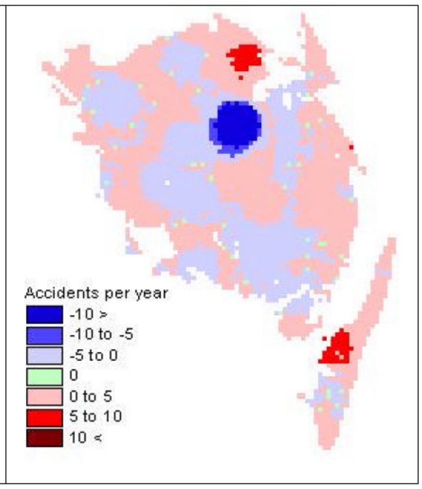


**Figure 13**. Accidents per km2 (mean within five km radius): "summer weekends" minus "fall at work".

When taking accidents per km2, it is very difficult to see any significant differences as shown in **Figure 10** and **Figure 11**. So, it is better to use cells within five kilometers rather than one kilometer as shown in **Figure 12** and **Figure 13**.

## Best Results for allocation of ambulances on Funen:

Based on the previous data analysis and by using Multi facility location allocation problem solution method, we can conclude the best results for allocation of ambulances on Funen as the following:

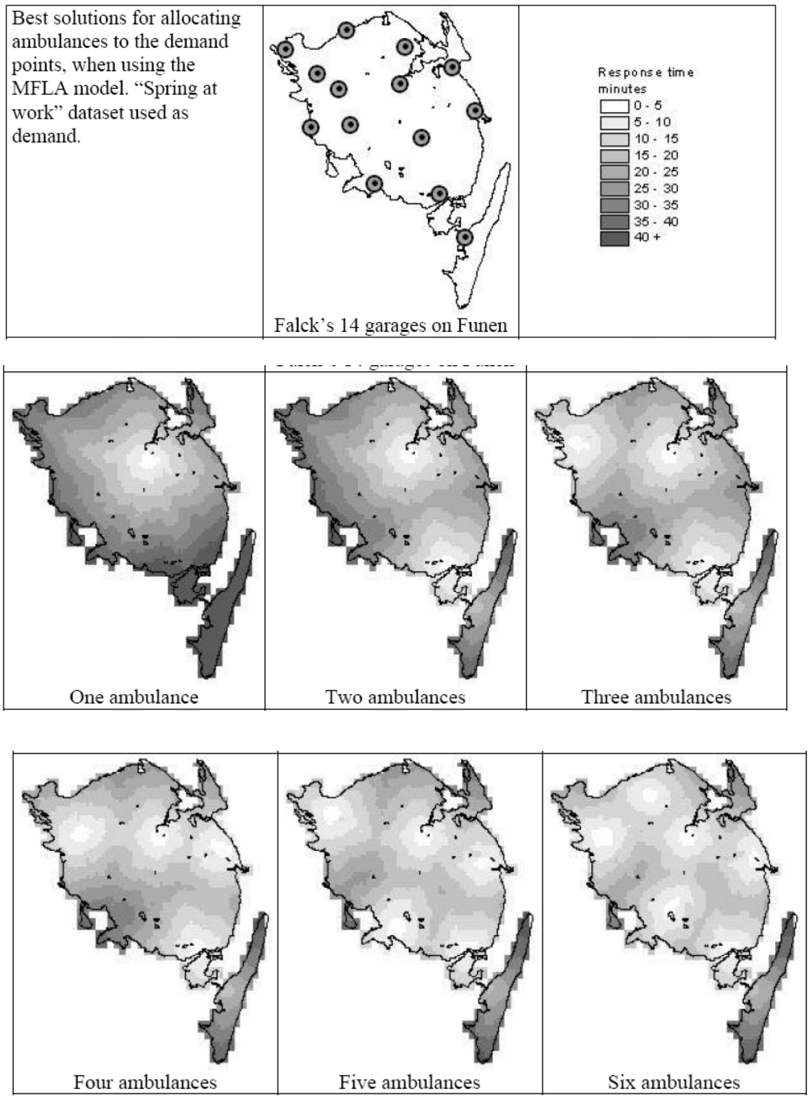


**Figure 14**. Best Results for allocation of ambulances on Funen.

## Assessing ambulance response performance:

GIS-based approaches have been adopted successfully to analyse the quality and timeliness of a range of emergency services including ambulance, fire, and police dispatching(Jeremy P,1999).

Now we will present a GIS-based application for Improving the ambulance service performance and achieving the following aims:

- Evaluating and improving EMS vehicle response, by presenting an **analytical model.**
- Design and implementing a valid **GIS- based framework** to assessing EMS vehicle response.

## An analytic model to assess ambulance response time performance:

The systems integrate a variety of associated technologies including Global Positioning Systems (GPS), Automatic Vehicle Location (AVL), Computer- Aided Dispatch (CAD), routing algorithms, electronic maps and in-vehicle navigation to provide real time tracking, dispatching and routing of emergency vehicles(Jeremy P,1999).

- AVL technology can be used to track the real time locations of an ambulance.
- GPS technology can display their locations on GIS-based computer maps.
- GIS is used in CAD to locate the addresses of calls on a geo-coded street network.

Automated EMS system uses current information on the location, type, and status of each vehicle to identify the optimal unit to respond to each call. Once the optimal vehicle is identified, the communication center dispatcher transmits a signal to the emergency vehicle's on-board computer to display a map of the surrounding area showing the vehicle's current location, the location of the emergency, and the best route to that location. Patients information such as: patient's name, nature of the injury, and whether lights and siren are required, is displayed by the computer. The vehicle driver then transmits a signal back to notify the communication center that their ambulance has taken the call.

## A statistical model:

The task of this statistical model is to :

1- Calculate the number of call are expected in an area (potential demand) and compare it with the actual number of call (realised demand).

2- Analyses ambulance response by mapping the number of calls that exceed of 14 min to reach the location of an emergency.

**Analytic model:**
This analytical model can assess response performance by using a set of five attributes. These attributes include:

1- The number of calls within a time interval (such as a work shift or per week),
2- The lapsed response time for each call.
3- The purpose of each call.
4- The date and time when each call is received.
5- The center location of the ambulance that responds to a call.

**The intention of the analytic model:**
To demonstrate how ambulance call data can be used more efficiently.

**The first dimension**: the analysis and visualisation of response time anomalies and the `normal' variation in ambulance performance level:
Areas where response times need to be improved can only be clearly visualised if anomalous calls are removed from the analysis to reveal the `normal' pattern of response performance.
All anomalous response times are separated from normal response times in order to help understand the cause, spatial distribution anomalies and to predict the likelihood of their occurrence in the future.

**The second dimension:** defines a complementary set of response indicators to evaluate trends in ambulance performance over space,

**The third dimension:** addresses the question of whether or not an ambulance service meets performance standards in a particular area: The variation in response times can help us to interpret the difference in response time between one area and the neighboring areas.

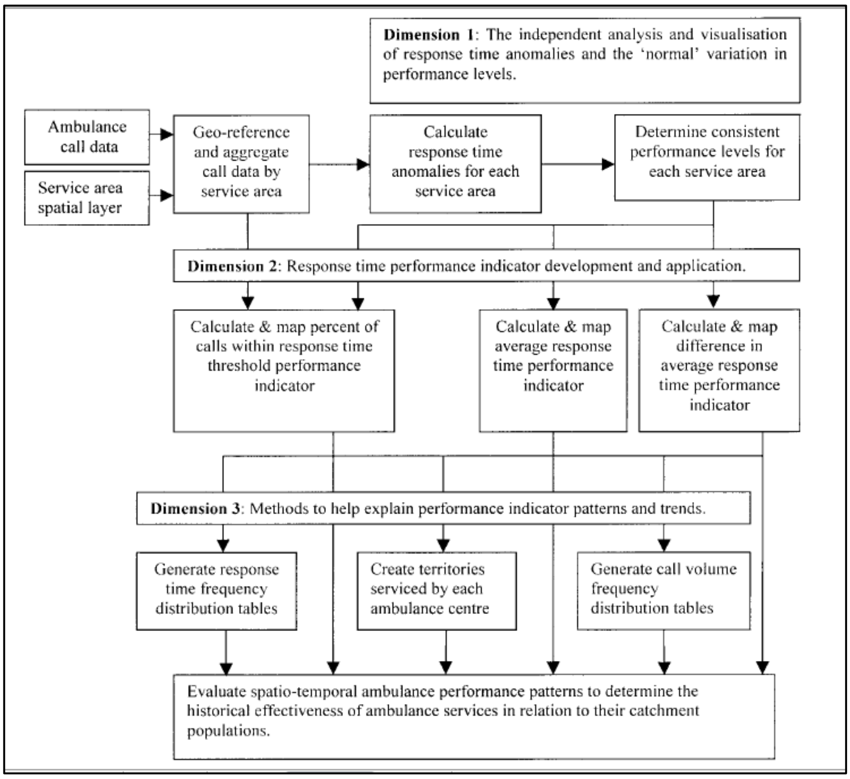


**Figure 15**. An analytic model to assess ambulance response time performance.

## GIS framework:

The framework describes the interaction between 11 components, including ambulance call data, spatial data, the system user, a graphical user interface, statistical analysis, spatial models, performance indicator calculations, built-in GIS functionality, mapping, evaluation, and decision making.

- The GUI (graphical user interface) helps the users to interact with GIS environment features. It also enable users enables users to generate performance indicator maps by specifying the parameters they need.
- EMS response mapping is the fundamental component of the GIS framework.It enable planners and to preprocess data, identify and visualise problems easily. Once problems are visualized, they will be refined by using statistical analysis and spatial model components.
- Statistical analysis and GIS database manipulation, spatial analysis and mapping functionality are programmed into the application to operationalise each component(Jeremy P,1999).
- By using this framework, planners can better target when, where, and for what type of calls ambulance response performance must be improved.

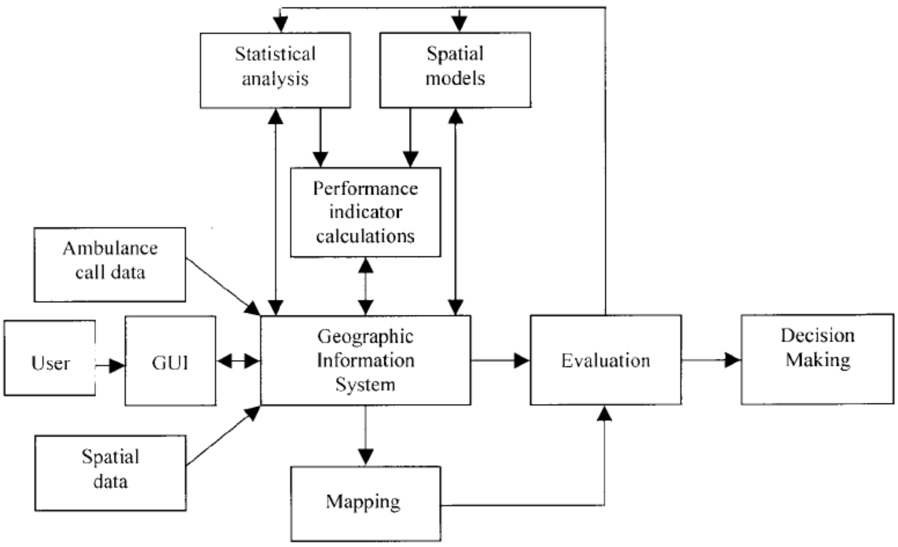


**Figure 16**. A GIS framework to evaluate ambulance response performance..

## Conclusions:

- GIS has a big importance in emergency health care sector and improving ambulance performance levels.
- In this paper, I have described a GIS , GPS, GSM based system which can offer an effective management of ambulance .
- The described GIS framework can assess ambulance performance and help in minimizing the response time.
- GIS plays a good role in determining the best location for ambulances to be located.

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