Issue paper

GIS technology and the combat of infectious diseases

How can GIS contribute to the rapid discovery and repression of epidemics of infectious diseases?

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Preface

This issue paper has been written as part of the examination of the course spm9321 (Design of Geographic Information Systems for business applications), taught at the Faculty of Technology, Policy and Management of the TU Delft.

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Summary

This paper explores the possibilities of the use of a Geographic Information System in the field of the early detection and repression of infectious diseases in The Netherlands. It also includes an overview of technical and organizational issues coming up when implementing a GIS in this area.

GIS are used in a broad range of applications in this field, foremost in the scientific area. In contrast, the current system for the registration of incidents in The Netherlands (ISIS) is very basic. However, it could serve as a base for a new GIS, which should comprise a registration database for the monitoring of diseases and interventions. It could be used as an early warning system, too. The database is also needed for more advanced applications, of which the identification of the source of contamination, information services for the public, fundamental research and the simulation of diffusion and of the effectiveness of potential measures are interesting. The use of a GIS is advantageous, because the information about infectious diseases is distributed, it helps in recognizing patterns and communicating information across professionals and the public, and it enables new applications that otherwise will not be possible.

For both technical and organizational reasons, it is recommendable to follow an evolutionary growth path. One should start with a basic functionality, and extend the system when new applications are ready for it. Cooperation with international organizations sharing the same information system needs can speed up and cheapen the development process. The existing Dutch Landelijke Coördinatiestructuur Infectieziektenbestrijding could be used as a platform to introduce the system and keep in contact with the end-users.

In the set-up of the registration functionality, the role of the municipal health organizations should be reconsidered. These organizations are key players in the current registration systems because of their role in distributing information, but that function can be taken over by a GIS. When using the system to publish information to the public, one should set up a procedure to be able to guarantee the quality of the information. Misinterpreted or unjust information can lead to social unrest. If the system's future capabilities to simulate the effectiveness of potential measures are used, one will have to answer moral questions about following a purely rational approach.

GIS seems to be able to play a key part in a new system for a better and faster detection and repression of infectious diseases, that should be gradually build up. However, several questions have to be answered before using all the functions.

Introduction

In our modern, open society, with people having direct and indirect physical contacts with a large number of other people, often in many places and over a great distance, we are very vulnerable to infectious diseases. The diffusion of these diseases can be very rapid. Moreover, these diseases are not only spread by natural causes, there is a risk of terrorist attacks or maybe even scientific mistakes that may lead to an outbreak. The success of treatment and the prevention of further infections depends largely on the speed of detecting the infections. Hence, an information infrastructure that supports this process can be of great value for national health care.
As most of the required information for detecting such a disease is geographically bounded, for instance the regions of contamination and the possibilities of diffusion by transport infrastructures, Geographic Information Systems (GIS)[1] could play an important role. This issue paper aims at getting more insight into the possibilities of GIS in the field of the rapid discovery of infectious diseases. As underlying case study the Dutch situation will be taken, merely because this helps in identifying organizational complexities in implementing a Geographic Information System. This paper will be relevant for both scientists, who are doing research in the field of the use of GIS in business systems, as well as policy makers in the public health or counter terrorist sector.

The main research question of this paper is as follows: *How can GIS contribute to the early detection and repression of infectious diseases in the Netherlands?* This question can be split up into several sub questions:

1. Which tasks could a GIS perform in the field of the early detection and repression of infectious diseases in the Netherlands?
2. How do current systems fulfill these tasks, and where is the introduction of a new GIS needed?
3. What are the technical requirements for information systems in these fields and how can current systems meet them?
4. What are the challenges and possible problems in using GIS for the identified tasks, and how can these be defeated?

This report is based on a somewhat eclectic approach, in which different fields of knowledge from the TPM faculty are used. Both organization and management as well as specific knowledge about GIS will be used. This paper will not deliver an implementation advice, but will predominantly identify some challenges and barriers in this GIS application field.

This paper has been structured along the line of the various sub questions. Paragraph 1 identifies the possible application fields for a GIS. In paragraph 2 the current registration system is described, and compared to the identified requirements. The next section (paragraph 3) gives an overview of the technical requirements and challenges, whereas the fourth section (paragraph 4) explores the organizational issues coming up. This paper finishes with a conclusion and a reflective discussion.

[1] In this paper the definition of GIS as cited in Grimshaw, 2000 (p. 28) is used: "A system for capturing, storing, checking, manipulating, analyzing and displaying data which are spatially referenced to the Earth."

1. Which tasks could a GIS perform in the field of the early detection and repression of infectious diseases in the Netherlands?

First of all, it is useful to explore the areas in which GIS are already being used, and which are by application or by technology related to the application of GIS in this paper. Boone (2000) explains the use of GIS in predicting infections, based on the identification of risk areas and spreading patterns. The system is used to support decision-making. In Peru there has been some experience with spatial pattern modeling too (Roper), which contributed to the insights on malaria transmission and control measures. Kistemann and others describe two examples closely related to each other; the use of GIS for back-tracing both water (Kistemann, Dangendorf & Exner, 2001) and food contamination (Kistemann, 2000) seems quite successful. Finally, GIS are being used for performing impact assessment on conditions for diseases (McSweegan, 1996). A combination of these systems should be able to form a system that facilitates the detection and repression of infectious diseases. Based on the observation that the technological possibility has been proven by these historical examples, the next step is to identify areas for the use of GIS in The Netherlands. An overview of the possibilities of GIS given by Gupta & Shriram (2004:2) has supported this task. In Table 1 a list can be found which sums up the possibly attractive uses in the field of infectious diseases.

Table 1 Various applications of GIS concerning the rapid discovery and repression of infectious diseases.

Very attractive	Maybe attractive
• Discovering diseases (early warning). • Monitoring diseases and interventions. • Identifying source of contamination, including water contamination. • Information services for the public. • Research on diseases, for instance to discover the properties of a new disease or variant of it.	• Monitoring utilization of health centers. • Simulation of diffusion and effectiveness of potential measures. (Forecasting epidemics.)

Very attractive applications

First of all, the system can be used as an early warning system for new outbreaks of infectious diseases. This is of vital importance, since a rapid discovery of an outbreak greatly contributes to the possibilities to contest the disease.

By monitoring diseases and interventions information close to real-time can be presented to professionals and policy makers. It is important to be able to identify (the size of) the problem, and to evaluate the effectiveness of the measures taken. This should not be confused with more fundamental research on the characteristics of diseases. With monitoring interventions is primarily aimed at answering questions about whether to take additional measures or not.

Especially in the case of a biological terrorist attack, it is useful to identify the source of contamination. Firstly, this helps in informing the people that may get ill from this contamination. And secondly, it can be useful in criminal or legal investigations.

The SARS epidemic showed that GIS could be very useful to provide the public with easily understandable information about the current situation (ESRI, 2004). By already having a registration of incidents, the monitoring diseases and interventions functionality can be

extended to a graphical public portal. This helps in communicating with the public, maybe arising awareness or, on the contrary, diminishing groundless worries and social unrest.
As mentioned before, the system could deliver data to fundamental research about the characteristics of infectious diseases, by providing detailed information about incidents and their dependences in time and geographic location.

Applications that are more difficult
The monitoring of the utilization of health centers is not classified as very attractive at first sight, because it is not clear whether there is a need to do this in The Netherlands, because shortages in hospital capacity only rarely occur.
Simulation could be used to predict the propagation of an epidemic. Using GIS for this purpose leads to a need for different systems to be integrated. This paper does not focus on the technical details, but due to its complexity it is obvious that technically it is the most difficult part of the system.

Level of applications
The identified applications can be categorized as operational, tactical or strategic. According to Grimshaw (2000:103) an operational system has a high data depth, but a low data breadth; in other words: it serves a specialist and narrow area. A tactical system combines a high data depth with a high data depth, whereas a strategic system is a combination of both a low data depth and breadth. Almost al applications could be characterized as tactical. Detailed information about infections is needed to get useful information from the system. On the other hand, this data is about a whole country (The Netherlands) or goes even beyond it, so the data is also bread. Of course strategic applications could be derived from this system, to provide aggregated information about infections. At last, the data entry by professionals could be characterized as an operational process, but the applications that use this data have a tactical nature. This observation is important, because it shows that the applications are data-intensive, which is also an indication that a GIS could be useful, because of its capabilities in storing and interpreting large data collections.

In Appendix A all the identified applications are enriched with scenarios in which they could be useful.

2. How do current systems fulfill these tasks, and where is the introduction of a new GIS needed?

The fundament of all the different applications of the GIS is a proper registration of incidents, because it is the most valuable and necessary data in the system. In The Netherlands there is an active registration of these incidents. In article 4 of the Dutch Law on Infectious Diseases (*Infectieziektenwet*) (Ministerie van Volksgezondheid, Welzijn en Sport, 1998) doctors are obliged to report certain types of infectious diseases to municipal health institutes (GGD's). The information is quite detailed, and includes the address of the infected person (article 5). The GGD's put this information in a national database, maintained by the national health research institute, part of the Dutch ministry of Public Health. This database is called ISIS (Infectious diseases Surveillance Information System, http://www.rivm.nl/isis). The exact details of this system are not publicly available, but the mere existence of it is an advantage in setting up a registration database as fundament to a GIS system covering the applications mentioned above.

However, an obvious problem of this system is the report of an incident from a doctor to a GGD. This can be done by telephone, fax or other rather archaic communication means, with a chance of delay and error in it. Another problem is the depth of the information provided. More information about the situation of the patient and the symptoms could be very useful in determining the exact type of disease and for fundamental research on diseases. In order to collect this information properly, however, a more advanced way of entering the data is needed, one that is closer to the professional. A system in which the doctors can enter data themselves seems an appropriate solution. This is one of the core capabilities of a GIS: providing a user friendly and direct interface to a database.

Another drawback of the current system is that it is not directly connected to international databases; although at this point it is difficult to discover the details of the system. In today's open world with a huge mobility of individuals, diseases do not care about national borders. The treatment of these diseases becomes more and more an international problem; a recent example of this is the SARS epidemic. The need for a global database to fulfill part or all of the tasks mentioned earlier becomes more urgent.

A final drawback of the ISIS system is that it is not related to any other database, but is a stand-alone, which makes a geographical representation impossible. ISIS cannot be classified as a true GIS yet, because geocoding addresses is not possible without relating them to basic data about addresses in The Netherlands. It is obvious that without a graphical representation of the data – for which a GIS is needed – pattern recognition, including the identification of a contamination source, and information services to the public could not be performed. This also holds true for the monitoring of health center utilization and fundamental research. The absence of integration with other databases makes the carryout of simulations impossible, too. Shortly, the identified tasks offer great opportunities, which could not be accomplished without some sort of Geographic Information System that could be based on the current registration system.

In brief, the current system makes sure that there is a registration of incidents, so this paper will not focus on the introduction of a registration obligation to professional. However, the possible advantages of a GIS in the field of *direct information entry*, *more detailed data collection*, *international connectivity* and *geographical representation* are very relevant and most of them have a connection with organizational implementation issues (see Section 4).

3. What are the technical requirements for information systems in these fields and how can current systems meet them?

Although the technical systems seem to be able to handle the requirements, it is necessary to elaborate on the technical requirements of the system, as far as they follow from organizational requirements. For instance, think about issues on collaboration between different organizations and the wish of an organic and evolutionary growth of the capabilities of the system. The requirements are based on the current registration system, general assumptions in (geographic) information systems literature and common sense. First of all, we will look at the requirements for the GIS infrastructure, which comprises the basis elements of the system, without paying attention to the applications used on it. The classification of requirements follows the subdivision of a GIS system into six components (following Longley, 2001:17), and can be found in Table 2.

Table 2 Infectious diseases GIS requirements.

Hardware
• No special requirements, although the hardware should be standardized (PC's) to reduce costs and enable a large number of professionals to use the system easily.
Software
• COTS (Commercial Off-The-Shelf) preferable above custom made software, due to lower costs, and proven reliability. • Web interface for professionals. • Should support fuzzy logic, which means that uncertainty of data could be included in the data itself.
Data
• Registration: Base data for mapping needed, with information about zip codes and addresses, population, water pipes, traffic (including air traffic!). (Un)certainty of data should be registered. • Base data should be maintained by an external organization (Topografische Dienst Kadaster), to prevent double work. • Should be in standardized format, for interoperability with other systems and possibly international agencies.
People
• *Skilled* users: intelligence in the people, not in the system. Epidemiologists, who are used to discover patterns in huge (medical) data sets, may be involved.
Procedures
• Because every little piece of information can be very valuable and the importance of the system for the public health can be enormous, an *obligatory* registration is needed. When these procedures are disobeyed, clear sanctions should follow.
Network
• The registration database contains private data about individuals, and hence should be protected. • Standardized (TCP/IP) for use over Internet. • Security and reliability are important because the system handles vital information and functions.

Now that we have identified the requirements, this list could be used to check whether technological problems are to be expected. Without doing a broad analysis however, it is obvious that all these requirements seem to be feasible with current technology. Another part of the feasibility analysis is the whether the GIS applications – the software and tools – are available. The examples of GIS use given in the first section illustrate that all of the identified applications have been used in the past. But, two remarks should be made. Firstly, these applications have been mainly in the scientific area. Possibly they do not fit in a business situation, when not only the functionality, but also reliability and user interface are important. Secondly, these systems have all been used solitarily, but they should be at least partially integrated with each other, because they use the same database. The challenges are in the field of modifying and integrating these systems for use in an operational environment. While systems integration often is technologically feasible, it should be borne in mind that there are uncertainties about the speed and costs of this process. Besides to this translation process, the preference of using off-the-shelf products should be fulfilled whenever possible.

4. What are the challenges and possible problems in using GIS for the identified tasks, and how can these be defeated?

The requirements mentioned in the previous section are directly related to the technical system, but the system affects organizational processes, cooperation between institutions and national policy on health care and emergency responses as well. A selection of some relevant issues will be elaborated on; these serve as an identification of possible organizational problems in setting up a GIS.

Actors: distributed setting

A first observation in the possible problems that arise when implementing the system is that the field of the recognition, treatment and registration of infectious diseases is placed in a multi-actor setting. Different actors, with different interests, are involved. It is useful to identify the main actors in this arena. First of all, the municipal health organizations (GGD's), which are set up mainly for prevention and recognition of diseases, are involved. They collect responses from doctors about diseases, and distribute it to the central information system maintained by the national health institute RIVM. This institute also performs both practical and scientific research on diseases, and is a part of the Dutch ministry of Public Health. Furthermore, doctors and hospitals are the professionals that have to do with the recognition and treatment of the diseases. Beside national institutes, international health organizations like the World Health Organization and the American Centers for Disease Control and Prevention could be interested in having access to up-to-date information about epidemics.

This environment, in which information has to be shared among geographically dispersed organizations, could be characterized as distributed. Distributed environments can benefit hugely from the use of information systems, but these systems have to be compatible with each organization's own systems. A related requirement is the standardization of the data itself; the semantics of them should be the same, so any professional in the field can work with them without having to dive into local classifications and so on. An underestimated problem lies in the difference in local and even individual habits. The one doctor is more eager to suspect a patient from having a certain disease than the other. It is an illusion to think that this problem can be fully eliminated, but at least standardized semantics contribute to the enlightenment of this problem.

Organizational implementation

To implement a GIS in this distributed environment, one should look for an organizational arrangement or cooperation to commit all parties involved. It is important to gain support from the people that have to work with the system; a top-down approach reduces the possible benefits of a system because the users do not have the feeling that they have had influence on a major work process – which is psychologically important to professionals – and because of the fact that opportunities to fit the system to user's requirements will not have been used. In The Netherlands there already is a platform in which the key players on fighting infectious diseases work together: the National Coordination Structure for Infectious Diseases Combat (*Landelijke Coördinatiestructuur Infectieziektenbestrijding*, www.infectieziekten.info). The organizations that bundle their forces in this platform, as well as their dependencies, can be found in Figure 1. It seems that most of the organizations involved in the use of the system are involved in this platform. One group, however, is not

very well represented here: the medical professionals, general practitioners and other doctors. It is to recommend that this group will be involved. The easiest way to do this is to invite the National Association for General Practitioners (*Landelijke Huisartsenvereniging*), which represents the largest group of affected professionals.
This part of the implementation comprises the user side, but there is also a platform that serves as a consultation platform for different players demanding or supplying geodata. Depending on the size of the geodatabase, it may be useful to participate in this platform, which is called Ravi (www.ravi.nl).

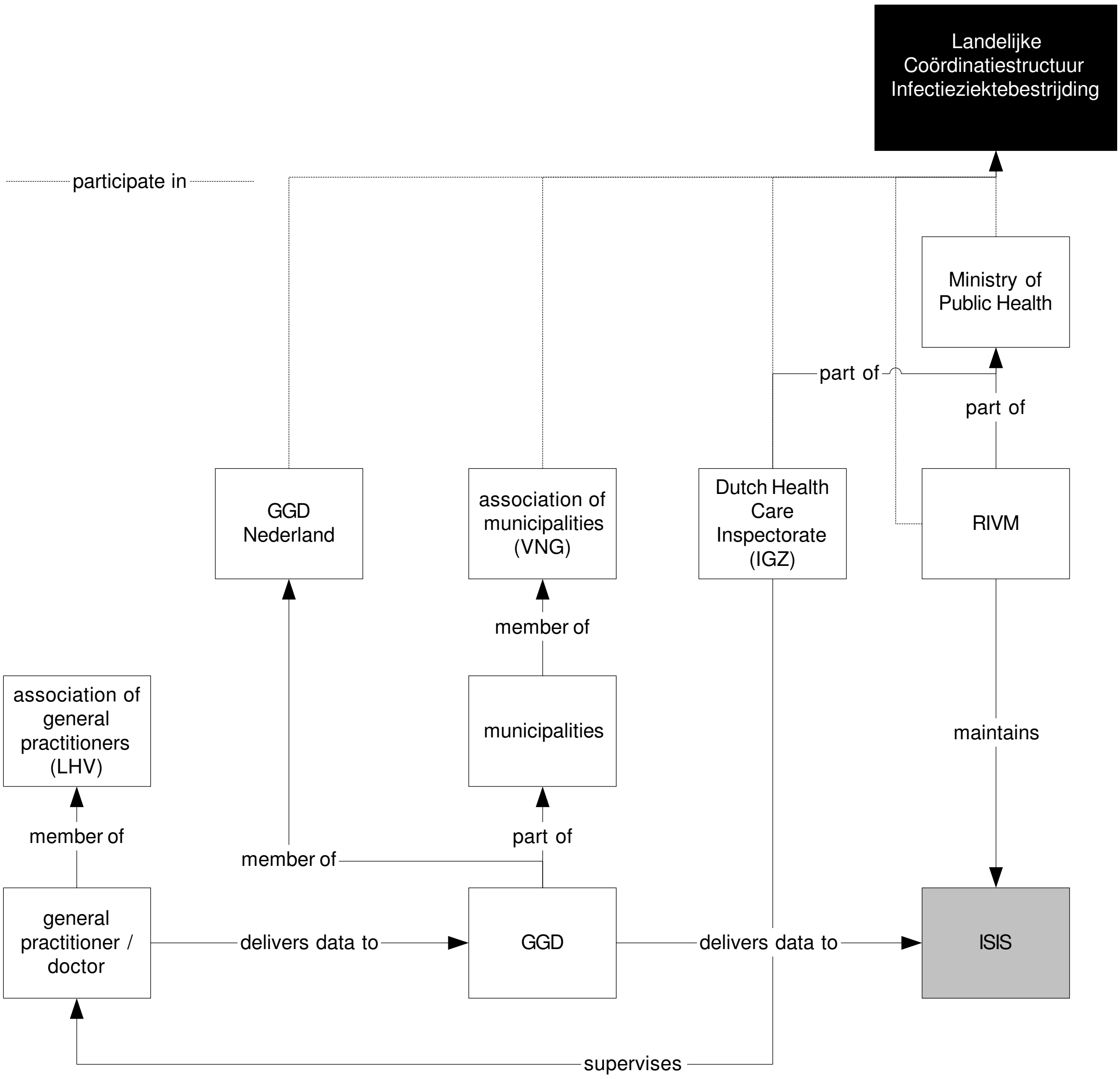

Figure 1 Actors involved in fighting infectious diseases.

Municipal health organizations and the quality of information

Human reviewing of information added to the database is essential to guarantee a high quality level of the data. This is especially true in a distributed environment, in which different people from different professions and different organizations have access to the system. In the current registration system, the municipal health organizations play an intermediary role in collecting the incident information. However, with a fully distributed system, which can be accessed through the Internet, it is no longer needed that a doctor first notifies the municipal health organization by telephone, fax, e-mail or other archaic systems, but he can enter the details of the patient himself. This implies a changing role for the GGD's, but they can still play a role in reviewing the data added to the system. Besides, they are the first level at which information can be combined to discover patterns. The GGD's are also responsible to initiate local action, when needed. Hence, the importance of the GGD's will not be diminished, but they will have to do less routine work; the chance of mistakes will reduce, too.

Evolutionary growth path
In introducing new information systems, there are several advantages of using an evolutionary growth model. Firstly, there is less to be changed than in the case of introducing a totally new system. In this case, the registration database ISIS can be extended for other purposes, but the experience with the ISIS system can be benefited from. A second advantage lies in reducing risks. It is obvious that small changes are less risky than larger ones. Related to this argument is the fact that incremental changes also allow parties to learn from mistakes and previous experiences; there are more intervention windows. A final advantage is the possibility to use parts of the system when they are ready, instead of waiting for the whole system to be available. For example, the simulation part of the GIS is rather complex, and should not delay the introduction of the monitoring part, which is much easier. A recommendable strategy is to start with the basic functionalities, and to extend the system gradually with the more advanced ones. The development of the different software applications and the integration of these into one system could be done in cooperation with other (international) organizations facing the same challenges.

Social acceptability of new measures
Simulations can be used to calculate the effectiveness of a set of measures to stop the diffusion of a virus. When more information is available in the decision process, new solutions become available. For instance, when there is a scarcity of vaccines, the most effective way to spread them can be simulated. The same holds true for a situation in which there is a scarcity of medical staff. All these solutions aim at the most effective way to stop the diffusion. However, it is questionable whether they are socially acceptable. Is it acceptable to treat just adults, and not elderly people, because the chance of infection is much lower among them due to their lower mobility? And is it feasible to treat only people in crowded urban areas? These moral questions come up with the new solutions that can be thought of. Deciding about threats to life is not only a technocratic issue, but affects emotions and interests of social (in)balance and equal rights. These issues must be thoroughly thought of, before they can be used in a simulation.

Quality of public information
When using the registration database to present information to the public about incidents, it is of the utmost importance that this information is correct. Because this information can be very valuable and will be re-used in press and among the public many times, it has a great impact on the experience of the situation. Therefore, it is also needed to clarify the meaning of the data, so people can draw right conclusions out of it. Think about chances of contamination and measures taken to defeat the diffusion of the disease. Non-accurate information can undermine governments' trustworthiness.

Conclusion

Information systems can deliver a huge contribution to the various fields of discovering and repressing infectious diseases. For most tasks, geographical data are necessary, as are

analyses based on geographical patterns. A large spectrum of tasks can be carried out with the support of a GIS; tasks which differ in complexity. The currently used information system in The Netherlands for the registration of incidents can be used as a base for developing a new GIS, but is certainly not appropriate for most tasks. It is preferable to use off-the-shelf products to implement a GIS, because of their proven functionality and reliability. As far as this concerns the GIS infrastructure, this does not seem to be a problem. But when it comes to the actual applications and the software and tools needed for that, these systems have not been integrated yet, nor are they already being used in an business environment. A translation must be made from the scientific to the operational area. Therefore, it is to recommend to follow an organizational growth path, and to start with the basic functionalities. For the development of the more advanced functions it is recommendable to cooperate with other (international) organizations.
Apart from these technical merits, several organizational consequences and dilemma's coming from the possible introduction of a widely implemented GIS should be borne in mind. Special attention must be given to the quality of information and the social acceptability of measures whose effectiveness can be calculated. Besides, the introduction of a wide GIS has consequences for the role of municipal health organizations. The already existing national coordination structure for the repression of infectious diseases (LCI) could be used to introduce a system among its partners. In an evolutionary growth model, it is not necessary to answer all these questions instantaneous, but they should be borne in mind when implementing a new application of the system.
Several problems have to be overcome, but it seems justified to conclude that GIS will be indispensable in the field of infectious diseases in the near future.

Discussion/reflection

Although the possible applications of GIS as described in this paper could be very interesting and may contribute to a more effective detection and repression of infectious diseases, it is important to stay realistic. In Information Technology, it is known that projects often last two times as long as projected, cost two times what is budgeted, and the functionality performs only half of the things required. Working with feasible targets, realistic budgets and development periods could prevent this. As indicated, the integration of various functionalities into one system, and the translation from these applications from a scientific to an operational environment can be hard.
It is recommendable to perform a cost-benefit analysis for each part of the GIS. However, one should not hesitate to take some risks in developing new systems. The simulation of diffusion may be the best example. It is not totally clear what this may contribute to the insight in and repression of diseases, but it could be very useful. Working at the front end of IT development involves risks. Cooperation with scientific systems to develop these systems before they are going to be used in practice seems a good idea.
This paper presented some easy-to-implement applications, but it also included a look to the (near) future. The utopist situation, which should be technically and organizationally feasible, is a system that can be used throughout many countries, and includes monitoring and simulation. To reach this situation, however, one should start with a realistic and somewhat small system for geographically monitoring diseases in The Netherlands.

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Appendix A: Applications and Scenarios

To get a better understanding of the possibilities of the different applications of GIS in the field of the rapid discovery and treatment of infectious diseases, each application will be detailed in a scenario. A scenario describes a possible use of GIS, and is written from a user point of view. It will not focus on technical details; instead it looks to work processes.

Discovering diseases
An infectious disease, with characteristics similar to SARS, starts to contaminate people in The Netherlands. Several general practitioners see symptoms of an infectious disease, and report these incidents to the national infectious diseases geodatabase. They cannot determine the disease type, so they classify these patients under "general, maybe dangerous infectious disease". An intelligent agent in the system discovers that several of these unidentified diseases have been entered into the database, and that they are concentrated in some regions. A warning message is sent to responsible national health officers, they can investigate whether this is an unnatural situation and whether additional research is needed to discover whether there is a public health problem.

Monitoring diseases and interventions
The basic functionality of any GIS system is the extraction of basic data from the database. This can be used to monitor the development and spreading of diseases and the effect of interventions. It helps getting insight into the scale of the problem, the areas at risk, and the registration of patients. The core capability of a GIS system, its graphical representation, can be extremely useful for these purposes. In the previous scenario, this means that all the contaminations of this disease are entered into the same geodatabase, and that at every moment an actual situation can be presented. The spreading of the diseases over time can be animated to help getting insight into the diffusion patterns.

Identifying source of contamination
After a few days it has become clear that a national health problem has emerged. The diffusion pattern indicates that some regions have been affected more than others. With simulations following the maximum likelihood method fictitious sources of contamination are entered into a simulation, and the probability that these sources would have lead to the current situation are calculated. Then, the most likely places are identified as possible sources of contamination. Further research could be done to get more details about these locations. In this case it is possible to discover that Amsterdam Airport Schiphol most likely is the source of the contamination. It is logical to assume that people in other countries are infected, too. By linking the national geodatabase to international data, one can find out which countries do suffer from the disease, too. People that have been in the airplanes flying between these countries and Schiphol should be warned that they might spread the disease.

An alternative way of warning these people or identifying the source of contamination is by collecting information about the places where infected people have been over a period of a few days. Where there are similarities, it is most likely that more people have been infected at the same 'cross point'.

Information services for the public
The great cities suffer from the disease, and people like to know whether they are 'safe' moving around in their own regions. Press, researchers and international organizations are

interested in the presence of the disease, too. A publicly available Internet information system can be helpful in providing this information. Information is only showed after manual reviewing, because the quality is very important and erroneous information can social disturbance.

Research on diseases

In the case of new diseases that have not been discovered before there is a great social and scientific interest in finding out the characteristics of disease. Think about the incubation period (the time in which one can bear the virus or bacterium causing the disease, but one does not experience the symptoms of it), the infection rate (how many infections originate from how many personal contacts) and so on. A geodatabase with sufficiently detailed information can provide the necessary data.

Let's examine the following problem: some infectious diseases 'make use' of so called super diffusers, people who are immune to the disease, but do spread them (Keulemans, 2003). This is a really dangerous situation for public health, because these people are very hard to identify, and cannot easily be put in quarantine, as is the case with people suffering themselves from this disease. However, when there are indications that a super diffuser is 'in the game', a system like this can help to simulate the movements of this fictitious person. By communicating this profile through the public, people that are possibly super diffusers can check by themselves whether they are one or not.

Monitoring utilization of health centers

When the epidemic grows to a scale that there is a possibility of scarcity in medical care, the GIS or a related system can be used to monitor the utilization and rest capacity of health centers. This can be used to route patients to the closest hospital that still has additional capacity. An additional variable can be introduced, to cluster patients and prevent them from traveling a large distance, hence increasing the risk of other people getting contaminated.

Simulation of diffusion and effectiveness of potential measures

Imagine the following scenario: In a cinema in Delft terrorists contaminate all the visitors of the movie with a virus causing an infectious disease. After the visit, they flow out to their homes; in the days after it they have visited many places, including their offices, sport clubs, and public places. In a situation when this contamination is known – possibly it is identified by the early warning function of the GIS – the system can be used to simulate the amount of infections in different regions. This depends on several factors, for instance the transport connections with the original region of contamination, the number of elderly people, the number of public places and the crowdedness of them and so on. The simulation can include various proposed measures and calculate their effectiveness. Think about the closing of public places and the distribution of vaccines.