The Role of GIS in the Decision Making Process at Rotterdamse Elektrische Tram (RET)

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Introduction

Geographical Information Systems (GIS) have emerged in the Dutch public transport industry since the disposal of digital road network data, user-friendly geographical software interfaces and more affordable software applications. The shift from a bureaucratic attitude to a more efficient and customer-oriented approach requires management tools to monitor, analyse and adjust public transportation operations. This essay articulates the future role and opportunities of GIS as a decision-making instrument within RET, the operator of the public transport network in Rotterdam The Netherlands.

The paper is structured in three sections. To clarify the view of RET on Geographic Information System, the first section discusses the definition of GIScience and GIS and how they relate to each other. The second part describes the history and developments in GIS in relation to the decision-making process in general. To conclude, the last chapter gives a practical interpretation of GIS components to support the decision-making process at RET.

The GI Science domain - How is GIS related to GIScience?

Although there seems to be a rather vague difference between Geographic Information Systems (GIS) and GIScience, a clear distinction in meaning can be narrowed down when scrutinising both terms.

As a consequence of the different constitution of GIS users and accelerating developments at a technological, theoretical and organisational level, it is difficult to define a comprehensive definition of GIS. An appropriate definition of GIS can be composed combining diverging views of GIS: the map, the database and spatial analysis view (Maguire, 1991) resulting in a broad set of proceedings, features and functions as visualised in figure 1.

Figure 1. The GIS domain

Geographic Information Systems are put to many uses, but providing the means to collect, manage, and analyse data to produce information for better decision-making is the common goal and the strength of a GIS using a full compilation of functions and applications.

GIScience on the other hand, as the subset of information science, is the study of the theory and concepts that lie behind GIS and the other geographic information technologies and considers fundamental questions raised by the use of (these) systems and technologies. (Goodchild, 1992)

According to David Mark, Geographic Information Science (GIScience) is defined as “the basic research field that seeks to redefine geographic concepts and their use in the context of geographic information systems. GIScience also examines the impacts of GIS on individuals and society, and the influences of society on GIS. GIScience reexamines some of the most fundamental themes in traditional spatially oriented fields such as geography, cartography, and geodesy while incorporating more recent developments in cognitive and information science. It also overlaps with and draws from more specialised research fields such as computer science, statistics, mathematics, and psychology, and contributes to progress in those areas. It supports research in political science and anthropology, and draws on these fields in studies of geographic information and society.” (Mark, 2000)

So in simple terms, GIS is the fundamental instrument for GIScientists to examine spatial areas of research.

A concise history of GIS and the significance of spatial decision-making

The following survey reveals the major events that formed the Geographic Information Systems as we know today supporting decision-making processes.

Starting in the early 1960s, the Canadian Geographic Information System (CGiS) was developed by Roger Tomlinson and Lee Pratt. CGIS, and more specific Tomlinson, introduced the term ‘GIS’ for the first time. The program aimed at storing geospatial data for the Canada Land Inventory and assisted in the development of regulatory procedures for land-use management and resource monitoring in Canada.

Before, it took thousands of person-hours to create paper map overlays at the same scale to utilise a suitability analyses. The decision-making process has been shortened dramatically in time and labour from weeks to hours.

In 1965, Howard Fisher founded the Laboratory for Computer Graphics (LCG). Fisher had a greatest interests in creativity and problem solving, and that led him to computer mapping. Before, in 1963, Fisher worked with a programmer, Betty Benson, to create the synagraphic mapping system (SYMAP). The main goal of SYMAP was to help raise the performance level of professional persons in city and regional planning and related fields through the more extensive and more sophisticated use of factual information. This has been made possible by the expanding field of computer science in combination with advanced statistical techniques, systems analysis, and similar analytical and decision-making procedures.

In the same year, Tomlinson recorded the video “Data for Decisions”. The recording provides an overview of the Canada Land Inventory Geo Information System and illustrates how GIS was used in the 1960s.

On 23 July 1972, the first Landsat satellite was launched. It was the start of continuous earth monitoring. The Landsat program provides over 44 years of spatial resolution data for applications that support policy makers in making decisions about their environment.

Visibility has always been the main factor for decision-making in visual impact assessment, as well as in other applications in archaeology, fire towers, radar sites and telephone transmitters (Domingo-Santos et. al., 2010). In 1975 the first known viewshed algorithm was published by Travis, Iverson and Johnson. Summarised, this algorithm is the basic logic in a visibility calculation, viewshed and visibility analysis. The algorithms are used to obtaining viewpoint location, target point location and elevation data. “Visible” or “not visible” targets support technicians and policy makers during the decision process.

Making the Global Positioning System (GPS) available to the public in 1985, opened up a tremendous set of opportunities. Measuring points, lines and areas and attribute x and y coordinates became easier and more accurate. Emerging local real-time differential networks accelerate the integration of GPS and GIS. Unfortunately, GPS still has limitations, mostly dictated by the laws of physics. Such limitations may cause misinterpretation of results or lead to false conclusions and decision making. Alternative positioning systems like GLONASS (Russia), Galileo (European Union) and the development of the Chinese Compass satellite system completes the fourth leg of the global navigation satellite system (GNSS) of independent global navigation systems. The combination of these global navigation systems will lead to more accurate data and improves the decision process.

Another important GIS was released in 1986: the Mapping Display and Analysis System (MIDAS) later renamed in MapInfo. MapInfo was the first desktop GIS product on the market. Together with multi-criteria techniques (MCE) MapInfo is used to describe, evaluate, rank, and select among different alternatives in a decision-making problem, according to a set of criteria. Therefore, both GIS and MCE share a common concern in providing better procedures for spatial decision-making support (Jankowski 1995).

The U.S. Census Bureau released a collection of geographic datasets including roads, buildings, rivers and lakes, as well as Census tracts areas for the first time in 1986. The dataset, Topologically Integrated Geographic Encoding and Referencing (TIGER) is public data and freely available. The fire chiefs in San Luis Obispo, USA, is an instance of this creating a public safety model based on Census data. Among other things, the safety model contains a base map with locations points like fire stations, hospitals and police stations. The model and data support fire chiefs to make decisions based on cost and consequences (Price, 2003)

With the advent of the Internet, the development of web-based decision support systems whose principal aim is to increase public access and involvement in environmental decision-making, a new era started. With the release of web-based GIS as a new tool for exchanging information, communities could get numerous benefits. For example: gaining access to usable information on the web; entering into new kinds of interpersonal and institutional relationships; improving the dialogue with government agencies, non-profit organisations, and other members of their community; and visualising and understanding their communities in ways that inform public debate and public policy (Schon, 1996).

Although Nokia already launched a smartphone in 2002, Apple’s released the groundbreaking iPhone including a touch-screen, GPS and mobile mapping in 2007. Together with Google Maps online mapping became accessible to the public. Mobile technologies enable civilians to be connected whenever and wherever they want.

ESRI, the company behind ArcGIS, launched ArcGIS Online in 2010. Their cloud-based geographic information platform simplifies sharing geographic data with every stakeholder. With a strong vision on data, ESRI realised that supplying digital content (maps, statistics and real-time geographical data) on top of the ArcGIS digital ecosystem creates added value for decision makers.

Not only ESRI has made technology and data accessible. Earlier, in 2004, Steve Coast founded OpenStreetMap (OSM). A crowdsourced platform where citizens are encouraged to create, judge and share geographic data yielding a free map of the world. As open source data, it is available for everybody acknowledging the Open Database Licence (ODbL) published by Open Data Commons (ODC).

Increasingly, governmental and semi-public organisations unlock their data as open data. In the Netherlands, the Cadastre, Land Registry and Mapping Agency made their Basic Registration Topography available as open data in 2012. Today, almost all data of the Cadastre is free accessible.

Supporting better decisions – application of GIS in public transportation

Surprisingly, no single Dutch public transportation operator has a long history in utilising GIS. No operator makes entirely use of the available GIS technology on the market. Only ProRail, responsible for the maintenance of the Dutch railway infrastructure, utilises GIS to carry out asset management and incident management.

RET, the operator of a bus, tram and metro network in the Rotterdam metropolitan area only started to develop a vision on GIS by the end of 2016. Using GIS to depict just the transportation network to the public, a growing awareness arose within the operations department applying GIS to make smarter decisions. The point of departure is an inventory of essential parts of geographic information components (Longley, 2015) in public transportation (figure 2).

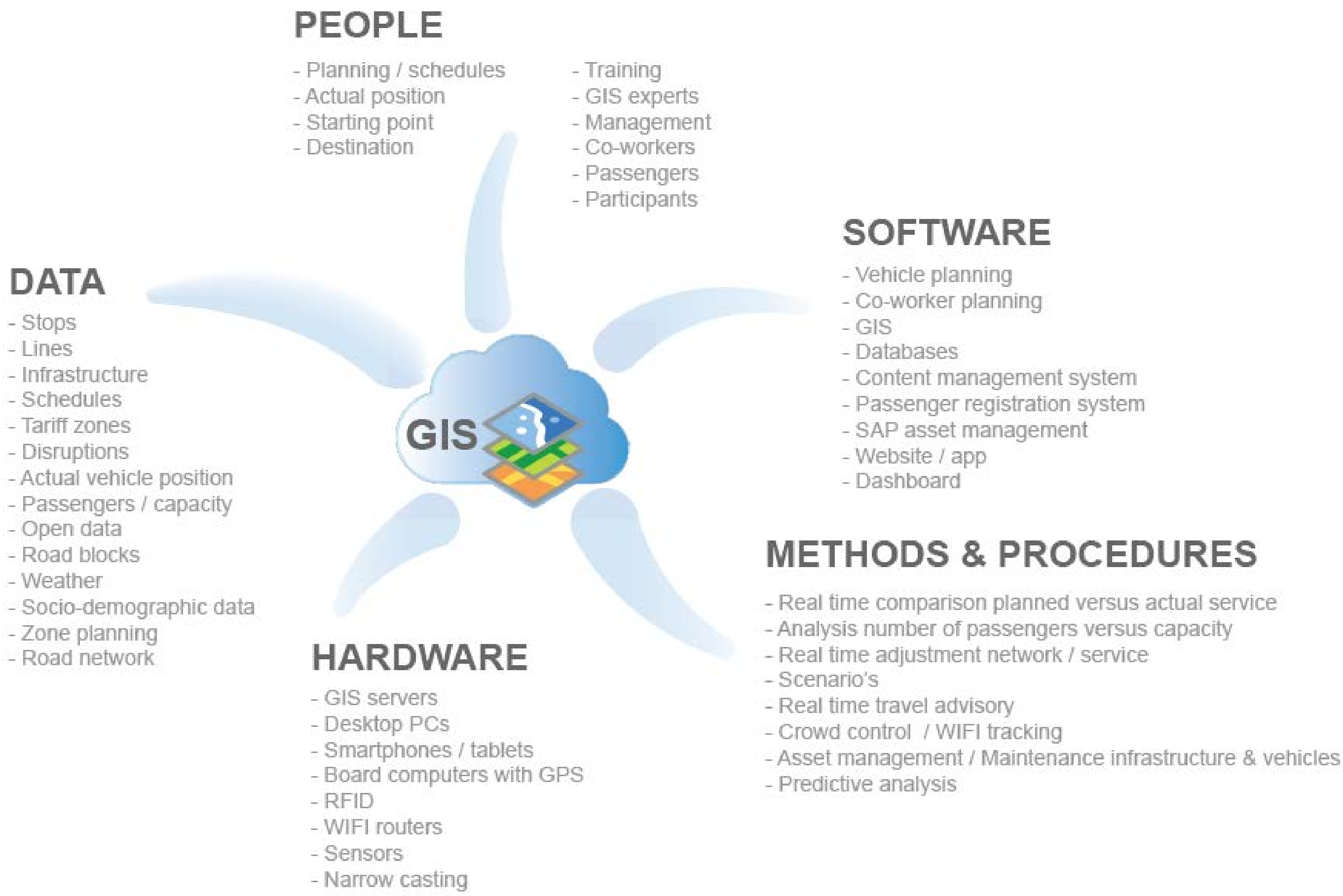

Figure 2. Geographic information components in public transportation

People
To support drivers to ride on time, help co-workers to optimise the network and inform passengers about routes, timetables and disruptions, geographic information is essential to make the right decision. A GIS will only be implemented, used and maintained successfully when qualified GIS experts are in place. Strict privacy rules bind the disclosure of the position of co-workers and passengers. These regulations need to be considered implementing a GIS before the public is invited to participate in the co-creation of applications and data.

Software
Public transportation operators in The Netherlands, including RET, use legacy systems that are business-critical. It is difficult and expensive to integrate spatial data and analysis tools into vehicle and co-worker planning systems. GIS unlocks critical data emanated from legacy systems and simplifies the decision-making process through visualising (real-time) data, spatial analysing tools and monitoring Key Performance Indicators (KPIs) on a dashboard.

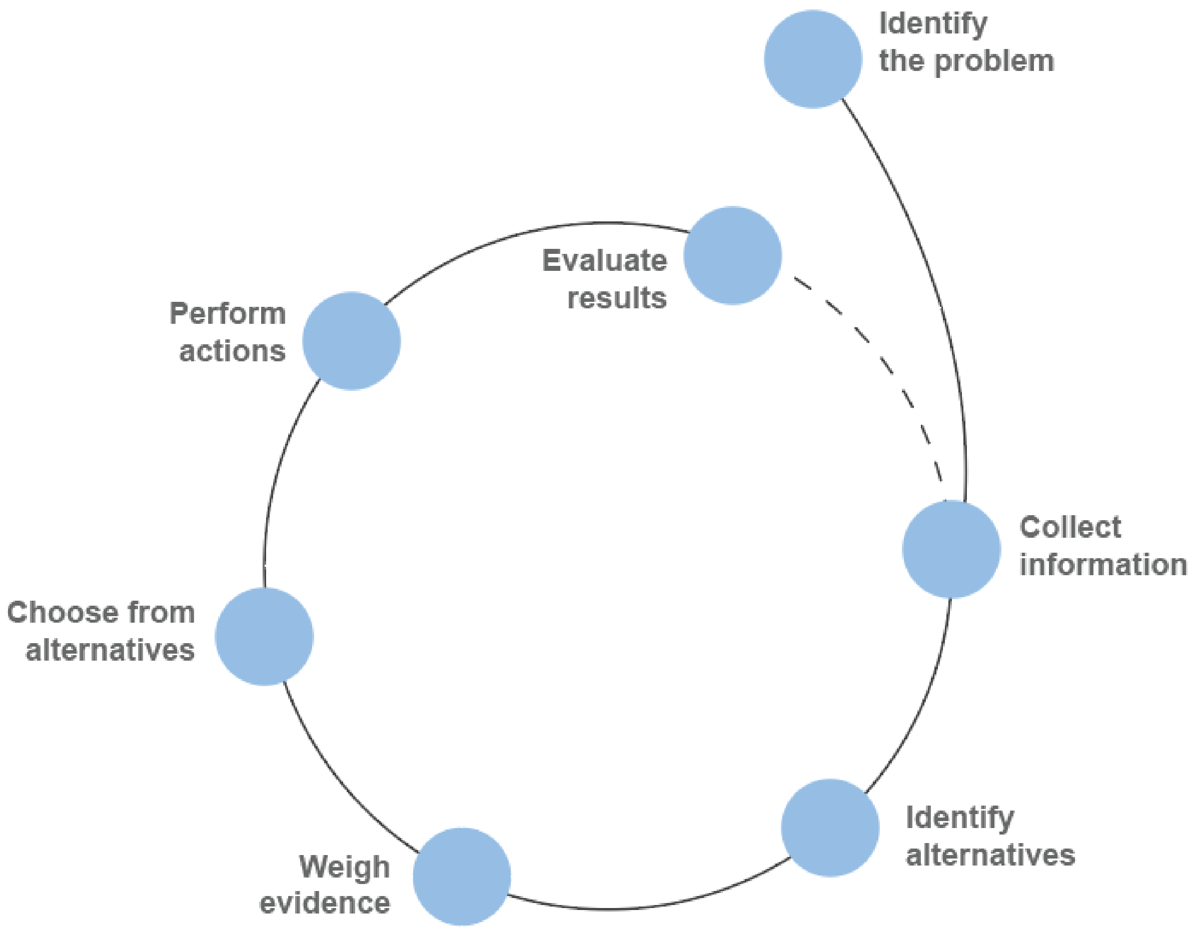

Figure 3. Decision-making process

Data
GIS should be the hub within RET, importing, processing and distributing data from internal and external sources. Data will be used to utilise asset management, routing, network analysis, analyse performance and market potential, adjust co-workers and notify passengers in real-time. Map data in public transport has to make a shift from 2D to 4D, adding a time component and street level imagery to visualise the environment assessing external effects.

Hardware
To use GIS to its full potential at RET, it is necessary to set up a modern, flexible and secure ICT architecture. This ICT environment includes data(base) servers, GIS servers and web servers, routers, a firewall, a (wireless/mobile) network, sensors, board computers, GPS and personal devices for co-workers. Passengers can access GIS information through web apps, web maps or a (mobile) website. Co-workers use mobile devices to collect data and get a real-time view and common operating picture. GIS experts utilise desktop computers to run GIS tools and approach online applications. Sensors have to be integrated into vehicles, stations, stops and the infrastructure (rails, switches, overhead wire and access gates) to measure and analyse usage and abrasion. Visualising and analysing sensor data will improve the decision-making process because it saves survey time, is more accurate and always available.

Methods & Procedures
Within RET it is complicated to share information because departments operate in silos and rely on different data sources and ICT platforms. Getting all disciplines agree on a uniform approach to data collection and management through a centralised GIS improves the opening up of data and ameliorate the decision-making process because co-workers employ the same data definitions and geoprocessing workflows. To manage operations, GIS plays an essential part in monitoring the actual stage, clarifying and analyse deviations to decide which modifications have to be deployed.

The implementation of GIS components

Implementing a GIS is a complex process. Stakeholders and actors have conflicting interests, existing systems have to adjust to couple GIS and exchange data. An implementation strategy should be in place considering user, infrastructural, software and hardware requirements, data acquisition, application development, testing (functional, technical and user testing), training, workflow migration, maintenance operations, budget and planning.

The assembling of a future-proof GIS, including data storage, geo-event servers, a geo-analytics servers and enterprise servers, is already intricated. At first, the focus will be on implementing GIS components that yield swift results such as training of co-workers, analysis of passenger data and visualization of disruption. A successful proof of concept convinces decision makers to take a step to the next level and release budget for more complex GIS components. Far more sophisticated is the implementation of scenario planning, predictive analysis and meaningful use of sensor data in public transport. Foreign operators, such as South Yorkshire Passenger Transport (ESRI, 2017) and Transport for London, have spent over a decade composing their current GIS.

Conclusion

Whereas GIS already celebrated its 50 anniversary, at RET, it is still in its infancy. The phenomenon ‘place’ applies to almost every activity and process in public transport. Fortunately, technical developments such as sensors, GPS, cloud computing and mobile networks, affordable and user-friendly geographic software applications encouraged RET to develop a vision on GIS. Simultaneously, limitations of current ICT systems in data interoperability and rising passenger expectations regarding real-time travel information put pressure on the implementation of a comprehensive information system. GIS provides both RET and passengers all the required functionalities to collect information, identify alternatives, weigh evidence, choose from alternatives, perform actions and evaluate results. Is GIS the holy grail to optimise the decision-making process within RET? Only when all components of GIS are in place: up-to-the-minute and reliable data, a modern ICT infrastructure, up to date installed GI software, established scenarios and procedures, and trained co-workers, are preconditions for an effective decision-making GIS application.

References

Publications

1.
Reference: Maguire, D. J. (1991). An overview and definition of GIS. Geographical information systems: Principles and applications, 1, pp. 9-20. Available through: http://lidecc.cs.uns.edu.ar/~nbb/ccm/downloads/Literatura/OVERVIEW%20AND%20DEFINITION%20OF%20GIS.pdf [Accessed 21 February 2017]

2.
Reference: Duckham, M., Goodchild, M. F., & Worboys, M. (Eds.). (2004). Foundations of geographic information science. CRC Press. Available through: Google Books https://tinyurl.com/m67mxf7 [Accessed 21 February 2017]

3.
Reference: Mark, D. M. (2003). Geographic information science: Defining the field. Foundations of geographic information science, 1, pp. 3-18. Available through: http://www.gisknowledge.net/topic/nature_of_gis/mark_defining_gisci_03.pdf [Accessed 23 February 2017]

4.
Reference: Jankowski P. 1995. Integrating geographical information systems and multiple criteria decision-making methods. International J Geographical Information Systems 9, pp. 251–73. Available through: http://www.tandfonline.com/doi/abs/10.1080/02693799508902036 [Accessed 27 February 2017]

5.
Reference: Price, M., Create Emergency Management Maps Using Census 2000 Data, ArcUser January – March 2003 ESRI. Available through: https://www.esri.com/news/arcuser/0103/files/tiger.pdf [Accessed 27 February 2017]

6.
Reference: Schon, Donald et al, 1996. High Technology and Low-Income Communities: Prospects for the Positive Use of Advanced Information Technology. Colloquium on Advanced Technology, Low-Income Communities and the City, MIT. Google Books Available through: https://tinyurl.com/k9ya9m8 [Accessed 27 February 2017]

7.
Reference: Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). Geographic information science and systems. John Wiley & Sons. Available through Vrije Universiteit Amsterdam Library website https://vu.on.worldcat.org/oclc/902599212 [Accessed 1 March 2017]

Website

1.
Reference: Data for Decisions, 2007. Department of Forestry and Rural Development [online] Available at: https://www.youtube.com/watch?v=eAFG6aQTwPk [Assessed 3 March 2017]

2.
Reference: Enhancing and promoting public transport, 2017. ESRU UK [online] Available at: http://resource.esriuk.com/category/local-government/page/2/ [Assessed 3 April 2017]