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Research Article

Building a spatial decision support system for tourism and infrastructure planning: technical solution and data integration challenges.

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Keywords

SDSS design,
Mobility planning,
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Destination planning

Abstract

Mobility planning in rural areas with a high number of tourists is important for creating sustainable destinations. By identifying mobility gaps in the transportation system, measures to improve the situation can be implemented. In order to identify such mobility gaps, decision-makers need a spatial decision support system (SDSS). The aim of this paper is to identify vital aspects of creating such an SDSS and to build a prototype. Two important aspects were identified, data and system design. The result of the analysis of available data shows a lack of data portals with disaggregated socio-economic and intra-destination travel data. Further, it shows that data on points of interest (POI) and public transit data are primarily found in company databases. The system design analysis showed that most SDSS today are relying on public data and are not designed to integrate disparate data sources. They are primarily developed to be used by experts. Based on these findings an SDSS that automatically integrates both public and private data was developed. It comprises a self-hosted web mapping system and several geospatial tools. Our main conclusion is that both data and system design are important aspects to consider when building an SDSS for mobility planning. By using the architecture proposed in this article, new data can easily be incorporated in an SDSS. Furthermore, the system design also facilitates the involvement of stakeholders in the planning process.

Highlights:

- *Data integration and system design are key elements when producing an SDSS*
- *A new SDSS for identification of mobility gaps in rural tourism destinations*
- *An SDSS that integrates data from multiple sources automatically*
- *Mobility planning tool for destinations and cross-border destinations*

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1. INTRODUCTION

Tourism has become one of the most important sectors of many countries' economies. In some rural areas, tourism is the biggest sector. To develop tourism in a destination, accessibility to attractions is important. Previous research has shown that intra-destination mobility by tourists is dependent on several factors. Some factors are related to the individual, while others relate to the physical characteristics of the destination or issues related to the trip (Lew & McKercher, 2006). In rural areas, the physical distribution of attractions is often less dense than it is in cities, which makes shifts to public modes of transportation more difficult. Consequently, many tourists are dependent on private cars in order to visit attractions in rural areas (Masiero & Zoltan, 2013). From a policy perspective, it is necessary to create a sustainable tourism industry. One way to help achieve this goal is to provide public transport to attractions in rural areas. By integrating mobility planning for citizens and tourists in the same process, it becomes easier to find positive synergies.

Many remote destinations have a lack of infrastructure, due to inadequate investments in roads, railroads, and other types of transportation systems, which causes these destinations to experience mobility gaps. These gaps occur in areas with a relatively high aggregated demand for transport at specific points in time, but where there are very few available transport solutions. By identifying such gaps, the transport situation in the rural regions can be improved. Developing a SDSS (spatial decision support system) that can integrate data from many data sources that contain important data makes it easier for policy makers to identify the mobility gaps in a region and help them solve these problems (Camarero, L., & Oliva, 2019) .

To build a SDSS information system that helps planners find mobility gaps in a destination, it is essential to understand what drives demand for transportation and where it is being generated within a region. In urban and regional spatial planning, it is important to be able to gain a good understanding of both the supply and the demand of transportation in order to be able to identify mobility gaps (Hörcher & Tirachini, 2021; Wang et al., 2022).

Demand for public transport is shaped by a multitude of factors, such as geographic location of the population, demographic structure of the population, geographic structure of the built environment, and the location of POI (points of interest) in an area. In tourism-dominated areas, the demand for public transport is added to this demand.

From a planning perspective, it is highly complex to shape the transport system in a way that makes the transport in a region sustainable and meets the demand of its citizens and tourists. The planning process involves several stakeholders and policy makers and the decisions affects the daily lives of citizens and visitors to a region. (Tomej,2019)

Several aspects are important in order to be able to implement a decision support system that can assist planners. One is the planning context in which the system is implemented. Who is responsible for public transports and who are the important stakeholders in the process? The literature has stressed that the ability to access important data and understand how they relate to each other is a key factor for successful mobility planning. Therefore, it is important that stakeholders are able to share and combine their own mobility data with other stakeholders in a region. For example, Andrienko et al. (2007) argued that geovisual analytics for spatial decision support must pay attention to how well a system supports collaboration among different stakeholders, how well it can communicate spatial information between them, and how flexible it is in terms of the different expertise among the users. The question is how to design a system that can present relevant data for stakeholders and, at the same time, be flexible and open for the users to add their own data and use analytical functionality (Rodela et al., 2017).

Another dimension of such a system is how spatial data is visualized. This is vital because one of the most important aspects of planning is being able to understand the spatial structure of an area. The planning tools that have been developed historically have often included some form of mapping component. The technology for accessing spatial data and maps and spreading the results of spatial analysis have developed since the 1990s. Smith (2016) described the development from the 1990s, when the first on-line map services began to appear on the market. Since then, there has been a steady increase in technical solutions. An important step was the introduction of Google Maps in 2005, and another was the birth of crowd-sourced data such as OSM (Open Street Map).

As Smith shows, there are three main approaches to building a web-based mapping tool (Smith 2016). The result of the first approach is an infographic web mapping system where the user can view static maps and geographical objects, but has limited options to add new features to the map and to zoom into objects.

The second approach leads to a cloud service web mapping system. This kind of system provides high-quality maps and is easy to set up because the database where the maps are stored is handled by another organization. The drawback is that the organization who is taking care of the map server puts a fee on the usage of the system, which makes it expensive to use. Another problem is that the analytical capabilities are pre-set by another organization, which prevents agile system development.

The final approach is to build a self-hosted web mapping system. It is more flexible and allows the organization to add a lot of analytical capabilities to the system, but is also more complex to build and maintain, because the database and all the data are handled by the organization that sets up the system.

Access to spatial data is vital when creating an SDSS for mobility planning. New data are becoming publicly available at a pace that has not been experienced before. When analyzing mobility gaps, two types of data are important: the first relates to the mobility offerings in a region and the second relates to demand for mobility services. The former consists of information such as frequency rate, route maps, and location of entry points to the public transit system, while the latter includes information regarding the origin of trips and destinations within a region, but also knowledge about the spatial behavior among the tourists.

There are a few challenges that currently hinder effective mobility planning at the destination level. One challenge is that this kind of analysis requires specialized knowledge in GIS by the user. Another challenge is that data regarding transport supply and travel demand are stored in different databases. These databases are accessible in several data portals, but they are not easy to find and the metadata (information about the data) is not coherent. Combining demand and supply data requires a lot of pre-processing by the user in order to make it ready for analysis. An SDSS that helps planners identify the mobility gaps would strengthen the ability to improve the mobility situation in areas where they are employed.
An SDSS that includes analytical tools for mobility gap analysis that are able to automatically collect and combine relevant data would also improve the ability of stakeholders to understand the mobility situation in their region. This makes mobility planning more effective and transparent and thereby helps planners improve mobility. Previous research has indicated that, in systems where stakeholders are important actors in the planning process, the decision support system needs to be open and accessible for actors outside of the organization (Schindler et al., 2020).

The present paper analyses vital aspects of creating an SDSS for mobility planning and describes the process of developing a prototype that overcomes the existing mobility planning problems. The system aims to use up-to-date spatial data covering supply and demand for public transport at the destination level in different geographical contexts. The system also provides the analytical tools needed to identify mobility gaps on disaggregated spatial level for non-experts.

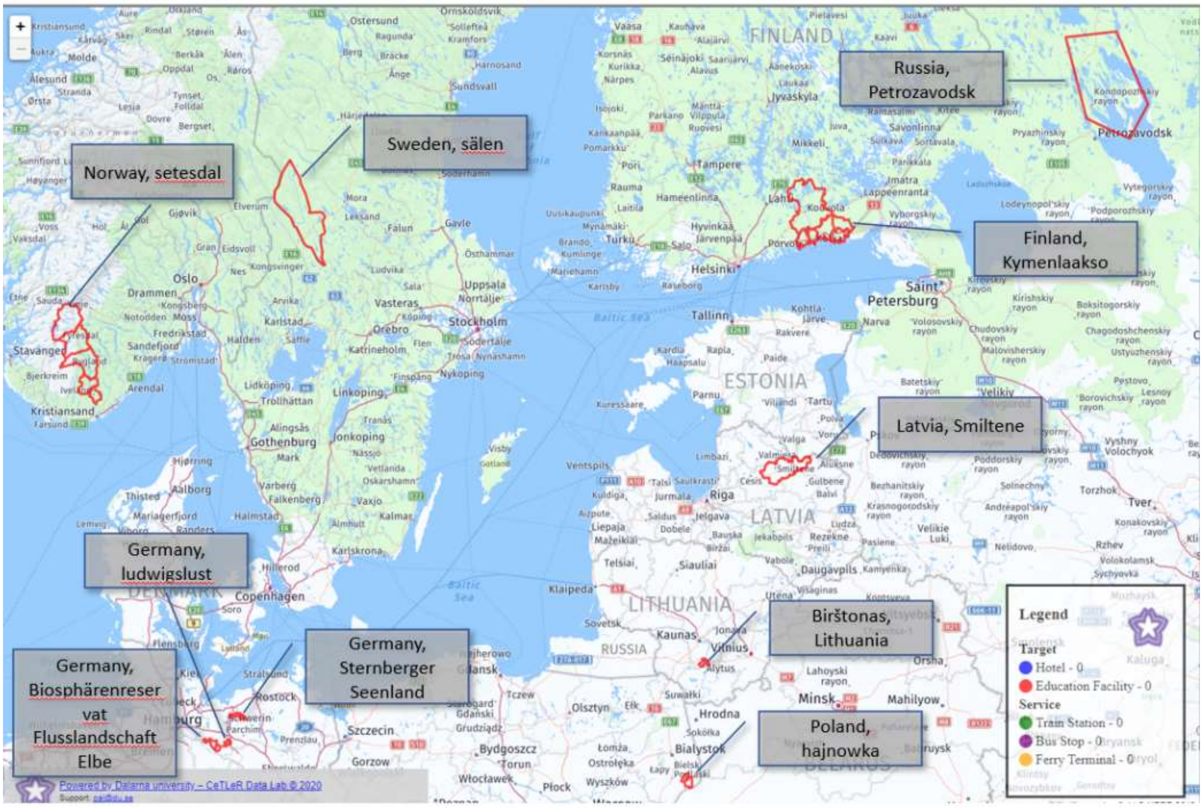
In creating this system, it has been essential to (1) identify relevant data sources and combine them; (2) investigate how spatial data have been used in existing SDSS and assess whether the same method can be applied to a spatial decision support system for identifying mobility gaps; and (3) compare the technical solutions for building a SDSS in order to use the most efficient technology for building the system.

The remainder of this article is structured as follows. First, the context in which the prototype was developed is presented. The next section analyzes intra-destination travel patterns by tourists and the availability of data used in mobility gap analysis. Finally, the process of developing the prototype is described. This section combines the conclusions from previous sections and uses them for the design of the DUGIS prototype.

2. BACKGROUND

The development of the SDSS was carried out within an EU-funded project called MARA (Mobility and Accessibility in Rural Areas). It was an InterReg project that started 2017 and aimed to improve the mobility in remote touristic areas around the Baltic Sea (Heldt et al. 2020). The partners in the MARA projects come from eight countries and consist of 12 regional and national public authorities. The geographic areas included in the project are located in countries in the Baltic Sea region (see Figure 1).

Figure 1 Geographic areas in the MARA project. Source: DUGIS system



At Dalarna University, the task was to evaluate existing decision support systems, assess the need for spatial data among the partners and to investigate the availability of the requested data. Based on the results of this analysis, a decision support system prototype was to be created. The idea was that, by analyzing transport demand and the available mobility offerings in these areas, the DUGIS system should be able to identify mobility gaps. This would make it easier for the destination planners to find new ways to improve the current mobility situation. To our knowledge, no decisions support systems are able to integrate disaggregated data from many different data sources that is suitable for this kind of planning endeavors.

The transnational character of the MARA project raised two major challenges. The first was the differences in data accessibility in the different countries, and the second was the differences in the planning context in which the system was to be implemented. These problems were addressed in two ways. Firstly, the system was built with the purpose of harmonizing data and delivering it in a convenient form to the user, regardless of what countries it is being used in. The data cleaning and data formatting was done by DUGIS before the spatial data was delivered to the user. In order to build a cross-national system that was flexible enough to meet the demand from various planning contexts, feedback was collected from the users at the MARA partner meetings.

2.1 Data acquisition and integration for mobility gap analysis

The first challenge for a planner who wants to analyze transport in a region is to find suitable data. This is a general problem in all spatial planning, especially in planning that incorporates different administrative areas and planning levels and many stakeholders, as was the case in the MARA project. The understanding of the mobility pattern within the destination often requires detailed data regarding visitor mobility. This is often provided by telephone companies and the data is often aggregated and expensive to buy.

Mobility and tourism has been a major topic within tourism studies. Many studies have addressed the importance of communications to reach a destination for a successful destination development (Prideaux, 2000; Duval,2007; Khadaroo & Seetanah, 2008; Van Truong & Shimizu, 2017). Another set of studies has analyzed mobility of tourists within a destination (Lew & McKercher, 2006; McKercher & Lau 2008). Some general characteristics of mobility within a destination are that people who rely on public transport tend to travel less than people who have access to private car. Another feature is that returning visitors tend to be more selective when it comes to places they visit than first-time visitors do. Family constellations also determine movement patterns within a destination. For example, families with children will have a different mobility pattern than elderly visitors without children. Time budget will also affect the mobility pattern; a longer stay means that a visitor can go to more attractions. Another important factor impacting which places visitors go to is related to the location of their accommodation, since the distance decay factor is present on a small scale as well as on longer distances (Zoltan, 2014).

Since the introduction of smartphones and GPS receivers, the number of studies that track movement patterns of tourists has increased (Zheng et al. 2022; Kim et al., 2022; Park et al.2020). These studies often aim to locate hotspots (that is, places where tourists agglomerate in space and time) and to analyze whether this leads to economic impacts. Another recent way of tracking the mobility within a destination is to analyze consumer usage of destination cards. These cards often allow free public transport and entrance to several attractions in a destination. By using the data generated, a lot of information about consumer behavior and mobility patterns can be extracted. An example of such a study is a consumer study by Zoltan (2015), where four different consumer segments could be found among the visitors to Switzerland. Three of these segments had a concentrated spatial activity pattern, while the other was traveling all over the studied destination.

Public actors have been developing legal and technical structures to improve the exchange of data between organizations. The results of this work have been the establishment of different spatial data infrastructure (SDI), a concept that incorporates all aspects that are important for distributing geospatial data. Hjelmager et al. (2008, p. 1296) defined the concept as follows: "*an SDI encompasses the policies, technologies, standards and human resources necessary for the effective collection, management, access, delivery and utilisation of geospatial data for a specific jurisdiction or community…*"

An important SDI that has been important for accessing spatial data has been the INSPIRE (Infrastructure for Spatial Information in Europe) directive. It is an initiative from the European Union for facilitating the building of a European SDI. It came into force in 2007 and should be fully implemented in 2021. The idea is to make spatial data exchange between Member States in the European Union easier. This is done by organizing legal and business-related issues connected to geodata within the union. INSPIRE is the largest data harmonization endeavor undertaken with regard to environmental data (Kotsev et al., 2015). As part of this directive, the Member States should also build and maintain specific geodata sets over, for example, land and building ownership registers (Kaczmarek et al., 2014; Dacko & Szewczyk, 2020).

When there are technical and legal structures in place, the data need to be gathered and accessible. There are currently several examples of portals where data can be shared. The growth in the number of portals has been tremendous and in 2016 there were more than 520 portals listed on the website Dataportals.org (Lisowska, 2016). By 2020, the number had risen to 590 (www.dataportals.org).

Despite the successful development of SDIs and data portals, several obstacles still exist. Firstly, it is difficult to find appropriate data due to fragmentation of the databases. Mulder et al. (2020) compared SDIs in four countries and concluded that there is still considerable fragmentation of the spatial data. Secondly, it is difficult for the user to know the quality of the data because there are currently many different metadata standards and this makes it difficult to combine the data (Lisowska, 2016). For planning purposes, data quality and metadata are important because high standards are placed on accuracy and up-to-date information.

The conclusion of the literature review is that, for a mobility gap analysis in a European context, the geoportals, including public data sources, do not provide all of the necessary data due to several reasons. Firstly, the aggregation level of the data is usually too high, which makes analysis on intra-destination level of the mobility situation impossible. Research shows that user-generated data such as data from mobile phones or travel cards are important for understanding the mobility pattern within a destination. This type of data is currently not publicly available for planning purposes in a wider European context. Secondly, the literature and the evaluation of the existing databases shows that there is no accessible data portal where both mobility offerings and mobility demand is placed. Finally, the Inspire directive has improved the data accessibility in some countries, but there is still large variation between countries.

For the mobility gap analysis, most of the useful data were found in private or user-generated databases. The inventory of these databases shows that the mobility offerings have a high temporal and spatial resolution and cover most destinations of the MARA project. The mobility demand is also partly covered by private company data sources. There are databases that include a lot of POI for tourists that are stored that are important origins and destinations for trips.

The biggest challenge when developing the DUGIS tool was accessing demographic data. Densely populated areas are important starting and stopping points for trips. In most countries in the MARA project, the data are aggregated to administrative areas and dependent on annual data. For tourists, the hotels are important for the micro-level mobility. The locations of hotels are easier to find since their position is stored in several databases.

For the development of the DUGIS platform, the accessibility and the ease of usage was of paramount importance. Although several private databases had relevant data where data could be accessed, there was still a need for data cleaning and formatting in order to use the data in an SDSS. Another issue with some data coming from private data sources is that they are often not free of charge.

The overall idea with an SDSS is to assist decision making with the means of spatial data and spatial analysis tools. The first SDSS were developed for solving business problems by integrating spatial and non-spatial data within organizations. However, since 2010, a larger portion of the SDSSs have been based on location-based services, where data is automatically updated in real time (Keenan & Jankowski, 2019). These services usually show the present situation, but lack analytical capabilities. Therefore, systems based on data-driven approaches for modeling land use have been introduced recently. An example is the online tool “What if”, where different scenarios can be explored in a planning tool (Pettit et al., 2020). By integrating several databases and analytical tools, users are able to calculate the effects of changes in the infrastructure and land use of a hypothetical investment in the infrastructure. Another example is a system based on the same ideas a decision support system for urban environment planning, where spatial data has been integrated in a decision-making tool to improve the urban environment (Tache & Popescu, 2020). A similar approach was also applied by Grêt-Regamey et al. (2017) in their work on developing a decision system for monitoring ecosystem services. However, these systems do not rely on updated information and are restricted to a specific geographical area.

Based on the literature on SDSS, it can be concluded that these systems are often tailored for one specific task and deploy a specific set of analytical capabilities. Some of them use multi-criteria analysis (Jeong & Ramírez-Gómez, 2018; Maleki et al., 2018), while others include spatial statistics to find hotspots or optimal locations based on location-allocation models (Yeh & Chow,1996; Tavana et al., 2017; Arentze et al.,2020 Dell'Ovo et al. 2020, Sakellariou, et al. 2020; Batsaris et al., 2021). To produce a more generic SDSS that can be used in spatial planning such as a mobility gap-analysis, greater flexibility, both in terms of available methods but also in terms of integrating multiple data sources, has to be implemented. Another benefit of a generic SDSS is that when new data sources becomes available, such as data on human mobility within a destination, they can easily be added to such a SDSS. It is also possible to allow for stakeholders to upload their own data and thereby improve the planning process at the destination level.

3. ANALYSIS

3.1 Development of the DUGIS system

Based on the literature review, several strategic decisions were made in order to study whether the current situation allows the construction of a support system for mobility planning, which is based on a third-generation SDI with analytical capabilities found in modern SDSS.

The planning of the DUGIS system consisted of several stages: (1) a survey of the demand from the partners in the different countries involved in the project; (2) inventory of available sources of information to be included in the tool; and (3) technical solution of the platform.

Involving the planners in the development of the DUGIS system by surveying the demand provided a better understanding of what kind of data is essential for mobility gap analysis. The partners were asked if they already possessed the requested data in their organization, or if they could obtain it from other regional or local actors. The survey was set up to also gather information related to stakeholder engagement in planning (see further Kiryluk et al., 2021) In some cases, the geospatial data were available within the partners' organizations and it was then integrated into the system. Most of the time data had to be search for in other data sources.

When analyzing the results from the survey, it was apparent that there was significant variation between the partners when it came to the requested demand for data. The data that the partners wanted to include in the tool can be organized into different categories: (1) data related to the transportation network, such as railroads and roads; (2) data regarding different POI (attractions, service facilities etc.); (3) information about public transportation, such as bus stops and railway stations (in relation to this, the partners wanted data on bus schedules, etc.); and (4) data related to what is causing the demand for mobility, such as size and location of permanent population and visitors.

3.2 Data storage and communication with data bases

Due to the specification of demand, the data for the DUGIS system was dependent on integration of various data sources, both private and public. Many of the official data portals developed in line with the intentions in the INSPIRE initiative store valuable data for planning purposes, such as transport network and population statistics in Sweden. However, to meet the demand from our partners, it was necessary to also include other kinds of data. Two types of data have been made available in recent years. The first is provided by private companies such as Google and TomTom, and the second comes from crowd-sourced databases as OSM (OpenStreetMap).

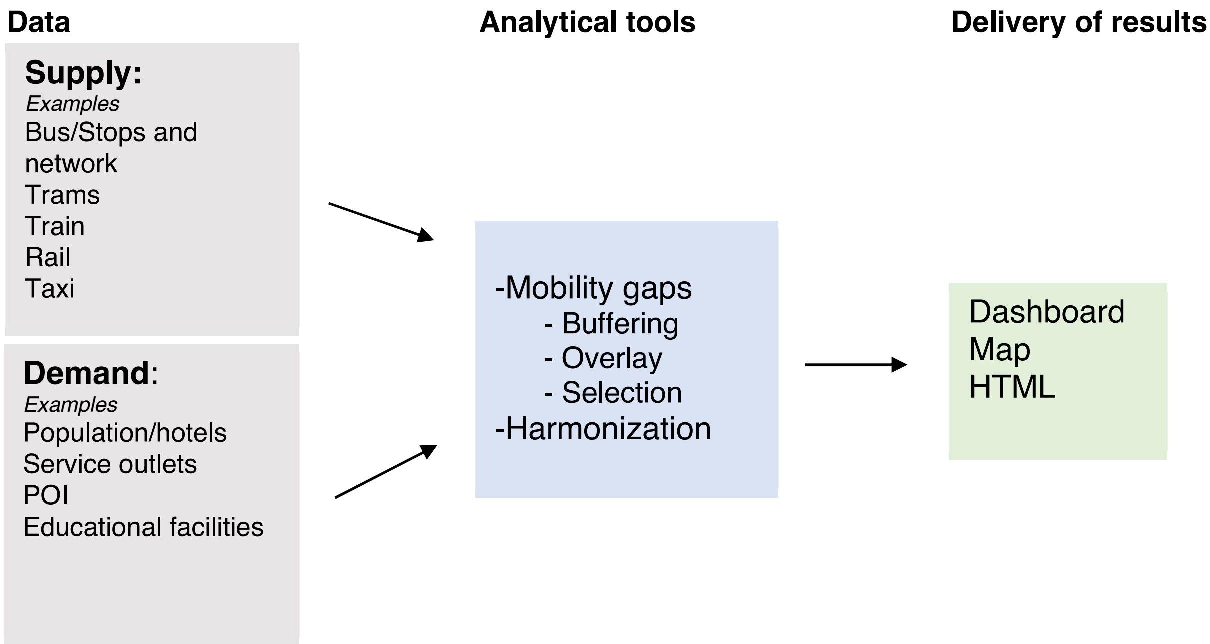
The list of data included in the MARA system in the case in Malung-Sälen-Trysil Area in Sweden is:

- GTFS (bus stops only)
- Google (hotels, train stations)
- HERE (education facilities, airports)
- TOMTOM (EV charging stations)
- Statistics Sweden (population, holiday homes)
- CeTLeR database server (MARA cases borders)

The main structure of the workflow is shown in Figure 2 below. The key elements for analyzing mobility in an area are shown on the left of the figure. These have been divided up into mobility offerings (supply) and mobility demand (demand). The offerings that were included are based on the results of the survey and include buses, trams, rail, taxis, and similar mobility services. Depending on the regional characteristics, the requests for mobility services were diverse.

The mobility demand in the model includes spatial data on where the demand for transport services is being generated, both by local citizens and tourists. In tourist regions, these spaces generate considerable demand for transport in the high season. Our survey indicated that the planners were interested in a long list of POI (points of interest), which was considered as origins and destinations for trips made by tourists. Therefore, shops, service outlets, and attractions were also included in the model.

Figure 2 Organisation of the DUGIS



3.3 Comparisons between different design options

Once the relevant data were identified, the system was constructed. Based on the overview by Smith (2016), all relevant stages in the development process were carried out. These steps include: (1) Spatial data preparation: in the case of the DUGIS system, this stage included writing code which could communicate with external servers and re-formatting the data. (2)

Data hosting and map serving: in this stage different methods were compared, including both a system where the data was stored on an external server and a solution where the data was stored on an internal server. (3) Web interface: the web interface was developed with the aim of keeping the number of analytical features low. This was done with the aim of making the system easy to use for non-experts.

In order to find a suitable technical solution behind a SDSS system that can integrate data from several data sources and provide the analytical capabilities included in Figure 2 above, it is important to compare the available technical solutions. Given the complex nature of mobility gap analysis, a rudimentary infographic web mapping system like that described by Smith (2016) would not be suitable. A decision was made to use either a self-administrated web mapping system or a cloud service mapping system. For planning purposes, the self-hosted web mapping system is usually regarded as the best solution because planning is a complex activity that requires flexibility. It also supports the flexibility and the openness of the system since it makes it easier to employ an agile developing approach of the system and for the developer to control the contents of the database.

To decide how to develop the system, three different technical solutions were constructed and compared. The first was a cloud-based system in which the analytical capabilities were based on standard GIS functionality from ArcGIS. This system was assessed and rejected because of high running costs and limited flexibility for the user.

The two remaining systems were based on open-source technology. In the first of these systems, the analytical capability and the maps were handled with the programming language R and the results of the analysis were delivered via an open source server called Shiny. The second system was based on a self-administered geodatabase and web-based delivery system. This system was set up on a local server at Dalarna University due to security and stability reasons.

The reason for testing two different ways of developing a SDSS is that the programming languages differ when it comes to how flexible solutions that can be created. C# is a fully object-oriented programming language, while R is more focused on statistical computing and relies on pre-developed packages for geospatial analysis. This means there is greater flexibility when developing applications based on C# technology, because the algorithms are created by the developer.

Table 1 Comparison of technical solutions for the DUGIS system

Comparison	C#	R Shiny
Server cost	24,000 SEK	24,000 SEK
I/O: Reading from MySQL database (1000 connection test)	1.1% failed	9.6% failed
Speed (filtering 59,000 features from 1,294,015 features)	3.6 Sec	8.2 Sec

Source: Tests of two solutions

Because the SDSS should be implemented in different geographical contexts and for many potential users, it should be easy to use, run without any delay, and be able to handle many requests without failing to retrieve the correct data. Therefore, three aspects were evaluated: price, stability, and speed. The result from this comparison is reported in Table 2 below.

Stability was measured as the number of times the systems failed to connect to the database and retrieve the selected features. When the connection fails, it needs to start again by re-sending the request to the database. This leads to longer waiting times for the user and the SDSS will be ineffective to use for the planner. The comparison shows that the C# system was much better than the R solution. The I/O, (input and output) of data into the database failed only 1.1 percent of the times in the C# solution, compared to 9.6 percent of the time for the R solution.

The assessment of how quickly features in the database could be filtered showed a big difference. Features can consist of POI; that is, important target areas for trips or origins of trips, such as residential areas or grid cells with population statistics. Complex spatial planning is dependent on a lot of spatial data in order to take into account the complexity of the planning situation. Therefore, the speed of filtering is important since it affects the usability of the system. Our comparison showed that the C# system filtered 59,000 features in a database, consisting of nearly 1.3 million features in 3.6 seconds. The R system needed 8.2 seconds to perform the same filtering. The superiority of the performance of the C# system is due to the underlying technology. The total amount of features in the database will affect the filtering performance of the system. This means that the more features that are included, the bigger the difference between the solutions will be.

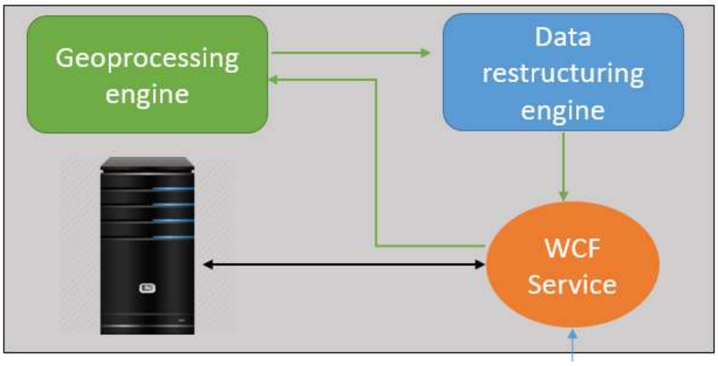
Based on the result of the analysis of the available technology and the comparison of the dummy systems, the decision was made to continue building a system based on Microsoft C# technology.

3.4 The DUGIS prototype

The prototype was built as a web-based application. This prototype does not include all features that exist in the DUGIS system, but for the MARA project it was considered the most suitable way of deliver the result of the gap analysis to the users. The final decision was made after communication with the partners in the project.

The structure of the system is depicted in Figure 3 below. The application handles both communication with the databases and the mobility gap analysis. It sends requests of data to the external servers. The restructuring engine cleans the answer i.e. removes duplicated data, harmonizes the spatial data (re-project and change reference system when necessary), and restructures it to a usable format. This is a major difference compared to existing GIS systems, where the user has to do all of this work before the data can be used for analysis.

Figure 3 DUGIS system



The geoprocessing engine divides the data into two lists: a target features list and a service features list. The former consists of educational facilities and hotels. The latter contains bus stops, train stations, and ferry terminals; that is, services that make travel to the hotels and educational facilities via public transport possible.

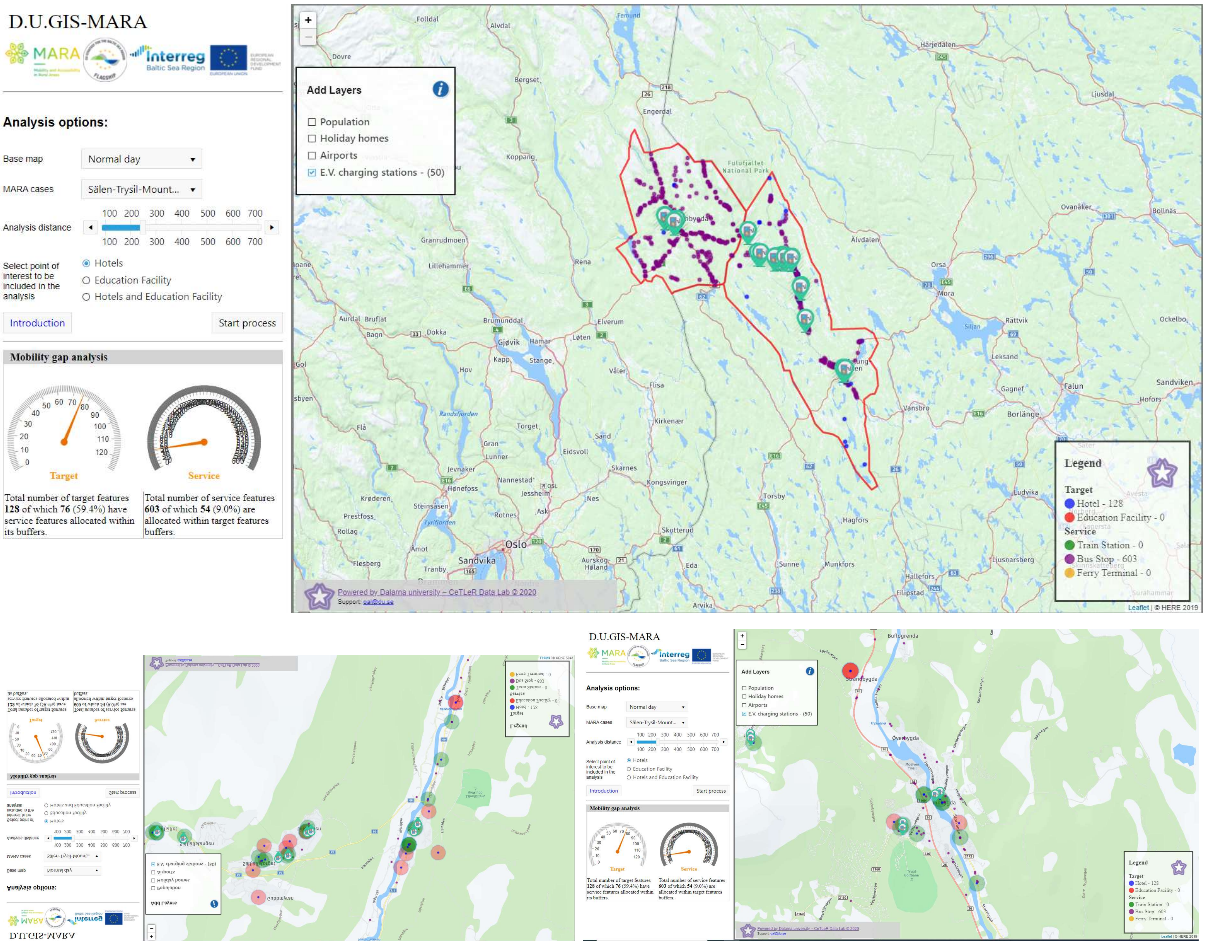
Firstly, all the target and service featured are plotted on the map. Secondly, the service features are buffered. Then the system automatically performs an overlay analysis, calculating the number of bus stops that falls within the buffers. The application provides the planner with information on how many target features are covered by public transport. The system also indicates where the mobility gap appears; that is, where there are no services within a buffer of a target feature.

3.5 Mobility Gap Analysis using the DUGIS prototype

Due to the set-up of the MARA Project, the development of the DUGIS system ensures that the stakeholders are involved in the development process. An example is the ability of the system to integrate organizational data from the stakeholders with the other data in the DUGIS system. The definition of the areas of interest for the planners in the DUGIS system was defined by the stakeholders, and spatial data over the borders were collected in each of the partner regions.

The example in Figure 4 shows an analysis where the mobility gap is performed in a rural area of Sälen-Trysil located on different sides of the border between Sweden and Norway. It is one of the largest ski destinations in northern Europe and the cross-border destination is functionally integrated with ski lifts and hotels operated by the same company on both sides of the border. The functionality of the DUGIS prototype is demonstrated in Figure 4 below.

Figure 4 Dashboard of the DUGIS web system



The DUGIS system calculates the availability of public transport close to the hotels in the region. The user can define the threshold value for the analysis and the mobility gap is displayed in the map window. If the buffer circles are red, it is a sign of a mobility gap. The user also obtains information about the overall situation in the region. In Figure 4, the dashboard shows the number of hotels and the share of these that are covered by transport services.

The availability of public data was added as options to the result analysis. The population data and the holiday home areas in the Sälen area are retrieved from Statistics Sweden through an API, and the charging stations in the area were collected from the website nobil.com, where most of the chargers in Sweden and Norway are accessible through an API. Below the dashboard, two areas – one in Sweden and one in Norway – are zoomed in on, showing the mobility gap analysis performed in two administrative contexts (The web portal of the DUGIS-system can be found at: http://mara.cetler.se/). With regard to destination planning, a clear picture of the situation on both sides of the border is important for creating sustainable transport at the destination. By using the DUGIS system, the planners at both sides of the border can understand where there is a mobility gap and where the public transport system should be modified to make it possible for tourists to use public transport instead of private car.

4. CONCLUSIONS

The aim of this paper is to identify vital aspects of creating an SDSS for mobility planning for remote tourism destinations. The inventory of the data sources shows that the Inspire directive has led to numerous national based geo-portals with a lot of public spatial data. However, for a mobility gap analysis, much of the necessary data is stored in private or user generated databases. The meta-data information in these databases is often lacking or of poor quality, which reduces the usability of this data in planning situations and makes it harder to combine data. Another conclusion is that data used in research on intra-destination mobility is not publicly available. Access to these types of data would improve the analysis of mobility gaps in the future.

The literature section shows that there are a vast number of existing SDSS for spatial analysis, although, to our knowledge, none that can assist planners to identify mobility gaps within tourist destinations in various geographical contexts. The analysis of existing SDSS shows that they rely on data connected to a specific geographical area stored in one or several national databases. This is a limitation when planning is carried out in an international context or in border regions. They are also developed for experts, which reduces the flow of information between the planners and other stakeholders in the region.

Based on the result of the literature, a SDSS prototype called DUGIS (Dalarna University Geographical Information System) was developed. It is a geographical decision support system that helps planners identify mobility gaps in all the regions included in the MARA project without having to be experts in GIS. The DUGIS system is an example of what Smith (2016) categorized as a self-hosted web mapping approach. This means that it is very flexible, since it is based on a self-hosted geo-database and self-developed programs for handling communication between servers and for performing gap analysis.

One of the reasons for developing a self-hosted web mapping approach was that it made the system flexible and, at the same time, possible to equip with tailored geospatial tools. This facilitates mobility gap analysis without expert knowledge, which strengthens the system as a platform for communication between stakeholders in a region.

To handle the challenge with multiple data sources, the data cleaning and data formatting was done by DUGIS before the spatial data was delivered to the user. DUGIS automatically integrates and harmonizes the data that is being requested by the planner.

The feedback from the users indicates that it is important that the tools included in the SDSS are easy for non-experts to use. Further, the results of our research show that an SDSS can be an important tool for local mobility planning, although some limitations in data availability and accessibility still limit the potential in some countries in Europe.

Further research on how to improve the data quality in the available databases is needed. Before implementing a common SDSS for local planning, quality assurance has to be performed. When combining different data sources, the quality of the data will differ between them, so data cleaning methods have to be developed in the future. There is also a lack of publicly available data, which is needed to understand intra-destination mobility.

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