CO$_2$ MINIMIZER TOOLBOX

Project Output O.T2.1

WP T2: Decision making tools for low carbon scenarios

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June 2019

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1. Introduction

Work Package 2 of the ASTUS project focuses on decision making tools for low carbon scenarios in transport and land use planning. Activities within Work Package 2 include:

- Activity A.T2.1: Review of existing tools for low carbon options in alpine space

- Activity A.T2.2: Further development of relevant tools

- Activity A.T2.3: Workshops with a sample of local stakeholders

Project outputs within Work Package 2 include:

- O.T2.1: CO_2 minimizer toolbox

- O.T2.2: ASTUS transnational methodology for low CO_2 scenarios

This report describes project output O.T2.1: CO_2 minimizer toolbox, a collection of prospective and future-oriented decision making tools assessing the social, environmental and financial impacts of potential innovative low CO_2 solutions, linking spatial planning and transport measures. Within ASTUS, project partners CEREMA, RSA FG iSPACE, TUM, UGA, and UIRS developed a total of ten tools. The delivered tools are beneficial for public authorities on all levels, infrastructure and service providers, interest groups, educational institutions, enterprises, and also citizens.

The methodological steps to produce the CO_2 minimizer toolbox are described in chapter 2, following this introduction. Detailed description of the ASTUS tools and their functions can be found in chapter 3 of this report. Following the tool development process, local stakeholders were asked to rate the tools in terms of their user-friendliness and usefulness. The evaluation results are presented in chapter 4. This report closes with some final remarks in chapter 5.

2. Methodological framework

The process to produce project output O.T2.1: CO_2 minimizer toolbox consisted of three steps: Review of existing tools, tool development, and tool evaluation. Each individual step is further described in the following sections. The steps are linked to Work Package 2 activities and deliverables.

2.1. Review of existing tools

Before developing new decision making tools, it is important to explore the state-of-the-art tools in use all over the world. Knowledge about existing tools may serve a reference for the tool development. At the same time, an already existing approach should not simply be reproduced. To this end, a thorough research was conducted to identify relevant existing tools in the context of low carbon mobility (Activity A.T2.1). The tools were categorized based on nine main characteristics:

- format of tool (online-calculator, excel based, software…)

- targeted users (public agencies, citizen…)

- ease of use (required input data, user guidance…)

- type of policies supported (accessibility, parking management…)

- type of expected outputs (mobility costs, living costs, emissions estimation…)

- expected emission outputs (CO_2, CO, PM…)

- geographical resolution at which the outputs can be examined (regional, municipal, corridor…)

- coverage area where the tool can be applied (country-wide, worldwide, state-wide…)

- modes analysed by the tool (cars, public transport, bikes…)

A template was developed by TUM to summarize all tools in a systematic manner. All project partners were invited to participate in the collection of existing tools. The resulting inventory contains a good mix of tools that are available for use by the general public as well as experts from public planning authorities. Most of the tools meant for public use are available as interactive online tools. The majority of the available tools can be assigned to four categories:

- Emission estimation and mode choice comparison tools

- Housing and/or transportation cost calculators

- Accessibility tools

- Public transport and private transport demand (and modal split) estimating tools

This first methodological steps resulted in Deliverable D.T2.1.1: Collection of existing tools for low CO_2 options. The tool inventory can be found on the ASTUS website:

https://www.alpine-space.eu/projects/astus/en/project-results/decision-making-tools/collection-of-existing-tools-for-low-co2-options

2.2.   Tool development

Following the review of existing tools, a number of tools were newly or further developed by ASTUS project partners (Activity A.T2.2). The following project partners were among the tool developers: CEREMA, RSA FG iSPACE, TUM, UIRS, and UGA. In order to make sure that the tools would be in line with the stakeholders' needs, a first session of workshops was conducted (A.T2.3). The aim was to present the objectives of the tools, gather input from the target group, and integrate the feedback into the technical tool development.

Each of the five tool developers produced two tools. In order to document all ASTUS tools in a homogenous manner, a survey for developers was designed. The developer survey responses provide detailed information regarding the functions of the tools, the planning process, and the tool construction. The information may serve as a user manual for the intended target group or as a guideline for external stakeholders interested in developing similar tools. Chapter 3 of this report provides detailed information about all tools, based on the information gathered in the developer survey.

2.3.   Tool evaluation

A second workshop session with local stakeholders was conducted close to or after the end of the tool development process (A.T2.3). The aim was to evaluate the relevance of the tools with the final users, i.e. understand how well the tools correspond to the stakeholders' needs and determine the tools' appropriateness for the given planning tasks and problems. A user questionnaire was prepared, addressing the user-friendliness of the tools as well as their usefulness for planning practitioners and professionals. In addition, the questionnaire contained four open questions, giving the users the opportunity to describe their experience with the tools. The evaluation results are presented in Chapter 4 of this report.

3. Description of ASTUS tools

This chapter presents all tools developed within ASTUS, describing the planning approach, tool functions, tool construction, and tool utilization. A total of ten tools were developed by project partners CEREMA, RSA FG iSPACE, TUM, UGA, and UIRS. Before addressing each tool individually in the following sections, the overview below presents the ASTUS tools by project partner.

CEREMA:

- **FORESIGHT** – a software for modelling urban sprawl scenarios and visualizing a territory's evolution in maps

- **LUCSIM** – a tool for modelling a territory's urban development based on existing land use and given transition rules.

RSA FG iSPACE:

- **Commuter Tool Pongau** – enables analysis of commuter flows on various spatial scales based on a commuter matrix

- **MORECO Household Calculator** – a web-based tool for comparing housing costs, mobility costs, and transport-related emissions at alternative residential locations

TUM:

- **TUM Accessibility Atlas** – a map-based tool to visualize catchment areas and calculate accessibility indicators using CO_2 emissions as underlying travel cost

- **CO_{2L}** – a spreadsheet for emission estimation and comparison of different scenarios based on a territory's aggregate mobility data

UGA:

- **Google Earth** – visualization of available data by means of satellite imagery in order to enable an interactive planning process

- **MobicosTER** – a spreadsheet to analyse travel distances, CO_2 emissions, and mobility costs of commuters and households based on current or potential mobility behaviour

UIRS:

- **UIRS Accessibility Atlas** – a map-based online tool for trip planning, calculation of isochrones, and presentation of accessibility indicators

- **GTFS Tools** – spreadsheets and GIS software to prepare transit timetables in GTFS format for publication on Google Maps

3.1.   FORESIGHT

Developer: Thomas Houet (University of Toulouse)
ASTUS contact: David Dubois (CEREMA)

FORESIGHT is a tool to model urban sprawl based on existing urbanization taking into account the attractiveness of territories and the influence of phenomena of linear urbanization or sprawl.

Study region

The study area covers the entire Bauges regional nature park and is based on the perimeter of six communities of municipalities or agglomerations (see Figure 1).

- This scope covers 188 municipalities.

- Total population in 2014 of 513,153 inhabitants.

From the CORINE Land Cover data, the artificialized spaces represent 23,041 ha in 2012 and it is observed a consumption of space of more than 2,100 hectares between 2000 and 2012.

Spatial particularities:

- High impact of the relief on the urbanization of the study area

- Existence of many documents planning urbanization on this great territory

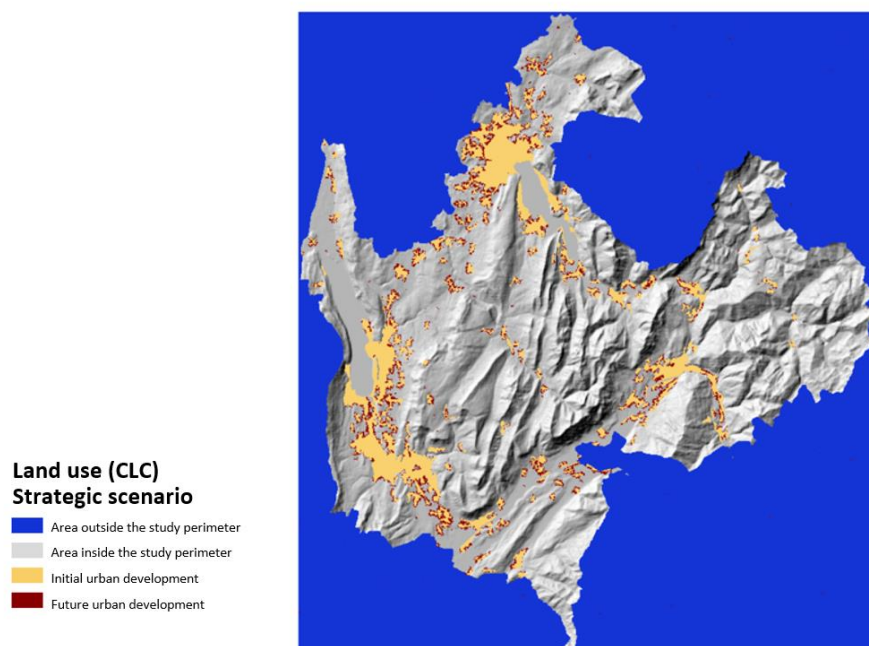- Absence of a unified strategic scenario of territorial evolution

Figure 1. Project region Bauges regional nature park.

The study area also covers the entire ARC Genevois and the SIAC (inter-municipal planning body, in charge of Thonon's SCoT - territorial coherence programme) (see Figure 2).

- This perimeter covers 247 municipalities, 92 municipalities on the Swiss side and 155 communes on the French side.

- Total population in 2014 of 1,019,549 inhabitants.

From the CORINE Land Cover data, the artificialized spaces represent 36,690 ha in 2012 and it is observed a consumption of space of more than 3,300 hectares between 2000 and 2012.

Spatial particularities:

- Cross-border territory

- Significant and highly differentiated spatial dynamics between territories, particularly between the French and Swiss parts of this study area

- Existence of many documents planning urbanization on this great territory

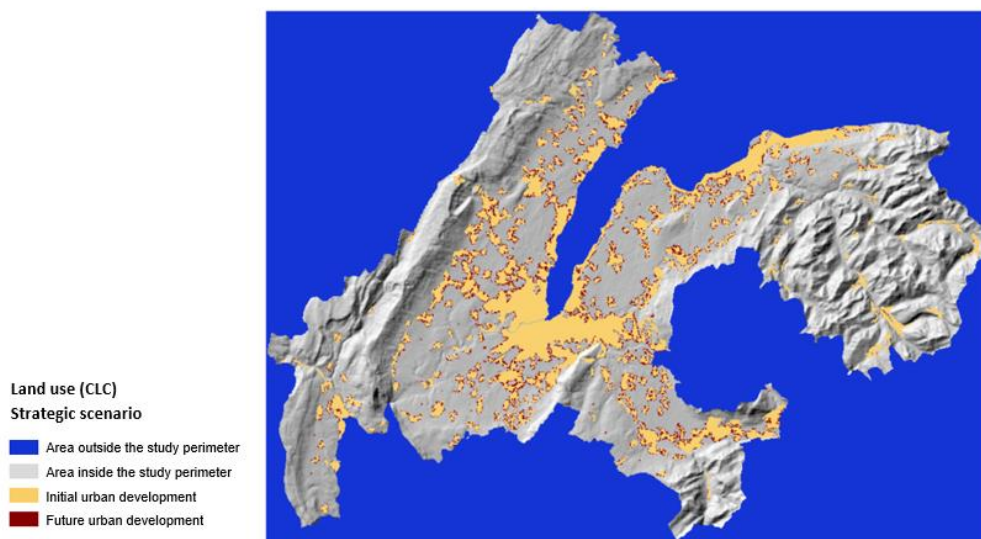- Absence of a unified strategic scenario of territorial evolution

Figure 2. Project region Thonon agglomeration.

Planning approaches

Purpose

The tool was developed as part of a European project ACCLIMAT. The objective of the project is to study the interactions between the processes of urban development, urban micro-climate, and climate change, this project allowed to present different scenarios of evolution of the territory of the metropolis of Toulouse. These different scenarios were based on the modelling of urban sprawl on the FORESIGHT software. The FORESIGHT model is based on the existing SLEUTH model (Clarke et al. 1997, Clarke and Gaydos 1998), which has been widely tested and recognized by the scientific community.

Intended user group(s)

Community in charge of urban planning in their territory

Benefits gained by the user from the utilization of the tool

- Studying the evolution of urbanization in a more or less long-term territory helps to reflect on what it is wanted for the future of the territory.

- FORESIGHT allows to quickly model different scenarios of evolution of the territory. These models make it possible to measure the potential impact of the various measures envisaged.

Main functions

- The software makes it possible to model urban sprawl scenarios by taking into account a map showing the attractiveness of the territory, the terrain, the road network (and, more broadly, the transport network), a space consumption envelope and different forms that urban sprawl can adopt (continuous urbanization, linear urbanization, spontaneous urbanization).

- The software produces annual maps of the evolution of the territory. The software also makes it possible to aggregate the results obtained from several simulations within a map of probability of urbanization of the territory.

Tool format

The tool is a software. The interface is coded in Java while the modelling engine is coded in C and C ++ language.

Tool Functions

Addressed emissions	*Analysed transport modes*
• None, the tool addresses urban sprawl	• No transport modes analysed

Output type	*Output format*
• Comparison of alternatives • Map-based results • Impact of land consumption	• Maps

Analysis unit	*Coverage area*
• Region • Municipality	• City • State/Province • Metropolitan area

Tool Development

Stakeholders involved

- University of Toulouse

Methodology

The software is not so much to represent a future image of the area as to enable a comparative spatial analysis of different simulations. The outputs are definitely not a prediction, which would be largely subject to debate as to why a particular sector was or was not developed.

For this reason, the objective should be to put forward different scenarios for the future development of the area, for use in each of the two software programs. Based on a handful of indicators, including land take and population growth, two scenarios had been drawn up: a baseline scenario and a strategic scenario (see Figure 3).

- The baseline scenario is based on projected population growth and land take figures, and the estimated level of protection of natural, agricultural and forest areas. The data for the baseline scenario is estimated from the observable trends in the area.

- The strategic scenario is based on data extracted from the area's main strategic urban development documents.
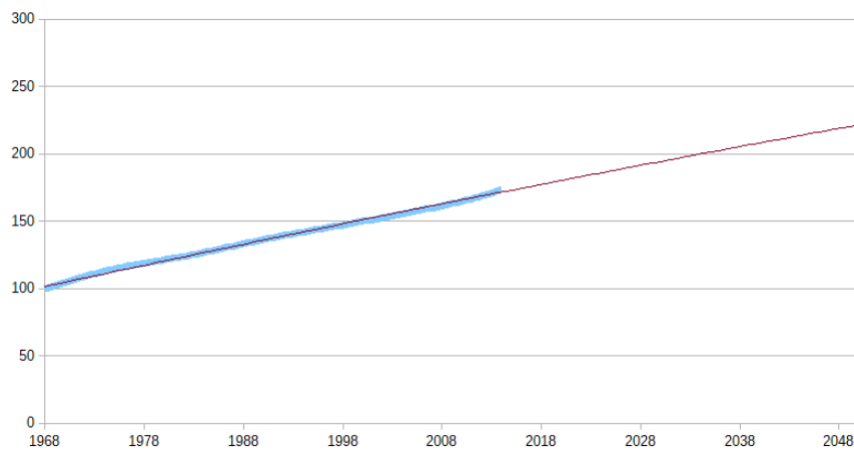
Figure 3. Example of population growth in the Bauges Regional Nature Park study area (base of 100 in 1968) between 1968 and 2016 (blue) and projection to 2050 (dark red) – Baseline scenario.

Furthermore, FORESIGHT is based on the SLEUTH model developed by Keith C. Clarke (University of California). The name SLEUTH is built from the initial data of the model:

S: Slope

L: Land cover

E: Exclusion

U: Urbanization

T: Transportation

H: Hillshade

The original SLEUTH model considers that:

- Urbanization is the result of 4 phenomena: sprawl, linear urbanization, urban growth (understand "oil stain" effect) and creation of new development centres (a set of points of the territory becomes the starting point of new phenomena of urbanization).
- Urbanization depends on the relief: the slope is more or less attractive and beyond a certain slope, it is no longer possible to create new urbanization.
- Urbanization depends on the transport network: at the origin of the phenomenon of linear urbanization, the transport network is a vector of urbanization.
- Some territories cannot be urbanized (typically the lakes, rivers, etc.)

The SLEUTH model then exploits a Monte Carlo method to determine the parameters for translating past dynamics (obtained by analysing two images of the territory on two given dates). It then introduces random variations to translate the non-linearity of urban systems (it creates by itself variations within urbanization dynamics but also urbanization phenomena).

Correspondingly, FORESIGHT is a foresight tool, that is to say a tool that can represent what the future of the territory could be from a scenario built by the user. The developer, Thomas

Houet, has therefore eliminated the random part generated by SLEUTH within the dynamics of space consumption and urbanization phenomena and the dependence of the model on past phenomena. While using FORESIGHT, it is the user who sets some information such as the space consumption envelope or the respective proportions of the different urbanization phenomena. Thomas Houet then integrated into the model an attractiveness map. FORESIGHT was then further developed to facilitate its use as the ability to create multiple stages within a single model.

Process

To conduct the experimentation with FORESIGHT software, it was necessary:

- To be able to use the software, i.e. to understand its functioning and to define the necessary data so that it can function

- To formalize different scenarios of evolution of the territory by relying on the strategic documents of the territory

- To carry out the modelling for each of the study territories by adapting the scenarios to the only data that can take into account the software

For the first step, the software is relatively simple to use, but requires GIS knowledge to prepare the geographical data necessary for the operation of the software.

For the second step, there was no document study in the territories that set a strategic framework for the evolution of the territory. It was necessary to quickly build a medium scenario by integrating and harmonizing the changes included in the strategic planning documents of these territories.

For the third step, the translation of these scenarios into input data for the software essentially involves the design of an attractiveness map. This preparation was done quite simply but it would have been possible to go further on the subject.

Data requirements

Data description	Data source	Data type
Initial urbanization map	CORINE Land Cover	Spatial
Relief map	EU-Dem	Spatial
Roads map	Open Street Map	Spatial
Attractiveness map	Automatically generated from previous data	Statistical

Software requirements

Program name	Program use
Java	Software is coded in Java language

C and C++	Software is coded in Java language

Tool Utilization

FORESIGHT is an expert tool. The operating principle of the software is simple even if the concepts and some algorithms used are very complex and robust. The use of the software requires GIS skills. For the preparation of an attractiveness map without exploiting the small tools integrated in the software, it is also necessary to have good skills in GIS.

The FORESIGHT software, in itself, is easy to learn to use and has a detailed user guide that rapidly equips users to begin modelling the area's development.

The modelling principle is clear and quite easy to grasp because the phenomena described can be directly linked to actual observations on the ground (urban scattering and linear development, for example, or the land take, etc.).

The FORESIGHT software can be a useful tool for modelling urban sprawl in an area. This easy-to-use software has useful features that make it possible to adapt the concrete specifics of the modelling processes to the areas. Apart from the software's numerical parameters, which have to be calibrated beforehand, the attractiveness map theoretically offers real possibilities for factoring the area's geographical information. This makes it quite simple for users to link it to the area's planning documents.

Data requirements

Geographical data which can be generated from GIS and common data like CORINE Land Cover or OpenStreetMap.

Software requirements

Java Runtime Environment 8.0

Tool impressions

The software generates urban sprawl maps, which might be considered an overly simple output (given that there is absolutely no characterization of the densification phenomena), but it has the advantage of being easy to analyse. Given the "automatic" nature of the software and a substantial degree of randomness in its workings, there is no point trying to use this tool for other than its intended conditions of use. More specifically, there is no point trying to:

- Analyse the results in too great a detail (for example on the scale of a commune or part of a commune)
- Model urban sprawl with overly small pixels
- Model scenarios that differ in overly subtle or microscopic ways

The tool should also be seen as part of a long-term forecasting approach and used to represent different scenarios for the area's future development, since the software's sole utility is to compare various possible developments of the area. However, the software's ability to rapidly generate a number of models and combine them into a probabilistic outlook (which is more useful than the random phenomena introduced by the software) is a real asset.

The visual analysis of the results, in particular, highlights the impact of land take and the patterns of urban sprawl. It was also possible to identify the impact of the distinctions added to the attractiveness maps, even if, on the other hand, it was more complicated to measure the latter in practice.

Figure 4 and Figure 5 represent the probability maps generated from FORESIGHT in the Thonon study area and the Bauges Regional Nature Park respectively, for the two evolution scenarios defined for the territory (trend scenario and strategic scenario). These maps were obtained by aggregating the information obtained from twenty simulations.
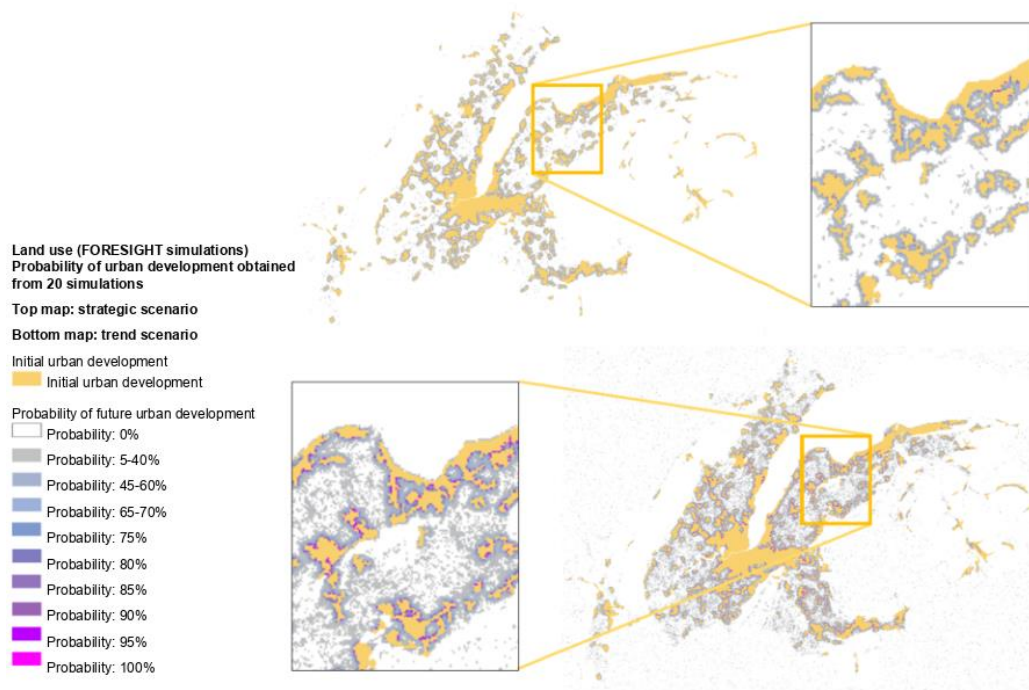
Figure 4. Map generated from FORESIGHT in the Thonon agglomeration study area.
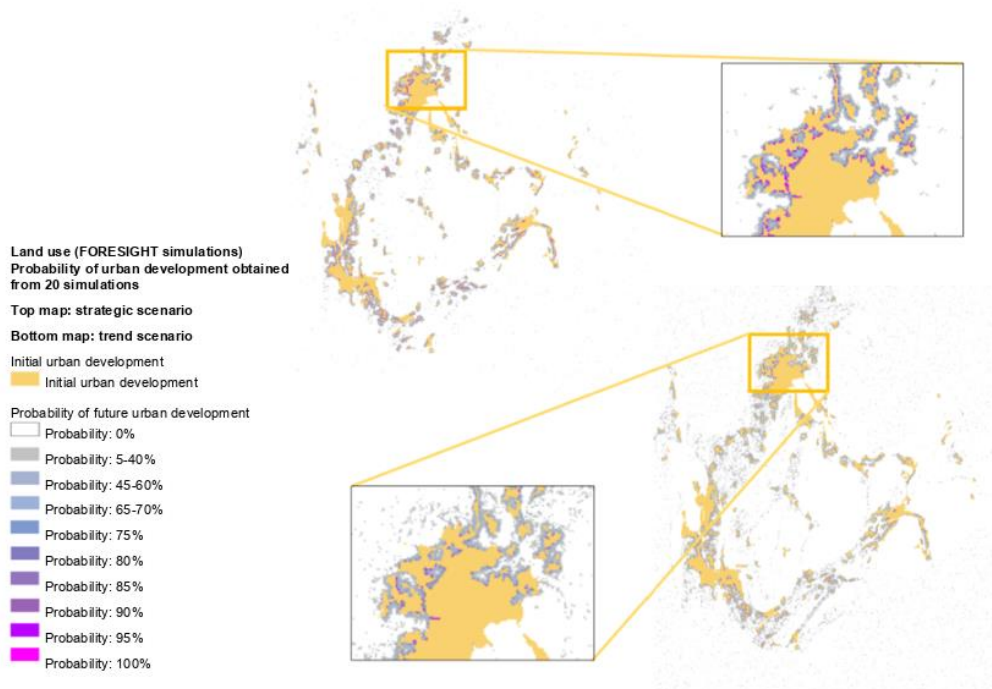
Figure 5. Map generated from FORESIGHT in the Bauges Regional Nature Park.

Given that the tool was capable of producing an image of what the study area might look like in the future, it delivers information that may be of direct interest to an area's decision makers: it shows the impact that urban sprawl might have, the impact of certain policy directions taken in urban planning documents and the combined, large-scale effects of all of these urban planning documents. With certain precautions, such as generating multiple models and combining the results, it is also possible to carry out a fine-scale analysis of the maps. This approach would provide a means of studying the impact of new urban development on aspects such as networks, mobility, infrastructure and facilities, and/or urban development patterns.

Options for further development

For the exploitation of the possibilities offered by the software FORESIGHT, several tracks are to be studied:

- Develop a way to create new attractiveness maps by integrating as much information as possible

- Finely measure the impact of the attractiveness map on the models

- Design a method of fine-grained analysis of the results obtained to better measure the distinctions between the different modelling and modelled scenarios

- Study all the possibilities offered by the software to translate the information contained in the strategic documents of a territory

3.2.   LUCSIM

Developers: Jean-Philippe Antoni and Gilles Vuidel (University of Bourgogne-Franche-Comté)
ASTUS contact: David Dubois (CEREMA)

LUCSIM is a tool to model the evolution of the urbanization of the territory taking into account the different types of land use and transition rules to define the geographical conditions allowing the evolution or not of the territory and its transformation into urbanized space.

Study region

The study area covers the entire Bauges regional nature park and is based on the perimeter of six communities of municipalities or agglomerations (see Figure 6).

- This scope covers 188 municipalities.

- Total population in 2014 of 513,153 inhabitants.

From the CORINE Land Cover data, the artificialized spaces represent 23,041 ha in 2012 and was observed a consumption of space of more than 2,100 hectares between 2000 and 2012.

Spatial particularities:

- High impact of the relief on the urbanization of the study area

- Existence of many documents planning urbanization on this great territory

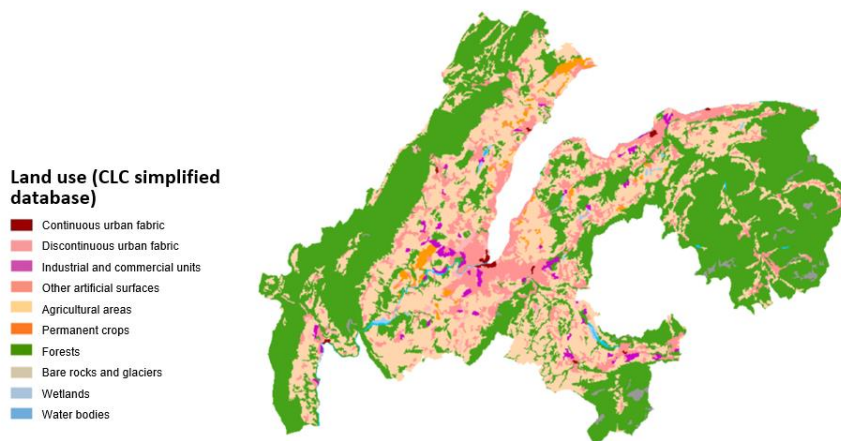- Absence of a unified strategic scenario of territorial evolution
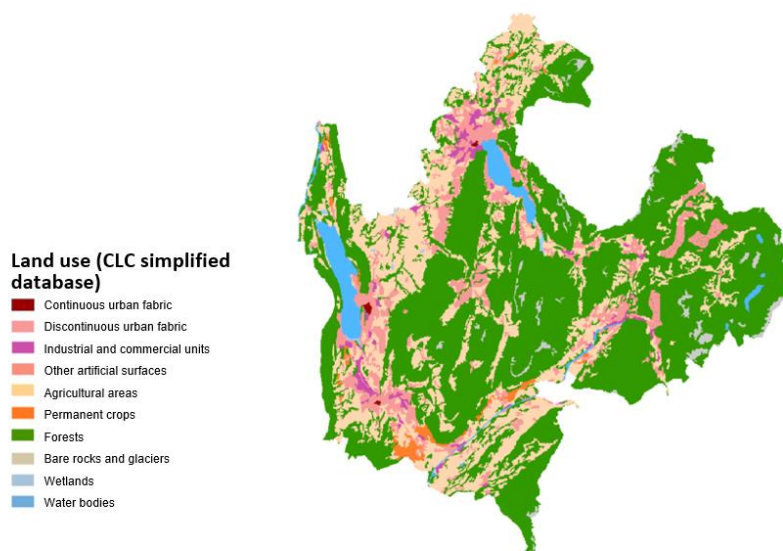
Figure 6. Project region Bauges regional nature park.

The study area also covers the entire ARC Genevois and the SIAC (inter-municipal planning body, in charge of Thonon's SCoT - territorial coherence programme) (see Figure 7).

- This perimeter covers 247 municipalities, 92 municipalities on the Swiss side and 155 communes on the French side.

- Total population in 2014 of 1,019,549 inhabitants.

From the CLC data, the artificialized spaces represent 36,690 ha in 2012 and was observed a consumption of space of more than 3,300 hectares between 2000 and 2012.

Spatial particularities:

- Cross-border territory

- Significant and highly differentiated spatial dynamics between territories, particularly between the French and Swiss parts of this study area

- Existence of many documents planning urbanization on this great territory

- Absence of a unified strategic scenario of territorial evolution

Land use (CLC simplified database)
- Continuous urban fabric
- Discontinuous urban fabric
- Industrial and commercial units
- Other artificial surfaces
- Agricultural areas
- Permanent crops
- Forests
- Bare rocks and glaciers
- Wetlands
- Water bodies

Figure 7. Project region Thonon agglomeration.

Planning approaches

Purpose

The tool was developed by the University of Bourgogne-Franche-Comté (Jean-Philippe Antoni/Gilles Vuidel) with the objective to develop a simple tool to model the evolution of a territory according to conditions based on land use. A cell can evolve if there exists in its environment more or less close such type of occupation of the ground.

Intended user group(s)

Community in charge of urban planning in their territory

Benefits gained by the user from the utilization of the tool

Studying the evolution of urbanization and land use in a more or less long-term territory helps to reflect on what it is wanted for the future of the territory. LUCSIM allows to quickly model different scenarios of evolution of the territory. The model makes it possible to measure the potential impact of the various measures envisaged.

Main functions

The software has been used in a mode of automatic generation of transition rules. That is to say that the set of transition rules used to model the evolution of the territory were generated by the software on the basis of algorithms based on the spatial analysis of two images of land occupation at two given moments. In this strict framework, the results obtained are not fully exploitable. Indeed, the evolution of the territory generated by the software is such that some spaces have been transformed while others are not, and for no reason other than purely technical. The generation of transition rules by the user is possible and makes it possible to think that other results can be obtained in this case but the experiment carried out within the framework of the ASTUS project did not make it possible to test this possibility.

Tool format

The tool is a software entirely coded in Java language.

Tool Functions

Addressed emissions	*Analysed transport modes*
• None, the tool addresses changes in land use	• No transport modes analysed

Output type	*Output format*
• Comparison of alternatives • Map-based results • Impact of land consumption	• Maps

Analysis unit	*Coverage area*
• Region • Municipality	• City • State/ Province • Metropolitan Area

Tool Development

Stakeholders involved

- University of Bourgogne-Franche-Comté

Methodology

The design principle of the LUCSIM tool is based on four ideas:

1. To visualize the dynamics. For that, we divide the territory into different "cells" and assign to each cell the nature of the occupation of the ground. By applying this principle to two images of the territory obtained on two different dates, we can then represent and describe the evolution of the territory.

2. Quantifying urban dynamics. We seek to answer the question of how many "cells" will evolve, and to what kind of land use. We cannot understand what happens if we consider what happens to only one cell. We have to aggregate this information on the whole territory and we obtain a transition matrix between our two images of the territory. This is the basis for constructing a Markov chain that expresses the state of a variable at a later time, based on past observations of that variable.

3. Locating urban dynamics: While we now know how many cells will evolve, the model then seeks to determine where these variations will occur. The model is based on the notion of spatial interactions, that is to say that we consider that each agent (not necessarily in the sense of "person") of the territory is interacting with others and that these relationships induce interdependent changes. When brought back to the question of land use, an interaction results from the difference that exists between two places. On the basis of

these considerations, the tool exploits a potential model (in a simplified way, we find here the notion of attractiveness map) responsible for describing these spatial interactions.

Knowing the number of cells that should evolve and their location on the territory, the question arises to know the nature of developments.

4. Differentiate urban dynamics. This is where the model uses a cellular automaton. It assumes that the category of each cell is determined by its neighbourhood and that its evolution depends on the evolution of its neighbourhood. We create the notion of transition rules. These transition rules seek to describe what could happen: densification, urban spread, etc. The difficulty of this phase is to translate into a simple and purely geographical rule, the various phenomena of construction of the city.

The built-in LUCSIM tool in the decision tree is one way to determine these rules.

It is important to remember that the purpose of this software is not so much to represent a future image of the area as to enable a comparative spatial analysis of different simulations. The outputs are definitely not a prediction, which would be largely subject to debate as to why a particular sector was or was not developed.

For this reason, the objective should be to put forward different scenarios for the future development of the area, for use in each of the two software programs. Based on a handful of indicators, including land take and population growth, two scenarios had been drawn up: a baseline scenario and a strategic scenario (see Figure 8).

- The baseline scenario is based on projected population growth and land take figures, and the estimated level of protection of natural, agricultural and forest areas. The data for the baseline scenario is estimated from the observable trends in the area.

- The strategic scenario is based on data extracted from the area's main strategic urban development documents.
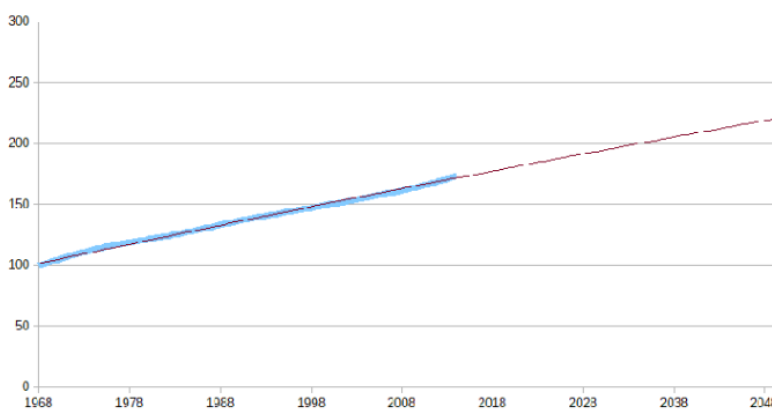
Figure 8. Example of Population growth in the Bauges Regional Nature Park study area (base of 100 in 1968) between 1968 and 2016 (blue) and projection to 2050 (dark red) – Baseline scenario.

Process

To conduct the experimentation with LUCSIM software, it was necessary:

- To be able to use the software, i.e. to understand its functioning and to define the necessary data so that it can function

- To formalize different scenarios of evolution of the territory by relying on the strategic documents of the territory

- To carry out the modelling for each of the study territories by adapting the scenarios to the only data that can take into account the software

For the first step, the software is relatively simple to use but requires GIS knowledge to prepare the geographical data necessary for the operation of the software.

For the second step, there was no document study in the studied territories that set a strategic framework for the evolution of the territory. It was necessary to quickly build a medium scenario by integrating and harmonizing the changes included in the strategic planning documents of these territories.

For the third step, the translation of these scenarios into input data for the software essentially involves the design of an attractiveness map. This preparation was done quite simply but it would have been possible to go further on the subject.

The rules generated by LUCSIM are exclusively geographical. The development of a given cell will depend on whether, in a specified neighbourhood, there are certain quantities of the various types of land within an initial land use layer. The effects of this type of rule are difficult to represent or to relate to traditional phenomena such as linear development or urban scattering, for example. LUCSIM's "fully automatic" operating mode is not explicit about this aspect.

Data requirements

Data description	Data source	Data type
Initial and past land use map	Corine Land Cover	Spatial
Attractiveness map	Can be automatically generated by the software based on initial land use map	Statistical

Software requirements

Program name	Program use
Java	Software is coded in Java language

Tool Utilization

LUCSIM is an expert tool. The operating principle of the software is simple even if the concepts and some algorithms used are very complex and robust. The use of the software also requires GIS skills. For the preparation of an attractiveness map without exploiting the small tools integrated in the software, it is necessary to have good skills in GIS.

From a functional point of view, LUCSIM is easy to start using in "fully automatic" mode, as experienced in the ASTUS project, even if the user guide is at best succinct.

Data requirements

Geographical data which can be generated from GIS and common data like Corine Land Cover or Open Street Map.

Software requirements

Java Runtime Environment 8.0

Tool impressions

The Markov chain can be used to cap growth in certain types of land use, it is not always possible to attain these thresholds and often the modelling process stops before this because the transition rules can no longer be applied in the area.

The changes do not include any notion of time, so are not regular in time or space. The first iterations of the model generally generate extensive change, while the last ones generate only very minor change.

Lastly, the changes modelled for the area are far from uniform:

- Some sectors display no change at all, while other show significant change.

- Changes to the discontinuous urban fabric sometimes resemble traditional urbanization phenomena (urban densification, linear development or urban scattering).

- Sometimes fictional phenomena known as "oil stains" or "snakes" appear.

As seen in Figure 9, the zoom in the map allows a more detailed analysis of the result obtained.
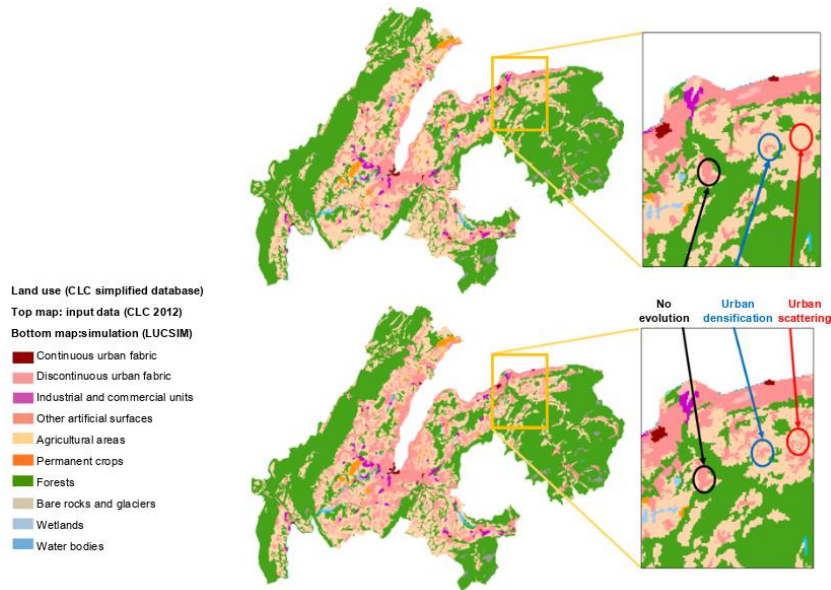
Figure 9. Map generated from LUCSIM in the Thonon study area.

In Figure 10 the zoom realized shows some of the phenomena generated by the software that are difficult to understand.
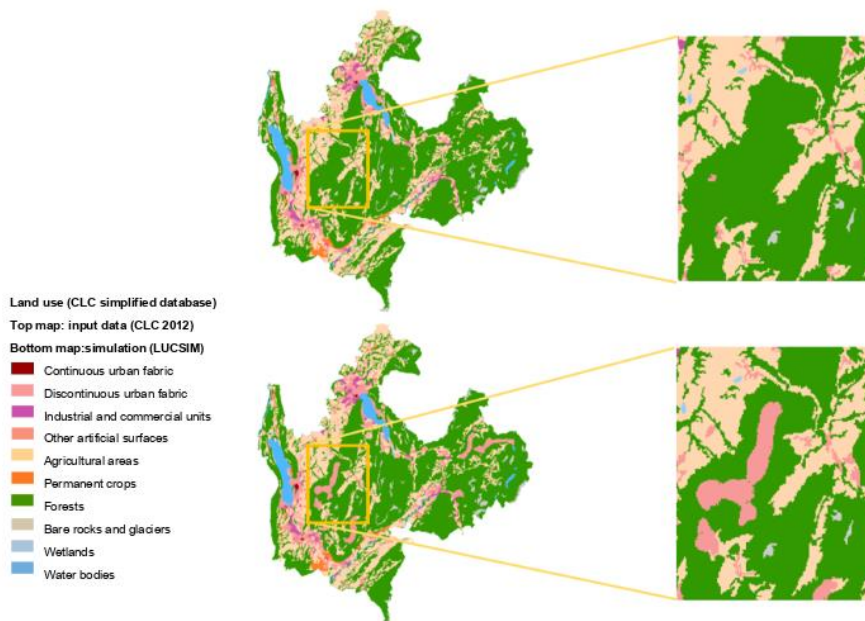
Figure 10. Map generated from LUCSIM in the study area of the Bauges Regional Nature Park.

Options for further development and conclusions

Stating specific options for further development would require a new experimentation by trying to generate own transition rules.

Given the results, is not possible to draw a conclusion about LUCSIM's suitability for use as a decision aid. In some respects, though, LUCSIM delivers very real benefits:

- LUCSIM can change different types of land use concomitantly, so would be capable of modelling certain densification phenomena.
- LUCSIM can also identify and model the impact of certain interactions between the urban environment and the natural environment, and, if the initial land use layer is sufficiently detailed, between the different types of land use in an urban environment. However, these possibilities were not tested in practice.

3.3. Commuter Tool Pongau

Developers: Dagmar Lahnsteiner, Anna Butzhammer and Thomas Prinz (RSA FG iSPACE)

The commuter tool Pongau is a strategic, prototypic instrument for analysis of commuter flows on various spatial scales. The tool is based on a commuter matrix (Statistik Austria, 2016) on a 250 m statistical raster grid. Therefore, a detailed analysis of in-, out- and inner-state/municipality commuter flows provides valuable information for transport planning and management. Moreover, a differentiation between working and education commuter within the analysis is possible.

Study region

Region of Pongau (see Figure 11):

- Association of 25 municipalities (3 cities) in the State of Salzburg

- Located in the South of the City of Salzburg

- 79.579 inhabitants (2016)

- 1755 km^2 area

- Characterized by alpine valleys and basin landscape

- Areas with scattered / disconnected settlements, especially in the rural / mountainous areas; mainly compact settlements, regional centres and small cities with good transport infrastructure in the valleys
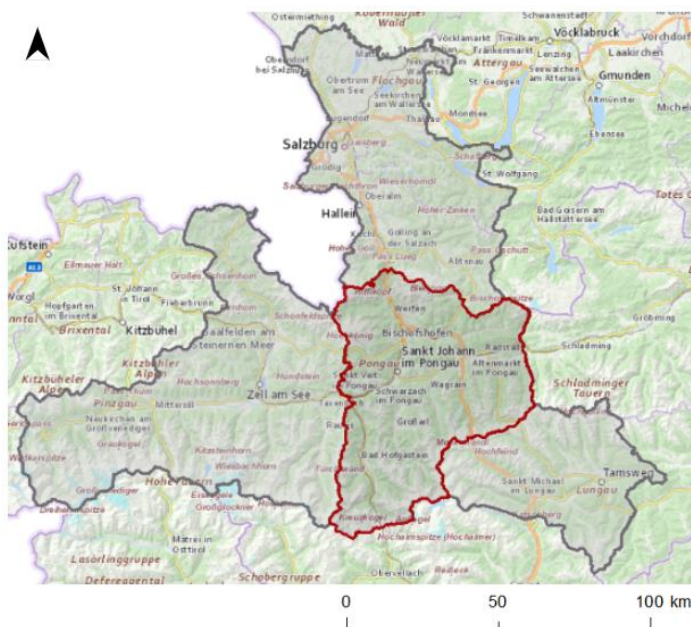
Figure 11. Study region Pongau.

Planning approaches

Purpose

Within the initial initiatives of the ASTUS pilot activities in the Region of Pongau, local authorities and transport associations required local transport data in order to identify potential fields of actions in the course of integrative transport and settlement planning. Hence, the commuter tool Pongau has been developed as an additional small tool within the ASTUS project in order to support the ASTUS pilot activities.

Intended user group(s)

- Local authorities
- Regional authorities
- Transport association

Benefits gained by the user from the utilization of the tool

- Detailed information on commuter flows
- Identify the potential for transport and settlement development actions

Main functions

- Origin-destination analysis of commuter matrix on various scales (statistical raster/location, municipality, region, district, state)
- Analysis of in-, out- and internal commuter
- Analysis of working commuter, education commuter

Tool format

- ArcGIS tool

Tool Functions

Addressed emissions	*Analysed transport modes*
• No addressed emissions	• No transport modes analysed

Output type	*Output format*
• Map-based results	• Numerical
• Location assessment	• Diagrams
• Potential mobility demand	• Maps
	• Tables

Analysis unit	*Coverage area*
• Region	• Nationwide
• Municipality	• (Worldwide)
• Specific location	
• Specific trip	

Tool Development

Stakeholders involved

• Associations

• Municipalities

The stakeholders where involved via ASTUS workshops.

Methodology

The tool is based on two parts: First a (spatial or non-spatial) selection of relevant origin-destination information regarding spatial or non-spatial criteria extracts all relevant data entries of the matrix. Afterwards an aggregation of the selected data sums up the relevant number of commuters on a predefined scale and according to predefined attributes (e.g. working, education commuter). Hence, it is possible to assess locations / areas according to their in- or out-commuters as well as to assess commuter flows between locations. The results are visualized in a map, table or diagram depending on the issue (see Figure 12).
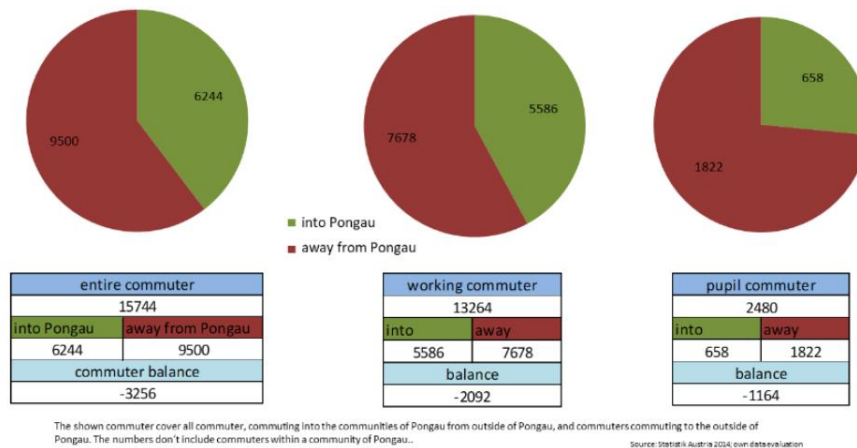
Figure 12. Commuters into and away from Pongau.

Data requirements

Data description	Data source	Data type
Commuter matrix (statistical raster 250m)	Statistik Austria 2014	Statistical and spatial
Municipalities	OGD	Spatial

Software requirements

Program name	Program use
ArcGIS	

Tool Utilization

Expert Tool: The utilization requires a GIS expertise

Data requirements

Commuter matrix

Software requirements

ArcGIS

Figure 13 shows the entire flow of commuters (working and education commuters) into and away from Pongau and the Austrian States.
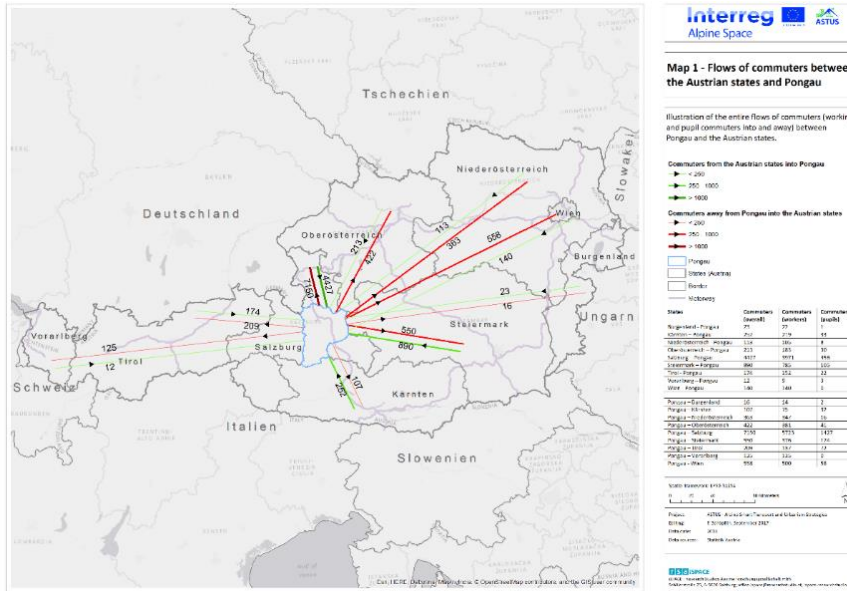
Figure 13. Map of flows of commuters between the Austrian states and Pongau.

In Figure 14, an illustration of 250 meter raster showing the commuters towards the clinic of St. Velt in Pongau can be seen. In addition, public transport stops are shown.
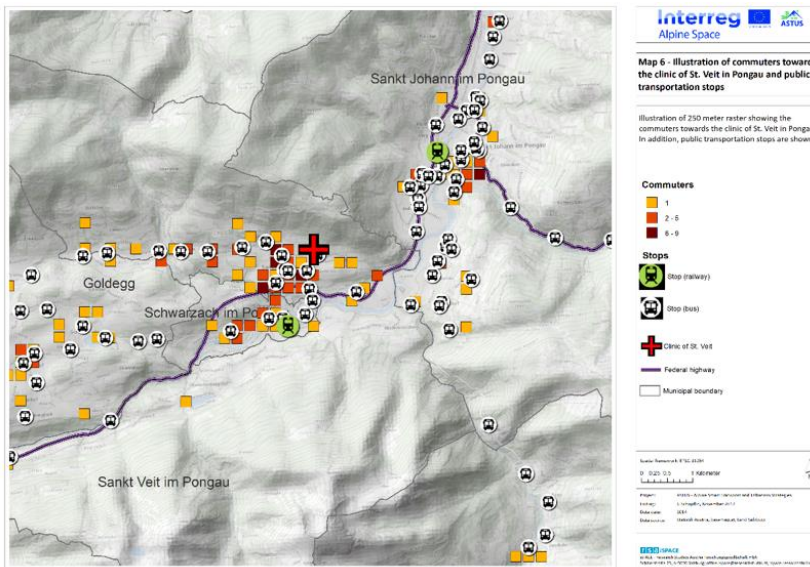
Figure 14. Illustration of commuters towards the clinic of St. Velt in Pongau and public transport stops.

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3.4.   MORECO Household Calculator

Developers: Bernhard Castellazzi, Anna Butzhammer and Thomas Prinz (RSA FG iSPACE)

The MORECO household calculator is a practical, web-based tool for comparing private personal costs of potential locations of residence. In detail, individual housing cost, travelling cost, travelling distances and travelling times are calculated based on the individual mobility behaviour and personal housing situation. In addition, information on the location are provided regarding the access to daily facilities within walking distance, the access to the next regional centre and the individual CO_2-equivalent emissions based on the personal mobility behaviour. The tool is especially helpful for housing decisions of private households.

Study region

State of Salzburg (see Figure 15):

- Covers about 7,156 square kilometres
- About 550,000 inhabitants
- High property pressure, especially in the City of Salzburg and its catchment area
- High and still increasing commuting activities
- Northern part of the state is characterized by the City of Salzburg and is a flat catchment area
- Southern part is characterized by remote, mountainous areas and valleys with functional, regional centres
- High CO_2 emissions produced by daily traffic
- Car affinity: 49 % car usage (Modal Split 2012)
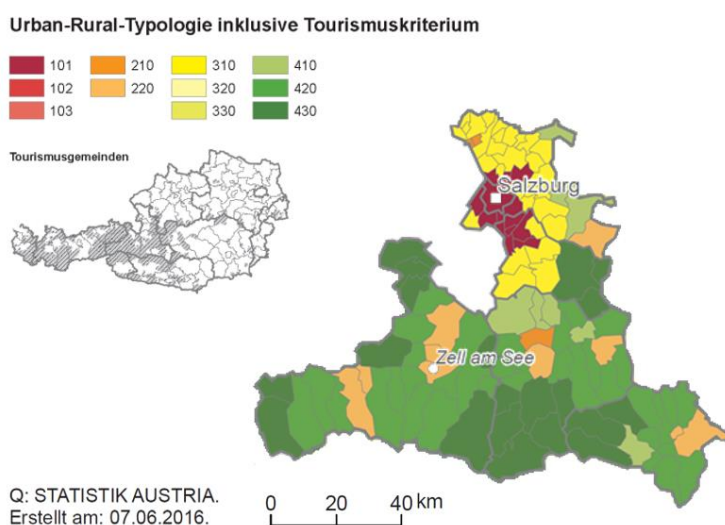
Figure 15. Urban-Rural Typology of the study region of Salzburg.

Planning approaches

Purpose

Further develop the MORECO Household calculator in order to raise awareness of the CO_2 emissions of the individual mobility behaviour influenced also by the location of residence, the transport options and the mode choice.

In order to raise awareness of sustainable mobility options, information on daily facilities and public transport options within walking distance are provided. Moreover, a new technical framework and user-interface support the usability and maintenance of the tool.

Intended user group(s)

- Private person
- Educational sector
- Planning authorities/companies focusing on spatial and transport planning

Benefits gained by the user from the utilization of the tool

- Raise awareness of residential and mobility costs in terms of monetary and CO_2-equivalent costs of the individual mobility behaviour
- Raise awareness of using multi- and intermodal mobility solutions
- Show interdependencies of housing types, housing location, mobility, costs and produced CO_2-equivalents

Main functions

- Location assessment:
    - Comparison of two locations regarding housing and mobility costs and expected CO_2-equivalent emissions (derived from the individual mobility behaviour)
    - Facilities within walking distance <15min: supermarket, school, sports facility, pharmacy, childcare, doctor, playground
    - Accessibility to the next regional centre: travel times for PT use & MIT
- Public transport assessment:
    - Service quality dep on the PT type (bus, train), the number of PT departures and the distance to the best PT stop
    - Name and walking time to the next PT stop
    - Departure interval & distribution of departures over the day at the next PT stop

- Name and walking time to the next PT station (if there is one within a 15 min walk)
- Departure interval & distribution of departures over the day at the next PT station

- Estimation of individual residential and mobility costs (monetary) based on the individual residential costs and mobility behaviour

- Estimation of CO_2-equivalent emissions based on individual mobility behaviour/routines

Tool format

- Web-application

Tool Functions

Addressed emissions

- CO_{2e}

Analysed transport modes

- Private car
- Cycling
- Public Transport
- Walking

Output type

- Mobility costs
- Emission estimation
- Living costs
- Comparison of alternatives
- Map-based results
- Location assessment

Output format

- Numerical
- Diagrams
- Tables

Analysis unit

- Specific trip
- Specific location
- Household

Coverage area

- Each location in the State of Salzburg/AUT

Tool Development

Stakeholders involved

- Associations

- Transport Companies

- Regional authorities

- Municipalities

- SIR

Multimodal CO_2 emissions of individual mobility behaviour:

- Analysis of individual trip segments by mode and length for estimating CO_2 costs

- Differentiated modes (key figures of total CO_{2e} emissions):

  - Car (motorized)

  - Public Transport

    - fuel motorized: Bus

    - e-motorized:

      - inner-city bus

      - train

      - tram

  - Walking

  - Cycling

Calculation of individual CO_{2e} emissions based on the equation of the ASTUS CO_{2L}:

$$CO_2 = \text{Pers} \times \frac{\text{Trips}}{\text{Pers}} \times \sum_m \text{mode share} \times \frac{\text{Pass} - \text{km}}{\text{Trip}_m} \times \frac{\text{Veh} - \text{km}}{\text{Pass} - \text{km}} \times \frac{CO_2}{\text{Veh} - \text{km}}$$

Process

Presentation of local infrastructure

- Developing routing logic for local foot paths to POIs (1: N) in Python

- Developing display method for UI (map and table based) (Javascript)
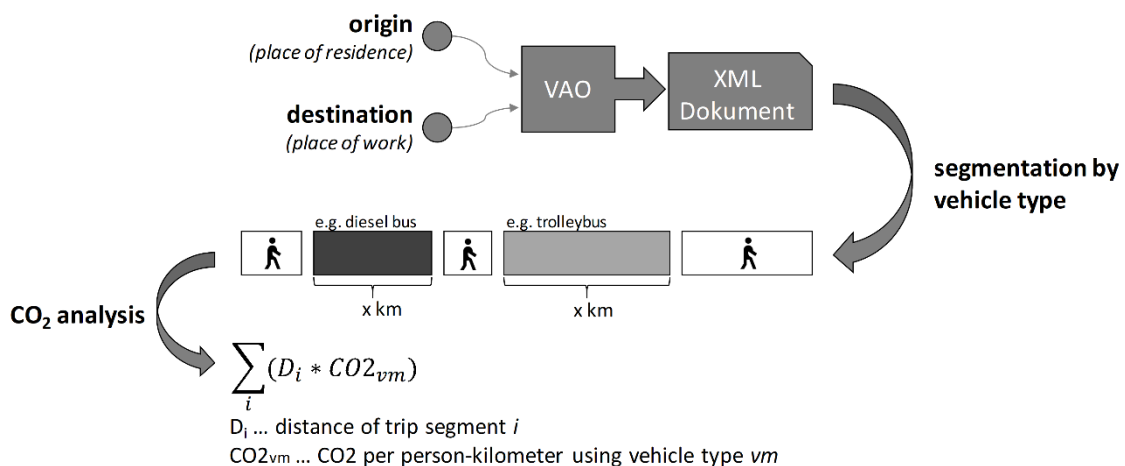
Figure 16. Process for calculating emissions in the MORECO Household Calculator.

CO₂ Analysis specific for commuting routes

- Identify a capable service for multi-modal routing

- Understanding service API attributes (request structure, request types, etc.)

- Development of parsing logic for service results

  - Depicting individual route segments

  - Classifying involved transport modes for each segment

  - Assigning CO_2 values to segments depending on transport mode and travel distance

- Visualization of CO_2 results for weekly commuting behaviour

Data requirements

Data description	Data source	Data type
Routing data	Verkehrsauskunft Österreich (VAO)	Transport
Emission factors by vehicle types	Umweltbundesamt 2018, VCÖ 2015	Technical
Basemap data	Basemap.at	Spatial
Points of interest	Open Street Map	Spatial
GIP – Graphenintegrationsplattform	Open Government Data (OGD)	Spatial

Software requirements

Program name	Program use
Python 3	On the server side the Python Web module requests and processes the public transport and individual transport route data, by parsing XML and evaluating its content. The User Interface requests the Python Web Module and displays the user specific content (Route lengths, transport costs, CO_2 values etc.)
Flask (Python Webframework)	
Javascript	
Openlayers 3 (Web mapping framework)	
React	
Bootstrap	

Tool Utilization

Basic skills in using a web browser and some understanding of digital maps are required.

Data requirements

No input data needed for the tool utilization

Software requirements

Any web browser

![Interreg Alpine Space logo with EUROPEAN UNION and ASTUS logos]

Step 1: Choosing residence location
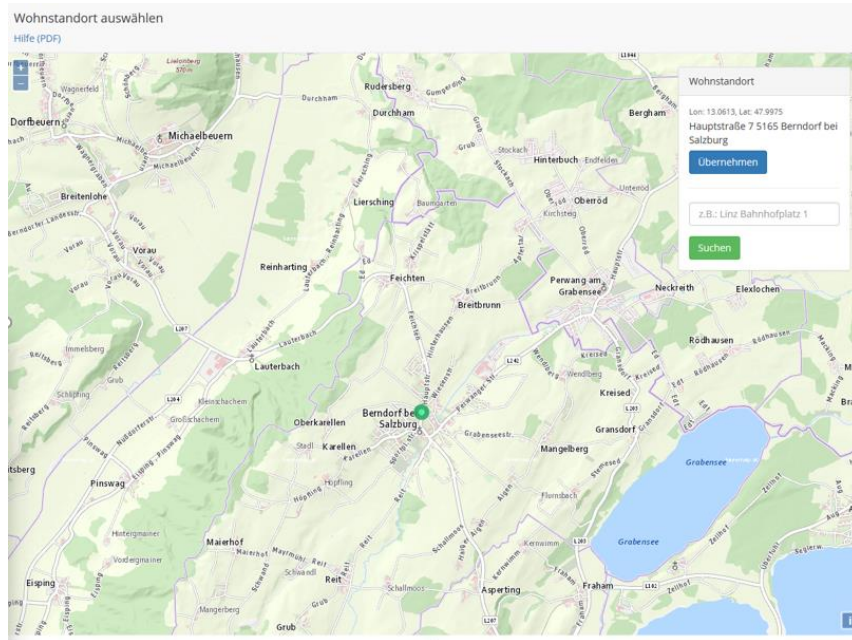
Figure 17. Location of residence selected.

Step 2: Getting mobility information

- Facilities within walking distance, e.g. school, supermarket, doctor, …

- Map-based result of facilities in the catchment area within walking distance

- Name, PT and MIT travel time to next regional centre

- Service quality of the PT

- Walking time to next bus stop and station

- PT service interval

- Number of departures by daytime
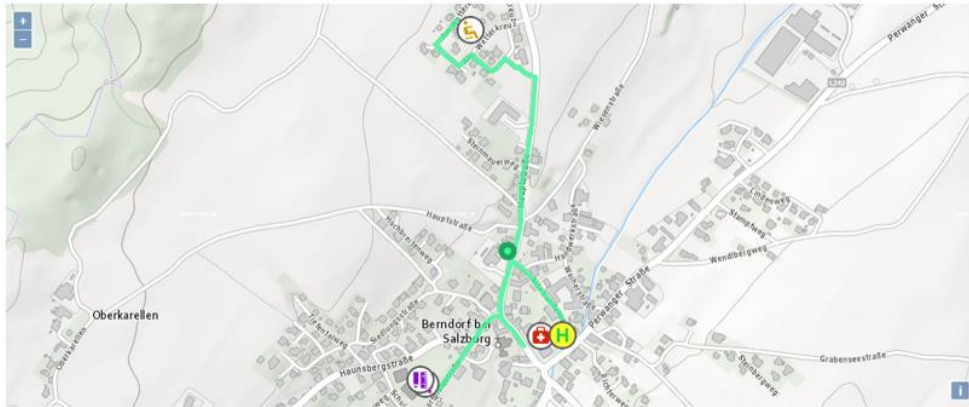
Figure 18. Information of study area.

Step 3: Getting information on housing costs

- Monthly housing costs (by rent or on purchase)

- Estimation of long-term financing is possible

Step 4: Individual daily trips by destination, mode, purpose, frequency

- Calculation of monetary and ecological travel costs, as well as travel times and distances

- Costs for private car (except fuel costs) and PT ticket per month

Step 4: Summary/ Factsheet

- On location characteristics regarding facilities and PT service within walking distance

- On mobility and residential costs, travel time, travel distances, CO2-equ- Emissions per month or year

Step 5: Comparison of locations

- Comparison of locations against the number of facilities within walking distance, PT service quality and accessibility to the next regional centre, as seen in Figure 19.

- Comparison of individual housing and mobility costs, as well as travel times, travel distances by car, and CO_{2e} emissions, as seen in Figure 20.
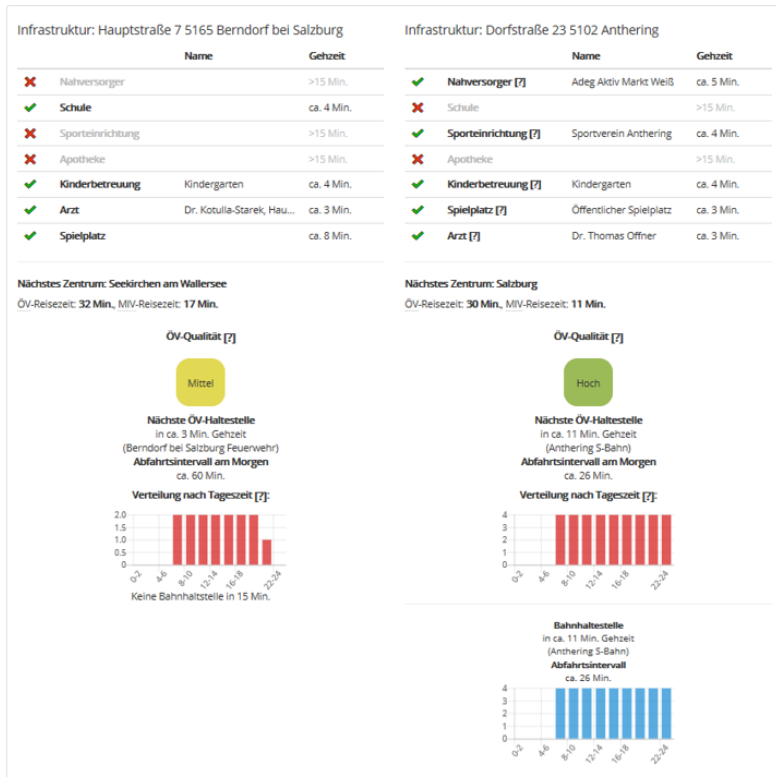
Figure 19. Location comparison table A.
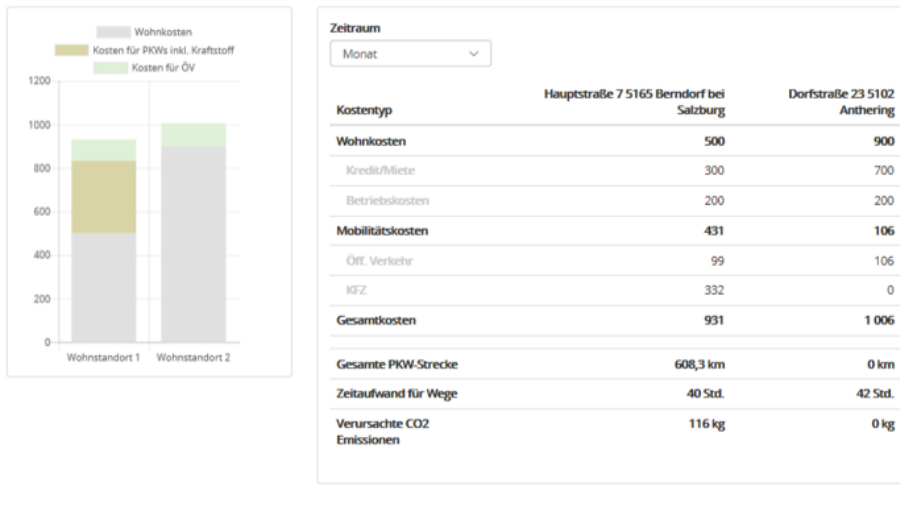
Figure 20. Location comparison table B.

Options for further development

- Functions: Integration of e-mobility solutions
- Spatial coverage: Nation-wide tool, enable cross-state analysis

3.5.   TUM Accessibility Atlas

Developers: Benjamin Büttner, Julia Kinigadner, Chenyi Ji (Technical University of Munich)

The TUM Accessibility Atlas is a strategic instrument for analysis and planning across all transport modes and on various spatial scales. Primarily, it is a database of structural and transport supply datasets that cover the geographic area of the European Metropolitan Region of Munich (EMM). The tool enables calculation of location-based measures of accessibility, which can be applied to relevant issues in the field of integrated land use and transport planning. The main objective is to improve multimodal accessibility in order to become more environmentally sustainable while also addressing spatial and social disparities.

Study region

The EMM is situated in southern Germany and covers about 30,000 square kilometres. It has six million inhabitants in total, of which 1.5 million are residents of the City of Munich. The region undergoes a continuing growth in employment and population and the negative consequences of transport activities become increasingly evident. Main planning issues relate to housing development, employment development and commuting.
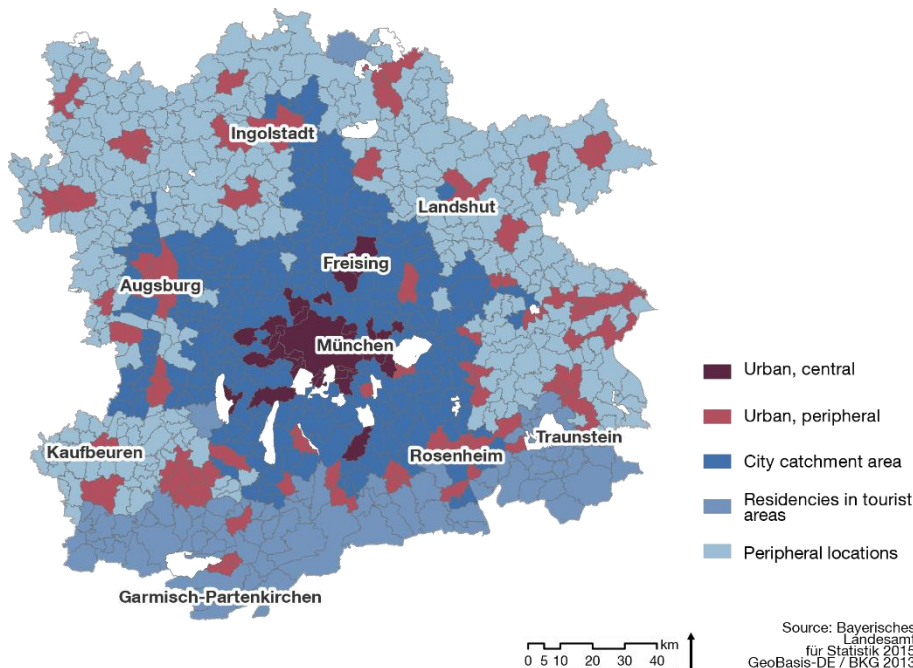
Figure 21. Spatial typology of the EMM.

Planning approaches

Purpose

Creation of a GIS-based tool to perform accessibility analyses in the EMM for scientific and practical purposes on different spatial scales:

- Supranational connection of the EMM to other metropolitan regions in Germany and Europe

- Gateways (airports, train stations, highways) of regional and supranational interest

- Integration of different subspaces on the regional level

- Analysis of small-scale interdependences on the local scale

Intended user group(s)

- Public organizations

- Planners working in the field of urban and transport planning

Benefits gained by the user from the utilization of the tool

- Understanding the joint impacts of the transport system and the land use system

- Visual outputs for discussion and decision-making

Main functions

- Analysis of travel costs (distance, time, money, emissions)

- Visualization of catchment areas

- Accessibility assessment of locations on various spatial scales

- Analysis of the accessibility impacts of land use and transport measures

Tool format

- GIS-based tool

Tool Functions

Addressed emissions

- CO$_{2e}$

Analysed transport modes

- Private car
- Cycling
- Public transport
- Walking

Output type

- Mobility costs
- Emission estimation
- Comparison of alternatives
- Map-based results
- Location assessment

Output format

- Tables
- Numerical
- Maps

Analysis unit

- Municipality
- Specific trip
- Specific location

Coverage area

- Metropolitan area
- City
- City borough
- Neighbourhood

Tool Development

Stakeholders involved

- Associations

- Transport Companies

- Regional Authorities

- Municipalities

- Technical University of Munich

On the technical level, the project was realized by the TUM Chair of Urban Structure and Transport Planning. The transport companies Münchner Verkehrs- und Tarifverbund (MVV) as well as Münchner Verkehrsgesellschaft (MVG) provided some of the required data. Besides that, an intensive methodological and conceptual exchange between the developers and the potential users (municipalities, regional authorities, associations) took place in various presentations and workshops.

The mathematical model of calculating location-based accessibility is:

$$A_i = \sum_{j=1}^{n} D_j \times f(c_{ij}),$$

where A_i = Accessibility of the origin location i, D_j = Destination potential at location j, f = Function to assess the spatial resistance, c_{ij} = Spatial resistance to overcome while travelling from origin i to destination j. In the case of location-based accessibility measures, the origin is related to all possible target destinations in a defined area. Each target destination has a certain potential, which is defined through the structural size of a location (number of inhabitants, shop area size etc.). The spatial resistance that needs to be overcome (travel costs) lowers the weight of the destination potential. Finally, the sum of the weighted destination potentials equals the accessibility of the origin.

Cumulative opportunities indicator: The cost function is a jump function, where the weight of the destination potential is either 0, if the destination is located outside a given threshold, or 1, if the destination is located within a given threshold. The threshold could for example be given in minutes of travel time. The cost function is:

$$f(c_{ij}) = \begin{cases} 0 \ if \ c_{ij} > c_{threshold} \\ 1 \ if \ c_{ij} \le c_{threshold} \end{cases}$$

Distance-decay or gravity-based indicator: The cost function is a continuous function, where the weight of the destination potential decreases with increasing travel costs. The parameter ß represents the intensity of down-grading of the potential at the target destinations. The cost function is:

$$f(c_{ij}) = e^{-\beta c_{ij}}$$

Process

Step 1: Preparing the transport networks

- Network topology: The first step involves extracting and processing data from OpenStreetMap in order to model the networks for road transportation and non-motorized transport. Some tagging errors and missing links require manual editing. For public transport, an existing transport model is used, which enables timetable-based analysis in combination with emission calculation.

- Fuel / energy consumption: Very detailed consumption data is available for cars in different driving conditions. The information for public transport is not as ample, causing a need to reduce the level of detail. The consumption per km is multiplied by the length of the considered network element, yielding the consumption on a particular link.

- Emission factors: The consumption is multiplied by the corresponding emission factor. The well-to-wheels emission factor in CO2 equivalents for diesel, gasoline, and electricity is used. The emission factors could easily be exchanged, e.g. for a tank-to-wheels approach.

- Occupancy rates: The emissions per vehicle-km need to be broken down to emissions per passenger-km. This step is quite easy for cars, but very complicated for public transport due to the large temporal and spatial variations in occupancy. Average values were used as simplification. The default network considers spatial variations to some extent, but does not consider temporal variations in occupancy.

- Generation of routable network datasets in ArcGIS: In order to model a realistic travel behaviour, travel time is used for the route choice rather than the lowest emission path. Thus, travel time needs to be added as a second network attribute.

Step 2: Preparing the structural data

- In Germany, structural data is freely available on the level of municipalities. However, a more detailed spatial resolution is typically not available. Structural data, such as population data, needs to be disaggregated to point data in order to enable more detailed analysis.

- Some of the data sources are incomplete or outdated. In cases where better datasets do not exist, a manual update of the available data is required.

Step 3: Analysing accessibility

- Suitable accessibility indicators and corresponding parameters need to be defined for the analyses. The required parameters, such as the cut-off value in the cumulative opportunities measure, are determined based on existing travel behaviour as well as emission reduction targets.

- Origin-destination matrices and service areas can be calculated in ArcGIS or Visum. Emissions are accumulated along the best route, which is chosen based on the shortest travel time

- Accessibility analysis is often based on zones or grid cells in order to reduce calculation effort. The size of the cells needs to be chosen according to data availability, calculation speed, as well as the size of the study area. The calculation of travel impedance requires distinct origins and destination on a point level. If cells are used, a representative location for the respective spatial unit needs to be chosen, e.g. based on density centres or main public transport stops.

Data requirements

Data description	Data source	Data type
Road network	OpenStreetMap	Transport
Fuel consumption data for conventional cars	Handbook Emission Factors for Road Transport	Technical
Energy consumption data for electric cars	Federal Environment Agency	Technical
Occupancy rates for cars	Federal Environment Agency	Transport
Fuel and Energy consumption public transport	MVV, German Railways, Fraunhofer IVI	Technical
Timetable information public transport	MVV, Google, Transport model	Transport
Occupancy rates public transport	MVV, German Railways, Transport model	Transport
Emission factors for diesel, gasoline, and electricity	Federal Ministry of Transport and Digital Infrastructure, German Railways	Technical
CORINE Land Cover	European Environment Agency	Spatial
Land use data (ATKIS)	Federal Agency for Cartography and Geodesy, Bavarian State Office for Surveying and Geoinformation	Spatial
Structural land use data (population, employment etc.) on municipality level	Bavarian State Office for Statistics	Spatial
Points of Interest (e.g. hospitals, tourist destinations)	Google, OpenStreetMap, own data collection	Spatial

Software requirements

Program name	Program use
ArcGIS	Generating network datasets and maps (open-source GIS programs could be used as well)
PTV Visum	Working with public transport timetable data
Microsoft Excel	Further processing table-based results from GIS analyses
Python	Programming in Visum and ArcGIS
SQL	Filtering and refining data, e.g. from OpenStreetMap
Visual Basic for Applications	Processing data in excel

Tool Utilization

The TUM Accessibility Atlas is an expert tool that requires a high knowledge of GIS and additional software. It cannot be used by untrained staff.

Data requirements

The required data for the tool utilization is the same as for the tool development. However, the user might input specific origins to be analysed in terms of their accessibility, e.g. potential locations for mobility stations.

Software requirements

For the utilization of the tool there are the same software requirements as for the tool development.

Tool impressions
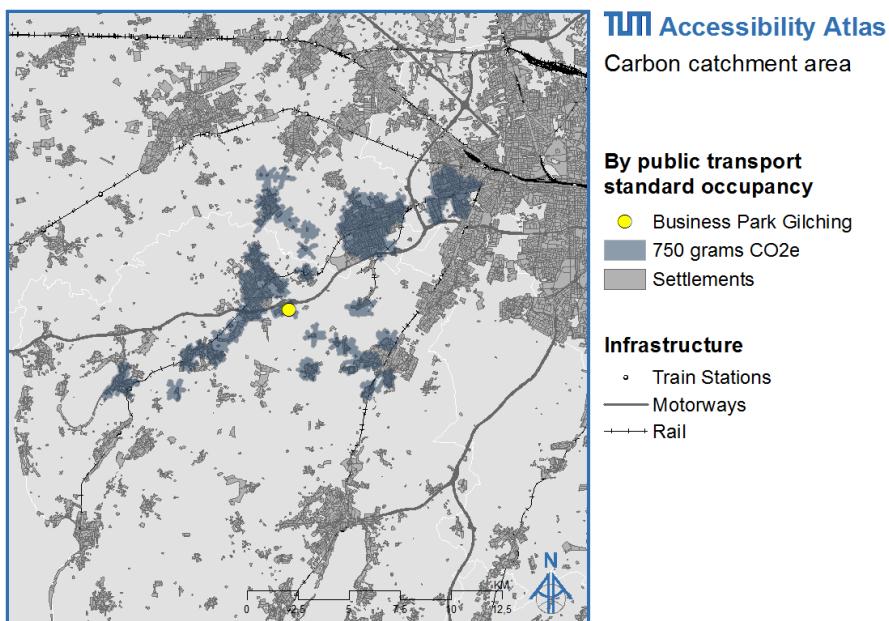
Figure 22. Example (a) of a map-based result in the TUM Accessibility Atlas.

The map in Figure 22 shows the carbon catchment area of a workplace location by public transport, assuming standard occupancy rates. The total number of workers accessible sums up to about 30,000. Spatial scale: county level, resistance: CO_2 equivalents (standard occupancy), accessibility indicator: cumulative opportunities.
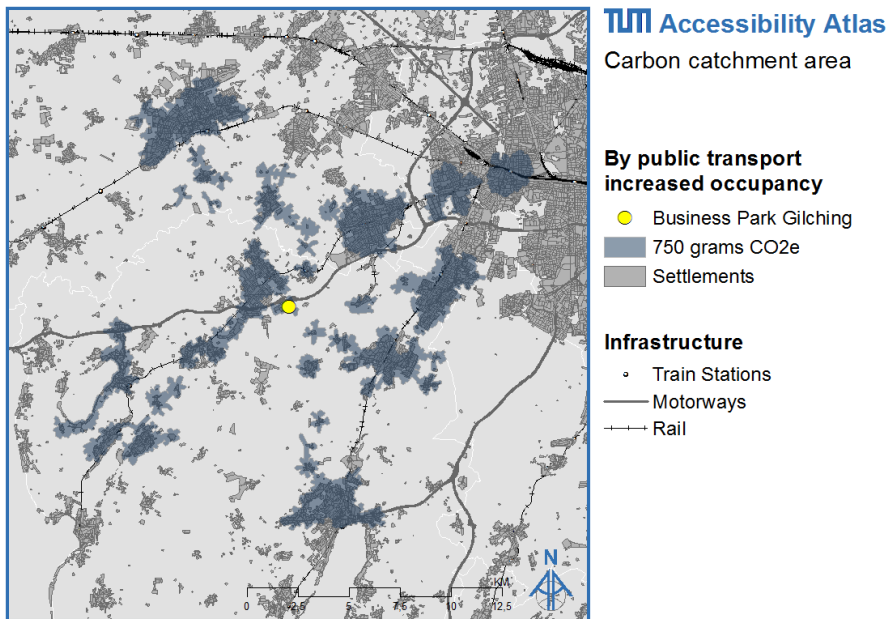
Figure 23. Example (b) of a map-based result in the TUM Accessibility Atlas.

The map in Figure 23 shows the carbon catchment area of a workplace location by public transport, assuming an increase in occupancy rates on all bus lines by 50 %. The total number of workers accessible increases to more than 60,000. Spatial scale: county level, resistance: CO_2 equivalents (increased occupancy), accessibility indicator: cumulative opportunities.

Options for further development

Functions:

- Enable dynamic, interactive accessibility analysis, possibly via a web interface

- Implementation of a specific application to enhance urban structure with respect to the distribution of employment and housing

- Enable modelling of intermodal travel behaviour and intermodal accessibility

Spatial coverage:

- Some of the data is limited to the greater Munich area and could be extended to cover the entire EMM region, including the adjacent areas (avoid fringe effects)

Data:

- Further refinement of data disaggregation methods

- Further improvement of the network model on local scales (walking and cycling)

- Merge all data into one common platform

- Enhance and update transport networks

3.6. CO$_{2L}$

Developers: Benjamin Büttner and Julia Kinigadner (Technical University of Munich), Gesa Volpers (Munich Transport and Tariff Association)

The CO$_{2L}$ calculates the CO$_2$ emissions from transport activities for a given spatial area. The toolkit is threefold: The first part is a calculator of CO$_2$ emissions. Territory-specific input data is required for the calculation. The second part of the toolkit provides sample input data. The third part provides the user with land use and transport planning measures, which can be implemented to reduce CO$_2$ emissions.

The CO$_{2L}$ was developed as an add-on to project output O.T2.2: ASTUS transnational methodology for low CO$_2$ scenarios. The tool supports the implementation of the transnational methodology.

Study region

CO$_{2L}$ is a transnational tool, where users are able to insert data for any specific territory, location or relation in order to compare baselines and scenarios.

Planning approaches

Purpose

The CO$_{2L}$ supports the quantification of transport-related emissions as well as emission savings.

Intended user group(s)

- Local authorities

- Decision makers

Benefits gained by the user from the utilization of the tool

- Calculate current emission levels (baseline)

- Identify options for intervention

- Highlight the emission reduction potential

- Support for the development of scenarios, strategies, and action plans

- Raise awareness

Main functions

- Calculation Sheet: The calculation sheet can be used to quantify emissions for both the baseline and a set of scenarios.

- Input data sheet: The file provides sample input data for calculating CO_2 emissions in different contexts.

- Measures for producing low carbon scenarios: The file contains a number of potential measures for low CO_2 scenario building

Tool format

- Excel calculator

Tool Functions

Addressed emissions	*Analysed transport modes*
- CO_2 - CO_{2e}	- Private car - Cycling - Public transport - Walking

Output type	*Output format*
- Emission estimation	- Numerical

Analysis unit	*Coverage area*
- Region - Municipality	- Any given area where suitable data is available

Tool Development

Methodology

The tool uses the following formula for CO_2 emission calculation:

$$CO_2 = \text{Pers} \times \frac{\text{Trips}}{\text{Pers}} \times \sum_{m} \text{mode share} \times \frac{\text{Pass} - \text{km}}{\text{Trip}_m} \times \frac{\text{Veh} - \text{km}}{\text{Pass} - \text{km}} \times \frac{CO_2}{\text{Veh} - \text{km}}$$

A number of parameters, which are unique for each system, determine transport-related emissions. Becker et al. (2009) suggest five parameters as influencing factors: number of people, number of trips, trip length, occupancy, and emission factor. Such a comprehensive approach makes it possible to capture a wide range of reactions and effects caused by systems changes.

Parameters:

- CO_2: Total Transport-related CO_2 emissions within a defined system

- Pers: Number of persons within a defined system

- Trips/Pers: Number of Trips per person within a certain time period

- Mode share: Percentage of trips travelled with mode m

- Pass-km/ Trip m: Average distance travelled with mode m on a single trip

- Veh-km/ Pass-km: Number of vehicle-kilometres per passenger-kilometre

- CO_2/Veh-km: CO_2 emitted by transport mode m over one kilometre

The product of the number of persons, the number of motorized trips per person, the distance per motorized trip and the inverse of vehicle occupancy corresponds to the number of vehicle kilometres travelled. The total number of vehicle-kilometres travelled within a defined system might be known from traffic counts or models.

In this case, a simplified formula as shown below can be used to calculate CO_2 emissions. This equation requires less data, but disguises the variety of underlying influencing factors:

$$CO_2 = \text{Veh} - \text{km} \times \frac{CO2}{\text{Veh} - \text{km}}$$

Data requirements

Data description	Data source	Data type
Estimated impact of measures	Various	Other
Input data (transport data)	Mobility surveys of given region	Transport

Software requirements

Program name	Program use
Excel worksheet	Calculation of emissions and comparison between baseline and scenarios.

Tool Utilization

Basic understanding of Microsoft Excel is required.

Data requirements

The user may use the input data from the toolkit as a reference. In order to calculate territory-specific results, the user needs to collect input data for the given territory and insert it into the toolkit. The required data include:

- Persons (population of the specific region)

- Trip rate

- Mode Share

- Occupancy rate

- Emission factors

Software requirements

Microsoft Excel

Tool impressions

Calculation sheet

1. As seen in Figure 24, this result box shows the total emissions in tons of CO_2. The emissions are calculated based on the input data in the other boxes. The formula mentioned in the methodology section is used for the calculation.

2. Users should insert the number of persons considered here.

3. The trip rate for the group inserted in [2] within the relevant time period shall be added here.

4. The lines below [4] represent all transport modes available. The default modes are "Foot", "Bicycle", "Car" and "Public transport". The line "Other" can be used to add another mode.

5. This column holds the modal split. The sum of all mode shares needs to equal 100 %.

6. The number of trips per person and mode is calculated based on the total number of trips per person in [3] and the mode share in [5].

7. Users should add the average trip length per mode in this column.

8. This column holds the number of vehicle-km per passenger-km or the inverse of the vehicle occupancy.

9. An emission factor in grams of CO_2 per vehicle-km is required for each mode.

Figure 24. Calculation sheet example.

Input data

The CO_{2L} entails a data sheet, containing sample data on trip rate, mode share, trip length, occupancy and emission factors (see Figure 25).

- The user can use the sample input data as a reference, but should use input data that is specific to the given territory for the emission calculation.

- Potential sources for input data include structural data from statistical offices, local surveys and inventories, as well as existing publications, plans, and models.

- Some input parameters might be difficult to determine directly. In this case, input parameters may be estimated based on data from comparable territories and local knowledge, considering the main determining factors of travel behaviour.

Country	Context	Year	Trips	Unit
Austria	National average	2013/2014	2.8	trips / person / day
Austria	National average	2013/2014	3.3	trips / mobile person / day
Austria	Large cities (excluding Vienna)	2013/2014	2.9	trips / person / day
Austria	Large cities (excluding Vienna)	2013/2014	3.4	trips / mobile person / day
Austria	Central counties	2013/2014	2.8	trips / person / day
Austria	Central counties	2013/2014	3.4	trips / mobile person / day
Austria	Peripheral counties	2013/2014	2.7	trips / person / day
Austria	Peripheral counties	2013/2014	3.3	trips / mobile person / day
Germany	National average	2008	3.4	trips / person / day
Germany	National average	2008	3.8	trips / mobile person / day
Italy	National average. 79.2 % of the population made at least one trip.	2015	2.1	trips / person / day
Italy	National average	2015	2.7	trips / mobile person / day
Switzerland	National average	2015	3.4	trips / person / day

Figure 25. Input data set example.

Measures sheet

The toolkit also includes a sheet which describes land use and transport measures and their possible impacts on the various levers (see Figure 26). The measures are supposed to help local authorities to identify and implement solutions in mobility and spatial planning.

Measure		Estimated impact on levers							
			Mode share						
	Pers	TripTrip Rate	Active Modes	Public transport	Car	Trip Length	Occupancy Rate	Emission Factor
Land use									
Densification	+	-	+++	++	---	---		
Mixed use		-	+++	+	---	---		
Access to public transport			++	++	--		--	
Public space			++	+	-			
Transit-oriented development			++	+++	---	---		
Active modes									
Streetscape design			++		--			
Bike lanes			++	*	--			
Bicycle highways			++	-	--			
Bike parking facilities			+	+	-			
Pedelec promotion / E-Bikes			++	-	--			
Public transport									
Public transport acceleration			+	++	-	+	--	
Climate efficient vehicles								---

Figure 26. Land use and transport measures sheet.

Options for further development

The tool could be developed further by periodic updating. This could be achieved by:

- Updating the input data for various typologies, based on recent surveys

- Conducting more research on measures and their impacts on the levers in various typologies

3.7. Google Earth

Developers: Grégoire Feyt, Valentin Ravier (University Grenoble-Alpes)

This tool has been tested rather than developed and has not required any computer scientist skills. The aim is to highlight the potential and the originality of a software like Google Earth for planning approaches. It can be used to show mobility flow in an interesting way and is capable of integrating almost every kind of data available (SHP, 3D, PNG, etc.). Easy to use, easy to set up, Google Earth can be used to support the decision making process during a meeting and is easily understandable by everyone.

The software ArcGIS Earth is very similar and could also be used instead of Google Earth.

Study region

The tool is used on two pilot sites located next to each other. The example shown in Figure 27 highlights different areas regarding the commuters' destination and geomorphology. It's used to know where the main commuting flow are and how it's possible to create solutions avoiding the use of cars. The tool allows to mix all the possessed data.

Figure 27. Mobility spatial typology in the pilot sites regarding the geomorphology.

Planning approaches

Purpose

The intention was to avoid developing/creating a tool because it takes a long time (most of the time longer than expected), cost a lot of money and nobody's sure of its efficiency until the end. Therefore, what was sought to do was:

- Use an open source software so everybody can use it

- Use a software capable of handling different kind of data (GIS, 3D, PNG, etc.)

- Use a software familiar, easy to use and talkative

- Find a software usable during meeting to support the decision making process

Intended user group(s)

- Everybody

Benefits gained by the user from the utilization of the tool

- Understanding the joint impacts of the transport system and the land use system

- Visual outputs for discussion and decision-making

Main functions

- Visualization of all the data available (catchment area, traffic jam, commuters flow…)

- Being able to instantly answer questions someone could have in a meeting (e.g.: how many cars are going through this road every day?)

- Add notes from participants in real time and cross it with the database

Tool format

- An open source software

Tool Functions

Addressed emissions	*Analysed transport modes*
• Depends on the added data	• Private car
	• Cycling
	• Public transport
	• Extra added data

Output type	*Output format*
• Mobility costs	• Pictures
• Living costs	• Maps
• Specific recommendations	
• Improvement measures	

Analysis unit	*Coverage area*
• Region	• Worldwide
• Municipality	
• Household	
• Corridor	
• Specific trip	
• Specific location	

Tool Development

Stakeholders involved

- Citizens

- Associations

- Interest group/NGOs

- Regional Authorities

- Municipalities

- City Councils

Process

Step 1: Preparing the data

Step 2: Adding the data in Google Earth

Step 3: Using the software in real time

Data requirements

Data description	Data source	Data type
Data from the INSEE	INSEE	Statistical
Data from Open Street Map	Open Street Map	Spatial
Traffic jam	Google map	Transport
Road count	Department	Transport
Extra added data		

Software requirements

Program name	Program use
QGis	Managing GIS data
SKETCHUP	Managing 3D data
INKSCAPE	Managing PNG data
Spreadsheet (Excel)	-

Tool Utilization

The use of the software Google Earth does not require high competences in software engineering or in any of the software related to the use of the tool.

Thanks to the Open Source, the user isn't force to produce data through QGIS, Inkscape, SketchUp. It is just necessary to add the data into the software and export it as a KML or PNG

file. Then these KML and PNG files are loaded into Google Earth and the only thing left to do is semiology.

The data needed must be picked by the person in charge of the tool regarding the needs of the project, the data available, the time of development available.

QGIS from managing the GIS data, SketchUp for managing the 3D data and Inkscape from managing the PNG data.

The example shown in Figure 28 focuses on different elements:

- 450 people live and work in the same area

- Almost all the people living in the dark red area are working in the light red area (Chambéry and its surrounding)

- Buses are available

This is an example of the kind of representation Google Earth can offer if the data is available. The aim is to easily highlight mobility issues on a territory. In this case, it can easily be seen that all the commuters are forced to all go through the same road at some point.

Figure 28. Commuter flow in a specific area.

Technical aspects:

- All the lines and the buildings in this figure are from QGIS imported as a KML file

- The dark and light red area are from QGIS exported as a KML file

- The logo is from an Open Source Website and imported as a PNG file

3.8.   MobicosTER

Developer: Grégoire Feyt (University Grenobles-Alpes)

MobicosTer results from the adaptation of the Mobicost tool developed in the MORECO project framework: as Mobicost web application was conceived in order to give to a given household an estimation of the *costs* (time and money spent, kg of CO_2 emitted) induced by its various annual mobility practices, MobicosTer uses the Mobicost computation core with a statistical approach cost in order to estimate these cost for all the commuters of a given area, depending on the current or foreseen mobility modes.

Study region

As regards the calculation of the costs related to household mobility, the territorial approach led to an experiment on the pilot sites of Cœur de Savoie and Parc Naturel des Bauges, for which some of the data had already been implemented as part of the MORECO program. The "territorialisation" of Mobicost thus made possible to move from estimating the overall costs (in euros, in time and in CO_2 production) of mobility for a given household to estimating at a local level the costs incurred by commuting.

As it works on daily commuting, the considered area is in fact larger than the pilot site perimeter. Indeed, some commuters work at more than 50 km such as in Grenoble or Geneva.
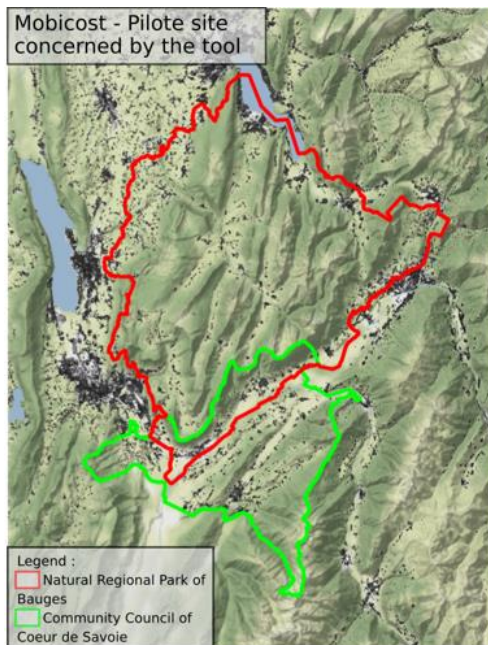
Figure 29. Project region concerned by the tool.

Planning approaches

Purpose

As regards the calculation of the costs related to household mobility, the territorial approach led to an experiment on the pilot sites of Cœur de Savoie and Parc Naturel des Bauges, for which some of the data had already been implemented as part of the MORECO program. The "territorialisation" of Mobicost thus contributes to switch from an individual to a collective perspective and to give objective elements for discussing and conceiving territorial policies or action plans. Particularly this information on global mobility costs can be helpfully compared with the available data on the local communities' global income or wealth in order to take in account the social dimension of mobility and housing in non-metropolitan area.

Intended user group(s)

Three levels:

- Implementation of the calculator: requires to collect, manage and compute various data types (statistical, geographical) a restricted to professionals with technical competencies and a good comprehension of the methodology.

- Use of the tool for simulating costs according to mobility policies: quite easy, accessible to mobility or land planners with a global comprehension of the principles.

- Local stakeholders: inputs and outputs quite easy to understand, discuss and/or modify in real time, possibility to change and discuss inputs and outputs in real time.

Benefits gained by the user from the utilization of the tool

The decision makers, local stakeholders, inhabitants can have a quite detailed analysis of the commuters' travel structure and by distance/zone/CO_2 emission/mobility costs and can look at this information against any other data available at these local levels (income, housing cost, etc.). An extension of MobicosTer allows to simulate in real time the believable saving (in money and CO_2) of a measure (car sharing, "soft modes") and can be used during a workshop. It is also easy to propose cartographical representation of the produced values.

Main functions

The main function of this tool is to make people realize the huge amount of money spent in commuting. It can lead to put in perspective the cost of public projects aiming to reduce the use and the need of several individual cars. For instance, the cost of creation of a bus line can appear impressive, but regarding the gain for households thus able to get rid of one car, it could contribute to make this project more acceptable. The critical question is then related to the local tax system and/or to the economic model.

Tool format

The use of MobicosTer requires a simple spreadsheet like Excel and could thus be accessible by internet. But its implementation requires some more specialized tools.

Tool Functions

Addressed emissions	*Analysed transport modes*
• CO_2	• Private car

Output type	*Output format*
• Mobility costs	• Pictures
• Emission estimation	• Numerical
• Comparison of alternatives	• Diagrams
• Map-based results	• Maps
• Specific recommendations	• Tables

Analysis unit	*Coverage area*
• Region	• State/province
• Municipality	• Metropolitan area
• Corridor	

Tool Development

Stakeholders involved

• Technicians, urban planners

The different stakeholders are involved in this process because of the reality the tool is showing. It is highlighted the fact that the Natural Regional Park isn't the right scale to work on mobility because it's inhabitants are divided in zones such as a watershed. People are leaving the mountainous area they're living in every day to go to work in the surrounding cities (it's most of the commuting flow but not all of them).

Methodology

In the Natural Regional Park of Bauges, it has been analysed the place of work of the pilot site inhabitants. This leads to the map and the graph seen in Figure 30.

- What MobicosTer allowed to create the graph, which indicates the numbers of commuters in the pilot site, the cost of mobility per year and the amount of CO_2 released by commuting per year in Kg.

- The data available is at the scale of a community, allowing a deeper approach.

- It was possible to group communities regarding the workplace of its inhabitants to help the creation of common transport for example
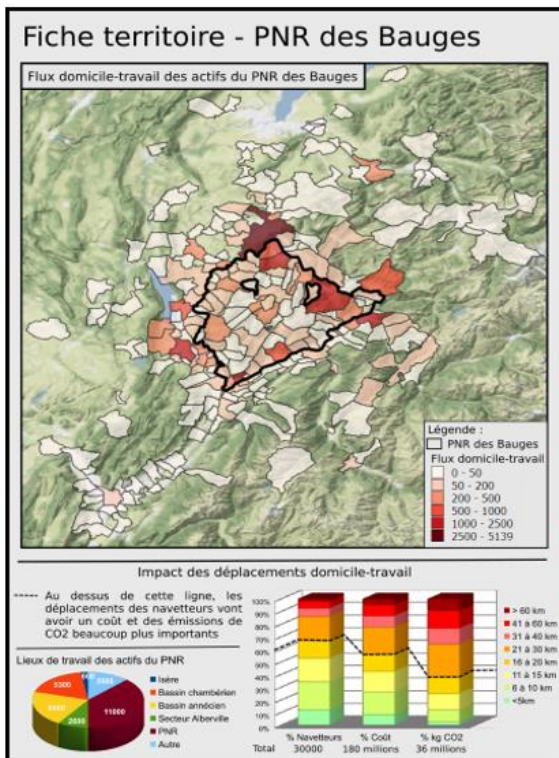
Figure 30. Example of the data needed to use Mobicost and its results.

This statistical adaptation of the Mobicost tool required both methodological changes and the inclusion of additional data, in particular concerning income, the number of vehicles per household, demographic data and the "origin-destination" of workers.

Statistical analyses could thus be produced at the municipal level, allowing a comparison between monetary costs and environmental (i.e. CO_2 emissions) costs linked to commuting and household incomes, thus highlighting spatial disparities in terms of vulnerability.

As it can be seen in Figure 31, it was able to create different zone in the pilot site regarding its inhabitants' workplace. This synthetic document can be more detailed by adding the road network, the quality of the traffic, etc. This allowed to worked differently on each areas because mobility and stakeholders are not involved at the same in each area created.
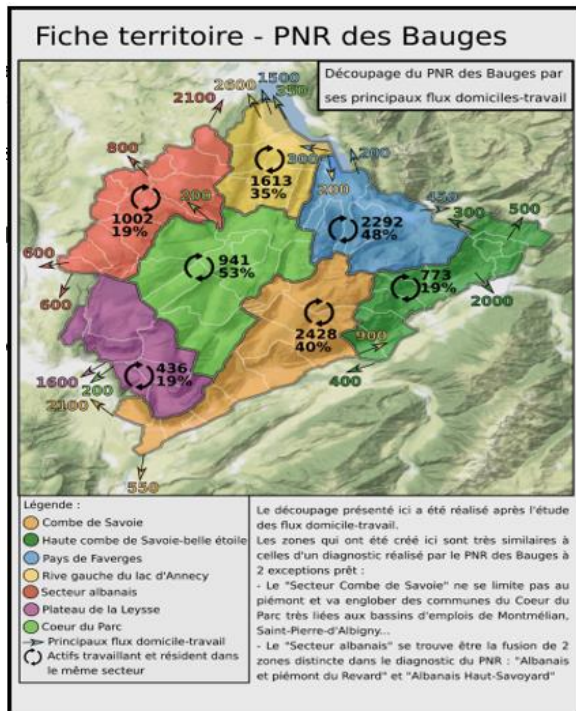
Figure 31. Different zones on pilot site regarding its inhabitants' workplace.

Process

Step 1: during MORECO, development of Mobicost as an individual service for householders.

Step 2: during ASTUS, territorialisation of Mobicost in order to estimate costs (€ and CO_2 emitted) for a given population of commuters thanks to a statistical approach.

Data requirements

Data description	Data source	Data type
INSEE socio demo	-	Statistical
MobicosTER data	-	Technical
SEVERAL technical data	-	Technical

Software requirements

Program name	Program use
Excel	-
Odomatrix (distances calculation)	-

Tool Utilization

The usability of the tool must be divided in two parts:

- Programming MobicosTER

  To estimate the cost of commuting and the amount of CO2 emitted, MobicosTER need a lot of programming and different data like the road network, the cost of gas, the cost of a car insurance, the cost of each tolls, etc.

- Extract data and analysis

  Once MobicosTER is set up for a specific area, data can be extracted and analyzed. This part requires a good knowledge of statistics and GIS if the aims is to create maps about mobility.

Data requirements

Only for simulation oriented use, Cf diapo 8

Software requirements

Spreadsheet such as Microsoft Excel

Tool impressions

The graph on Figure 32 highlights the fact that there is a different "level" of commuting. For example, 10 % of the commuters drive less than 5 km to go to work, the column on the right show the cost for its household and on the further right, the amount of CO_2 emitted. It can be observed that if people are driving more than 20 km to go to work, the cost and the amount of CO_2 emitted goes up rapidly.
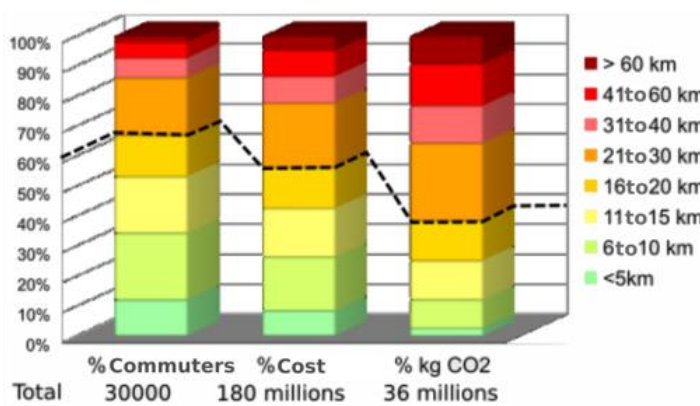
Figure 32. Natural Regional Park of Bauges regarding the workplace, how long is a commuter journey, the cost for its households and the kg of CO_2 emitted.

The map in Figure 33 refers to the different type of commuters regarding the distance of their commute and the income of their household. Figure 34 exemplifies a summary data table with different objectives and the respective specific results.
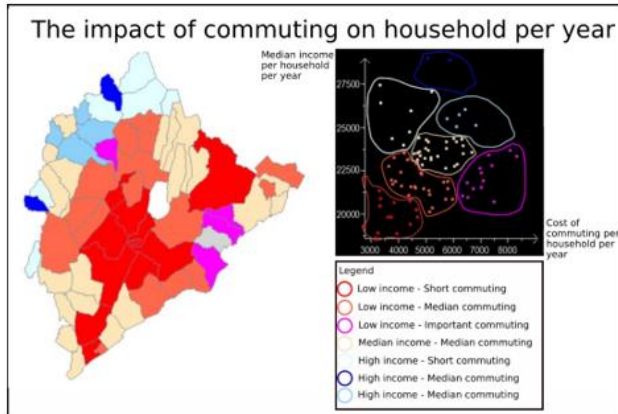
Figure 33. Impact of commuting on household per year.

Commuting distance	OBJECTIVE : SOFT MODES				OBJECTIVE : PUBLIC TRANSPORT				OBJECTIF : CAR SHARING					SUM OF EFFECTS		
	target % of commuters involved	Corresponding commuters Nb	Global CO2 saving/year	Money saving by getting rid of one car	target % of commuters involved	Corresponding commuters Nb	Global CO2 saving/year	Money saving by getting rid of one car	target % of commuters involved	Nb persons by car voit.	Corresponding commuters Nb	Global CO2 saving/year	Money saving by getting rid of one car	target % of commuters involved	Global CO2 saving/year	Money saving by getting rid of one car
Intra-municipalit	20%	759	156	1803990	0%	0	0	0	0%		0	0	0	759	156	1803990
<5km	15%	341	117	903741	0%	0	0	0	0%		0	0	0	341	117	903741
6 à 10 km	6%	294	215	958289	3%	147	108	479145	0%		0	0	0	440	323	1437434
11 à 15 km	3%	132	150	550339	5%	220	249	917232	15%	2	659	748	2751696	1011	1146	4219267
16 à 20 km	0%	0	0	0	5%	165	292	887341	15%	2	496	876	2662022	661	1168	3549363
21 à 30 km	0%	0	0	0	5%	205	558	1398989	15%	2	614	1674	4196966	819	2232	5595954
31 à 40 km	0%	0	0	0	0%	0	0	0	10%	2	126	480	1047840	126	480	1047840
41 à 60 km	0%	0	0	0	0%	0	0	0	5%		46	249	467994	46	249	467994
> 60 km	0%	0	0	0	0%	0	0	0	5%		26	183	352267	26	183	352267
total		1 526	638	4 216 360		737	1 207	3 682 706			1 967	4 209	11 478 785	4 229	6 054	19 377 850
Balance/current situation	6,0%	-1,6%	-3,5%		2,9%	-3,0%	-3,0%			7,7%	-10,4%	-9,4%		16,6%	-14,9%	-15,9%

Figure 34. Summary table.

3.9.   UIRS Accessibility Atlas

Developer: Simon Koblar (Urban Planning institute of the Republic of Slovenia)

UIRS Accessibility Atlas is inspired by the TUM Accessibility Atlas. It is an online tool designed for transport and spatial planners. The tool consists of two elements. One enables users to choose any location in Slovenia and calculate isochrones for a given time or to plan a trip between selected origin and destination. The other part is an online map with accessibility information for different locations. The accessibility data was calculated in advance, which enables more complex calculations than real time calculations.

Study region

The tool covers the entire territory of Slovenia (20,273 km^2). However, data for public transport in some cities are not available because public transport (PT) providers do not have appropriate data.

- Two million inhabitants.

- Different types of PT: national rail, national bus network and city bus network in some bigger municipalities.
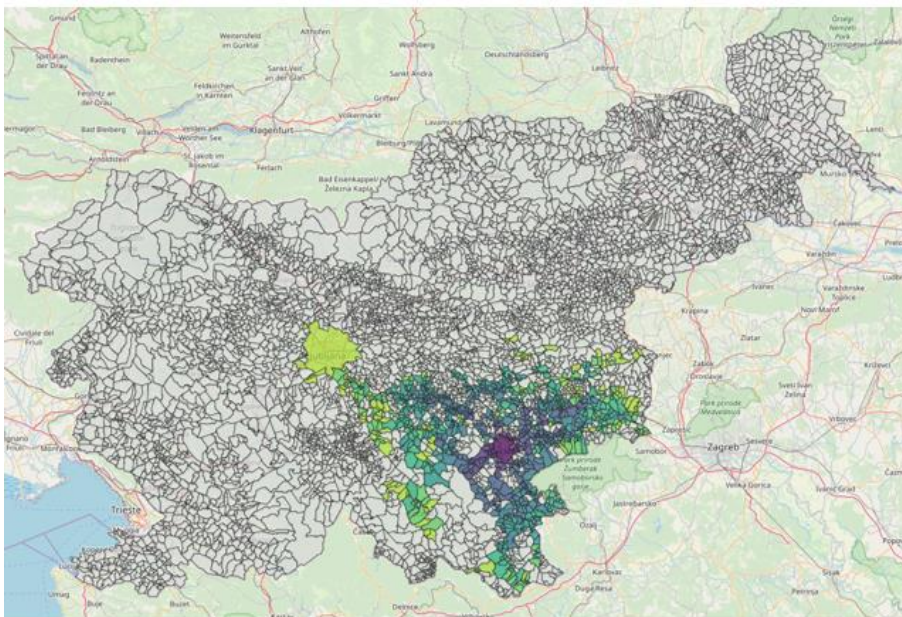
Figure 35. Area covered by the tool.

Planning approaches

Purpose

Creation of open source tool to analyse accessibility in Slovenia to facilitate transport and spatial planning. The main objective was to include public transport and other sustainable mobility modes and to be able to modify input data in order to test different scenarios. We opted for open source tools to have better flexibility and to be able to further develop and use the tool regardless of available funding. Open source tool can also be used by other institutions.

Intended user group(s)

- Traffic and spatial planners in municipalities

- Ministry of the environment and spatial planning

- Ministry of infrastructure

Benefits gained by the user from the utilization of the tool

- User will get better understanding of accessibility with different modes of transport. This can be used to improve e.g. public transport, or to plan new developments in areas with good accessibility with sustainable mobility modes.

Main functions

- Open trip planner backend – the backend of the application enables batch analyses with no graphical user interface. Results can be imported to GIS or SQL database for further analyses.

- Online dynamic accessibility atlas – users can choose location, travel mode and time, the tool calculates isochrones.

- Online accessibility atlas – a list of various accessibility indicators.

Tool format

- The backend of the tool is from the open source project Open Trip Planner.

- Accessibility atlas is available online, batch analyses are possible on a PC

Tool Functions

Addressed emissions	Analysed transport modes
• Not provided at this stage	• Private car
	• Cycling
	• Public transport
	• Walking

Output type	Output format
• Comparison of alternatives	• Numerical
• Map-based results	• Maps
• Location assessment	• Tables

Analysis unit	Coverage area
• From local to national level	• Country

Tool Development

Stakeholders involved

- Ministries

- Municipalities

The tool was developed at Urban Planning Institute of the Republic of Slovenia. The pilot sites, City municipality of Novo mesto and City municipality of Velenje, were actively involved in tool development. They assisted with gathering PT data and discussed what they expect from the tools. Ministry of the environment and spatial planning and Ministry of infrastructure are involved as observers. They also discussed usability of the tools and gave ideas for further developments of the tools.

Process

Step 1: Gathering and preparing data

- Open Street Map data is not complete for Slovenia. Data quality for the area of the Novo mesto and Velenje municipalities was improved, to increase accuracy in pilot sites. After these modifications, the data was downloaded.

- Gathering GTFS. GTFS files were gathered for all available locations. For Novo mesto and Velenje it was necessary develop a specific GTFS data.

- Centroids of the settlements – to calculate accessibility between settlements their centroids had to be defined. The centroids were located in a location where the majority of population lives, not into the geometrical centre.

Step 2: Analysing accessibility

- It was analysed the accessibility from all settlements in Slovenia to 15 regional centres with public transport during the morning rush hour, that is between 8:00 and 9:00 with 6 minutes' increments. Then the minimal travel time in this time window was calculated.

- Calculation of isochrones to regional centres.

Step 3: Developing online tools

- An online map was developed using Leaflet.

- Graphical user interface for dynamic accessibility atlas was already included in Open Trip Planner.

- A website was created to guide users to the relevant tools and explain how to use them.

Data requirements

Data description	Data source	Data type
Road network	Open Street Map	Transport
PT timetables for rail and regional busses	Ministry of infrastructure	Spatial
PT timetables for Velenje and Novo mesto bus network	Own data collection	Spatial
PT timetables for Ljubljana bus network	Ljubljanski potniški promet	Spatial
PT timetables for Maribor bus network	Marprom	Spatial
Elevation model	GURS	Spatial

Software requirements

Program name	Program use
Open Trip Planner	Open Trip Planner is the backbone of the tool. It is an open source java program.
R studio	R studio was used for batch analyses – sending requests to OTP.
Leaflet	Leaflet was used to make the static accessibility atlas.
Access	Access was used to analyse generated tables from OTP.
Qgis	Qgis was used to join spatial and attribute data.
javascript	Javascript is used in OTP and Leaflet.
R	R is used in R studio.
SQL	SQL is used to analyse attribute data in access.

Tool Utilization

The online tool is easy to use, for batch analyses expert knowledge is required.

Data requirements

No data needed to use the online tools

Software requirements

Internet browser

Tool impressions

The dynamic part of the accessibility atlas, shown in Figure 36, is a web tool that enables calculation of isochrones for different travel modes.
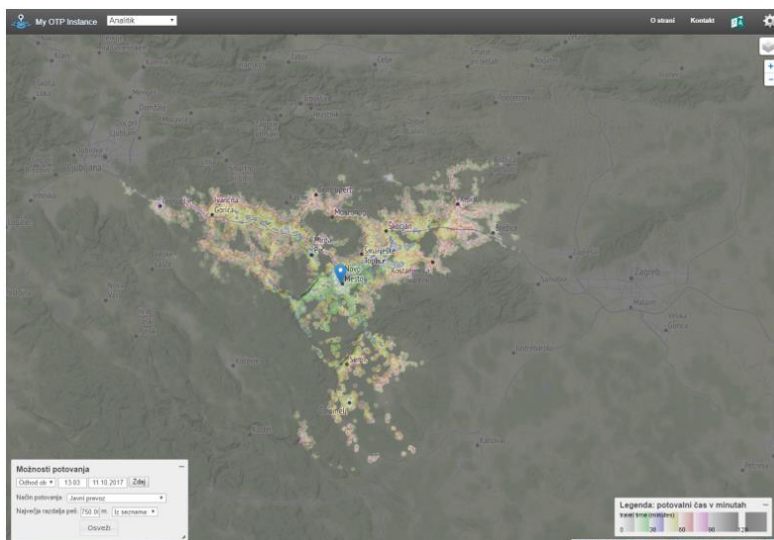
Figure 36. Dynamic accessibility atlas.

The static part of the accessibility atlas, shown in Figure 37, is a web tool that enables displaying different accessibility data.
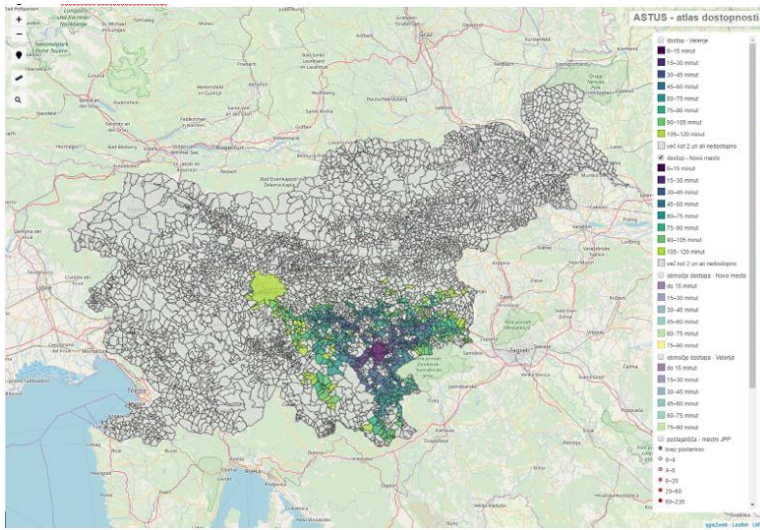
Figure 37. Static accessibility atlas.

Options for further development

An own Graphical user interface could be developed, for dynamic accessibility atlas and enable downloading isochrones. It would be also beneficial to include some overlay tools to be able to calculate the number of inhabitants inside the accessible area.

More data needs to be included into the static accessibility atlas. If there are many layers, the current menu will not be sufficient also responsiveness of a map would be greatly reduced. Maybe a different tool will need to be used to create an online map – postgre SQL + geoserver + openlyers could be a good option.

3.10. Google Maps - GTFS Timetables

Developer: Simon Koblar (Urban Planning institute of the Republic of Slovenia)

City municipalities of Novo mesto and Velenje have local bus networks. The service is paid by municipalities and run by a service provider. Their internal schedule data do not allow exports to GTFS data that is used in Google maps to show transit data. Schedules were generated in GTFS format and published on Google maps. Now potential riders can plan their trips using Google maps website or smartphone app.

Study region

City municipality of Novo mesto is one of the two Slovenian ASTUS pilot sites (see Figure 38). It has a population of 36,533 inhabitants and covers an area of 298.5 km^2. The tool is more relevant, where the local bus transport is operating.

Figure 38. The project area – City of Novo mesto.

On the other hand, the city municipality of Velenje has a population of 32,802 inhabitants and covers an area of 83.5 km^2 (see Figure 39).
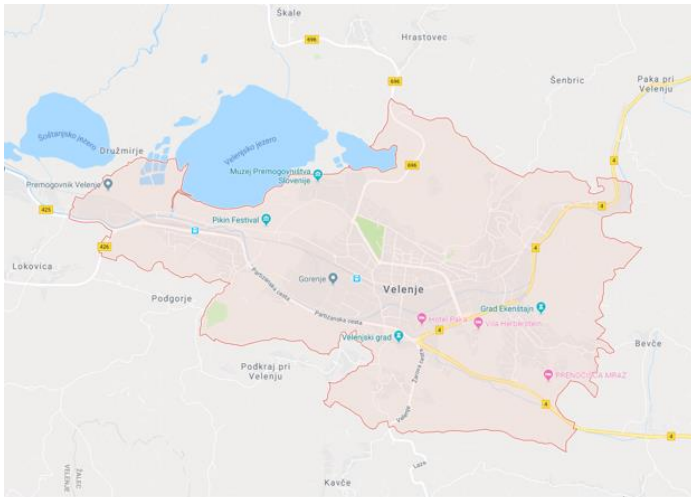
Figure 39. The project area – City of Velenje.

Planning approaches

Purpose

There was no easy way to plan a trip with local buses in the City municipalities of Novo mesto and Velenje. Since it would be too difficult to develop an own trip planning app it was decided to put effort into producing high quality GTFS timetables and publish them on the well-known platform Google maps. This will improve user experience when planning a trip, hoping it will also increase ridership.

Intended user group(s)

- GTFS tools: Public transport operators, municipalities

- Google Maps: General public, (potential) public transport users

Benefits gained by the user from the utilization of the tool

- GTFS tools: Enable easy production of GTFS timetables

- Google Maps: Improve trip planning with public transport

Main functions

- GTFS tools: Trip planning. Now data is available for all modes of public transport in the City municipalities of Novo mesto and Velenje (rail, regional and local bus).

- Google Maps: This makes it possible to plan a trip using different modes of public transport.

Tool format

- GTFS tools: Excel spreadsheet and GIS software for timetable creations

- Google Maps: online tool with mobile app (android and iOS).

Tool Functions

Addressed emissions	*Analysed transport modes*
- No addressed emissions	- Public transport

Output type	*Output format*
- Comparison of alternatives - Map-based results - Trip plans	- Written explanations - Maps

Analysis unit	*Coverage area*
- Specific trip - Municipality - Specific location	- City - Country - City borough - Neighbourhood - Metropolitan area - Specific address

Tool Development

Stakeholders involved

- Transport companies

- Municipalities

The tool was developed at the Urban Planning Institute of the Republic of Slovenia. For gathering data and explaining dilemmas the developers cooperated with transport companies and municipalities.

Methodology

GTFS (general transit feed specification) is the format used by Google Maps. The key task was therefore to convert the existing schedules into GTFS structure. Figure 40 shows data tables and their relations. GTFS schedules were also needed for the UIRS Accessibility Atlas also developed within the ASTUS project.
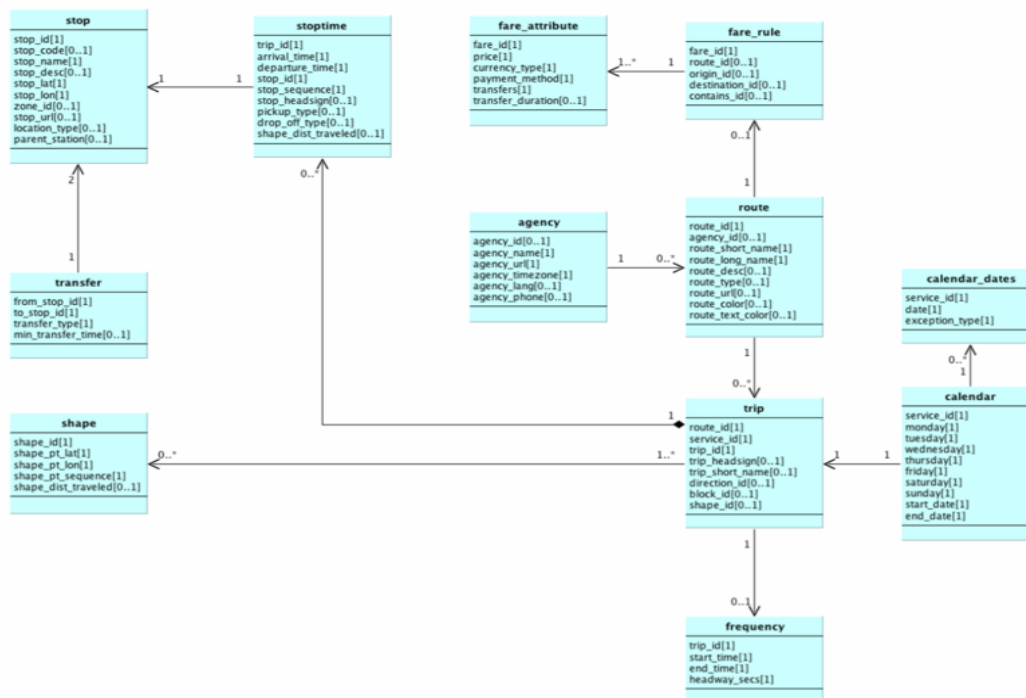
Figure 40. GTFS data structure.

Process

Step 1: Applying for access to transit partners' dashboard

- This process can take some weeks, Google has to check the application form, usually they have questions about the service etc.

Step 2: Generating GTFS files

- ArcGIS was used to draw lines and stops and export it to TXT files.

- Schedules were converted to GTFS using Excel. The problematic part was to define an appropriate coding for lines and departures.

Step 3: Uploading GTFS files to Google transit

- Uploading is easy, but it takes some time for google to process the files. Before they publish schedules they manually check them and usually have some suggestions on how to improve the quality. At times they also do not understand the local context properly.

- After the schedules are published, it is easy and quick to upload new GTFS files with changed schedules. It takes only a few days for updated schedules to be published.

There were some problems with encoding in local language. The encoding in TXT files had to be changed to UTF-8 manually. Also, it was necessary to change the digit group separator and decimal symbol to the English variant, otherwise the excel tool did not work properly.

Data requirements

Data description	Data source	Data type
Timetables for local bus transport in Novo mesto	City municipality of Novo mesto	Transport
Timetables for local bus transport in Velenje	City municipality of Velenje	Transport
Bus stops for Slovenia	Ministry of infrastructure	Transport

Software requirements

Program name	Program use
Microsoft Excel	Microsoft excel was used to convert timetables to GTFS data format.
ArcGIS	ArcGIS was used to draw lines and stops and to extract coordinates. Open source QGIS could also be used.
Web browser	Web browser – to upload data to Google transit
VBA – for writing macros	VBA – Visual basic macros in Excel were used to convert timetables to GTFS

Tool Utilization

Manipulating and generating GTFS files requires special skills in GIS and database management. Google Maps, on the contrary, is well-known and easy to use.

Data requirements

No specific input data

Software requirements

- GTFS tools: Excel and GIS software for generating GTFS timetables

- Google Maps: Internet browser or app

Tool impressions

The Excel tool with macros helped to transform human readable timetables into GTFS. Figure 41 shows a sheet where departure times for all lines were inserted.
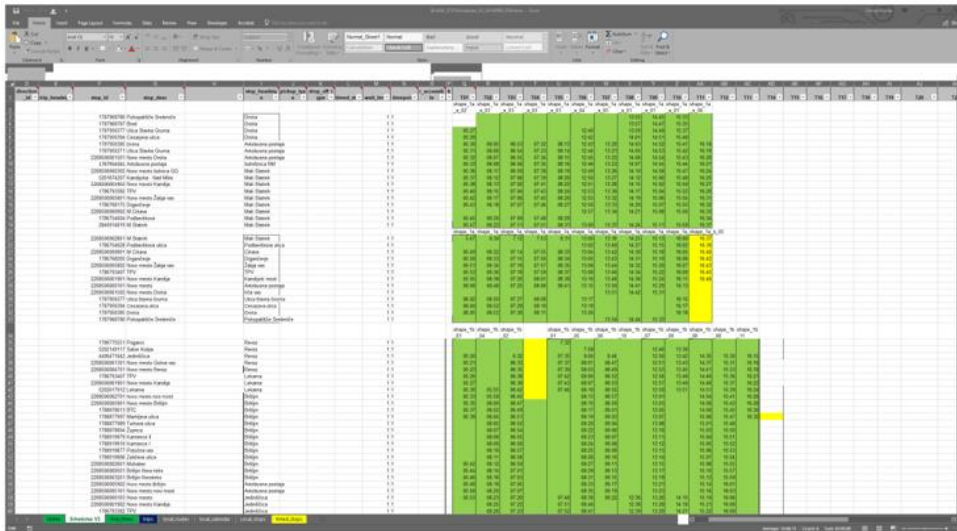
Figure 41. Excel tool to convert schedules to GTFS.

As a first step, schedules are produced in GTFS, then they are uploaded to Google Transit. First it was necessary to ask for a permission to access the service. It is free of charge for public transport with regular schedules, but the process can take a few weeks. When schedules are published, later updates are accepted within three days (see Figure 42).
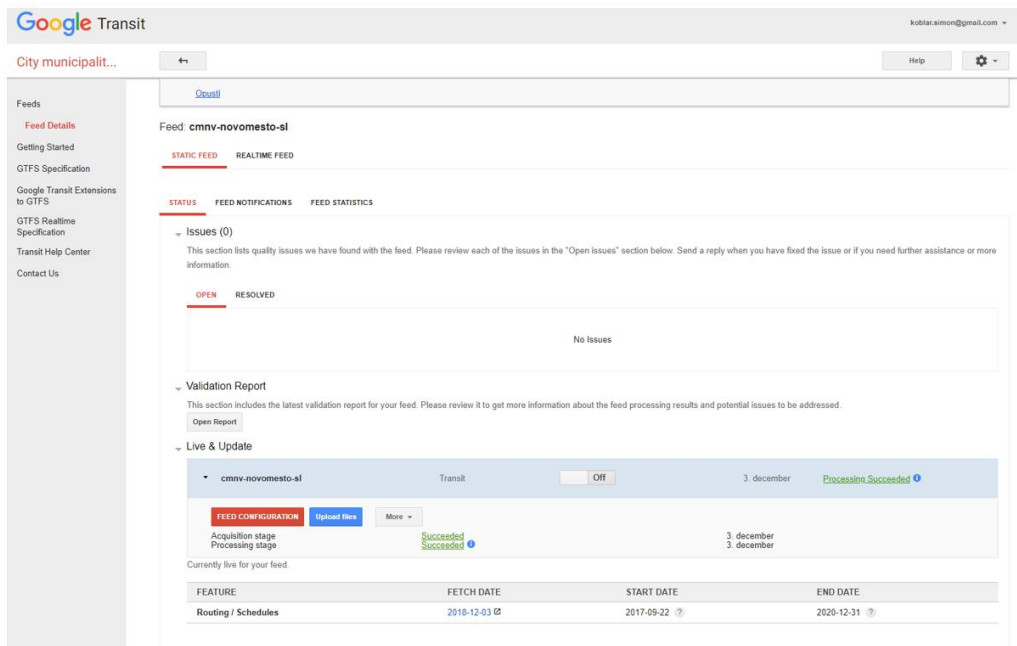
Figure 42. Google transit impressions.

Options for further development

Real time updates could be published to google maps using GTFS-real time. This requires more work – buses need GPS sensors and GSM transmitters, a server processing all this data and publishing it to Google Transit would be needed.

4. Evaluation of the tools with the final users

4.1. Questionnaire design and response

As a concluding activity of Work Package 2, the local stakeholders and potential tool users were asked to evaluate the tools in terms of their added value for planning and decision making. Several workshops were conducted in different pilot sites, during which one or more tools relevant to the participating stakeholders were evaluated based on a questionnaire. When more than one tool was part of a single workshop, multiple questionnaires were completed, one for each tool. The users rated their level of agreement with seven statements for each of the two aspects user-friendliness and usefulness. The questionnaire also provided space for comments (see Figure 43). The four open questions related to options for further improvement of the tool, the means of communication and presentation, the likeliness of using the tool in practice, and potential further comments regarding the tool's relevance.

Figure 43. Questionnaire to evaluate the tools with the final users.

Each tool was evaluated by four to ten users belonging to different local organizations. Figure 44 provides an overview of the number of respondents per tool.

Number of respondents

Tool	Respondents
FORESIGHT	4
LUCSIM	6
MORECO Household Calculator	4
TUM Accessibility Atlas	10
CO2L	10
Google Earth	5
MobicosTER	7
UIRS Accessibility Atlas	8
Google Maps - GTFS Timetables	8
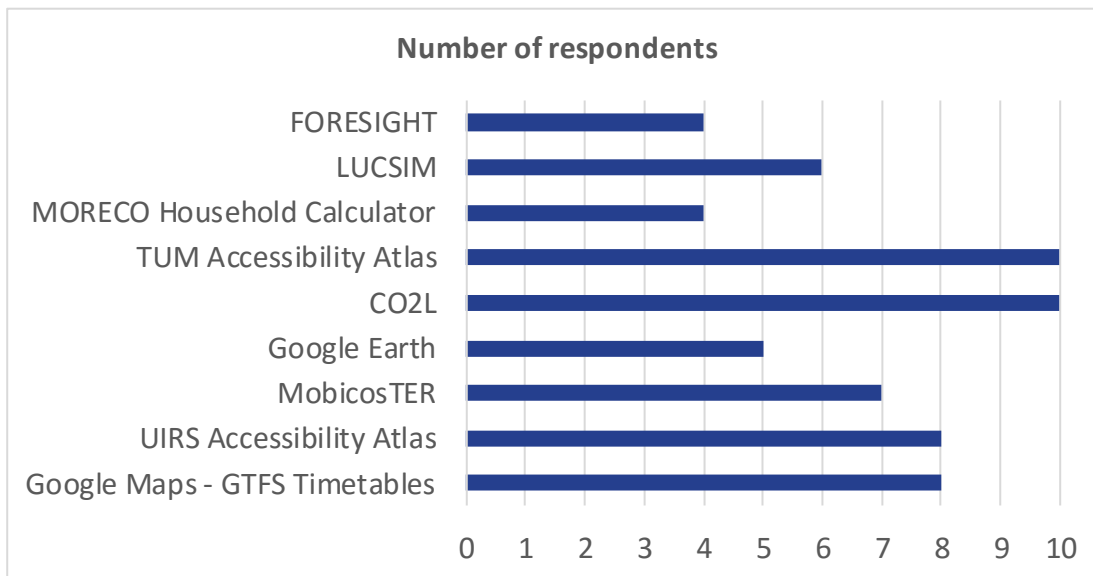
Figure 44. Number of respondents per tool.

4.2.   Evaluation results user-friendliness

For the user-friendliness evaluation, the fact or quality of being simple to use was graded. Factors such as the design interface, the skills required to use the tool, the management and understanding of the inputs and outputs, as well as the overall speed of the tool were taken into account.

As seen in Figure 45, most of the users agree that the tools are easy to use. More than 80 % of the respondents agree with the ease of usage of Google Maps – GTFS Timetables. Also the MORECO Household Calculator and Google Earth have a high percentage of approval. All respondents but one selected the not applicable option for the TUM Accessibility Atlas, reducing the significance of the resulting approval rate. Some users indicated that the user interface could be more interaction-friendlier. Regarding the neutral and missing answers, a few users stated that they need to experiment with the tool hands-on before being able to assess the ease of usage. The LUCSIM tool scored the biggest percentage of disagreement. Some users indicated that the tool is complicated to use and that there is the need for a manual of utilization to avoid surprising results.

The tool is easy to use
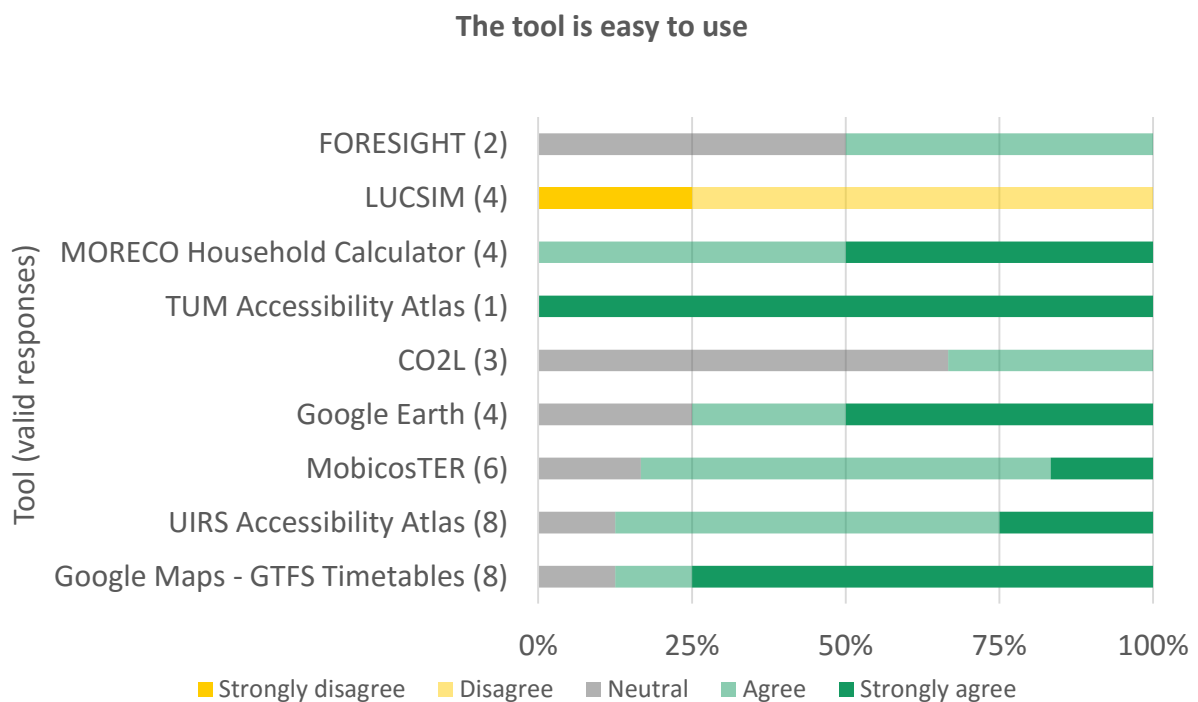
Figure 45. Ease of usage of the tools.

Figure 46 shows that most of the users agreed that their organization has the skillset required for operating the open source tools Google Maps – GTFS timetables and Google Earth. Also the vast majority agree to have the required skills to use the FORESIGHT, $CO_{2}L$ and TUM Accessibility Atlas tools. Few disagree to have the required skills to use MobicosTER, UIRS Accessibility Atlas and MORECO household calculator. A little more than half disagree for the LUCSIM tool.

My organization has the required skills to use the tool
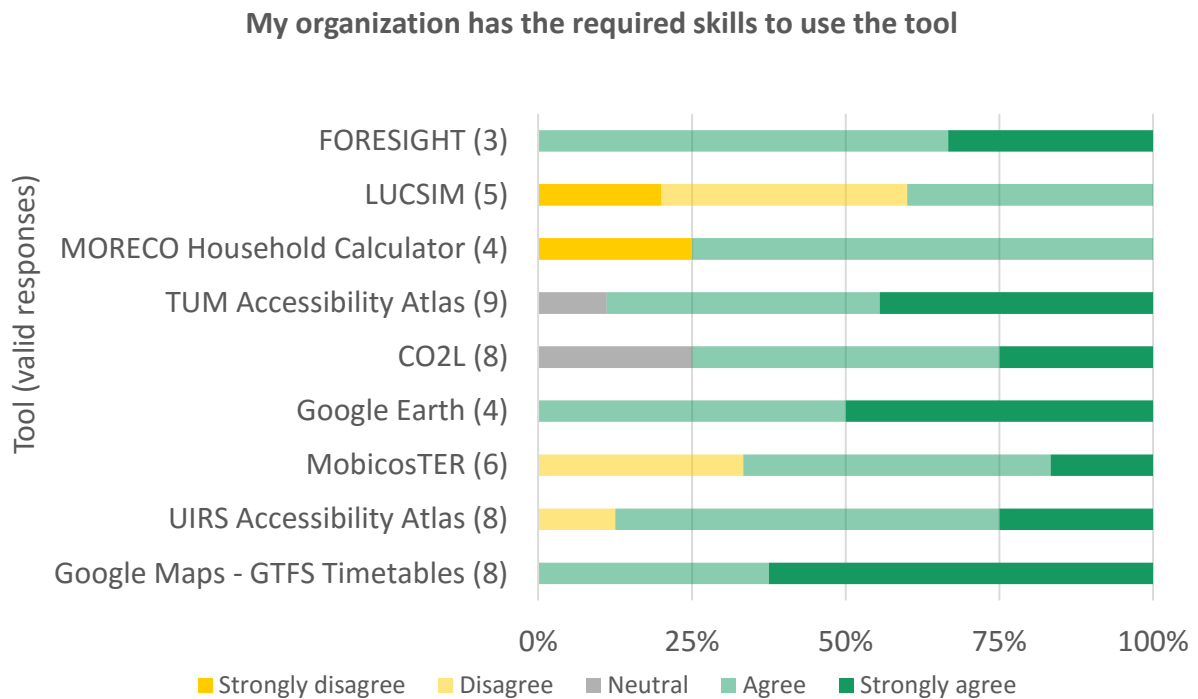
Figure 46. Skills sets required.

More than 80 % of respondents found that the MORECO Household Calculator, TUM Accessibility Atlas, UIRS Accessibility Atlas and Google Maps - GTFS Timetables are both rigorous in theory and usable in practice (see Figure 47). Doubt regarding the balance between scientific rigour and practical usability exists for FORESIGHT and LUCSIM and to some extent for MobicosTER and UIRS Accessibility Atlas.

The tool strikes a good balance between scientific rigour and practical usability
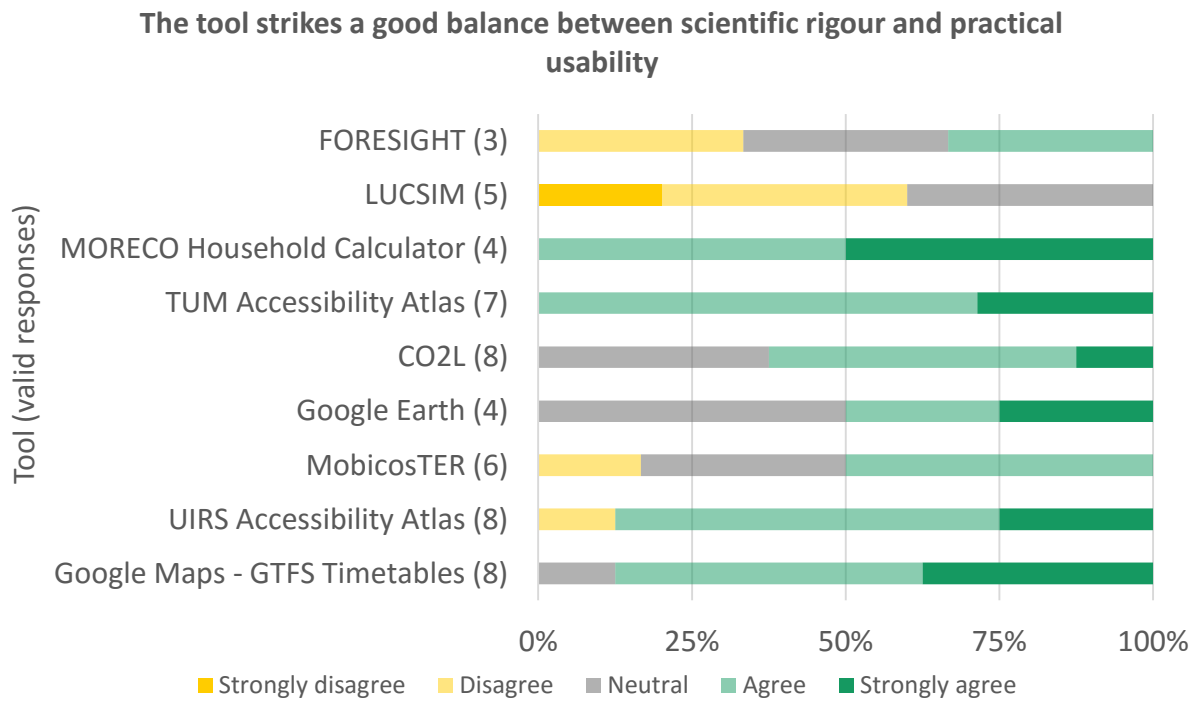
Figure 47. Balance between scientific rigour and practical usability.

As shown in Figure 48, the operation and functioning of MobicosTER and Google Earth are easy to understand. Also UIRS Accessibility Atlas received positive comments from the users, while some users pointed out the necessity to include a short description of the methodology in order to understand the results and outputs better. LUCSIM seemed to be difficult to understand for the users because of the complex setup.

It is easy to understand the input data, assumptions and calculations behind the tool
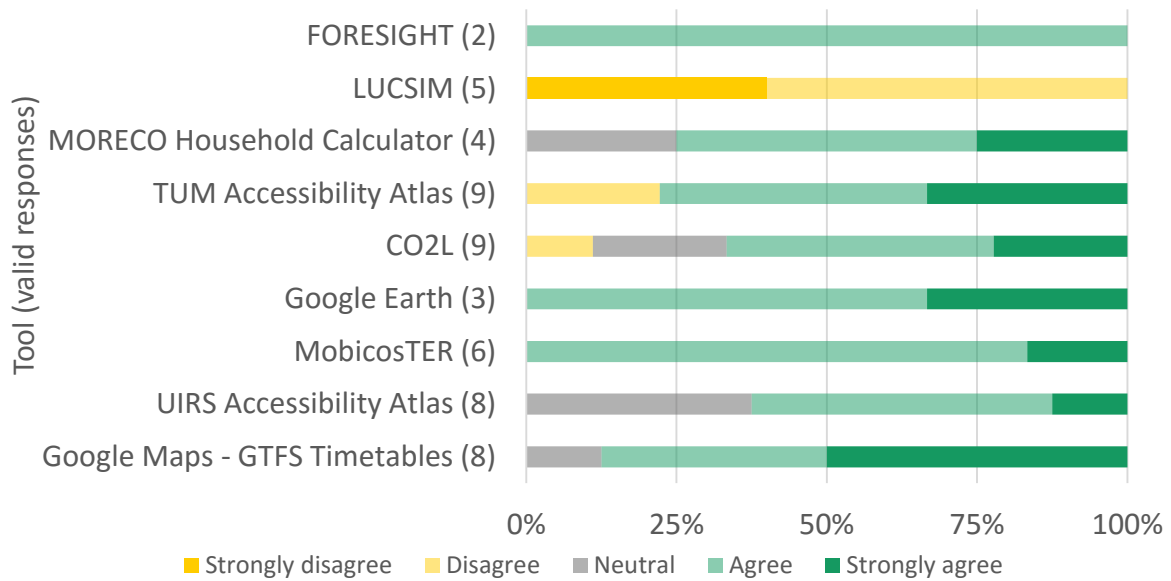
Figure 48. Ease of understanding the backend of the tool.

Quite a number of respondents feel that they need to be able to understand the tools in more detail in order to be able to use them effectively. Regarding Google Maps - GTFS Timetables, some users emphasized that the tool itself does not need improvement, but the data does, especially the timetables at the state level.

I do not feel I need to understand the input data, assumptions and calculations behind the tool to use it effectively
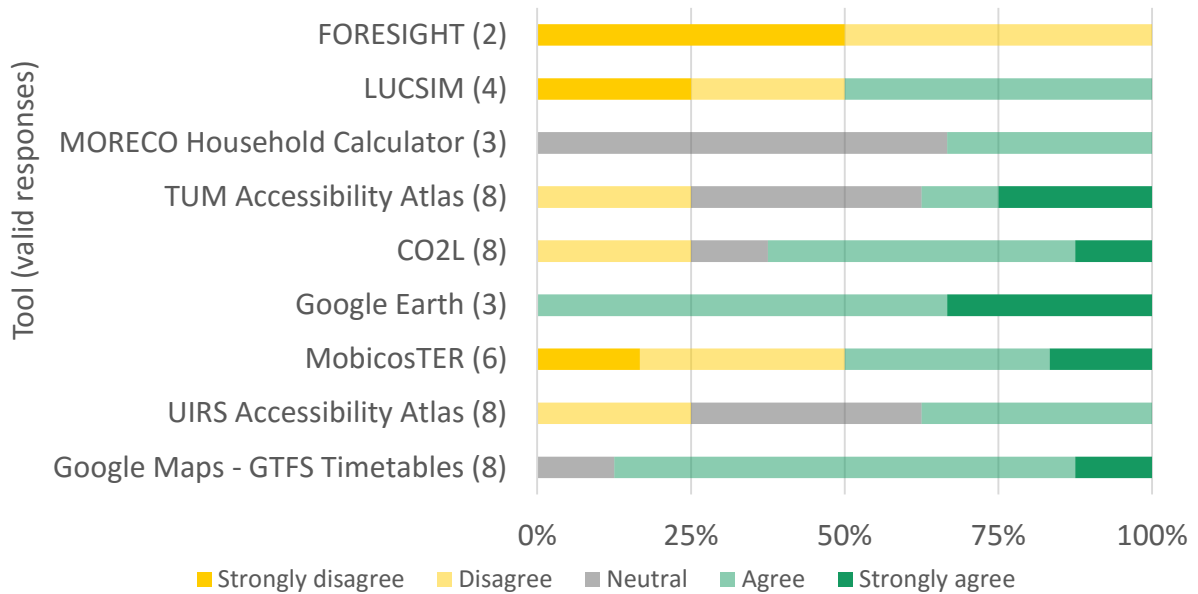
Figure 49. Need to understand the backend of the tool.

The tools have received mainly good ratings regarding the ease of understanding the outputs (see Figure 50). Especially visual, map-based tools perform well in this aspect. For the CO_{2L}, some users indicated that having relative emission results for the purpose of comparison is important and can make the obtained results less abstract.

The tool outputs are understandable and easy to interpret
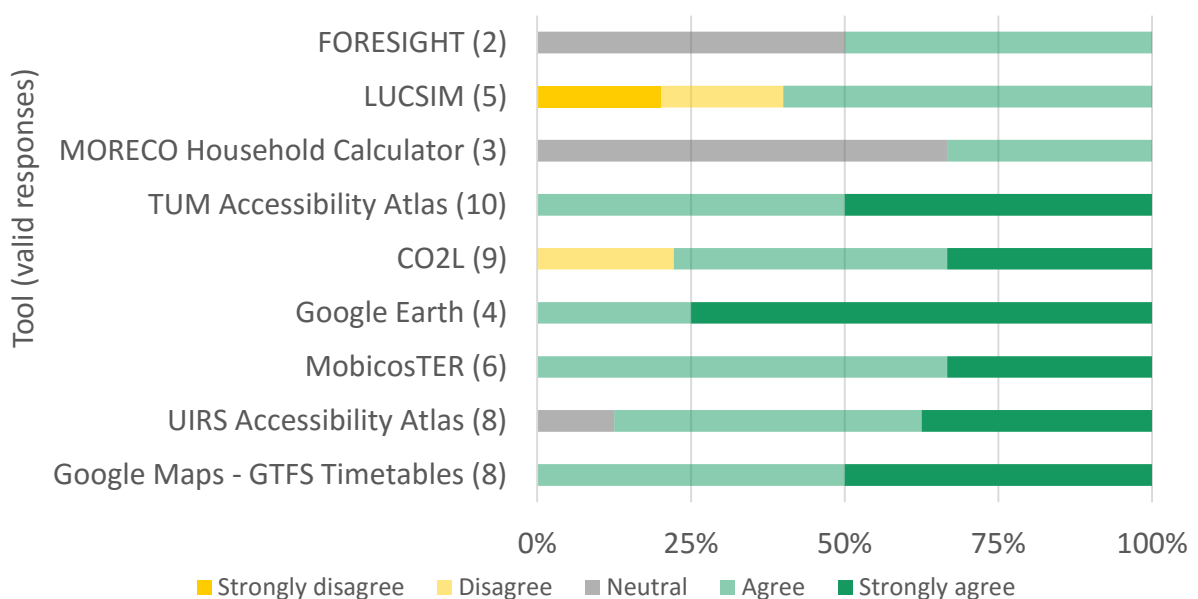
Figure 50. Ease of interpreting the tool outputs.

As shown in Figure 51, the MORECO Household Calculator and Google Earth, being dynamic and interactive tools, performed well in terms of calculation speed.

The tool performs at a sufficient speed for real time adaptations
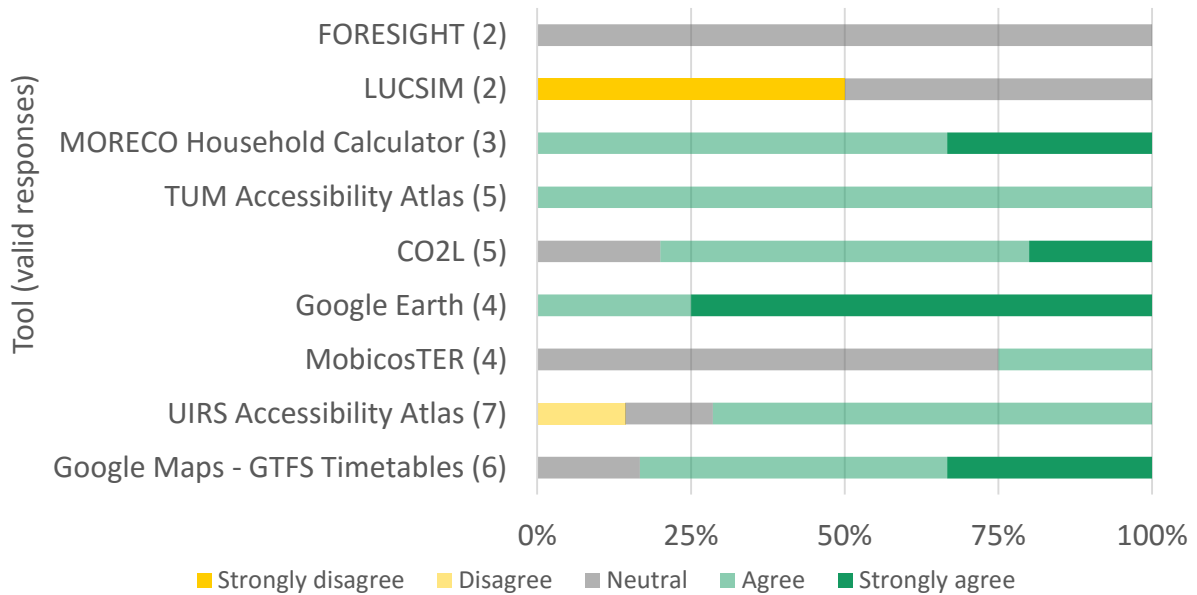
Figure 51. Performance speed of the tool.

4.3. Evaluation results usefulness

In this section the added value for real-world planning issues was evaluated. Factors such as the value of outputs for strategy making, the quality of outputs and the overall previous expectations were taken into account.

Figure 52 shows that all tools have performed fairly well in terms of encouraging discussion and interaction among multi-disciplinary stakeholders. The quantitative outputs of CO_{2L} are rated valuable in this respect. For the UIRS Accessibility Atlas, some users stated that it is a very useful tool and proposed to present it to additional stakeholders, such as municipalities or regional development agencies in order to get additional feedback and improvement ideas.

The tool outputs are valuable in supporting interaction and discussion amongst stakeholders
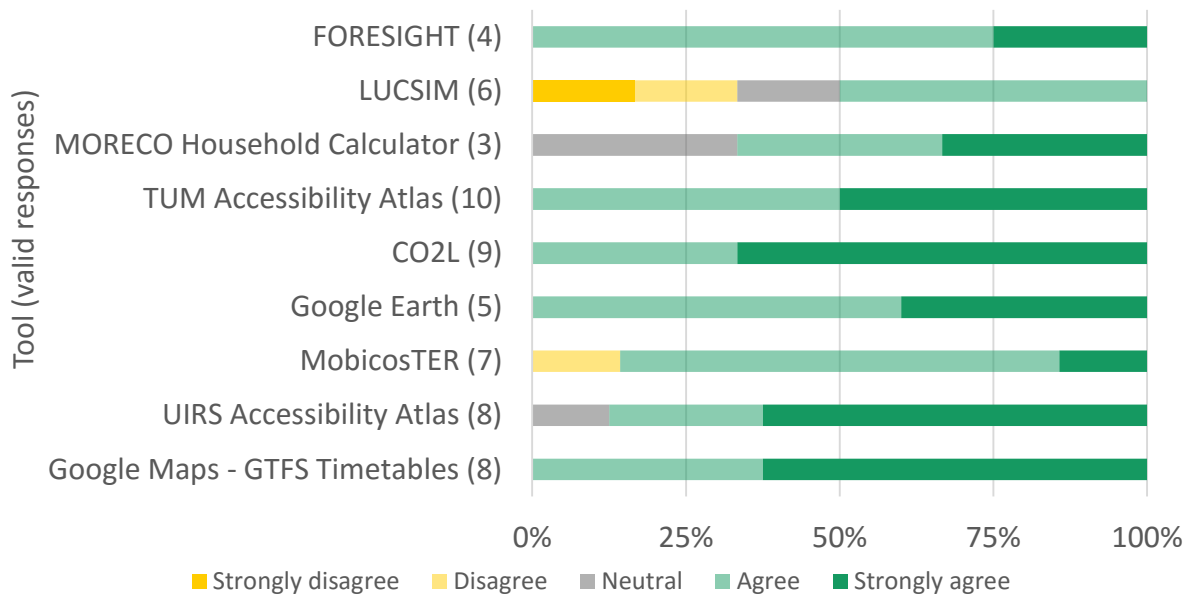
Figure 52. Value of the tool outputs for stakeholder discussions.

Figure 53 shows good results for all tools in terms of their value for strategy making. The strongest agreement for this statement corresponds to the accessibility tools UIRS Accessibility Atlas and TUM Accessibility Atlas. For the TUM Accessibility Atlas, it was implied that the tool could be used for the assessment of alternative locations for new housing construction. As for the UIRS tool, it was expressed that the tool is useful to substantiate or check initiatives for new spatial developments, for the elaboration of sustainable transport strategies, and for planning and management of public transport. Despite some disagreement, users indicated that LUCSIM could be useful for the decision-making process during the preparation of strategic planning documents. Specific use cases include the development and visualization of urbanization scenarios as well as the development of hypotheses. Furthermore, some users pointed out that the CO_{2L} is very useful for making informed decisions, specifically regarding the achievement of CO_2 emission reduction targets. The tool can be used to retrieve important numbers for proposed resolutions, generate CO_2-balances, and create concepts for climate protection. According to the workshop participants, the MORECO Household Calculator could be used as a decision support tool and for comparisons in the context of spatial planning issues. For the MobicosTER, it was communicated that the tool can be used to raise awareness of elected representatives during the development of planning projects or while thinking about the deployment of alternative mobility offers to the individual car. The GTFS tool enables the detection of "grey zones" in the territory, which are not accessible by public transport. Other potential applications include the possibility to use the tool in spatial planning, e.g. when planning new housing areas, or for public transport management and simultaneously as an incentive for the promotion of sustainable mobility.

The tool outputs are valuable in developing strategies
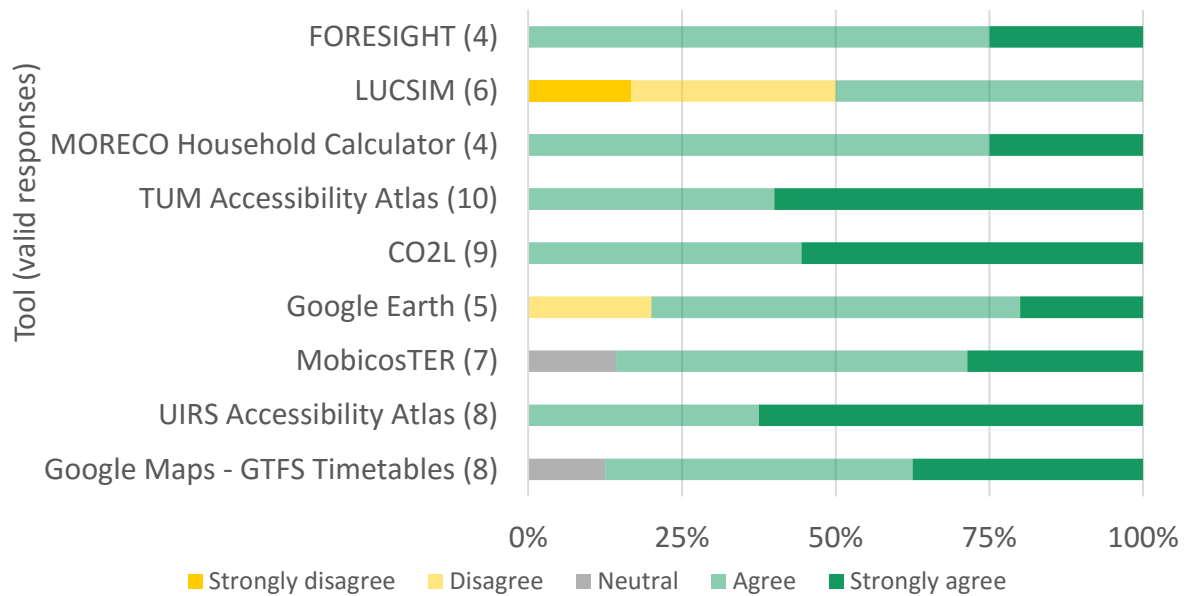
Figure 53. Value of the tool outputs in strategy development.

Figure 54 highlights that both visual and numerical outputs can be used for communication with decision makers. However, large complexity or difficulty of understanding the underlying methodology and assumptions represent a barrier in this area.

The tool outputs can be communicated effectively to non-expert decision makers
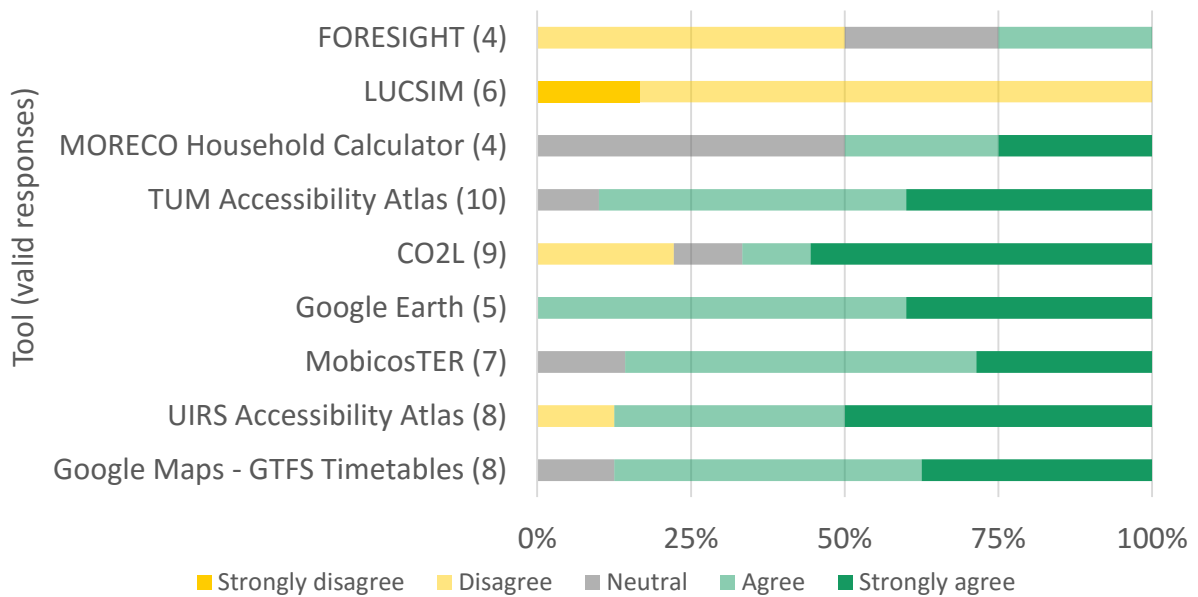
Figure 54. Ease of communication of tool outputs to non-experts.

Figure 55 shows to what extent the users agree that the tools perform on an appropriate spatial scale. Some users indicate that FORESIGHT is only usable at a large scale and on a long period of time and requires a deeper and more precise analysis. Users suggested that FORESIGHT and LUSCIM can be developed further to be used at a smaller spatial level in order to be useful for analysis on a regular basis.

The level of detail (spatial extent) of the tool corresponds to the problem under discussion
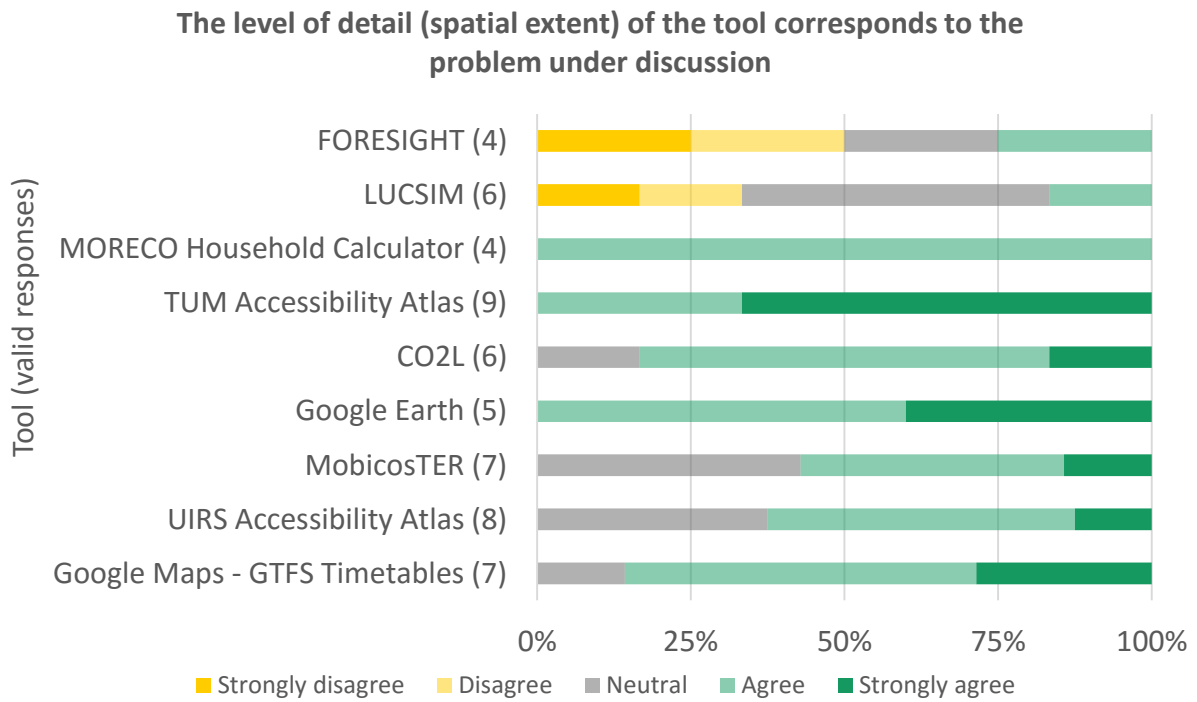
Figure 55. Level of detail (spatial extent).

Regarding the soundness of tool outputs (see Figure 56), TUM Accessibility Atlas and CO_{2L} have received a high rating. Overall, many users were neutral in this respect.

I have confidence in the soundness and quality of the tool outputs
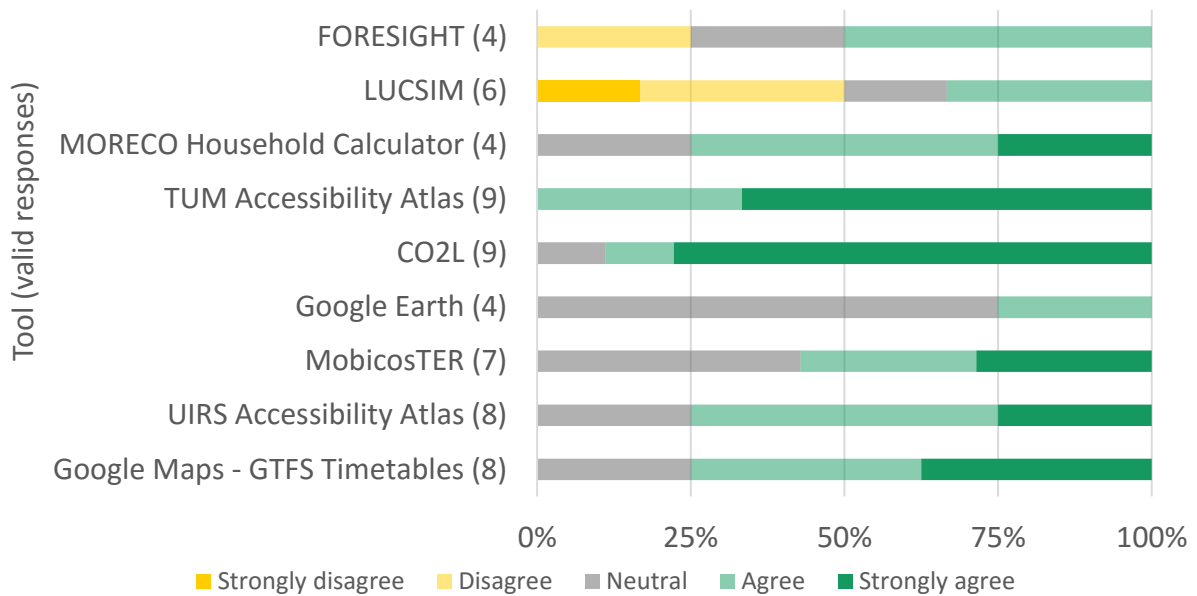
Figure 56. Soundness and quality of tool outputs.

Figure 57 shows that many users were neutral in terms of the fulfilment of their expectations, possibly due to a lack of specific expectations. On the contrary, UIRS Accessibility Atlas and GTFS Timetables met the expectations of most users.

My expectations of the tool before the workshop were met
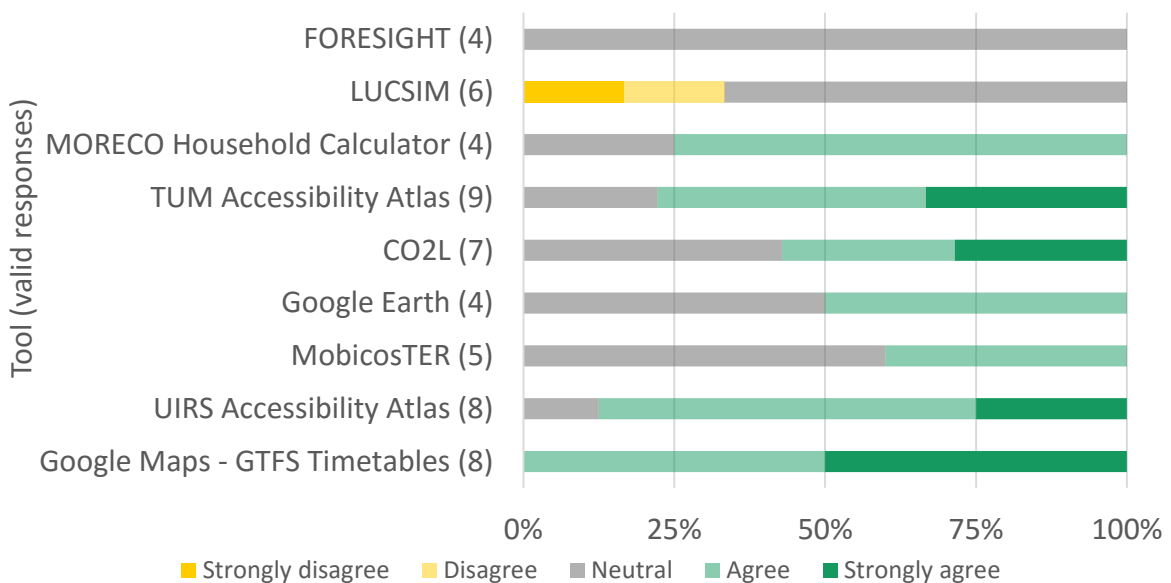
Figure 57. Fulfilment of expectations.

Almost all users agree that the tools can be useful for future planning practice, as seen in Figure 58. Specific recommendations for further improvement were given for some of the tools.

I would like to have access to the tool for future use
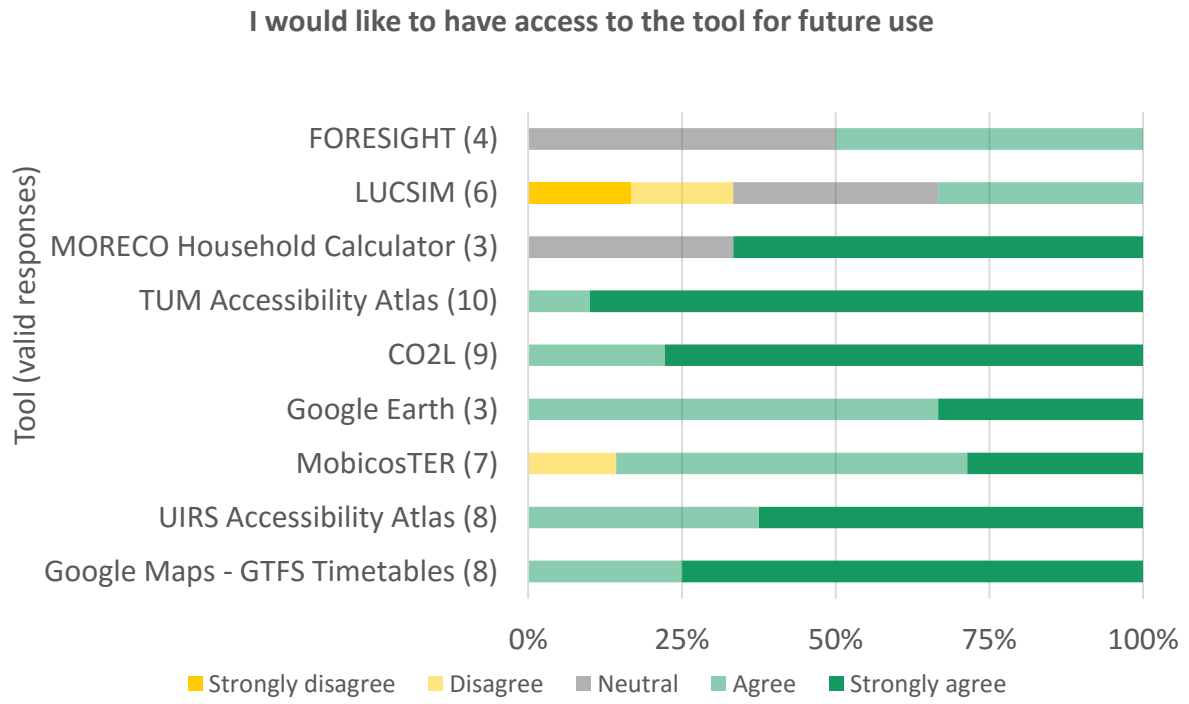
Figure 58. Access to the tool in the future.

5. Final remarks

The CO_2 minimizer toolbox aims to support the identification, but also implementation of low carbon solutions in transport and land use planning. The tools developed within ASTUS vary in scope and intent, thus offering a wide range of potential applications. Overall, the tools have been evaluated positively by the users and are likely to be applied further on within Work Package 3 of ASTUS, but also beyond the end of the project.

Furthermore, similar tools could be developed and applied elsewhere. The ASTUS project output O.T2.1: CO2 minimizer toolbox also aims to inspire stakeholders from other territories, who are willing to reduce transport-related CO_2 emissions.

In order to enable external parties to get a quick overview of all ASTUS tools, fact sheets were produced, providing the most relevant information about each tool at a glance. The fact sheets can be found on the ASTUS website:

https://www.alpine-space.eu/projects/astus/en/project-results/decision-making-tools/co2-minimizer-toolbox

List of Figures

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