Operationalize and Interactively Visualize Sustainable Transport Indicators (STI)

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July 2012

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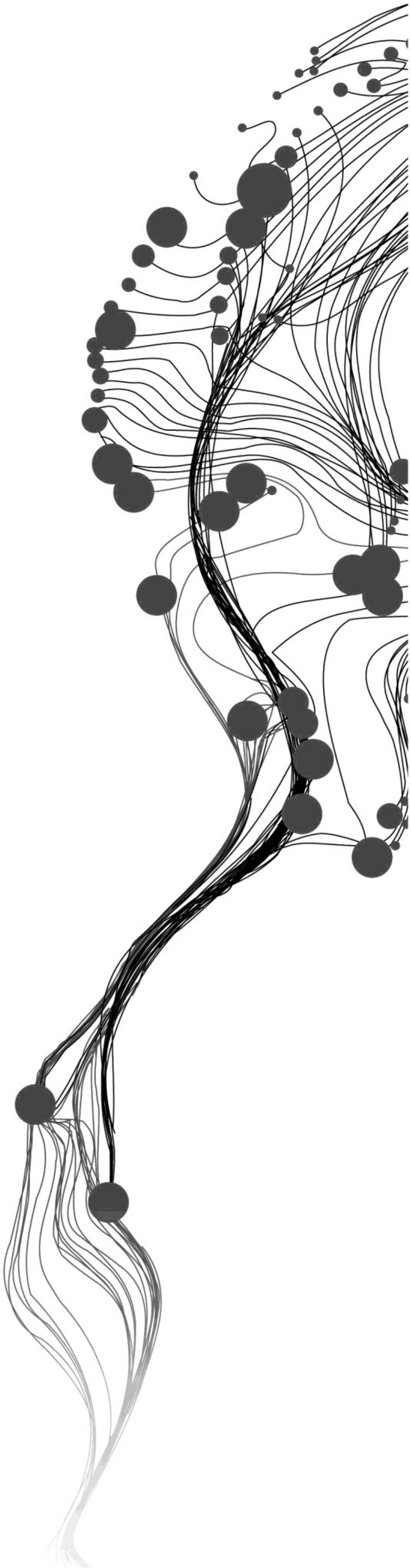

Operationalize and Interactively Visualize Sustainable Transport Indicators (STI)

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Enschede, The Netherlands, July, 2012

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
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Dedicated
To my Dad, Mom
& my dear Sister

ABSTRACT

Visualization techniques and tools are now given considerable attention. The facilities that have been provided by the field of dynamic visualization make it contributes in many areas, particularly with regard to knowledge transfer. At the same time and with the dream of reaching sustainability that has become the goal of all nations. Based upon, this study is exploring the feasibility of using dynamic visualization techniques in displaying sustainable transport indicators.

To achieve this aim, the research is divided into two parts theoretical review and practical implementations. The objective of the first part is to conceptualize frameworks to operationalize and visualize sustainable transport indicators dynamically. The objective of the second part is to implement the proposed conceptual frameworks. The implementation process carried out using database of "the mobility survey in the Netherlands" MON.

The theoretical output of this research is conceptual framework for operationalizing sustainable transport indicator, and another one for visualizing sustainable transport indicator interactively. On the other hand, the physical output is a pilot interactive interface for sustainable transport indicators for Overijssel province in the Netherlands.

Keywords: sustainable transport indicator, dynamic visualization, interactive interface

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Enschede, 2012

Heba Fekry

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1. INTRODUCTION

Discovering the importance of visualization tools in supporting handling complex data led to increasing interests in exploring more about them. Since then, visualization techniques and tools are given considerable attention. (Huang, 2003). In this context the aim of this study is to explore the capabilities of Interactive visualization techniques in visualizing sustainable transport indicators (STI). It is basically reviewing the experiences of the contemporary technology in facilitating the knowledge transfer process. In order to place this experience in a scientific framework, key concepts of the research are discussed and analysed by reviewing publications on this topic. From key publications on "Sustainable Transport Indicators STI" and "Interactive Visualization Technologies" - the main concepts in the study – it can be observed that interests about these topics are in a rapid increase since the last decade(Hegarty (2004) & Pinter, et al. (2005))

As for sustainable transport indicators, many opinions are found about the importance of STI in general and others, specifically about its importance within the transportation planning process. In General, Litman (2009) declares that sustainable transport indicators have become necessary in measuring progress, or evaluating the system performance, to determine its ability to achieve specified sustainability targets. Adding that, it becomes necessary to integrate sustainable transportation concerns among the ordinary activities of transportation agencies.

One the other hand, concerning interactive visualization technologies, Hegarty (2004) discusses the power of visualizations. He witnesses that there are lots of advanced information technologies that has made the production of powerful visualizations of information - like presenting animated diagrams or images as video clips - easier than before. Moreover, dynamics that occur in hypermedia systems and interactive interfaces make browsing the information more smoothly, rather than in the case of searching information in printed sources. Although these kinds of graphics are essential for displaying STI, as well as any other indicators, there isn't any argumentation about the most appropriate methods to visualize STI.

In this chapter justification for the topic choice and the steps through which the research is going to pass to accomplish the research aim. The introduction chapter is composed of five main parts. The first is "Background & Justification", which give insight to the two main concepts of the research; Sustainable Transport Indicators (STI) and Interactive Visualization. It contains definitions and justifications for the significance of both concepts in practical. Second is "Conceptual Model" for more understanding to the relations between the concepts and the mean by which the main research aim is going to be achieved. Third is the "Research Problem, Objectives & Questions", which aims at defining the exact problem that has been drawn from what has been reviewed about the main concepts in this research and formulating the main research objectives and questions that have to be found out, in order to get the research main objective done. The final is the "Research Framework", which describes the sequential phases of the research, to facilitate the follow up.

1.1. Background & Justification

Rising transport emissions contribute to international environmental problems like terrestrial and aquatic ecosystems destruction by different means (e.g. acid rain, global warming). Since one of the basic conditions of sustainable development is that pollution emission rates don't exceed the environmental assimilative capacity, it is obvious that present transport systems need fundamental changes towards sustainability (Greene & Wegener, 1997). Sustainable transport indicators contribute in evaluating the progress of countries and institutions towards sustainability, for making many decisions on different spatial levels, for example; national and regional level (Castillo & Pitfield, 2010). Due to the great attention to achieve sustainable development, the attention in using performance indicators has increased, as they are basically used for monitoring the impacts of specific decision or action. They offer quantified evidence about investments and performance of programs. Moreover, they help to illustrate data and statistics in a comprehensible and concise format (EPA, 2011).

Among numerous interpretations to visualization theories and utilities, Keim, et al. (2006) accept dynamic visualization as an efficient information exploratory means for showing and communication of abstract relevant data using interactive visual interfaces. He defined it as "creation of materials that summarize the results of an analytical effort, presentation as the packaging of those materials in a way that helps the audience understand the analytical results using terms that are meaningful to them, and dissemination as the process of sharing that information with the intended audience". With respect to the practical utility, Dühr (2006) believes that visualizing theoretical perspectives of policy-makers and planners helps better understand of decisions consequences in strategic spatial planning Griffon, et al. (2010) add; it gives virtual vision of the different management choices, that can lead to very similar or to very different futures.

With regard to the means that illustrate data and statistics, graphics have been used since long times in representing information. The determination of illustration means, whether statically or dynamically, is based on type of audience, data relations, and required level of interaction (Maceachren & Kraak, 1997).

Carley (1981) & Archibugi (1998) have declared a number of challenges that have emerged in the field of operationalizing indicators, in general. One challenge is the spatial data. Most of the indicators used in urban and regional development, tend to be geographically based. While, Carley (1981) considers the administrative boundaries as a framework for data, Archibugi (1998) discuss choice of appropriate spatial scale "or administrative boundary for measurement particular phenomenon. Carley (1981) observes that the administrative boundaries that are often used as a framework for data compilation do not always match with the ideal spatial scale of measurement for a particular phenomenon. He notices that indicator values are highly responsive with the definition of the spatial units for which data is prepared, and by changing the definition to the boundary; the outcomes of the analysis probably change. Archibugi (1998) also discussed spatial scales, and he noticed that the choice of appropriate spatial scale of the problem has Influential role on the results of the analysis. For example, some issues are best dealt with at the neighbourhood level "e.g.: environmental improvement", while others are more appropriately measured at city or regional scales. However, choosing scale of measurement is constrained by the availability of existing statistical data.

Even nowadays the availability of many data sources, they still required lots of processing work to convert data into usable format. Although micro-data for numerous subject areas is now available, they tend to be published at different spatial scales. In order to develop indicators, these datasets have to be converted into common spatial framework. Matching between different spatial scales, like postcodes and census geographies is not straightforward process; it's always developed by expert researchers. This means that, this no doubt poses hurdles to users who are not expert in manipulating data (Coombes & Wong, 1994). Taking into account what Zuidgeest, et al. (2005) explain about the significance of identifying sustainable transport indicators through its three fundamental dimensions (spatial scale, social characteristics of the users, and transport mode used, according to its objective. Therefore, there is a need for a conceptual framework contributes in operationalizing sustainable transport indicators.

The second challenge as discussed by Keim, et al. (2006) is about data interpretability and scalability. It is still not easy gaining insight through higher-level view of information out of lots of details. Adding to that, the efficiency of visualization tools to display large data sets in terms of either the number or the dimension of individual data elements is not an easy operation that could be done automatically without proper framework appropriate to a particular phenomenon. It's a process consisting of a series of operations, including data collecting pre-processing, knowledge representation and decision making. Visualization not only means creating a mental image, but also concepts and graphical representation of data, with many and different ways of non-best identification, although some kinds of data can be directly visualized on the geographical maps.

1.2. Conceptual Model

Conclusion of the previous, mapping and dynamic visualization are seen as promising tools to asses and communicate sustainable transport at urban and regional spatial levels. Consequently, a conceptual model (Figure 1-3) is developed to link the different concepts used in the study. Since the ultimate goal is to make the current transport system a sustainable transport system (Figure 1-1), there is need to tool to evaluate the performance of the current transport system toward sustainability (Figure 1-2). In order to utilize scientific theories to have supportive tool, we need theories that contribute to form conceptual frame work to define methodology to operationalize Sustainable Transport Indicators & to define methodology to publish Sustainable Transport Indicators in a dynamic way.

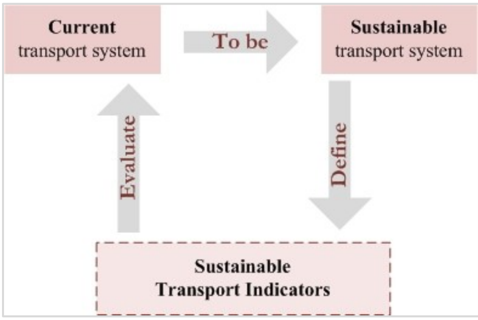


Figure 1-1: Sustainable Transport Indicators

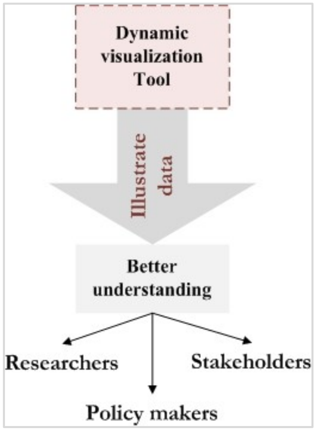


Figure 1-2: Dynamic Visualization Tool

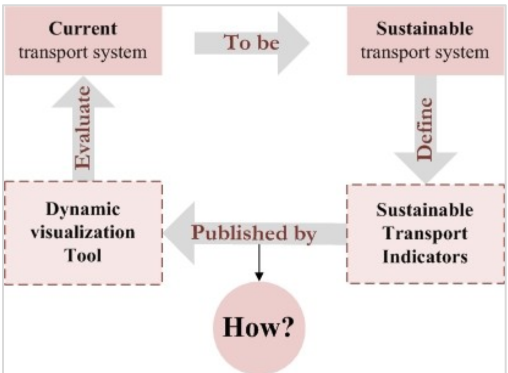


Figure 1-3: Conceptual model

1.3. Research Problem, Objectives & Questions

Concluding from the previous observations, mapping and dynamic visualization are seen as promising tools to asses and communicate sustainable transport at urban and regional spatial levels. In order to be more specific, the aim of this research is to develop a concept and geographical information framework for implementing selected sustainable transport indicators. This framework is used to further operationalize and visualize selected indicators using Overijssel province in The Netherlands as the case study. Dynamic visualizing techniques will be deployed to demonstrate and interpret results from operationalizing selected sustainable transport indicators. To summarise, the research problem mainly addressed by the main question which is: **How to Visualize Sustainable Transport Indicators interactively in an executable and practical approach?**

And so, the two main objectives are:

A. To conceptualize the framework to operationalize and interactively visualize sustainable transport indicators (STI)
B. To Operationalize and interactively visualize Sustainable Transport Indicators

To achieve both objectives a list of questions and sub-objectives are prepared to act as guiding steps during the research.

1. How to conceptualize framework to Operationalize Sustainable Transport Indicators?
   - Define sustainable transport indicators
   - Define conceptual framework to operationalize sustainable transport indicators
2. How to conceptualize a framework to visualize Sustainable Transport Indicators interactively?
   - Define interactive visualization
   - Define conceptual framework to visualize Sustainable Transport Indicators interactively
3. How to Operationalize Sustainable Transport Indicators?
   - Identify methodology to define Sustainable Transport Indicators
   - Identify methodology to formulate Sustainable Transport Indicators
4. How to visualize Sustainable Transport Indicators interactively?
   - Identify methodology to implement Sustainable Transport Indicators
   - Identify methodology to visualize Sustainable Transport Indicators interactively

1.4. Research Framework

The Research framework describes the main tasks, to achieve the main research objectives. Deriving from the field of sustainable development theory, the concept of sustainable transport system is defined via literature review and by finding out the conceptual framework required to operationalize sustainable transport indicators. Concerning Dynamic Visualization tool, the techniques used in the presentation of indicators are explored, to propose the technique by which sustainable transport indicators are visualized. With regard to the possibility to implement the proposed conceptual frameworks, a geo-database is prepared for Overijssel province in the Netherlands as the area of study, while GIS visualization technology is used in the technical implementation part. Noticing that the main purpose is to evaluate the extent to which the principle of sustainability is achieved in the current transport systems.

The research is divided into five main chapters, excluding introduction and conclusion chapters. Second third, fourth and fifth chapters intend to answer the research sub-questions using certain tools (Figure 1-4). The following is description to what is expected to be found in these chapters.

- Chapter two provides a literature review about Sustainable Transport Indicators STI. The sequence of the chapter starts at discussing the concept of sustainable transport and defining its main dimensions and the principles that should be considered when implementing defined indicators. The main output is the conceptual framework for operationalizing STI, which is also the answer of the first research sub-question.
- Chapter three is literature review about interactive visualization techniques. Like chapter two, in this chapter definition for interactive visualization techniques review some examples for interfaces to answering the second research sub-question. And so, the main output is conceptual design of an interactive interface for STI.
- Chapter four is the implementation part in the research. Some of the common indicators which are already used in quantifying performance of transport systems will be selected, to be operationalized according to the developed conceptual framework. The main output is the methodology of working with real data, applying the proposed concepts.
- Chapter five is main outputs of the research. Its presentation and discussion for the results showed by prototype of STI interactive interface.

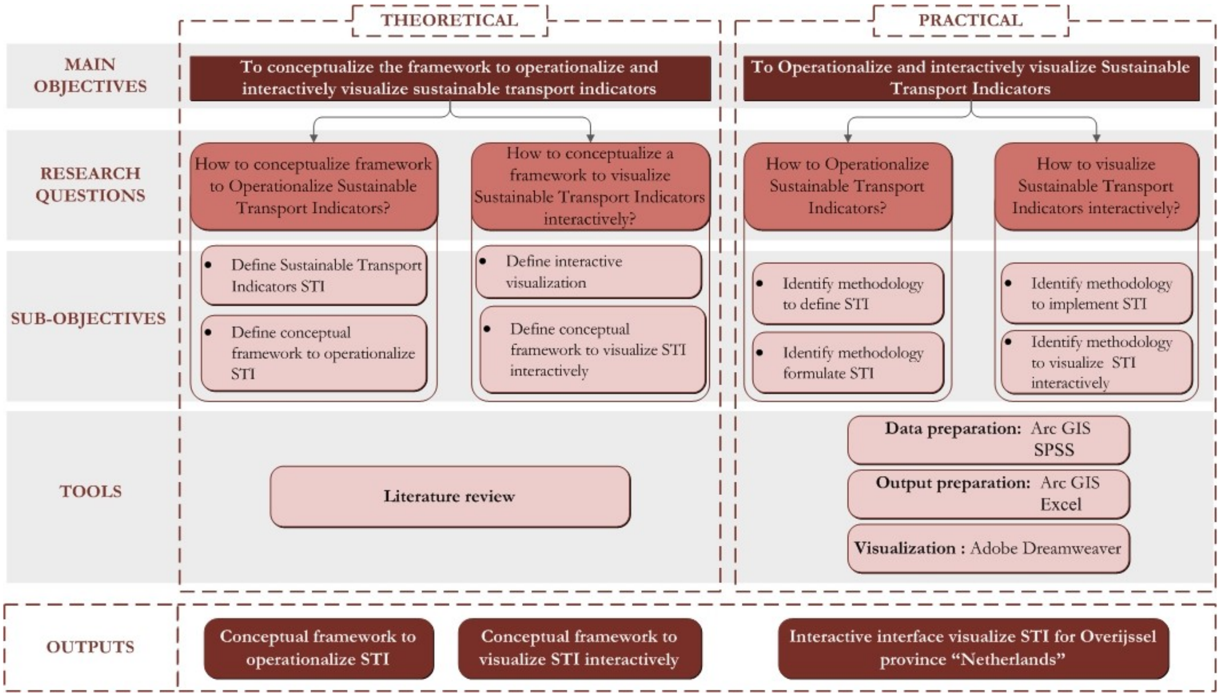


Figure 1-4: Research Framework

2. SUSTAINABLE TRANSPORT & SUSTAINABLE TRANSPORT INDICATORS

Most of this part is literature review about sustainable transport systems, to explain more about the most essential dimensions that have to be considered when operationalizing Sustainable Transport Indicators "STI". The objective of this part is matching between Sustainable Development aspects and sustainable transport system to come up with framework by which STI can be operationalized. In order to understand sustainable transport indicators, sustainable transport system are firstly need to be defined and identified. After that, there would be an opportunity to know more the characteristics of sustainable transport indicators, to be as a base for conceptualizing operational framework for such indicators.

2.1. Sustainable transport

Since the World Conservation Strategy (WCS) first used the term "sustainable development" in 1980 the concept has found global prominence and was considered as a global mission(World bank, 1996). Since that time, several authors have provided definitions for sustainable development in general and sustainable transportation as a part of sustainable development. These definitions are mainly based on the one developed by the World Commission on Environment and Development, which states that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). In other words, it's a way of development that meets the needs of the present, without cutting down the future ability to meet the same needs. The ambition for applying the concept of sustainable development led to an enormous attention to Sustainable transportation, which has had big impacts on economy, social equity, and the environment (Rogers, et al., 2008). Thus, "sustainable transportation" has become a term for expressing sustainable development in the transportation sector. Having sustainable transportation system become one of the major concerns in planning and decision making worldwide (Litman & Burwell, 2006; Rogers, et al., 2008).

Since the principles of sustainable development is the verification of sustainability on three aspects: environmental preservation, economic efficiency, and social equity, then the case should be similar for achieving sustainable transportation systems. What is noticeable about current transportation systems is that they are obviously unsustainable, because of their impacts (Haq, 1997; Hensher, 2008; Zietsman & Rilett, 2002), as they:

- Consume natural (non-renewable) resources without enabling the production of substitutes.
- Disturb ecological system by seizing much fertile land to provide transportation infrastructure.
- Cause environmental pollution by emitting greenhouse gas (GHG) from motorized vehicles, which is a major cause of climate change.
- Cause acoustic pollution, with lots of side effects on public health reducing human intellectual progress.
- Cause traffic unsafety, leading to a lot of accidents and victims every day.
- Create congested roads which become a common transport related problem all over the world, causing high economic losses.

This is in addition to economic and social impacts that can be inferred from the users of each transportation system separately.

Therefore, many researchers and organizations have articulated their different views about specifications of sustainable transportation systems, which also considered as recommendations for achieving sustainability in transportation sector Skutsch, et al. (1994) consider sustainable transportation systems as those systems that achieve environmental, economical and social sustainability, all together. In their opinion, those systems can be achieved by reducing emissions, improving fuel efficiency, and promoting public transport and non-motorized trips. Black (2000) after that comes with his perception about sustainable transportation system, which is the system satisfies the current mobility and transportation needs without compromising the ability of future generations to meet these needs. According to Akinyemi and Zuidgeest (2000), a sustainably developed transport system is one where the transportation system meets people’s needs, in terms of mobility, accessibility and safety within limits of available or affordable environmental, financial and social recourses. For Zuidgeest and van Maarseveen (2000) sustainable transport system maximise the level of essential mobility, cost and safety of people’s travels in an area without exceeding its available resources. And then, Bertolini, et al. (2005) declare their point of view, which describe systems that make people switch from using private cars to other means of transport, such as public transport, green modes, or walking by means of modal shift policies as sustainable transport systems. Another detailed definition is that one by the Centre for Sustainable Transportation (CST, 2005), which defines sustainable transportation systems as those systems that provide the basics needs of safe access for individuals and societies, consistent with human and ecosystem health, and with equity within and between generations. Moreover, they offer affordable, efficient and economically transport modes, while limiting consumption of resources, emissions and waste, production of noise, as well as reuses and recycles its components. As conclusion, what has been deduced from these definitions is that Sustainable Transport Systems are those systems that:

- limit consumption of resources
- limit production of emissions, waste and noise
- Reuse and recycle its components
- Considers human and ecosystem health
- Considers affordability and equity
- Offers efficient and economically transport modes
- Promotes public transport and non-motorized trip
- Satisfies the current and future people’s needs in terms of mobility, accessibility and safety

2.2. Sustainable transport indicators

Describing Indicators as communications tool, Hák, et al. (2007) summarize the significance of indicators and explain what indicators can do, and should do in knowledge transfer. It is also possibly be the reason behind the increasing need for indicators since the early 1990s. However, the real intention to use “sustainable indicators” was in the United Nations Conference on Environment & Development (UNCED, 1992), which intended to involve sustainable indicators in decision making at all levels (e.g.; International, National, regional, etc). Consecutively, emphasis was placed **in** Istanbul during the Second United Nations Conference on Human Settlements (UN Habitat, 1996) further reinforced the necessity of guiding and tracking the progress toward achieving sustainability using sustainable indicators. On the sidelines, sustainability indicators, quality of life indicators, and performance indicators terms, came more to light (Swain & Hollar, 2003). Later on, various definitions and descriptions about indicators have been published, including Wong (2006) definition, which states that indicators are “statistics that provide some sorts of measurements to a particular phenomenon of concern”. He considers indicators as a tool to substantiate and rationalise resource distribution, justify its functionality in assisting policy making. Within the context of sustainable transport, an important challenge facing the objective of achieving sustainable transport systems is evaluating the system’s situation. Therefore, indicators are an important tool for making decisions and measuring progress (Litman, 2009). They contribute to evaluating the performance of transportation systems at different geographical levels (eg: regional or city level). And can be used for comparing between different locations, for detecting where more intervention towards a more sustainable transport system are needed (Castillo & Pitfield, 2010). So, they should concern the impacts of transport systems on the different aspects of sustainable development concept, which aims achieving social, economical, environmental sustainability (Zuidgeest, et al., 2005).

To identify transportation problems, some researchers tried to determine the harmful effects of transport regard the three aspects. Focusing on the environmental aspect, Hansen-Turton, et al. (2007) refer to climate change as a top priority challenging sustainable development. The Greenhouse Gasses (GHG) emitted from human activities have the most direct destructive impact on it, and the major contributor to these emissions is the transport sector by its motorized vehicles(Hensher, 2008). Looking at the economical aspect, the affordability of the transport modes to the population is central. For example, cars cannot be considered as an affordable transport mode for all users, as it's expensive and a lot of people can't afford it. Regarding social aspect, thousands of deaths and serious injuries result from transport accidents because of unsafety of the transport system (Greene & Wegener, 1997). Furthermore, some economical aspects lead to social impacts. For example, social exclusion of some cultural or economical groups due to the lack of access to affordable transport alternatives is a social impact of economical aspect. The three dimensions of sustainable development are interrelated and must be simultaneously addressed when addressing sustainable transportation systems (Ramani, et al., 2009).

Considering the three aspects; the centre for sustainable transportation (CST 2005) has declared fundamental achievements of transport systems. To achieve economic sustainable development, transport system should provide affordable transportation services and coordinated actions across all modes of transport. For social sustainable development, the system should meet highest possible safety and security, and provide efficient and comfort transport modes for people and goods. While the environmental sustainable development the system have to limiting consumption of the environmental resources, producing less emissions, waste and noise. Finally, to achieve sustainable transport Bertolini, et al. (2005) give four main recommendations on how to promote sustainable transport:

- Advanced land-use policy measures: Encourage legislations for distance reduction, which promote use of green transport modes.
- Reduction of travel needs: Reinforce internet for non-travel activities like online shopping, jobs, or study.
- Innovative alternative fuel: Explore more efficient alternatives for the current fuel using in the motorized vehicles.
- Advanced transport policy measures: reduction of using motorized modes by promoting Public transport and non-motorized modes.

Unfortunately, most of those recommendations are either not applicable worldwide or don't concern all sustainability aspects except transport policy. Meurs and Haaijer (2001) conclude that advanced land-use policy measures could be a long term alternative for future generations, not for the current ones. Moreover, for developing countries its potential is yet marginal as many have no access to fast broadband internet. About innovative alternative fuel, it may save the environment, but it still wouldn't be efficient in solving congestion problems. Concerning transport policy measures, they should target all aspects of sustainable transport to be useful. Environmental aspect is targeted by reducing GHG emissions through reducing the number of vehicles used for making trips. The economical aspect is realized by means of providing affordable transport mode alternatives. While, accessibility provided by the transport system to all population groups is achieving the social aspect. Thus, there is need to qualify and quantify the above mentioned aspects of sustainable transport and guide the development of sustainable transport policy measures in certain areas. And this is precisely the reason for using sustainable transport indicators. If we look at any transportation system we can find that, the two basic components are the transport mode and the user. To translate these aspects to quantitative dimensions, the following interpretations can be made:

- Environmental aspect = transport mode used
- Social aspect & Economic aspect = socio-demographic characteristics of the users of the transportation system
- Geographical scale = Geographical zone that the indicator is expressing at, or the sustainability level of the transportation system at that scale level.

2.3. Conceptual framework to operationalize sustainable transport indicators

Before describing the conceptual framework, first the reference units for the STI should be defined. The meaning of the Reference units here as described by Litman (2011) is the measurement units that would be used to measure the indicator impact. Therefore it is always per mile, per trip, per vehicle, per dollar or per capita. It means that it shouldn't be always the same, because the choice for the reference units affects how the problem is defined, and thus, how it can be solved.

The goal which is now the main for all the governments is to implement policies aims reducing greenhouse gas emissions. This goal wouldn't be realized unless firms and households behave in a more environmentally manner (Horne, et al., 2005). To be realistic, it is still fundamental to understand the preferences of households about transportation system, to provide a more attractive service to them (Bergman, et al., 2011). So, to understand preferences of users among transportation modes, the measurement is based on the number of users for the transport modes, and not the distance covered by the mode.

With regard to the conceptual framework, sustainable transport indicators - as mentioned before - can be operationalized in three dimensional levels (social-demographic dimension, transport modes dimension and spatial dimension). To operationalize accessibility for different age categories, for example, is conceptually demonstrated in **Error! Reference source not found.**, Figure 2-1 & Figure 2-2 show conceptually, the combinations between elements of two dimensions of sustainable transport indicators. Socio-demographic scale and transport mode represented by X & Y axis, each of them consists of certain elements (**Error! Reference source not found.**). Figure 2-2 illustrates these combinations in three dimensional levels. Combination such as (X1, Y1, Z1) represents (Users of age from 18 to 30 using public transport / spatial level 1). Going in Z direction represents different spatial scales (spatial level 1, spatial level 2, and spatial level 3). While, going in Y direction represents different transport mode (public transport, cycling, walking). Using dynamic visualization techniques will be possible for a user to zoom interactively through these three dimensions to study levels of transport sustainability in the case study area Overijssel. For example, dynamic moving in (A) axis direction (Figure 2-2) presents users of age from 18 to 30 using public transport in various spatial scales (spatial level 1, spatial level 2, and spatial level 3). While moving in (B) axis direction (Figure 2-1, Figure 2-2) present users of age from 18 to 30 in pc4 using different transport modes (public transport, cycling, walking).

At the end, reminding that the main objectives of this chapter are to define sustainable transport indicators and the conceptual framework to operationalize sustainable transport indicators, to answer the first research question which is: How to conceptualize framework to Operationalize Sustainable Transport Indicators? Concerning the define of sustainable transport indicators, there are various opinions on the definition, but what is common is that they are tools for measuring and evaluating the performance of transportation systems, toward achieving social, economical, environmental sustainability. Consequently, the conceptual framework to operationalize sustainable transport indicators is composed of three dimensions; each of them reflects one of the sustainability aspects. They are, transport modes, socio-demographic characteristics of the users and Geographical dimension. It's the turn now to form appropriate framework to interactively visualize STI.

X axis represents age categories "socio-demographic scale"	Y axis represents Transport mode "Sustainable modes of interest"	Z axis represents spatial scale
X 1 = age from 18 to 30 **X 2** = age from 30 to 50 **X 3** = age > 50	**Y 1** = Public transport **Y 2** = Cycling **Y 3** = Walking	**Z 1** = spatial level 1 **Z 2** = spatial level 2 **Z 3** = spatial level 3

Table 2-1: Examples for the elements of three dimensions

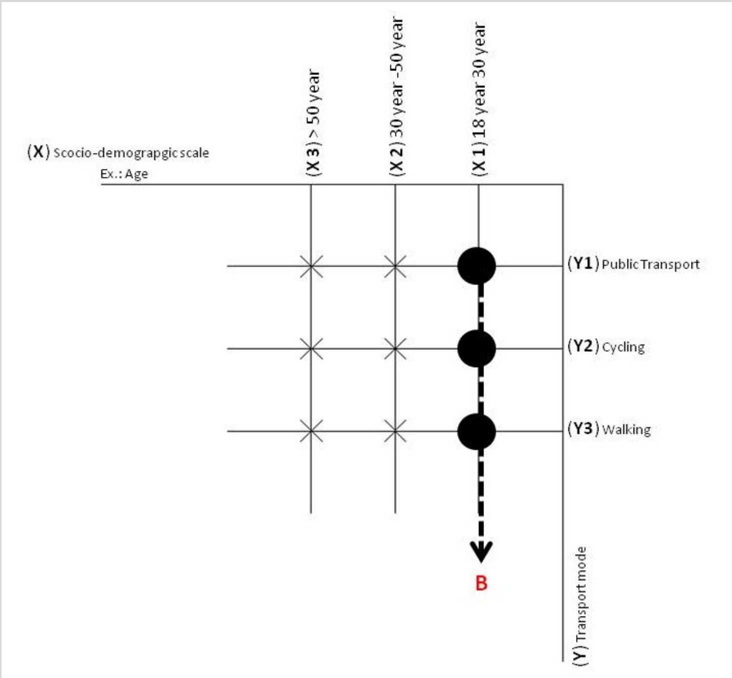


Figure 2-1: Combination between elements of two dimensions

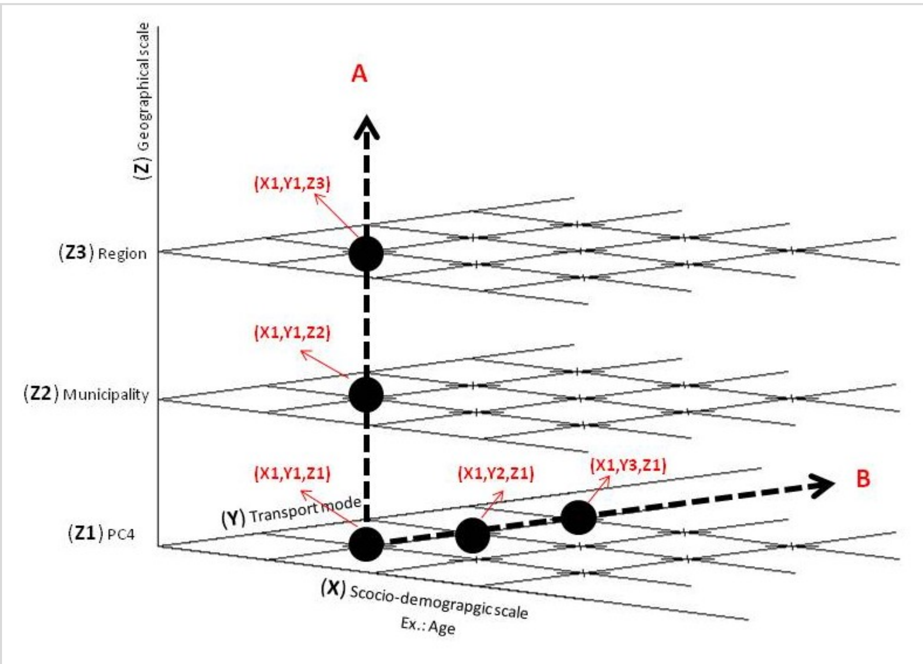


Figure 2-2: Combination between elements of three dimensions

3. DYNAMIC VISUALIZATION & INTERACTIVE VISUALIZATION OF SUSTAINABLE TRANSPORT INDICATORS

This chapter is also literature review, but this time about the other concept of the research which is the interactive visualization techniques. Similar to the previous chapter, it starts with discussing the concept of dynamic visualization, the interactive visualization techniques and exploring some of the already existing interactive interfaces that deal with indicators. Then, propose conceptual framework to visualize Sustainable Transport Indicators interactively.

3.1. Dynamic visualization

Visualization of spatial data is evidently linked to maps, which are the ultimate tools to give insight in spatial relations. Maps are the result of translation or conversion process of spatial data from databases, to be maps or map-like products such as those linked to multimedia, virtual reality or animation (Kraak, 2007). Thematic maps are well-known examples of static visualizations beyond geographic maps that show the spatial pattern of a theme such as climate characteristics, population density, etc. Furthermore, the use of modern visualization technology proposes many new possibilities for geographical visualization tasks, help to explore, understand, and communicate spatial phenomena (Nöllenburg, 2007).

Geovisualization term is short for geographic visualization science. It was explained according to the 2001 research agenda of the International Cartographic Association (ICA) Commission on Visualization and Virtual Environments as a process to "integrates approaches from visualization in scientific computing (ViSC), cartography, image analysis, information visualization, exploratory data analysis (EDA), and geographic information systems (GIS) to provide theory, methods and tools for visual exploration, analysis, synthesis, and presentation of geospatial data" (MacEachren & Kraak, 2001).

Other definitions take a more human-centred approach and describe geovisualization as "the creation and use of visual representations to facilitate thinking, understanding, and knowledge construction about geospatial data" (Longley, et al., 2005), or as "the use of visual geospatial displays to explore data and through that exploration to generate hypotheses, develop problem solutions and construct knowledge" (Kraak, 2003). It is clear that geovisualization process is a multidisciplinary task. Taking into account the human who uses visualizations to explore data and construct knowledge (Nöllenburg, 2007).

In case the amount of spatial data to be presented becomes huge, a creative approach is needed in design the map to keep it readable. Thus, most GIS users are searching processes and requirements for better understanding and presentation. It's still difficult to deal with series of maps especially if presented individually on-screen. Therefore an interactive dynamic visualization considered to be a solution to the complex requirements of the cartographic display (Kraak, 2007).

Dynamic visualization has a great impact on the viewer, adding to capabilities in dealing with different kinds of data, such as terrain surfaces or urban environments. As well as, thematic data like, data on climate or population density. Dynamic visualization not only tell a story or explain a process, but also have the capability to expose spatial relationships and trends which would not be clear when looking at the individual maps only.

The demand for dynamic maps arises largely from the need to deal with temporal factor in any analysis, which can't be obtained from static maps. In a comparative context, Static paper maps have limited capabilities in visualizing models of for instance planning operations. They can be used to identify and compare patterns in a spatial context only, and support us determining what patterns exist, where they exist, how they exist, and identify how they are compared to other spatial patterns. However, Dynamic visualization does offer opportunities to work with moving symbols and design options. Dynamic representation can illustrate changes in space (position), in place (attribute), or in time, deepens our understanding and exploration of the data (Castronovo, et al., 2009; Kraak, 2007).

Dynamic maps allow viewers to track multiple locations of phenomenon occurrence simultaneously, and provide users with a visual analytic capability that allows more careful consideration of the nuances within the data. It is important to recognize that the major strength of dynamic geo-visualization approach is being an exploratory tool to catalyze the scientific process by propagating potential research questions and future directions (Castronovo, et al., 2009).

Before propose dynamic visualization techniques it's important to identify who are the users of these indicators. This is in order to avoid failure of the indicator, or being un-useful. Mainly, there are three groups of indicators' users with different requirements can be identified. The first group are "Non-specialists" such as media and decision makers. This group needs very simple and well structured information. The second group are local governors, policy implementers and checkers, NGO's, research funding bodies and industry. These groups of users require intermediate level of details and simplifications. The last group are policy makers and academics, who need the technical level of information. It's useful before implementing and processing indicators to identify which of these groups is the user, to conceder their needs (Hák, et al., 2007).

Users of indicators	Requirements from indicators
Voters	Helping them identifying actions that they can take, and actions that government should take. To be applicable and relevant at an individual or local level and conceptually clear. To be few in numbers, simple, and with no technical or methodological information
Media	Clear set of information, that they can build up their stories Simple, with clear message and assessments, which enable journalists making statements "stabilizing, worsening, or improving"
Decision makers	Simple information that provides overview, with some analysis which highlights areas where action should be taken Targets are important
Local governors	To be able to disaggregate the information, in order to target policy appropriately To be applicable and relevant in different geographical scales
Policy implementers and checkers	To get wide range of indicators that are clearly defined and stable in terms of methods and data requirements and can be used to monitor progress over time Guidelines and clearly formulated targets, objectives, and policy effectiveness indicators
NGO's	Information for use in campaigns to raise public awareness and lobby politicians Wide range of indicators with some analysis, including access to technical documentation, guideline, and possibly data, to be made available on the web

Industry	To provide engagement incentives, an appropriate language (eg.: eco-efficiency, cost effectiveness, etc.) Can anticipate future trends, for investments needs and costs
Policy makers, developers, and designers	Comprehensive set of many indicators to inform specific areas of policy To focus on the interlinkage between the separate pillars Provide links to outlooks and scenarios and to costs when designing policies Linked to existing indicators or data
Academics	Very specific data, as input to studies, models. And in evaluating and developing methods Detailed assessments, analyses, and reasoning behind the analysis
Research funding bodies	Set of indicators as a basis on which to evaluate whether to select further projects proposal for funding Information on data availability, the conceptual basis of indicators, methodology, feasibility, and reliability

Table 3-1: Users of indicators (Hák, et al., 2007)

Considering policy makers and academics as target users for this research mean that the required dynamic visualization technique is the interactive interface.

When designing dynamic visualization environment, four main aspects should be considered; interface, maps, legend, and linkage with the database (Kraak, 2007). Keeping in mind that dynamic visualization is being used to provide a better insight to understand particular geographic phenomena.

Interface: According to user type, the interface should be designed. Researchers, decision makers, and other within such fields require tools that allow for interaction while viewing the animation. Watching it play would not answer many of their questions. They need tools that can directly go to a certain map, to make it more exploratory environment than just presenter to spatial data(Dykes, et al., 2005).

Maps: Maps in the dynamic process are not different from any other maps, and will cover only part of a screen, leaving free space for other info to be demonstrated (DiBiase, et al., 1992).

Legend: Dynamic display aiming at explaining the meaning of the map by symbols. However, the legend always has a dual function. Besides the ordinary role for explanation, it can also be a tool for navigation. For example, in the temporal dynamics it helps travelling through time. The combination of legend considered being an interpretation device, which allows the user to answer more interesting questions then those would be answered by just looking at the frames passing by (Kraak, et al., 1997).

Linkage with the database: The link between the database and the interface of the dynamic environment depends on the visualization strategy (presentation or exploration). For presentation purposes, maps are already pre-prepared and they are just being showed by requesting them. While for exploratory environment, querying the database should produce the dynamics (Kraak, 2007).

3.2. Interactive Visualization

Nowadays, geovisualization's communication aspects are shifting towards higher levels of interaction (Nöllenburg, 2007). Different authors have seen "Interactive geovisualization" in different ways. While Dykes, et al. (2005) describe “interaction” as the key defining characteristic of visualization, (MacEachren, 2001) see “interaction” as a key factor distinguishing geovisualization from traditional cartography, and define it as “an active process in which an individual engages in sorting, highlighting, filtering, and otherwise transforming data in a search for patterns and relationships”.

Buja, et al. (1996) introduced the characteristics for general interactive geovisualization He highlight the two main important characteristics of "interactive visualization techniques" which are "focusing individual views" and "linking multiple views".

- Focusing individual views

Focusing means any interactive modification that help selecting what to see in a single display and how it is seen. That is to say there is need to more control to, for example, allow users zooming in or out of the map to increase or decrease the level of detail about the underlying geographic features (rivers, cities, lakes, etc.). Also the display of spatial features such as rivers, mountains, roads, etc. can be switched on or off; depending on the user's requirements, as they may cause noise in a map if they are all in (Andrienko & Andrienko, 1999).

Modification of the colour scheme is another important aspect. Assigning colours or colour ranges to classes is a simple way of interaction with maps. Statistic values like mean and median are normally used as reference value, as the value range of an attribute in *classed* maps is divided into a set of intervals and a distinct colour is assigned to each one. In case of dealing with huge amount of value and to avoid poor colour resolution, map the full scale of colours to a sub-range of values (eg.; one colour with its ranges for each sub-range, and the extreme values with different colours) (Andrienko & Andrienko, 1999). Generally, giving users the opportunity to change some properties (eg.; selecting, zooming, etc.) allows them to see the same data from numerous perspectives.

- Linking multiple views

The key potential of interactive visualization technique is linking multiple views of the same data simultaneously. This process is usually combined with "*brushing" process*, (eg.; selecting particular objects on the screen by pointing on them). Since different views should be linked in a geovisualization system, it should be available for users to select spatial object on the map and analyze their behaviour using the remaining views.

The potential of interacting with multiple linked views are numerous, and the number, type, arrangement of the views, depending on the specific geo-visualization task which is required by the user, and the available space on the screen. The interactive principles introduced in this section all concern a key aspect of avoiding seeing-wrong or not-seeing errors which are unlikely to be visible.

Dynamic mapping which is the depiction of changes, in temporal and non-temporal animations. The temporal animation displays time in a temporal sequence, while the non-temporal animation explains spatial relations by presenting separate maps in a sequence that is not related to time, but offers a changing representation of a phenomenon (Kraak & Klomp, 1995). Kraak (2007) explains three main dynamics or animation type of geospatial data according to time series, successive build-up, and changing representations. Dynamic time series is dynamic change of spatial pattern according to timing issue, which can be seconds, weeks, or years. Weather broadcast is good example of this type. It displays changing of temperatures during week or a day. Dynamic successive built-up often represent complex processes by showing subsequent map layers that explain the logic of the structure. Throughout this type of animation, several attributes are displayed, while time is fixed. As an example, presenting structure of a city starts with topographic layer, followed by infrastructure, land use, etc. Dynamic change representation offers the viewer a general view at a particular phenomenon. With this type, graphic or classification perspective is represented, while attribute and time are fixed. For example, representation of only population density attribute at particular time, for various geographical scales (city, province, country, etc).

3.3. Interactive Interfaces "Examples"

The interactive interface is tool which has been used widely in showing indicators in many websites. It has been applied to show various indicators and linked them with different spatial zones in global scale, and in local scale as well. By reviewing the existed interactive interfaces, it has been observed that they are differing in their techniques and means of showing the indicators. The main purpose of reviewing such interfaces is specifying the basic components which are normally exist in an interactive interface showing indicators. Interactive interfaces in WorldBank (2012), CBS (2012)an d NRC (2012) websites are going to be discussed and analysed. They are used as guidance to observe their basic components and the way by which the users are dealing with them to extract required information, assuming that they are made for decision makers and researchers based on their requirements. As well the difficulties which I observed - as researcher users – in getting information are listed. The common components to be discussed are mainly:

- Selecting menu
- Map
- Output

3.3.1. World Bank

The World Bank website is in itself an interactive interface, where some changes in results are happened according to the different selections. Figure 3-1 is an interactive interface dealing with indicators, and contain:

- Selecting menu

The process of interacting with this interface starts with the "selecting menu" (Figure 3-1, 1), which contains list of indicators existing in the website. As there are a lot of indicators, they are divided into groups or themes so as to make searching for indicator easier for the user. "Feature indicators" is the place where list of themes appear and the user select the closest one to what he want. Accordingly another list appears contain all the indicators under this theme.

Another mean for searching is "searching window" where the user can write in it the exact required indicator to be shown. This option is helpful for only those who have previous knowledge about the existing indicators, not for new users. Regardless the mean in use, the information about the selected indicator is shown on map and some other outputs (Figure 3-1, 2)

- Map

It is one of the methods for presenting indicators. It shows whole countries of the world in different colours classifying countries into classes according to their score of indicator (Figure 3-1, 2). In addition bar for the years, to specify the year which the user want to view data for. Legend and zoom are tools to facilitate using, reading and understanding the map. Moreover, some other buttons used to change the represent by which the indicator is shown as it could be shown either in colours or by circles.

- Outputs

They are the other methods for presenting indicators, and they are different in their format (Figure 3-1, 3).

- Text: is a short explanation of the indicator, what does it mean, measure, etc.
- Table: it contains exact indicator score for each country.
- Graph: contains group of diagrams comparing the score of indicator of each country (s) with another country (s).
- DataBank: where the user can create queries to generate tables, charts and maps out of groups of time series data for different topics.
- Download: used for saving required data, maps, tables, etc.
- Share: to spread /send among people who may be interesting in it.

Figure 3-1: WorldBank interface

3.3.2. CBS

CBS (2012) is Statistics Netherlands website which is responsible for collecting, processing data and publish statistics for policymakers and scientific research. According to the interactive interfaces that appears when the user choose a certain indicator (Figure 3-2), the three elements which we mentioned before are observed again.

- Selecting menu

Its list is similar to the one in WorldBank, but the CBS indicator list contains a smaller number of indicators. This list shows the European Union countries only. It's also divides the indicators into groups/themes. From these themes the required indicator can be chosen. And then, the information about the chosen indicator appears in "maps" and "outputs" sections.

- Map

A map of the European Union appears coloured (as it is mentioned before about WorldBank map, 3.3.1). In addition, a year bar is shown. The difference between this map and the previous one is that there is a bar through which the user can control the way the classes are classified (eg. manually, equal intervals, etc.). This option helps the user to reach more accurate information.

- Output

Concerning the additional information it differs from that in WorldBank. Figure 3-2 shows a diagram of indicator scores for the whole European Union countries, at the same time, the country is coloured by the same colour in the map. In the graph, the countries are arranged according to the score of indicator in an ascending order, to facilitate comparing a certain country with all the other countries. Moreover, there are some explanations about the indicator. The options that are found in this interface are:

  - Pdf tab for users to save information
  - Full Screen to give the user more clear vision (Figure 3-3). Contrary to WorldBank, the map in the CBS interactive interface is an interactive map.

The interactive map does not only show some information, but it is also a way of reaching an additional information. When the user click a certain country, the map disappears and a graph appears instead to show a comparison between score of indicator of the years and score of indicator average (Figure 3-4).

3.3.3. NRC

NRC "Nieuwe Rotterdamsche Courant" is a newspaper which is published in the Netherlands daily, and it contains "Interactive map". NRC is totally different from both WorldBank and CBS. Here the user doesn't go here or there to select the indicator and see the outputs. Everything is displayed always in one window (Figure 3-6), while in WorldBank and CBS the user need to go through some steps in the website before reaching information of the indicator.

- Selecting menu

In the selecting menu the user can find all the indicators, this is because they are very few compared with the two previous interfaces. The selecting menu is composed of tabs for five indicators and a time bar for selecting the required year. Consequently the information appear on the map and also in the reserved area for the graphs (Figure 3-6, 3).

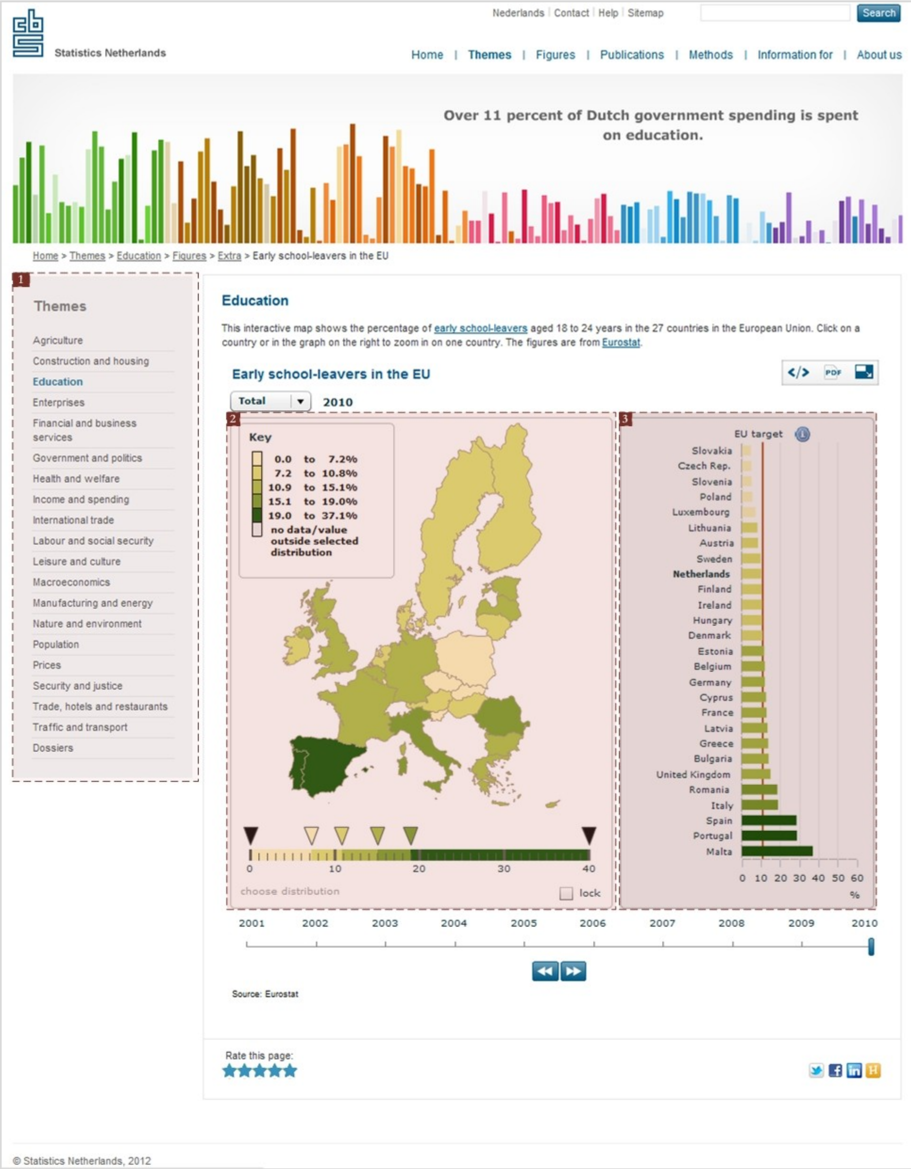


Figure 3-2: CBS interface

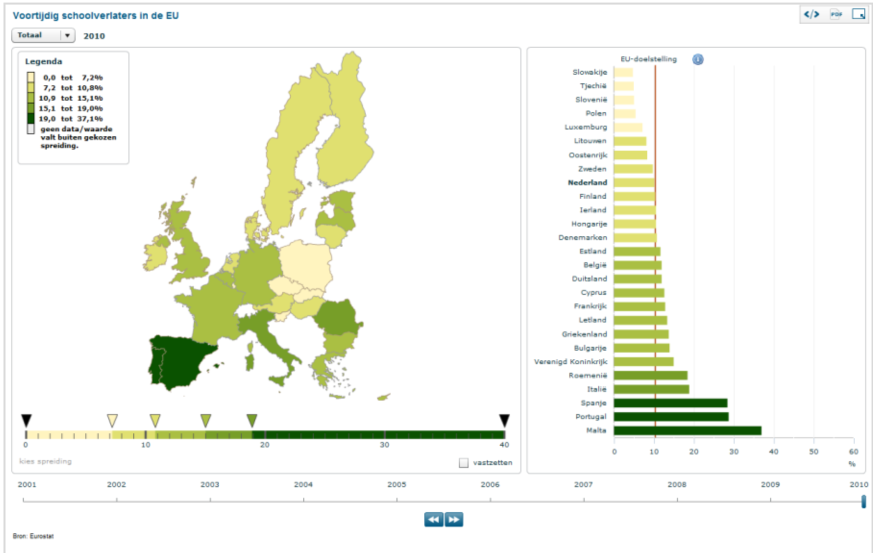


Figure 3-3: CBS fullscreen interface

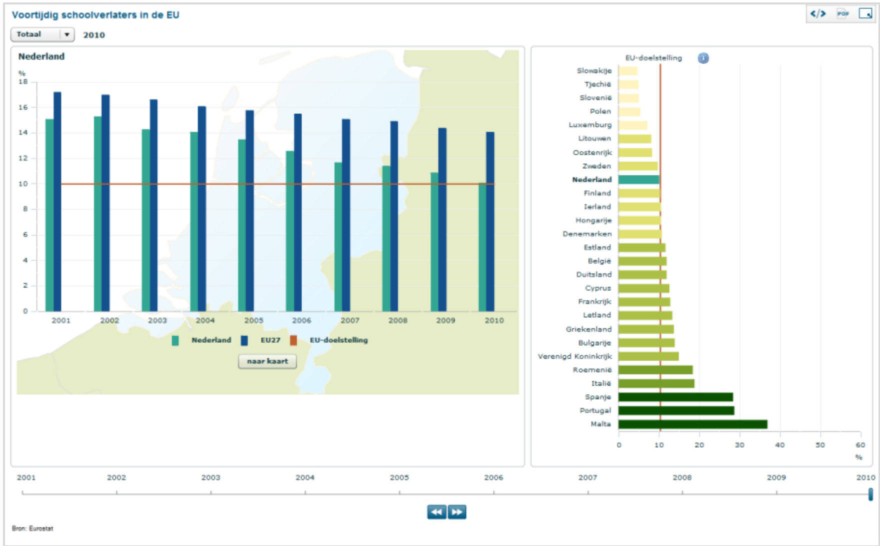


Figure 3-4: CBS graphs

- Map

Interactive map plays the same role similar to that of CBS, as it is a way of showing the information about all the countries on this map. Also the user can use it to choose the country which he/she needs more information about. This information both to be chosen from selecting menu or from the map itself, and then list of graphs shown in the output area

- Outputs

It appears in the same interface as in (Figure 3-5, 3), at the same time selecting menu and map also appears to the user. In this case the user select an indicator, a diagram appears showing the same score of indicator for each country.

This section was very required and useful to observe how the interactive interfaces are look like, and how they display indicators. Moreover how the user (for instance researcher like me) can reach required indicator, and also to observe the difficulties that may face the user. According to what has been discussed, the conceptual ST interactive interface is formed.

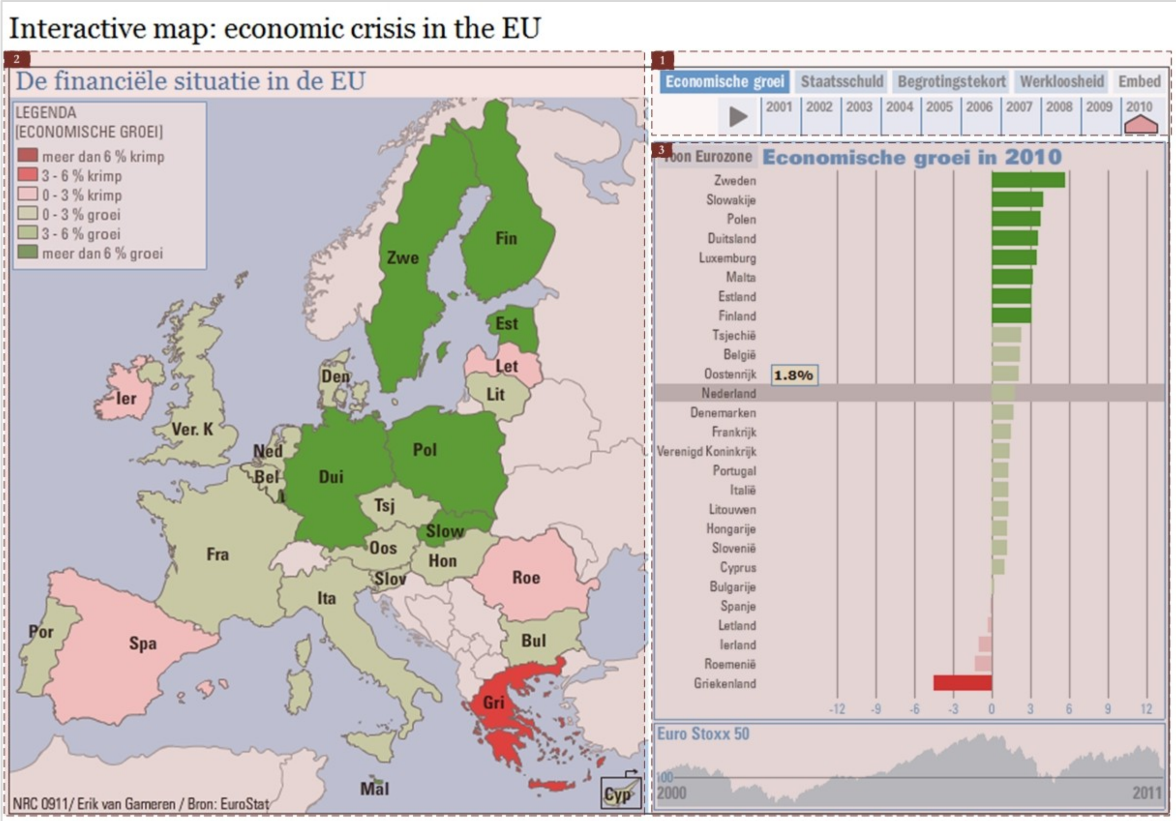


Figure 3-6: NRC, interactive map. Comparisons

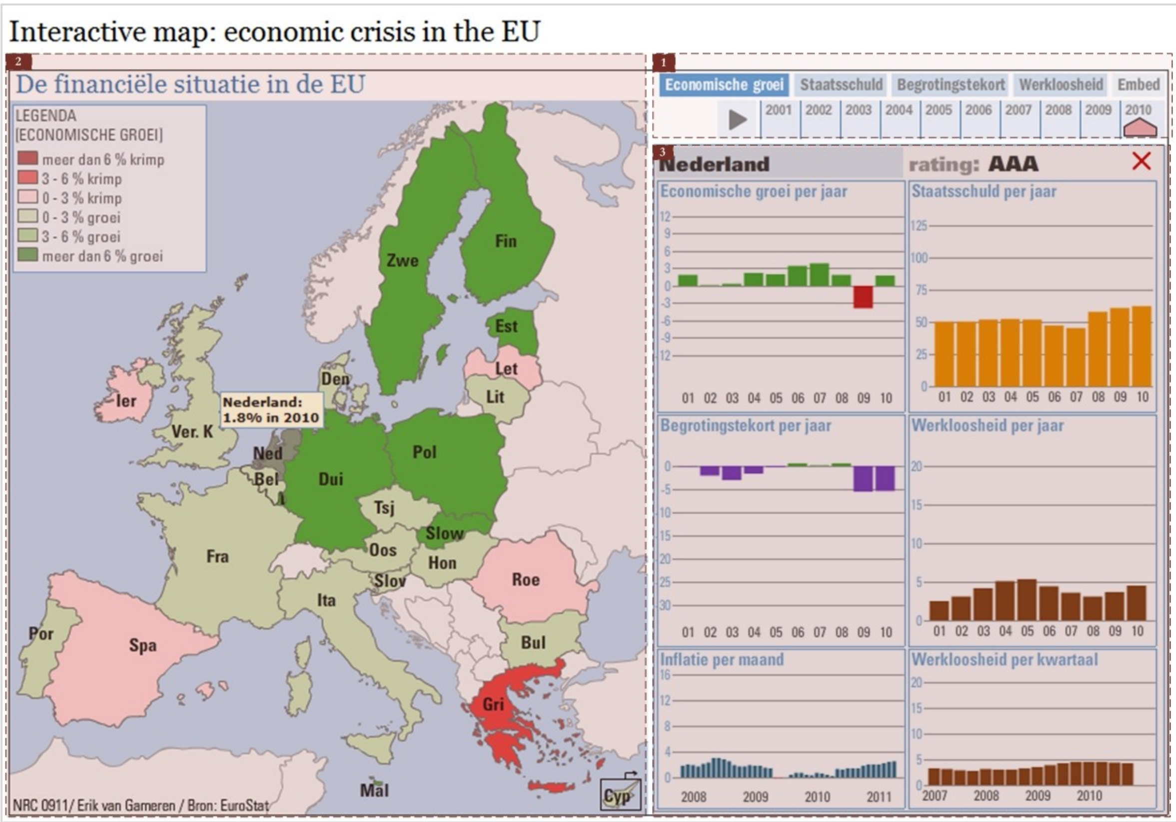


Figure 3-5: NRS, interactive map. Graphs

3.4. Conceptual framework to visualize Sustainable Transport Indicators interactively

Through what has been reviewed about the principles of dynamic visualization environment, it has been recognized that there are some tools used widely to facilitate the presentation of information, which are supposed to be identified by indicators. The same tools are adapted to fit the special character of STI. In the following, a general description for the main tools of the interface and the relations linked between them. On the other hand, detailed description of the component of the interface to get a clear image of each component separately, in order to be guide for the implementer for STI interactive interface.

Selection menu, maps, and outputs are three basic elements required to be present in STI interactive interface (Figure 3-8). It's mentioned previously several times in this report that the STI is formed through three dimensions. In this sense, selection menu is kind of a list from which the elements that composed an indicator are selected. The left side of the conceptual interactive interface (Figure 3-8, 1) explains the selection process of STI elements. It shows the sequences of selections that help guiding the user in forming an indicator. The selections sequence starts with spatial dimension, then transport mode dimension, socio-demographic dimension, and finally the year of the indicator. These selections lead to production of map and outputs.

The map, which is described in the middle part of the conceptual interactive interface (Figure 3-8, 2), is mainly for illustrate the selected indicator. Although the indicator is prepared for each spatial zone separately, the role of the map remains to present the result of the indicator for all zones in the same spatial level in a simple and abstract way. In other words, spatial zones could be classified to number of classes (e.g. three or four classes reflecting the higher, medium, and lower scores) according to the indicator score. These classes are presented in different colours, texture or symbols, just to give an overview about scores. The map is not only for displaying indicators, but also it is a tool to access more detailed information about certain zone. In addition to what the map provided about indicators, it can also be used in presenting other spatial information in order to give more significant information. For example overlaying different layers such as transportation infrastructure, services, and bus lines with indicator score could give more insight about real reasons of the transportation system performance.

The outputs represented in the right part of the conceptual interactive interface (Figure 3-8, 3) composed of different kinds of information and representation means, such as text, tables with numbers, graphs. Each of them is displayed under certain domain, to make it easier for the user and to avoid messing up. The main four domains are description, data accuracy, comparisons and graphs.

- Description is definition for the composite indicator, data used, how it is measured, etc. More over detailed information such as names of zones under selected spatial level are shown, linked with the score and the class of the composite indicator for each zone.
- Data accuracy is presentation of the sample size of users, through which the indicator is calculated.
- Comparisons domain is presentation of comparisons between different spatial zones according to their indicator score.
- Graph domain is displaying information for certain spatial zone that can be selected from the map.

This was a general overview about the conceptual interactive interface of STI. The following is more detailed description of the component of the interface.

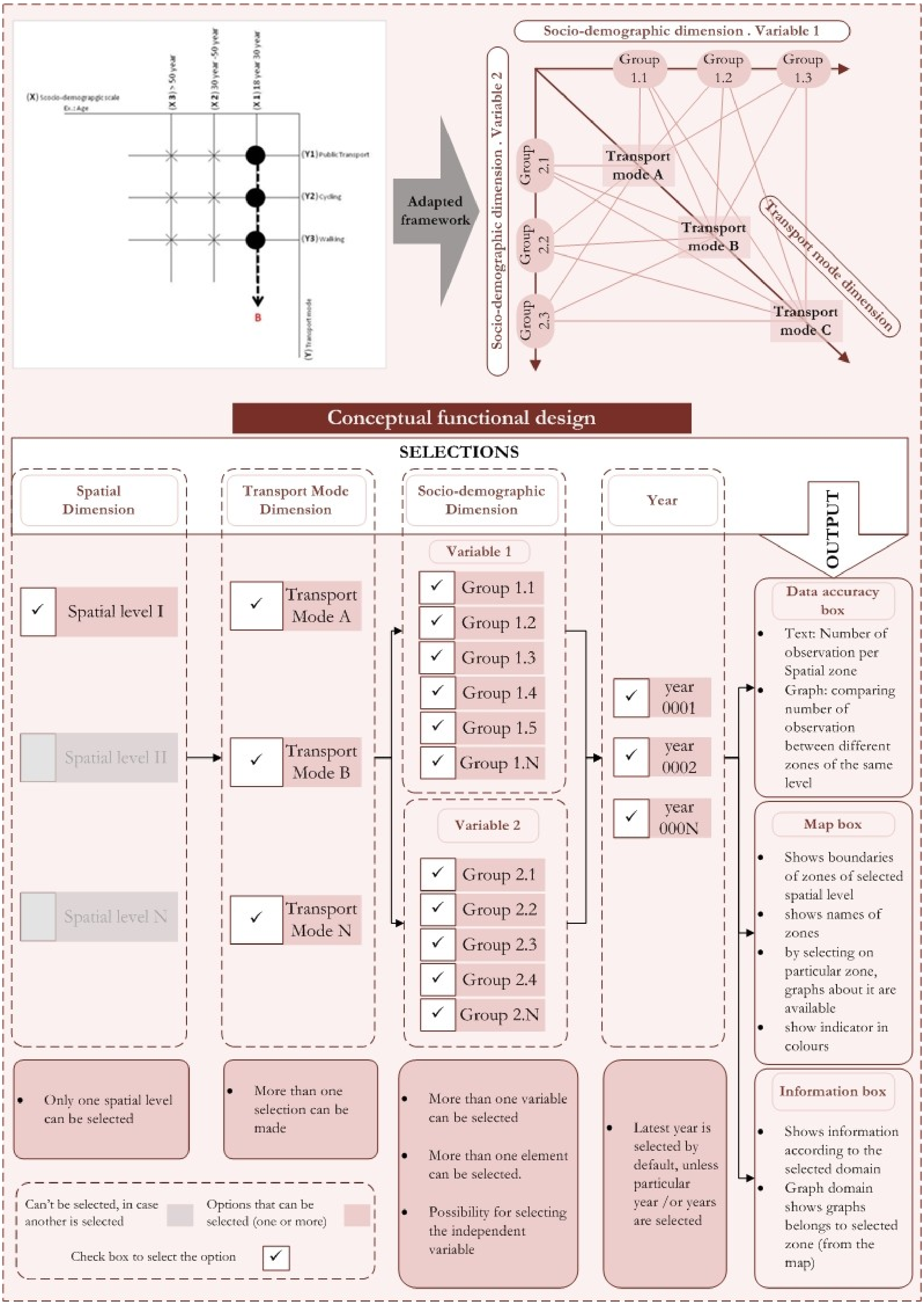


Figure 3-7: Adapted framework

- Selection menu

Selection menu as mentioned before is the way to form the indicator in an interactive interface. It is the implementation of the STI operationalization framework (Figure 3-7). It is used to make the selection process of the STI elements in a rational sequence. This sequence starts with determining the spatial dimension, and it's only one level that can be selected. This is because the results of the indicator for different levels have different results (e.g.: adding, subtracting and dividing the results gives insignificant figures), which may cause a technical error. This condition is not applied for the other two dimensions, as the elements of them depend on the number of users, which can be combined.

The second step is to determine the transport mode, which is to be queried. Here you can select more than one transport mode by combining the users of the two/or more transport modes and calculate their percentage of the users of all available transport modes. For instance, if the available means of transport are walking, cycling, and public transportation. Possible to combine users of cycling and walking, then calculate their percentage of the total users of cycling, walking and public transportation all together. The formula would be:

(Users cycling + Users walking) / (Users cycling + Users walking +Users of public transport) x 100

The third step is to determine the socio-demographic dimension. The different with this dimension is the multiplicity of its variables, and consequently, the multiplicity of their elements. For instance, if, gender, age and economic level are considered to be the variables of this dimension, and their elements are as follows:

- Gender: Male / Female
- Age: < 25 years old / 25 to 40 years old / 41 to 60 years old / > 60 years old
- Economic level: < 10000 per year / 10000 to 20000 per year / 21000 to 30000 per year / > 30000 per year

The simple case is to determine for instance the extent to which the population belonging to certain group of age (e.g. from 25 to 40 years old) choose particular transport mode for mobility (e.g. bikes). The formula would be:

Users of age between 25 to 40 years old cycling / Users of age between 25 to 40 years old (cycling + walking +Use public transport) x 100

The more complicated case, is to determine for instance the extent to which men belonging to certain group of age (e.g. from 25 to 40 years old) choose particular transport mode for mobility (e.g. bikes). Notice that in this case two socio-demographic variables are considered, the formula would be:

Men of age between 25 to 40 years old cycling / Men of age between 25 to 40 years old (cycling + walking +Use public transport) x 100

The final step in this sequence is selecting the year of the data required to calculate the indicator. Similar to transport mode and socio-demographic dimensions, selecting more than one year is applicable, resulting to an indicator output reflects period of time.

Such steps are not more than clicking some buttons in the interface, and all the calculations and outputs are either are pre-prepared for all the possible combinations or are processed instantaneously. Based on these choices, ranges of information are composed and are displayed, either in a simple and brief within map section, or in detailed in the output section.

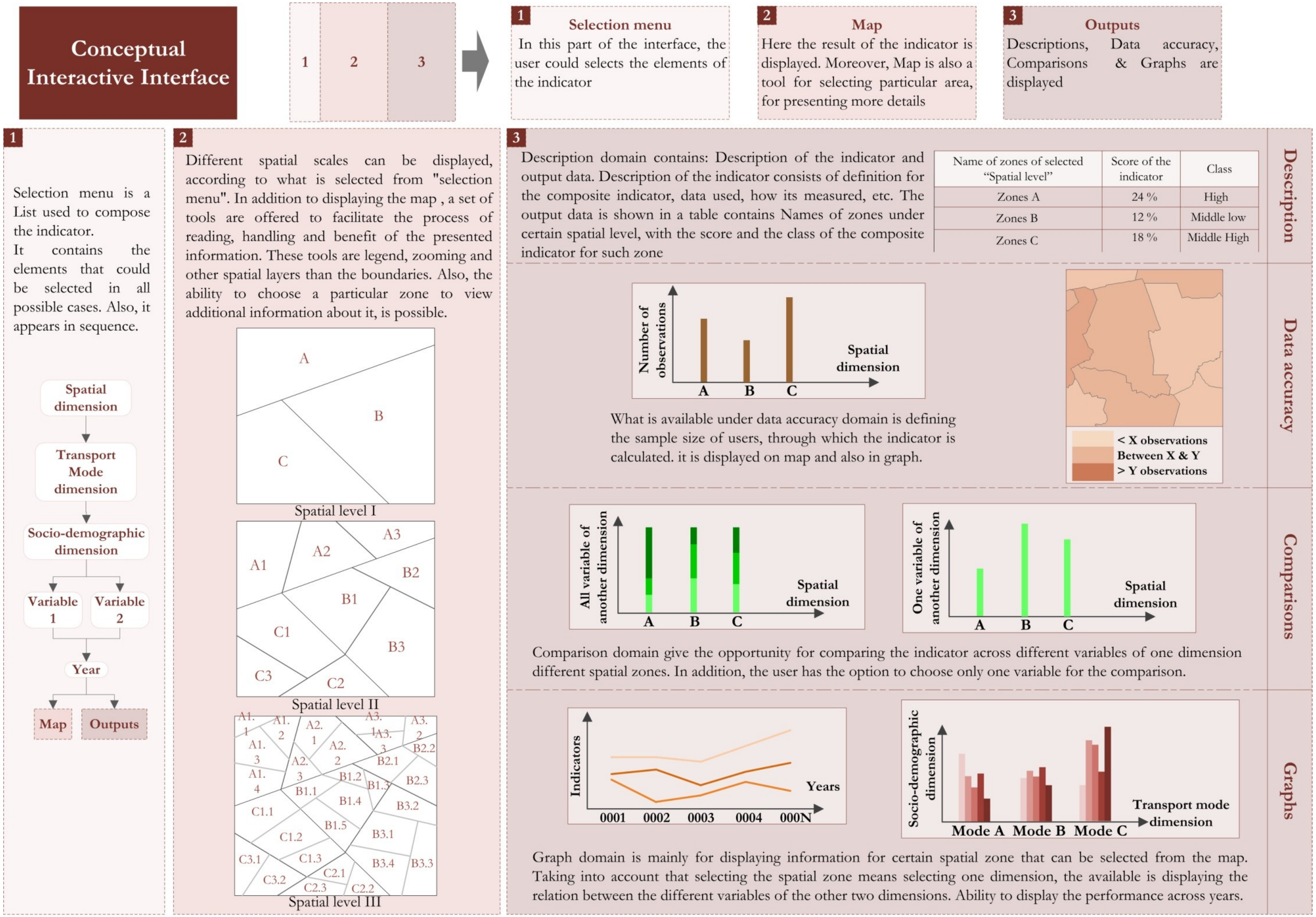


Figure 3-8: Conceptual interactive interface

- Map

After completion of the selection of the elements of the indicator, a set of percentages are available. Each of them reflects the performance of each spatial zone separately. These percentages can be divided into groups (Highest, average, lowest), to be easier for the user to recognize the level of a particular zone compared to the rest of zones. This can be done by a map, represents these groups in colours. As usual, some tools are offered with the map like legend, scale, north arrow, etc. In terms of interacting, it is expected from the map to be a means to gain access to detailed information about certain areas.

The presence of other types of information that can be displayed on the same map (e.g.: public transport lines, locations of services, etc.) can make the map something like decision support tool. And to interpret the reasons that make some areas score lower percentages than other, it may be useful for the user to overlap other information about infrastructure, distribution of services, etc. For instance, if the displayed indicator is the percentage of green modes usage by people of age group between 12 and 17 years old to educational destinations, the lower percentage of usage might be due to the inequality of distribution of high schools, or because the roads infrastructure are not as same as those in areas characterized by higher percentage of usage. These assumptions can be confirmed, if the user was able to combine between the results of the indicator and what can affect them, using a map. This requires the availability of other spatial information, which is expected to be beneficial to the user.

- Output

Output section is the other format of the useful information about the indicator. Because of the existence of different types of these formats (e.g.: text, tables, graphs), they have been distributed among four domains:

    - Description

Where definition information about the indicator that is likely to be the subject of research from the user is displayed.

Definition: A general definition of the indicator, state the objective of the indicator calculation. For instance, it can be “The extent to which the population of age between 25 & 40 years old take "the green modes" as chosen transport mode”

Explanation: it’s an explanation of the elements of the indicator. Using the above example, the elements of the indicator will become:

Spatial dimension: Municipality

Transport dimension: Green modes “represents cycling and walking together”

Socio-demographic dimension: age group between 25 & 40 years old

Year: for the time between 2005 & 2009

Measure: This is more explanation of what the indicator is measuring. For the same example, the explanation is: “The percentage of population of age between 25 & 40 years old using green modes, out of all users of the same age group”

Users of age between 25 to 40 years old using green modes / Users of age between 25 to 40 years old using (cycling + walking +Use public transport) x 100

Output data: scores of the indicator for each zone are displayed separately. It’s the name of each zone, with the score of the indicator, and the class by which zone is classified as.

- Data accuracy

The purpose of the data accuracy is to display the information about the sample size that used in the indicator calculation. For instance, in the case of account the percentage of users of age between 25 & 40 years old using green modes, the displayed sample size would be number of observations (or interviews) for age group between 25 & 40 years old. The significance of data accuracy is making the user aware of what is behind this indicator, and to be free in considering the final percentages as a reflection of reality or not. Certainly, if the data on the number of population is available, then it will be better to display the proportions of the sample size to the total population for each zone, as they are more expressive than the abstract figures.

In any case, these numbers / percentages can be presented by graphs showing the name of each region and its sample size. Can also be shown on the map showing zones divided into classes depending on the sample size (the same way as described in Map section).

- Comparisons

Here the user can find a set of graphs that compare zones with each other according to the indicator score. The comparison may be between one element from two variables, or between more than one element of one variable to one element of the other variable. For instance, the comparison can be between different zones to one transport mode or to all transport modes.

- Graphs

Since it is possible to display detailed information about particular zone if it has been selected from the map those information become visible under graphs domain. In this case, the relationship between transport mode dimension and socio-demographic dimension can be displayed. Moreover, displaying changes of the indicator across different years is possible. Meaning that, graphs that consider spatial dimension can be visible under comparison domain, while graphs that consider the two other dimensions are visible under graph domain.

At last, this chapter achieves the two objectives of the second research question which is How to conceptualize a framework to visualize Sustainable Transport Indicators interactively? About the definition of interactive visualization, simply it's the environment where the user can interact with its elements. Its four main aspects are; Interface, Maps, legend and it should be linked to database. As for the conceptual framework to visualize Sustainable Transport Indicators interactively, an interactive interface commonly consists of three main components displays information about indicator(s). These components are; Selecting menu, Map and Outputs.

4. IMPLEMENTATING PROTOTYPE OF INTERACTIVE INTERFACE OF "STI" FOR OVERIJSSEL PROVINCE

The operationalization process is going to be executed through two phases. The beginning is the theoretical phase where exploration of the case study and available data take place. Then, the practical phase starts by searching the doable STI that are already used anywhere, and chose examples that can be implemented the available data. The output of this phase is definition for elements of sustainable transport indicators to be visualized.

Selection of appropriate performance indicators is a very important task and should be based on the type of analysis (planning, operational, or strategic), level of analysis (project, network, or regional), and the specific purpose for which the measure should be used (system performance, project selection, or impact assessment).When selecting and implementing sustainable transport indicators, the Transportation Research Board (TRB) in their annual report (Litman, 2009) recommends the following requirements:

1. **Understandable and useful**: The indicators should demonstrate the impacts of transportation activities as clear as possible for any groups involved in whatever analysis phase. In other words, phrasing indicators in understandable mean is an essential matter in selecting indicators to achieve its purpose. Not only clarity is necessary, but also usefulness is even more required. At the end, we develop indicators for others, so we should first identify the user to prepare proper output for them.
2. **Data feasible to collect**: The indicators may rely on available data or special required data. Anyway, data needed for operationalizing indicators should be feasible to collect, of adequate quality, and standardized (in case collected by different institutes). Moreover, it should be as much as possible comparable and measurable toward sustainable objective.
3. **Comprehensive and balanced**: Selected set of indicators for evaluating sustainable transport should include the major aspects of sustainable transport issues, economical, social, and environmental issues. At the same time, we should avoid duplication. Many indicators point to similar issue, as many indicators reflect impacts of more than one category. For example, mode can be an indicator for accessibility, affordability, emissions, and many other impacts. So it's better to pick it to reflect one of these impacts (eg: accessibility).
4. **Performance target**: It could be specific measurable objective to be achieved by deadline. If it's not specified, at least the desired direction of change should be apparent. For example, if emission reduction target is not specified, the trend of emissions production (increasing or decreasing) is still indicating direction of the progress (either toward or away from sustainability).
5. **Data Disaggregation**: Data should be disaggregated to support different dimensions of the indicators that have been mentioned previously. For example, specifying data required for operationalizing affordability may be transport mode, economic level of the user, and spatial scale, while equity it can be transport mode, age or gender or physical abilities, and spatial scale.
6. **Level of analysis**: It's recommended that the indicator reflects the ultimate impacts of concern rather than the intermediary impacts. For example using "days of poor air quality" as an indicator reflecting the interaction of the pollutants with the atmosphere, better than using "tons of pollutant emissions".
7. **Reference unit**: It is the measuring scale, by which problems are defined and solutions are prioritized. As an example, measuring the emission impact can be more significant by "per capita" than being "per trips or per vehicle".

4.1. Select Sustainable Transport Indicators

There are two requirements to define real Sustainable Transport Indicators for certain case. First, is to identify the area of study and review the transport indicators of their interest. For this research the case study is The Netherlands. Second is giving an insight about available data for the analysis. Concerning that, Netherlands mobility survey is the available data.

4.1.1. Case study

In the face of the global climate change, the EU has been dealing with "limiting the global climate change" as a task. Consequently, reduction of the "Global Greenhouse Gas Emissions" to half of its current levels by 2050 is the goal to be achieved. And so, significant changes are needed in the transport sectors, as well as other sectors to have low-carbon society by that time. According to EU (2001), the widespread use of the automobile is irrational. The authors argue that the automobile's energy usage versus passenger capacity is relative inefficiency when compared to the energy usage and passenger capacity in other transportation options such as buses and trains. Therefore, number of strategic choices is made about how to realise a low-carbon society.

As in most of the European countries, the Netherlands has also experienced increasing pressure of transport on the environment. Since the 1950s mobility has continuously been increasing, and pronounced shifts have also occurred in the modes of transport used. In terms of mode of transport, from the early 1960s onwards there is an explosive growth in the ownership and use of cars (SWOV, 2010).

The latest report from Central Bureau of Statistics CBS (2011) announced that, the mobility of the Dutch is still increasing, but the rate of increase is retreating. Although Today, mobility in the Netherlands remains dominated by the car (SWOV, 2010), Dutch spend the most time travelling to work and back, and travel-to-work times are increasing year on year. Otherwise, the traffic accident death toll is declining, as well as, air pollution from road traffic. At the same time, about half of the Dutch population are still affected by traffic noise.

The availability of studies about the users of the Dutch transportation system gives an insight to the kind of information that would be useful for transportation decision-makers. Some of the Dutch studies have been concerned monitoring transportation systems performance is exploring the relationship between socio-demographic characteristics of transportation users vs. the used transport. Steg (2003) is one of the researches about the users of the Dutch transportation system. It conducts questionnaire study among representative sample of the Dutch population to describe who may be open to use public transport more often in the Netherlands. Steg classifies transport users by Gender, Age, Economic level and Marital Status. It is interesting to know that Women, younger people, low-income groups and singles use their car relatively less often than do men, older age groups, higher income groups and couples/families.

The advantage of Steg (2003) study is that it allows to make the comparison between the different types of users of the transportation system. It could be the focus of attention for developing projects - for example - about the standards that Dutch transport system need to be to fulfil needs of private cars users. As far as this study provides general information about the most frequently users for cars, in order to be considered during the development projects of public transport efficiency (e.g. How to make public transport attractive for these groups), but it still lacks a lot of details to prioritise areas for such development projects.

This study was not the only one that is concerning socio-demographic characteristics of transport users. SWOV (2010) is one of the recent studies that are looking in the field of mobility in more detail. SWOV, the Dutch national road safety research institute, contributes to improving road safety through scientific research. As the mobility is an important factor in road safety researches, the SWOV has conducted research about mobility on Dutch roads using mobility data carried out by the Dutch Ministry of

Transport's Centre for Transport and Navigation (DVS), the Netherlands Institute for Transport Policy Analysis (KiM) and Statistics Netherlands. The subject of the research is mobility distribution "represented in the travelled distance" across transport modes, age groups and journeys motives.

The disadvantage of this study is, as mentioned about the previous study that its lacks what can helps decision makers to prioritize places for development projects. At the same time, it gives more detailed hint about sub-groups that could be utilized in mobility researches for the Netherlands.

What is concluded is that is that the distribution of average usage of "Transport modes" across "age groups" and "journeys motives" might be useful for Dutch transportation decision-makers. Besides, they represent the recommended performance indicators. This means that information about the "age" and "journeys motives" of users of each type of transport mode is needed, to compare the different between them. This kind of information can be obtained through survey among the users of Dutch transport system.

4.1.2. Available data

Data is an actual requirement and problem to indicator development. Without a good quality dataset, it's simply not possible to produce reliable indicator. In some cases, innovative methodologies and analytical techniques can help overcoming some of the problems. Although the rapid developments of information technology, the application of geographical information systems and database managers have largely enhanced information-handling capacity, the real concern still how to capture efficiently and effectively reliable information. Though no data source is void of drawbacks, national statistics and any other official data still the most important information source when implementing indicator. The speciality of using official datasets is their credibility, which make it more accepted by the users (Ramani, et al., 2009).

Fortunately, information about the "age" and "journeys motives" of users of each type of transport mode which is needed for implementing the indicators is available in what is called MON (Mobility Survey in Netherlands).

MON (2009) has been organized by the Ministry of Transport and National Water Centre for Transport and Shipping. The purpose of MON survey is getting information about continuous daily movement behaviour of the Dutch population. It is a national research, implemented through a written and telephone survey, based on a random sample of the population. The survey goes through four processes; sampling, fieldwork, data entry and weighting and elevation. The two major end products of MON are the database and table book. The database contains all MON the results of the standard survey. The table book contains the most important and most consulted data summaries from MON (2009). The main concern of the survey is the trip, and many aother detailde information about. For example, the socio-demographic characteristics of the person who make the trip, transport modes used during the trip, time and purpose, etc. This kind of information restrains the method by which the indicator are implemented and even the matter which the indicators are showing.

4.2. Formulate Sustainable Transport Indicators

The process of forming Sustainable Transport Indicators "STI" is the aim of this part of the research. The commonly indicators used in following up the performance of transportation systems towards sustainability are going to be reviewed. Besides, taking a general idea about the transport indicators that is already used in the area of study. Then form the Indicators.

4.2.1. Review examples of Sustainable Transport Indicators

Environmental protection agency, United State EPA (2011) describes opportunities to incorporate environmental, economic, and social sustainability into transportation decision-making by using performance indicators. These indicators allow decision-makers to quickly observe and monitor the effects of transportation systems. EPA provides examples of some practical sustainable transportation performance indicators that are already being applied in monitoring transportation systems. The indicators mainly concerns transportation decision-making at the regional or metropolitan level, although they could be used at the local level.

Increase transportation options and improve accessibility to jobs and other destinations while protecting the environment is seen as the main goal of transport systems to enhance sustainability. Therefore, "Transit Accessibility" and "Mode Share" are the proposed performance indicators that can help transportation agencies evaluate the performance of transportation system of their regions toward the sustainability goals, and also allow a region to compare itself against peer regions. Noting that what is meant by "Transit Accessibility" is the ability of people to reach destinations using public transport, while "Mode Share" indicates the proportion of trips taken by different modes.

Measuring performance of any transportation systems differs according to the area where the study is held. The reason is that each country/unity has its own transport system. The development programs of the transportation system formulated upon development orientations, economic potential and the culture of its inhabitants. Therefore the first stage of the formulation process is to identify the area of study and describe its own transport system, as well as its transportation development programs.

4.2.2. Compose Sustainable Transport Indicators

Based on examples that have been reviewed about the subject of sustainable transport indicators, taking into consideration properties of "MON", elements of each dimension of selected indicators to be implemented are defined. As well as, elements of dimension of combined indicator (combination between selected indicators)

- **Indicator 1: Mobility Distribution across Journeys Motives**

Definition: The usability of transport modes for certain purposes.

Description: Mobility Distribution across Journeys Motives reflects the convenience choice for transport mode to certain purpose or destination. It can be measured in terms of the usability of transport modes to different purposes (to work, shopping, entertaining, etc.).

Measure: The measure of the indicator is the "Percentage of trips by transport modes to certain purpose, compared to the total amount of trips to the same purpose".

Socio-demographic scale: Calculation is for the total trips addressing (Business – Visits – Shopping - Education – Recreation)

- **Indicator 2: Mobility Distribution across Age Groups**

Definition: The usability of transport modes by certain age group

Description: Mobility Distribution across Age Groups reflects the convenience choice for transport mode by certain age group of the population. It can be measured in terms of the usability of transport modes by the user of ages among (30 – 39) or (50 – 59) or (75 +) years old.

Measure: The measure of the indicator is the "Percentage of trips by transport modes by certain age group of users, compared to the total amount of trips by the same age group".

Socio-demographic scale: Calculation is for trips addressed by different age groups (N.B. Following numbers refers to the age of the user): (0 – 11) (12 – 17) (18 – 24) (25 – 29) (30 – 39) (40 – 49) (50 – 59) (60 – 74) (75 +)

- **Indicator 3: Mobility Distribution across Journeys Motives across Age Groups**

Definition: The usability of transport modes by certain age group for certain purpose.

Description: Mobility Distribution across Journeys Motives across Age Groups reflects the convenience choice for transport mode by certain age group for certain purpose or destination. It can be measured in terms of the usability of sustainable transport modes according to (age group) of the user, to different purposes (to work, shopping, entertaining, etc.).

Measure: The measure of the indicator is the "Percentage of trips by sustainable transport modes by certain age group of users to certain purpose, compared to the total amount of trips by the same age group to the same purpose".

Socio-demographic scale: Calculation is for trips addressed by different age group (0 – 11) (12 – 17) (18 – 24) (25 – 29) (30 – 39) (40 – 49) (50 – 59) (60 – 74) (75 +), addressing (Business – Visits – Shopping - Education – Recreation).

For all indicators:

Geographical scale: The main geographical scales for this research are (Corop level – municipality – Postal code 4)

Sustainable mode: Dealing with sustainable transport modes is going to be in two forms:

Economical and Municipality levels: all sustainable transport modes represented as one group. At that level the comparison is between sustainable transport and unsustainable modes.

Postal code 4 level: sustainable transport modes represented by two groups, which are "Public Transport" group and "Green Modes" group (Green modes represent cycling & walking). Again the comparison includes unsustainable modes.

4.3. Implement Sustainable Transport Indicators

The process of visualizing the indicator is about converting available data to information (e.g.: number/percentage) and then to an interactive interface. Therefore, the first step is to prepare all the outputs of the indicator (e.g. maps, graphs) in static form. Then use static output in the dynamic interface, to get sustainable transport indicator visualized interactively. Here is a description for the process of converting indicators from its conceptual form to numerical values. This process is done in two steps; Data Preparation and Calculating Indicators. Data Preparation is the step of going deeper into the information available in MON database. Then, arrange the final database that will be used in calculating the indicators. While Calculating Indicators is the step of explaining the calculations that were made between different values, to get to the final percentages of the indicators. The following is the explanation of the two steps in detail.

4.3.1. Data preparation

Preparation of the data has gone through several steps (Figure 4-1) starts with taking a look at the content of the database. What has been found is huge amount of data, where the number of surveys ranging between 40,125 and 66,482 survey, while number of records is between 138,296 and 231,899 per year.

Since the aim of the implementation of these indicators is to test the capabilities of the DV techniques on displaying STI, as well as avoiding the technical problems, which often result from dealing with the prodigious quantities of data - as the technical issues are not among the objectives of this research - the province scale has been considered to be area of study, instead of the whole Netherlands. Overijssel province has been selected randomly among the Netherlands to be the case study of this research. It consists of three different spatial scales, which are 3 Corop areas, 26 Municipalities and 290 Postalcode 4 (PC4). And, the numbers of records in Overijssel ranged, between 1775 and 3490 record per year.

Preparation process starts on smallest spatial scale (PC4), And that to solve all data problems (e.g., missing, repeated data, etc.) that may affect final results especially on the bigger spatial scales. The first observation is that the number of PC4 that don't have any information ranging between 61 and 102 per year, moreover the number of surveys per PC4 ranges between 1 and 70, per year. Since these figures may be too small when divided (e.g., number of surveys divided across transport modes, journeys motives and age groups), the idea of creating database composed of all the surveys from more than one year contributes to the formation database with maximum number of surveys per PC4, and minimum number of PC4 without information.

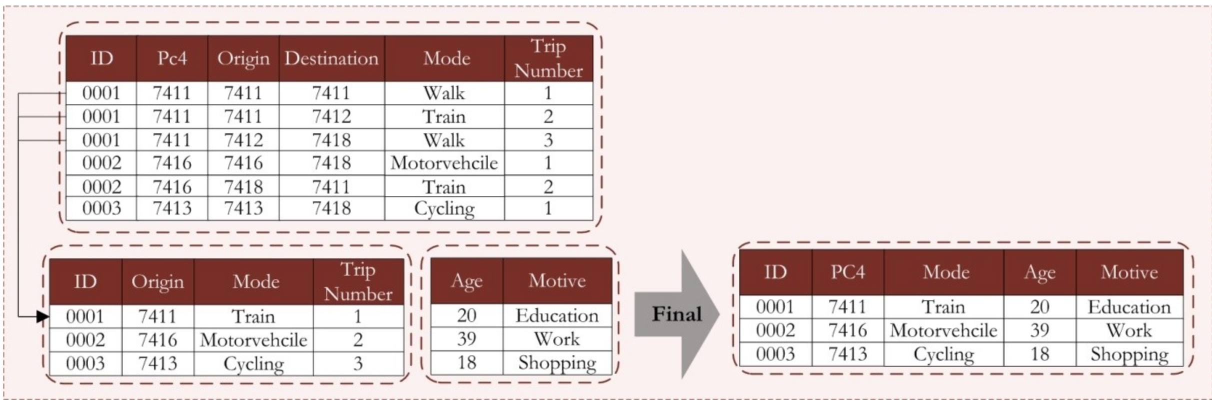
During this process it has been discovered that there is a difference between schema of 2004 database and other years. 2004 misses "Person IDs", which are used in the calculation of all indicators (e.g., number of person IDs divided across transport modes). Therefore, data of 2004 were excluded and final database has been configured by aggregating data from the years 2005 until 2009.

As mentioned previously, MON data is centric on trips undertaken by individuals, therefore, for each trip number of transfers that have taken place to reach certain destination. Since our attention is the type of transport modes used; regardless of the number of transfers, the transport modes for each trip are summarized to only one mode, so that the selected transport mode is the least sustainable transport mode used for that trip. As transfers are recognized by pc 4 of origin and destination, they are coded with numbers according to their order from origin place to the destination. The selected transport modes are matched with the place of origin

After adjusting the means of transportation it has been confirmed that Person ID has information about Transport Mode, Age, Journey Motive and origin PC4 of the trip. During the review, some (person ID) has been found duplicate. After making sure that this duplication didn't have any significance, the repeated have been deleted.

At this stage, we have a database with all required data to bring out the indicators, and then it has been joined with Base map "ArcGIS feature class" of Overijssel province. After the join, it has been found that number of PC4 in the MON are more than those of the ArcGIS feature class, and some other PC4 in the ArcGIS feature class without any information in the MON. Those extra PC4 that are not belonging to Overijssel province are removed from the database.

Finally, we have a database for Overijssel province with total number of surveys 13745, number of surveys per PC4 ranges between 1 and 254 for the period from 2005 to 2009, and with 25 PC4 having no surveys.



ID	Pc4	Origin	Destination	Mode	Trip Number
0001	7411	7411	7411	Walk	1
0001	7411	7411	7412	Train	2
0001	7411	7412	7418	Walk	3
0002	7416	7416	7418	Motorvehcile	1
0002	7416	7418	7411	Train	2
0003	7413	7413	7418	Cycling	1

ID	Origin	Mode	Trip Number
0001	7411	Train	1
0002	7416	Motorvehcile	2
0003	7413	Cycling	3

Age	Motive
20	Education
39	Work
18	Shopping

ID	PC4	Mode	Age	Motive
0001	7411	Train	20	Education
0002	7416	Motorvehcile	39	Work
0003	7413	Cycling	18	Shopping

Figure 4-1: Data preparation

4.3.2. Indicators preparation

As the process of data preparation starts with the smallest spatial scale (PC4), this is also what happened when calculating indicators. The main reason behind that is to save time and effort expended in repeating all the detailed calculations required to get single indicator at one spatial level. Processing indicators on the smallest spatial level given the opportunity to get the indicators on the higher spatial scales by aggregating outputs rather than repeating all calculations.

The process of calculating indicators is a series of selections, which occurs between the three dimensions of the transport indicators. Summing up the number of users by certain mode of transport from particular spatial zone and belonging to the same sub-group of certain socio-demographic characteristic is representing the first step in calculating an Indicator. While finding out the percentage of such users, out of total number of users belonging to the same sub-group using all transport modes or out of total number of users using certain transport mode, is the step of getting the score of the indicator. All indicators go through the same steps, but with different level of complexity depending on number of sub-groups of socio-demographic dimensions, which are included. The following is an explanation to the implementation methodology of each indicator, which is already formulated for the implementation (section 4.2).

- **Indicator 1: Mobility Distribution across Journeys Motives**

The process of calculating the indicator begin with summing up the number of users (represented in Person ID), who are using the same transport mode, to the same purpose (motive of trip). Means that, for instance, the number of users using green modes to education is placed in new column called "Green to Education". The same process is repeated for all possible combinations, to have at the end long table with all these combinations for each pc4 level (Table 4-2). After calculating all the possible relationships between the elements of the transport modes and motive of the trip, comes the stage of the calculating the percentages which is our main goal (i.e.: the indicator). The process is done by dividing the number of users of certain transport mode to particular purpose by the total number of users of the same transport mode. The final percentages are considered to be the required indicator, which will be displayed then in several ways and with several tools.

- **Indicator 2: Mobility Distribution across Age Groups**

This indicator also goes through the same steps as like the former one. The only difference between them is the variable of socio-demographic dimension. Whereas in the former was "motive of trip", it is now "age group". Calculating the indicator would be by summing up the number of users (represented in Person ID) who are using the same transport mode, in the meantime belonging to the same age group. Then, divide the number of users of certain transport mode belonging to particular age group by the total number of users of the same transport mode (Table 4-4).

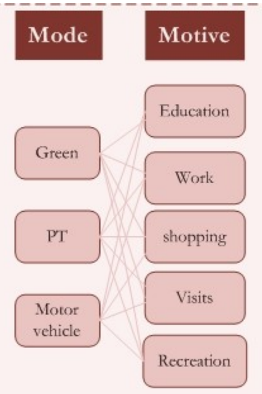
- **Indicator 3: Mobility Distribution across Journeys Motives across Age Groups**

This indicator differs from the two former indicators for being a composite indicator by merging two variables of socio-demographic dimension. This makes the process of calculating the indicator more complex. Again, the calculation process starts with summing up the number of users who are using the same transport mode, to particular purpose, and belonging to particular age group. For the percentage of the indicator, for the percentage of the indicator, it's by dividing the number of users of certain transport mode to particular purpose, and belonging to particular age group by the total number of users of the same transport mode and at the same time either to the same purpose or belonging to the same age group (Table 4-3).

To get the indicator for higher spatial level for any of these indicators, just aggregate the numbers prepared for calculating the percentage to the required level (Table 4-1).

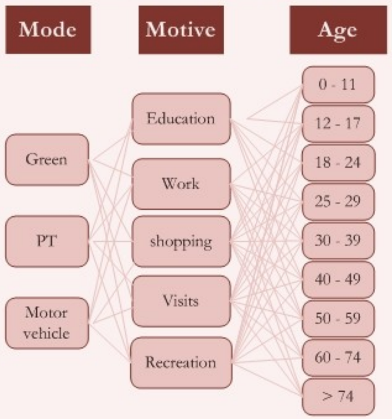
Corop	Municipality	PC4	Green to Education	Green to Work	Green to shopping	Green to visits	Green to Recreation	Total
Overijssel	Hengelo (O.)	PC4 [illegible]51	4	0	0	0	0	5
		7552	3	0	5	1	3	12
		7553	2	1	3	0	4	10
	Municipality	7556	3	2	2	2	5	14
	Enschede	7534	0	0	1	0	6	7
		7535	0	0	0	0	1	1
		7541	0	0	0	0	5	5
Corop		7542	1	0	1	0	9	11

Table 4-1: Indicator preparation for higher spatial level



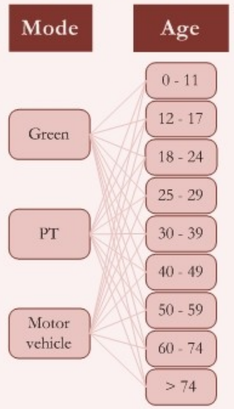
PC4	Green to Education	Green to Work	Green to shopping	Green to visits	Green to Recreation	Total
Number	12	2	2	2	8	26
%	46%	8%	8%	8%	31%	100 %

Table 4-2: Mobility distribution across journeys motives



PC4	Green Education 0 -11	Green Education 12 -17	Green Education 18 -24	Green Education 25 - 29	Green Education 30 - 39	Green Education 40 - 49	Green Education 50 - 59	Green Education 60 - 74	Green Education > 74	Total
Number	2	12	14	0	1	0	0	0	0	29
%	7%	41%	48%	0%	3%	0%	0%	0%	0%	100 %

Table 4-3: Mobility distribution across journeys motives across age groups



PC4	Green 0 -11	Green 12 -17	Green 18 -24	Green 25 - 29	Green 30 - 39	Green 40 - 49	Green 50 - 59	Green 60 - 74	Green > 74	Total
Number	0	2	10	8	6	0	2	7	3	32
%	0%	5%	26%	21%	16%	0%	5%	18%	8%	100 %

Table 4-4: Mobility distribution across age groups

4.3.3. Visualization

There are many techniques used to make an interactive interface. Some display pre-prepared outputs, while others prepare these outputs on request. In this study, the required outputs are going to be prepared, and then they will be displayed interactively. Since the interactive interface needs functional design to work upon it. The process of visualize Sustainable Transport Indicator dynamically go through two steps. The first is preparing functional design of the interactive. The second is preparing the materials needed to be displayed by the interface.

It had been discussed in3.4) the conceptual functional design for STI which is used in selecting the elements of the indicator. On apply this functional design on Overijssel province, considering MON data, some points have been modified.

Going step by step through the functional design, starting with selecting spatial level then transport mode is typically like the conceptual functional design. The modification starts at the level of selecting the variable of socio-demographic dimension.

It has been mentioned before that the sample size at pc4 level is too small to be used for calculating the STI. This is also the same reason to develop two functional designs, because there are some selection wouldn't be applicable for the small spatial scale. Which means that, the case of displaying composite indicator (i.e. selecting more than one variable of socio-demographic dimension) is inapplicable for small scales, because as much as the number of elements increase, the numbers of combinations increase. This leads to breaking figures significantly. For instance, the number of compositions of Indicator 3 "Mobility Distribution across Journeys Motives across Age Groups" is:

3 transport mode element x 5 Journeys Motives elements x 9 Age Groups = 135 combinations

Taking into account that, the number of observations per PC4 ranges between 1 and 254 observation means that, it still not enough to be broken to 135 parts. Practically it could be, but most of these combinations would score zero. Therefore, for the pc4 level, only one socio-demographic variable can be selected. This also means that, the greater the sample size, the greater the ability to form a more detailed indicators. The same problem appears when selecting the year, which is reflected by the indicator. For that, it's not allowed to select certain year for pc4 level, while it's possible for the higher levels. (Figure 4-2 & Figure 4-3) show the different combinations that are available for the bigger and smaller spatial scales.

To summarize, during this chapter the third research question is answered by identifying and formulating STI applying Transportation Research Board (TRB) recommendations for selecting and implementing sustainable transport indicators, which are:

- Choose understandable and useful indicators: based on the Dutch and International studies, noticing that the Netherlands is the case of study.
- Data Feasible to collect: Using national data about "Mobility survey in the Netherlands" MON
- Comprehensive and balanced: Include main dimensions of STI
- Performance target: Performance toward sustainability " mobility with sustainable transport modes"
- Data Disaggregation: Availability of required information
- Level of analysis: Users of transport system
- Reference unit: per Capita / Per spatial dimension / per year (or group of years)

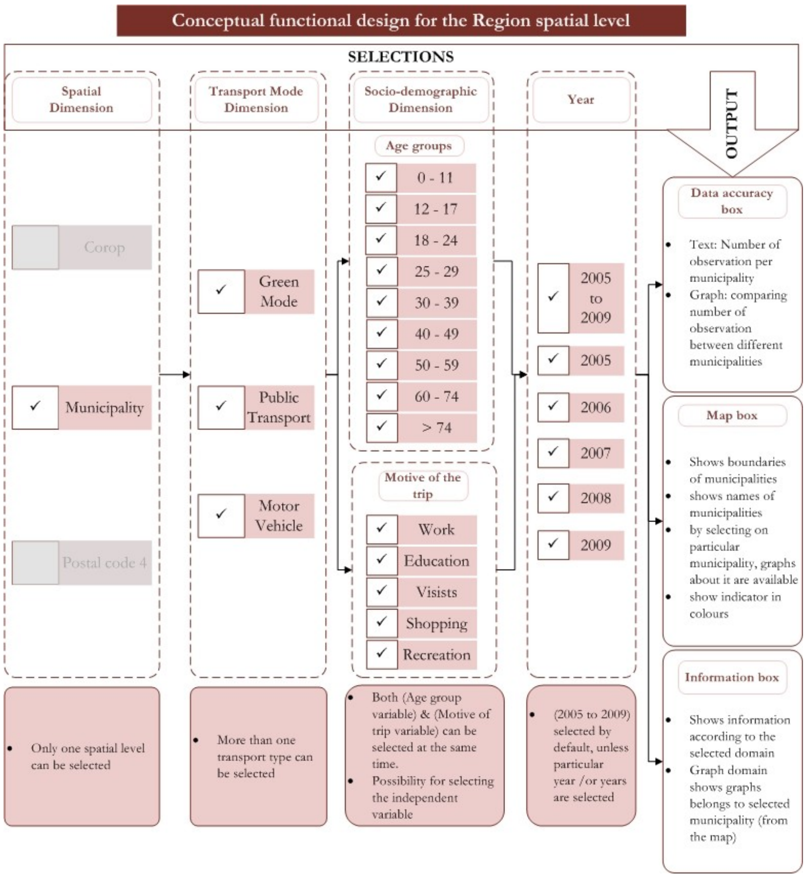


Figure 4-2: Conceptual functional design - Region spatial scale

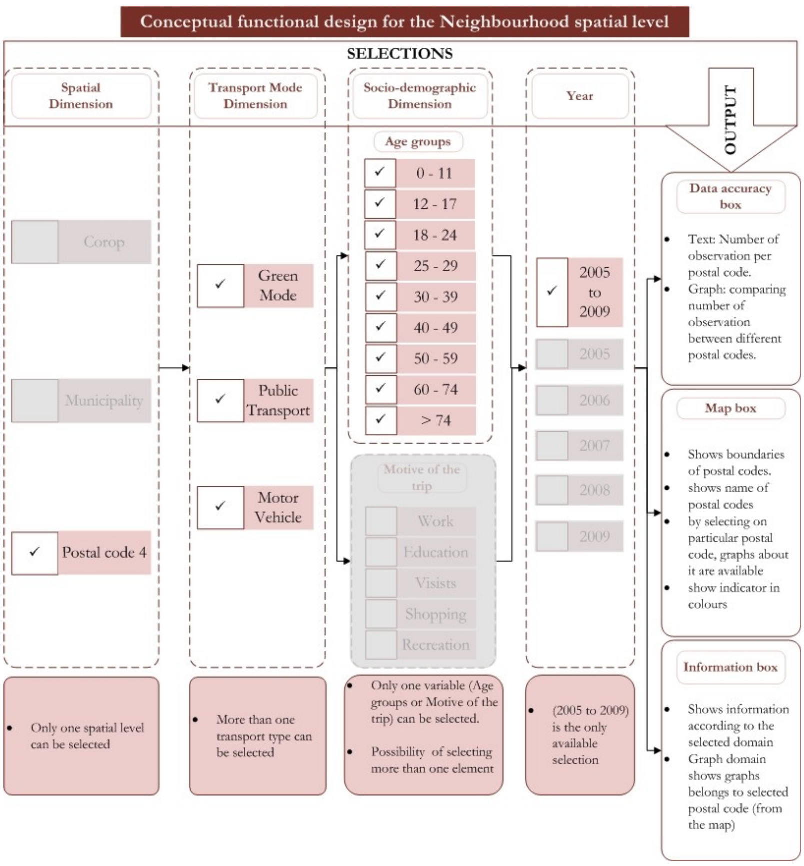


Figure 4-3: Conceptual functional design - Neighbourhood spatial scale

5. RESULTS

The stage of applying the interactive interface is considered an appliance stage for the conceptual interactive interface using visualising software. In this research a prototype for the proposed STI interactive interface shows the main components of the interface. According to conceptual interactive interface which was previously shown in (section 3.4), the three main components (selecting menu, map, outputs), and they are presented three main sections side by side in the interactive interface (Figure 5-1). During this chapter indicators for three different spatial scales are described, as well as all suggested outputs for one spatial scale is shown.

5.1. Selection menu & Maps

The first section appears on the left side of the interface is the "Selecting menu" section, which is transformation of conceptual function design into tabs in the interface (Figure 5-2). It aids the user in choosing the most appropriate elements of the dimensions the required STI. The available selections in this "selecting menu" are:

Spatial dimension	Transport Mode	Year	Age	Trip Motivation
➢ Corop (Group of cities) ➢ Municipality (City scale) ➢ Postal code 4 (Neighbourhood scale)	➢ Green Modes (Walking & Cycling) ➢ Public transport ➢ Motor vehicles	➢ 2005 ➢ 2006 ➢ 2007 ➢ 2008 ➢ 2009	➢ 0 – 11 years old ➢ 12 – 17 years old ➢ 18– 24 years old ➢ 25 – 29 years old ➢ 30 – 39 years old ➢ 40 – 49 years old ➢ 50 – 59 years old ➢ 60 – 74 years old ➢ > 74 years old	➢ Work ➢ Education ➢ Visits ➢ Shopping ➢ Recreation

Table 5-1: Elements of the implemented STI

Adding to them two extra taps:

- ➢ Generate maps: The user clicks on it after selecting all STI elements to show all information about the indicator in two other sections "map and outputs".
- ➢ Uncheck all: The user clicks on it to cancel all selection have been made in order to start from the beginning. is shown by clicking "Uncheck all" tab.

The second section appears on the middle of the interface is "Map" section, represents abstract information about selected STI In the home page the Netherland map appears with Overijssel province highlighted, and with north arrow and scale bar. Some of the common facilities that have been found in the similar interactive interface are added on the left side of the "Map" section as following:

- Zoom in: to enlarging specific spatial area of the map
- Zoom out: to show more spatial zones in one screen
- Zoom all: to show the whole map on screen
- Layers: to open or close layers like urban areas, public transport lines, etc.

- Information: contain information about map that may be interesting for user, such as area, population, etc.
- Print: to facilitate printing process.
- Sittings: user can use to change the setting to suit his/her needs. These setting are for instance, maps' colour, measurement unit, etc.

The third section appears on the right side of the interface is "Outputs" section. This section consists of four tabs and area for presenting information. Contents of all tabs will be discussed later in details. And so, the following is discussion of "Mobility Distribution" indicator for the three different spatial dimensions, with more details about "Outputs" of the indicator on the Municipality special level.

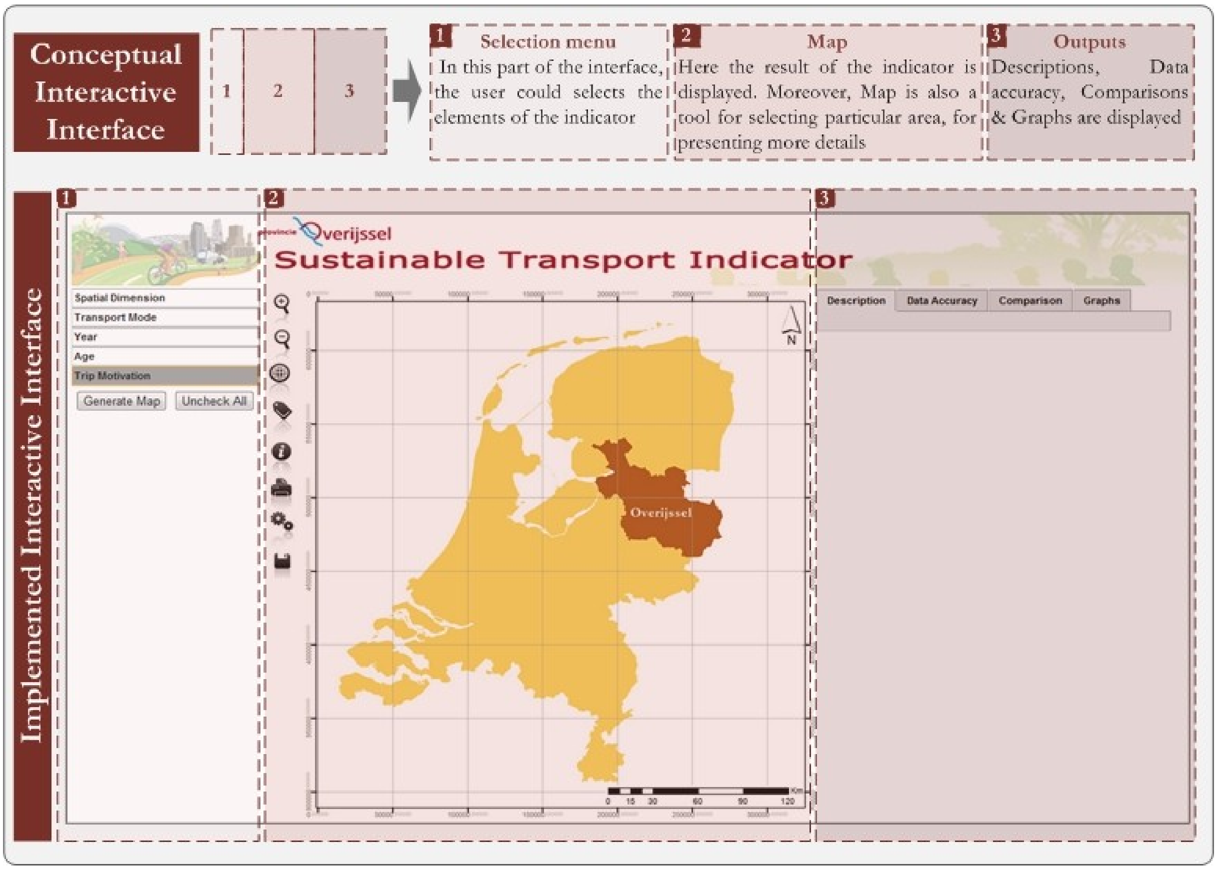


Figure 5-3: Home page of STI interactive interface (Prototype)

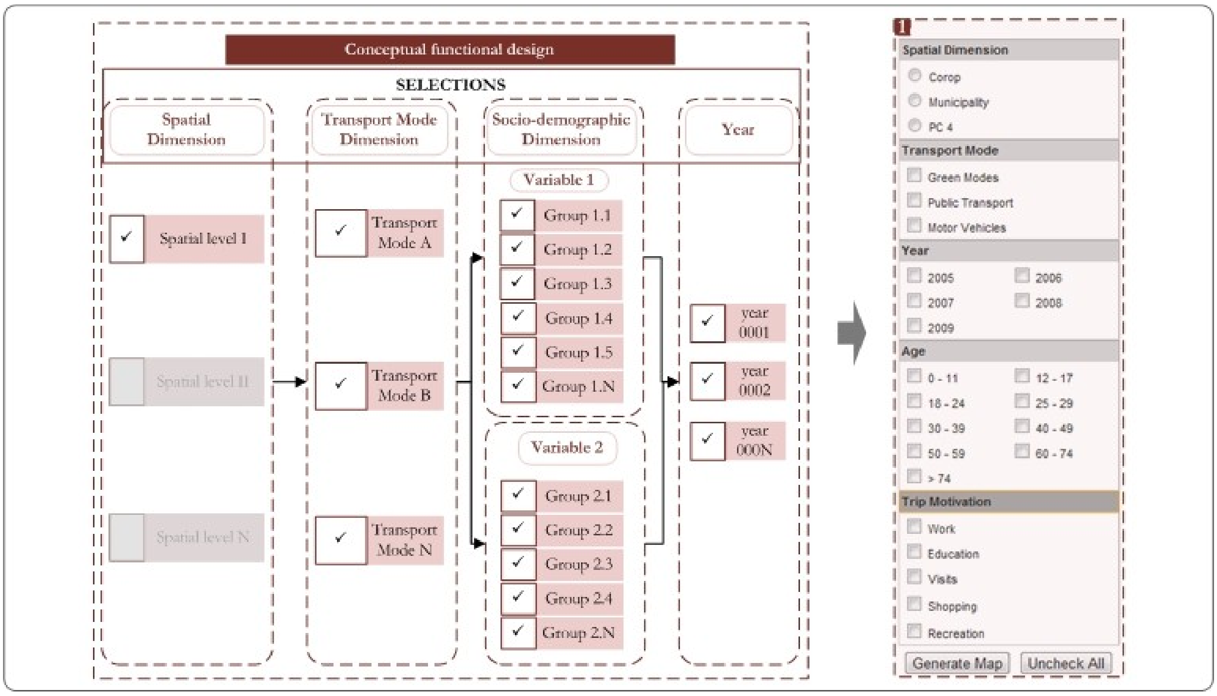


Figure 5-4: Conceptual functional design & Selecting menu

- **Indicator 1: Mobility Distribution across Journeys Motives**

The first indicator is about users who take sustainable transport modes to work (Figure 5-3). Description of the indicator is as following:

Definition: The extent to which sustainable transport modes "Green modes and/or Public transport modes" are taken as chosen transport mode to work

Explanation: The elements of the indicator are

- Spatial dimension: Postal code 4
- Transport dimension: sustainable transport modes (Green modes "represents cycling and walking together" & Public transport modes)
- Socio-demographic dimension: Work as motive of trip
- Year: for the time between 2005 & 2009

Measure: Percentage of trips with Sustainable transport modes to work out of total trips by all modes to work

(Trips by green modes to work + Trips by Public transport modes to work)/ Trips by all transport modes to work x 100

Classes of scores:

- Low: 0% - 9%
- Medium Low: 9.01% - 27 %
- Medium: 27.01% - 44%
- Medium High: 44.01% - 67%
- High: 67.01% - 100%

Significant values:

- Mean: 28%
- Median: 27%
- Minimum value: 0% (60 Analysis unit)
- Maximum value: 100 % (7 Analysis unit)

The descriptive information and the map show the user that 7 PC4 is the neighbourhood with the highest percentage of usage of sustainable transport modes to work, while60 PC4 is the one with the least percentage.

- **Indicator 2: Mobility Distribution across Age Groups**

Here only one transport mode has been used for those groups of people who are between 25 to 49 years old (Figure 5-4). Description of the indicator is as following:

Definition: The extent to which green modes are taken as chosen transport mode by users of age between 25 & 49 years old

Explanation: The elements of the indicator are:

- Spatial dimension: Corop
- Transport dimension: Green modes (represents cycling and walking together)

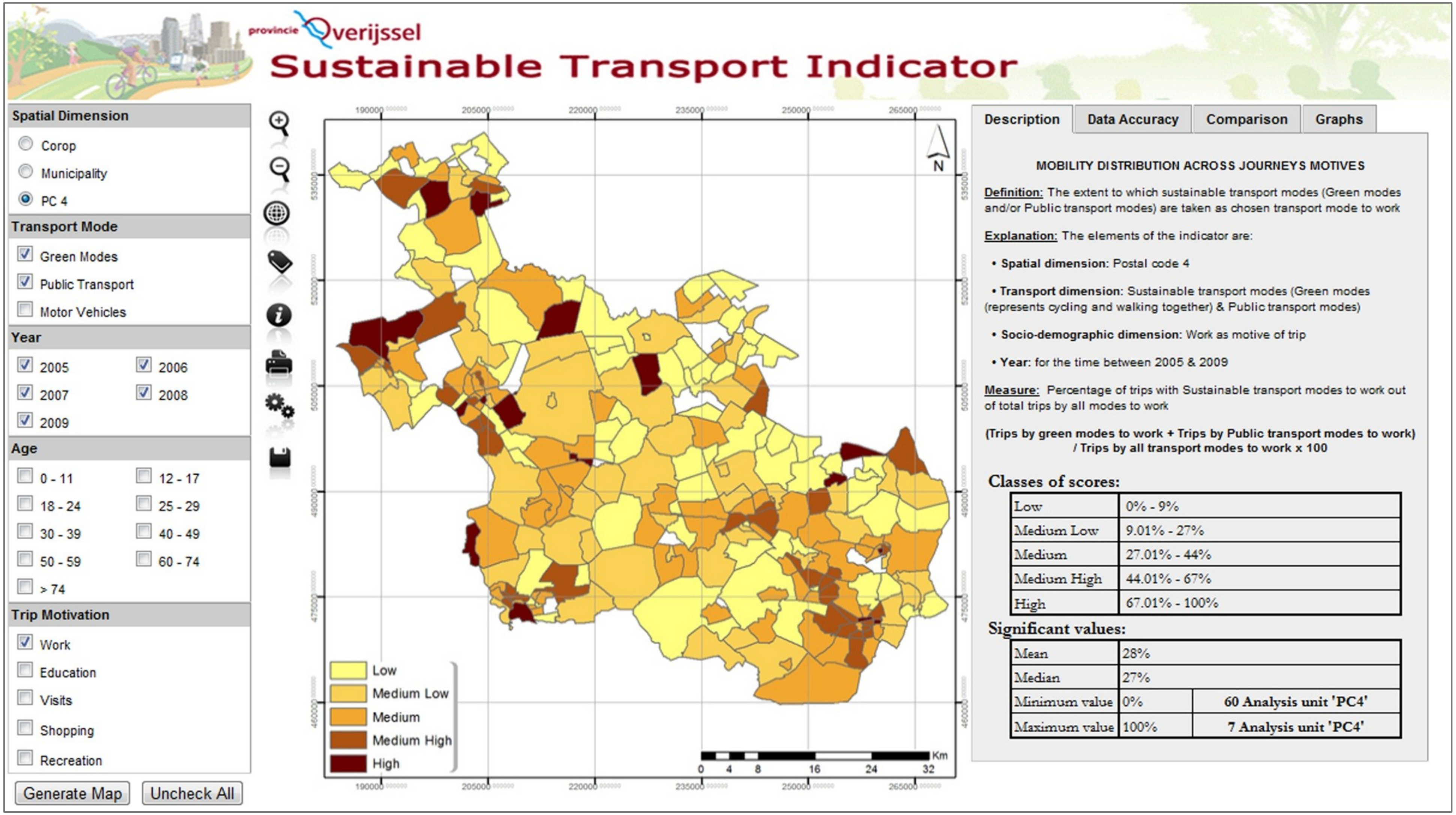


Figure 5-5: Screenshot: indicator for PC4 level

- Socio-demographic dimension: Users of age between 25 & 49 years old
- Year: for the time between 2005 & 2009

Measure: Percentage of trips with Sustainable transport modes by users of age between 25 & 49 years old out of total trips by all modes by the same group of users

(Trips by green modes by users of age between 25 & 49 years old /All trips by users of age between 25 & 49 years old x 100

Classes of scores:

- Low: 29.79%
- Medium: 29.99%
- High: 32.69%

Significant values:

- Mean: 30.83
- Median: 29.98
- Minimum value: 29.79% (Zuidwest – Overijssel)
- Maximum value: 32.69% (Noord- Overijssel)

Since there are only three regions, the map shows the user that Noord- Overijssel is the region with the highest percentage of users of age between 25 & 49 years old using Green modes, followed by Twente, while Zuidwest – Overijssel is the one with the least percentage among them.

- **Indicator 3: Mobility Distribution across Journeys Motives across Age Groups**

This example is concerning those users who are of age between 25 & 49 years old take sustainable transport modes to work (Figure 5-5). Description of the indicator is as following:

Definition: The extent to which sustainable transport modes "Green modes and/or Public transport modes" are taken as chosen transport mode to work by users of age between 25 & 49 years old.

Explanation: The elements of the indicator are

- Spatial dimension: Municipality
- Transport dimension: sustainable transport modes (Green modes "represents cycling and walking together" & Public transport modes)
- Socio-demographic dimension: Work as motive of trip & Users of age between 25 & 49 years old
- Year: for the time between 2005 & 2009

Measure: Percentage of trips with Sustainable transport modes to work by users of age between 25 & 49 years old out of total trips by all modes to work by the same group of users

(Trips by green modes to work by users of age between 25 & 49 years old + Trips by Public transport modes to work by users of age between 25 & 49 years old)/ Trips by all transport modes to work by users of age between 25 & 49 years old x 100

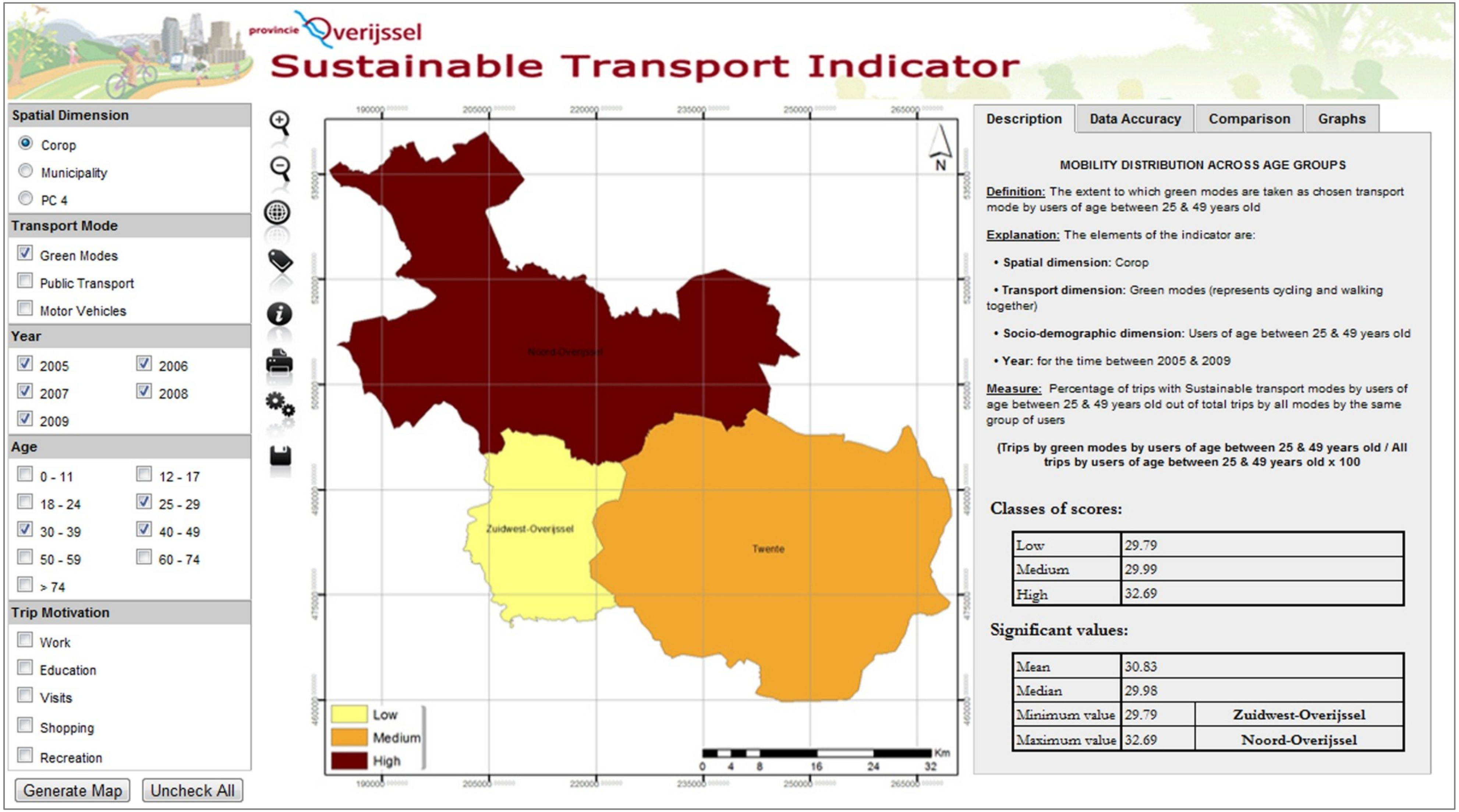


Figure 5-6: Screenschot: indicator for Corop level

Classes of scores:

- Low: 13% -17%
- Medium Low: 18% - 22%
- Medium: 23% - 28%
- Medium High: 29% - 34%
- High: 35% - 41%

Significant values:

- Mean: 25
- Median: 25
- Minimum value: 13 (Tubbergen)
- Maximum value: 41 (Zwolle)

The descriptive information and the map show the user of the interface that Zwolle is the municipality with the highest percentage of users of age between 25 & 49 years old who use sustainable transport modes to work, while Tubbergen is the one with the least percentage. Among all other municipalities - from the map - it's clear that there are 6 municipalities where people's of age between 25 & 49 years old usage to sustainable transport modes is the least.

5.2. Outputs

5.2.1. Data accuracy

Applying to what have been described in the conceptual framework, data accuracy is shown by map and diagrams (Figure 5-7 & Figure 5-6) Both of them show number of samples used from each municipality for the indicator. Which means that number of samples used for this indicator is the number users of age between 25 & 49 years old using all transport modes to work.

For general information, the map (Figure 5-7) summarises the results by presenting these countries in categories according to their score of indicator. The map is used to show these categories for those users who does not like to deal with details. The key in this map prepared to present categories in numbers to facilitate joining between numbers and spatial dimension. In other words, if the user chooses specific area he can easily choose them from the map directly and recognize range of its score.

For more details, in the diagram (Figure 5-6) which present exact number of observations of age between 25 & 49 years old using all transport modes to work for each municipality; "Zwolle" has the maximum number of samples (262 samples), while "Bathmen" has the minimum (16 samples). Showing such results provide an opportunity for the user to decide for which area the indicator can reflect the situation in it, and for which the indicator can't.

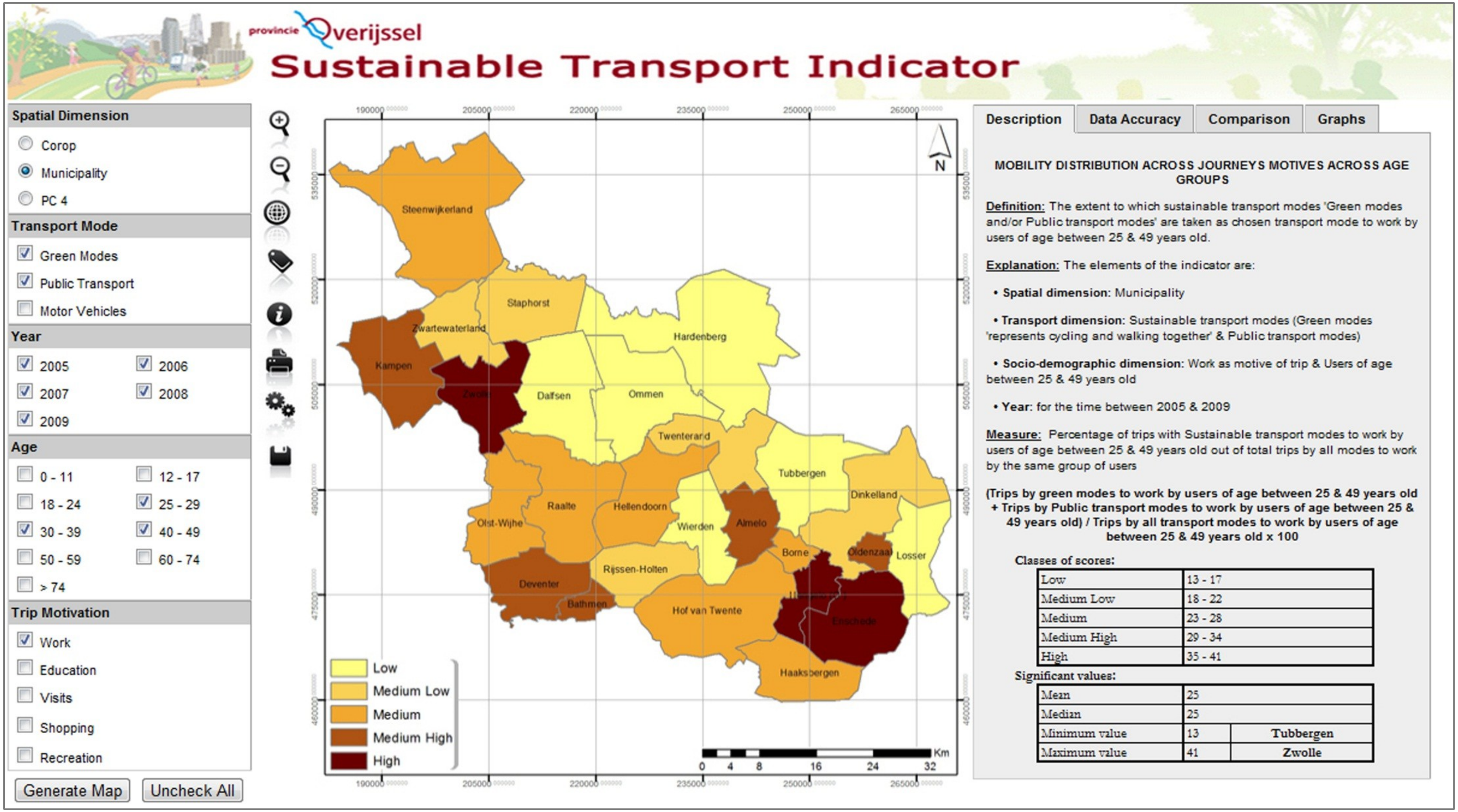


Figure 5-7: Screenschot: indicator for Municipality level

5.2.2. Comparisons

This tab includes three different graphs aims comparing different spatial zones according to their score of indicator. The first graph (Figure 5-10) compares the percentage of using different transport modes in all municipalities of Overijssel provinces. From the comparisons some significant information are shown. For instance, "Kampen" shows the maximum usage of the green modes, while "Ommen" shows the minimum usage, and vice versa for the usage of motor vehicles ("Kampen" shows the minimum usage and "Ommen" shows the maximum). Concerning usage of public transport, "Deventer" shows the maximum usage while "Tubbergen" shows the minimum.

The second graph (Figure 5-9) shows almost the same comparison but this time the comparison is between sustainable transport modes (public transport & green modes) and motor vehicles. Almost similar to the previous results, "Kampen" shows the maximum usage for the whole ST modes, and "Steenwijkerland" joined "Ommen" in showing the minimum usage for ST modes. This kind of information is assumed to be significant information for decision makers in case of investigating for ST usage.

The third graph (Figure 5-8) in this tab targets STI, which means comparing the percentage of users of age between 25 & 49 years using ST modes to work verses motor vehicles users from the same age group for the same purpose. The graph shows different results than the previous one which also was targeting the same transport modes but in general. "Zwolle" shows the maximum usage of ST modes for those groups of people, and "Tubbergen" shows the minimum, with difference about 20 %.

5.2.3. Graphs

This tab includes four different graphs, all about one spatial zone which is in this case "Enschede". They aim present relations between two other dimensions of STI (Transport modes vs. Socio-demographic dimension). The first graph (Figure 5-14) is comparison between the percentage of usage of the different transport modes in "Enschede". It shows that half of the users make use of motor vehicles, and almost the second half use green modes, while the usage of Public transport is about only 3%.

The second (Figure 5-13) and third (Figure 5-11) graphs show the percentage of usage of each transport mode to each trip motive, and vice versa. To avoid conflicting between the meanings of the two graphs, (Figure 5-13) distributes total number of trips to certain purpose across different transport modes while (Figure 5-11) distributes total trips by certain transport mode across all trips purposes. And so, from the second graph (Figure 5-13) we can find that maximum usage for motor vehicles is for visits purposes, while the maximum for green modes and also for public transports is for educational purposes. For shopping purposed the usage is almost distributed equally between ST modes and motor vehicles. From the third graph (Figure 5-11) what can be clearly observed is that the maximum percentage of trip by each transport mode is to work by motor vehicles, to education by public transport and to shopping by green modes.

The last graph (Figure 5-12) is the exact result of the indicator which its elements have been selected from the (selecting menu). It shows that the percentage of trips by ST modes by users of age between 25 & 49 years old going to work is 37%, out of the total number of trips to work by the same age group in Enscehede.

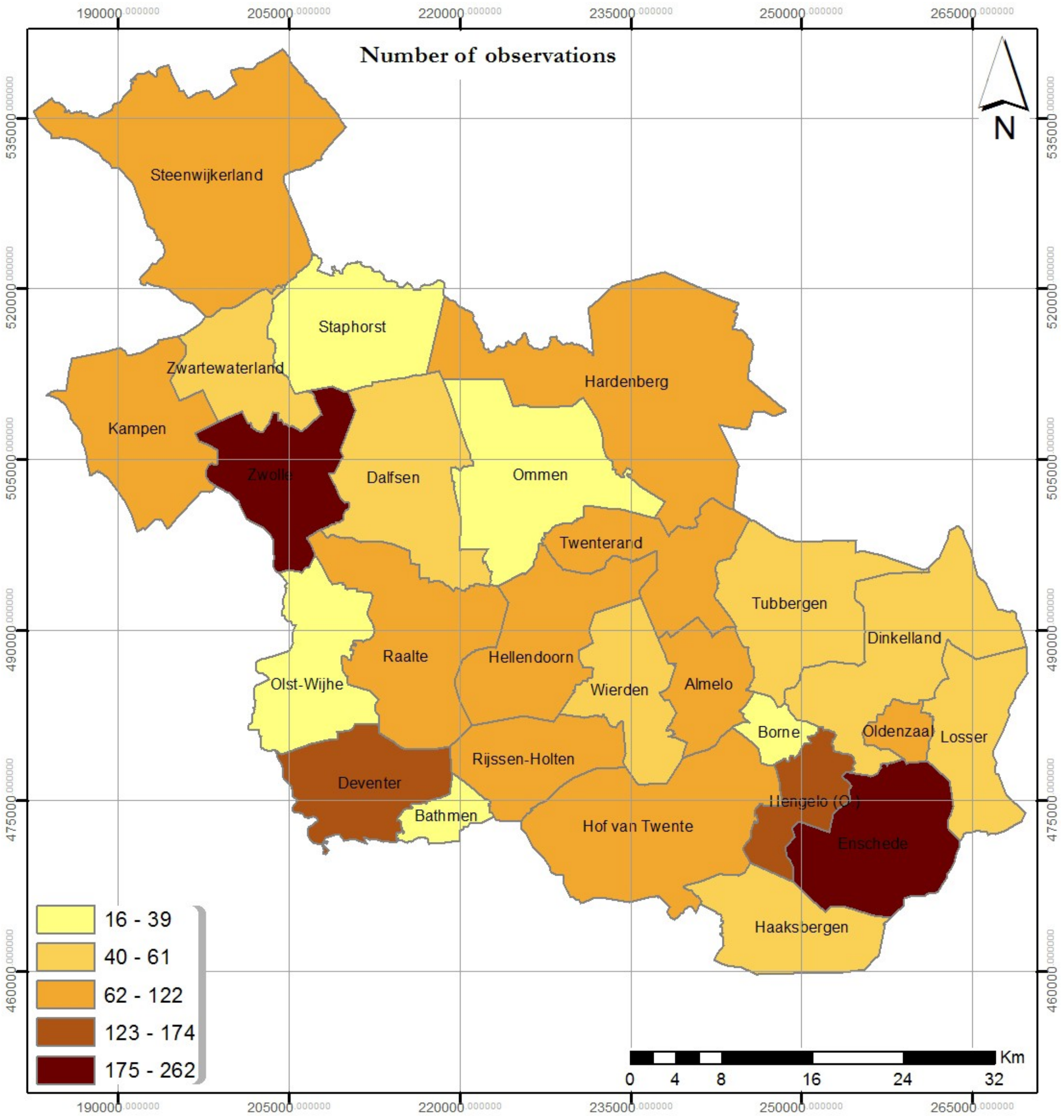


Figure 5-9: Number of observations: Classes

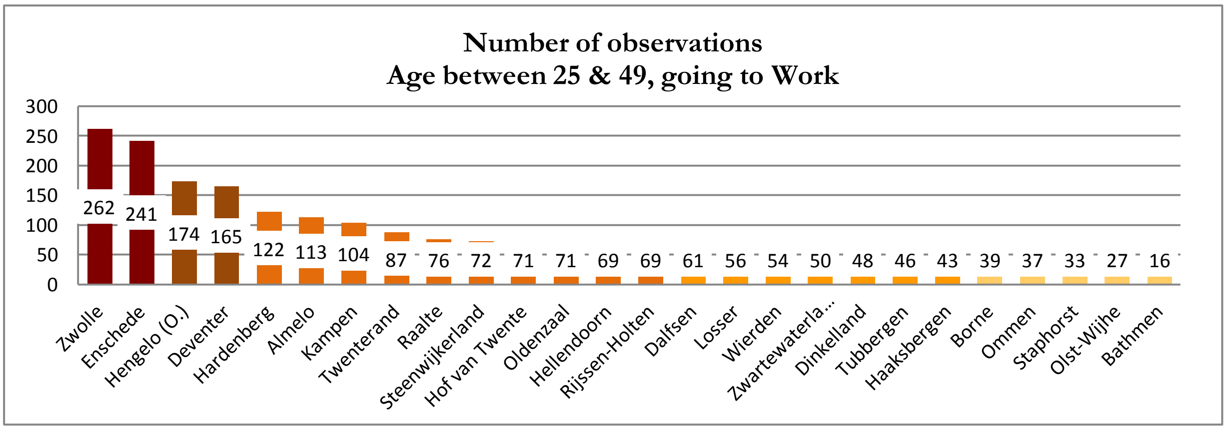


Figure 5-8: Number of observations: exact numbers

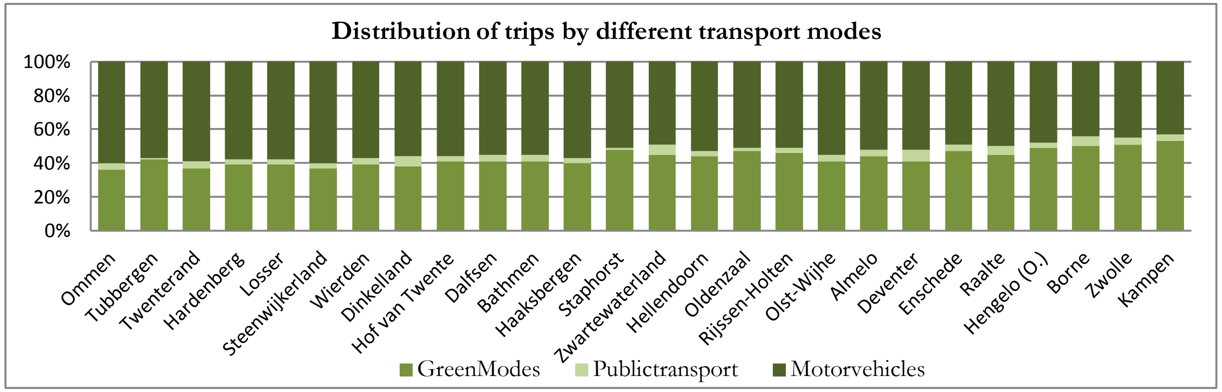


Figure 5-12: Distribution of trips by different transport modes

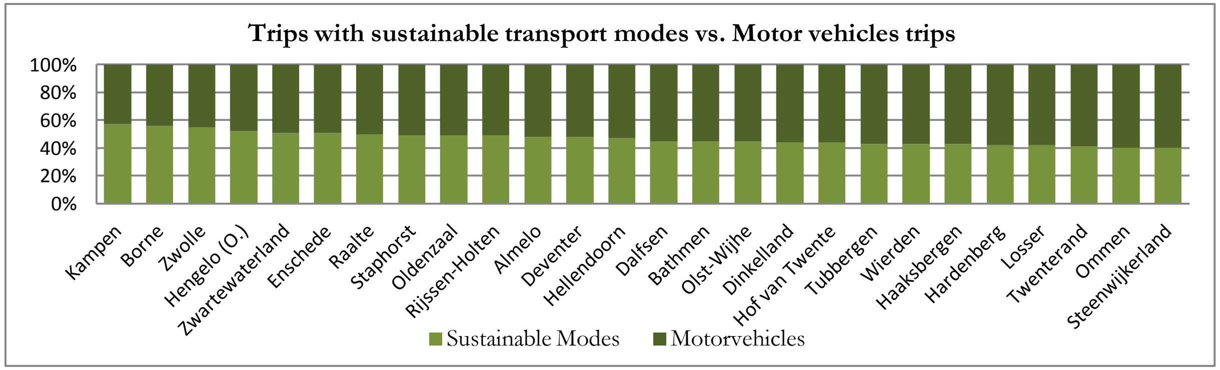


Figure 5-11: Trips with ST modes vs motor vehicles

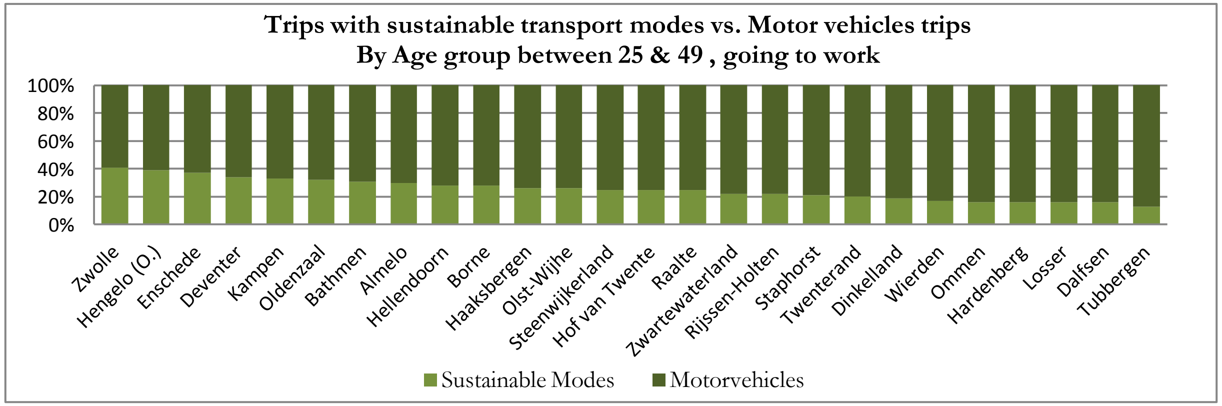


Figure 5-10: Trips with ST modes vs Motor vehicles, by age group 25& 49, going to work

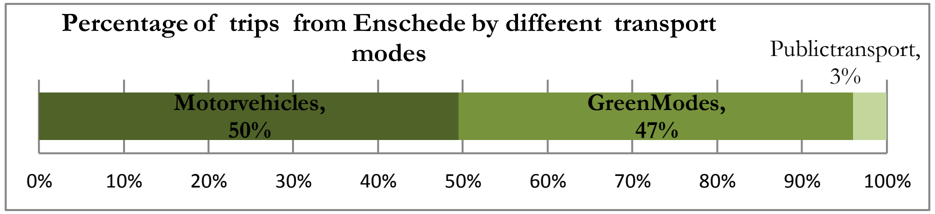


Figure 5-16: Trips from Enschede

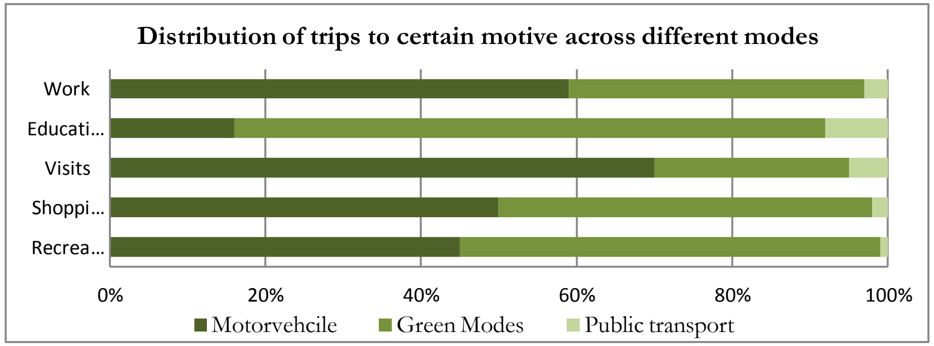


Figure 5-15: distribution of trips to certain motive

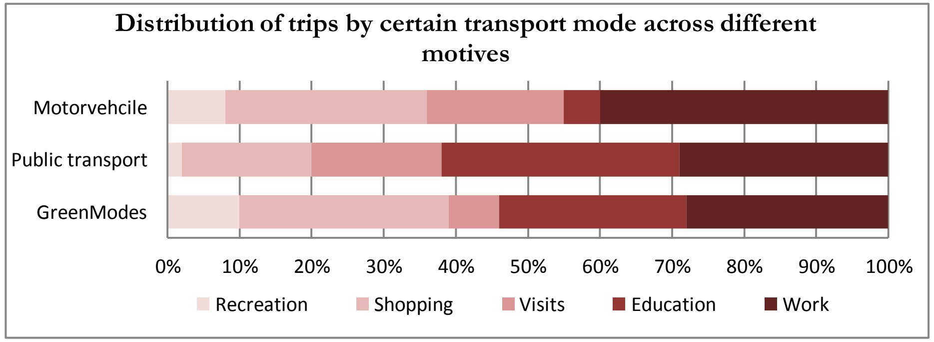


Figure 5-13: Distribution of trips by certain transport mode

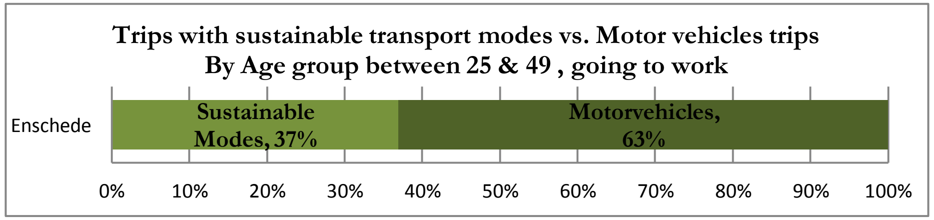


Figure 5-14: Trips with ST modes vs Motor vehicles, by age group 25& 49, going to work - Enschede

6. CONCLUSIONS

This is mainly outline for the most important findings of this research. It starts with the main conclusions concerning the achievements toward the main research objectives. Followed by the main limitations and finally some recommendations for further studies are provided.

- Conclusions

Concerning the achievements towards the main objectives of this research:

1. How to conceptualize framework to Operationalize Sustainable Transport Indicators?

The main objectives to answer this question are to define sustainable transport indicators and the conceptual framework to operationalize sustainable transport indicators, Concerning the define of sustainable transport indicators, there are various opinions on the definition, but what is common is that they are tools for measuring and evaluating the performance of transportation systems, toward achieving social, economical, environmental sustainability. Consequently, the conceptual framework to operationalize sustainable transport indicators is composed of three dimensions; each of them reflects one of the sustainability aspects. They are, transport modes, socio-demographic characteristics of the users and Geographical dimension. It's the turn now to form appropriate framework to interactively visualize STI.

2. How to conceptualize a framework to visualize Sustainable Transport Indicators interactively?

The answers of this question is achieved by definition of interactive visualization, and define the conceptual framework to visualize Sustainable Transport Indicators interactively About the definition of interactive visualization, simply it's the environment where the user can interact with its elements. Its four main aspects are; Interface, Maps, legend and it should be linked to database. As for the conceptual framework to visualize Sustainable Transport Indicators interactively, an interactive interface commonly consists of three main components displays information about indicator(s). These components are; Selecting menu, Map and Outputs.

3. How to Operationalize Sustainable Transport Indicators?

The answer of this questions achieved by identifying and formulating STI applying Transportation Research Board (TRB) recommendations for selecting and implementing sustainable transport indicators, which are:

- Choose understandable and useful indicators: based on the Dutch and International studies, noticing that the Netherlands is the case of study.
- Data Feasible to collect: Using national data about "Mobility survey in the Netherlands" MON
- Comprehensive and balanced: Include main dimensions of STI
- Performance target: Performance toward sustainability " mobility with sustainable transport modes"
- Data Disaggregation: Availability of required information
- Level of analysis: Users of transport system
- Reference unit: per Capita / Per spatial dimension / per year (or group of years)

- Limitations

There are mainly two kinds of limitation. Although the consultation of the target users of the indicators and the tool has a great deal of importance, it did not have time during the period of study. Thus, the actual requirements of the Dutch policymakers concerning evaluation of transportation systems still undefined. The second is that the study relies only on MON, which has been limiting the selected indicators, way of implementation, and the indicators measures.

- Recommendations

    - On the subject of the project, it's recommended to apply the proposed conceptual framework for the whole Netherlands database, and assess its efficiency in practice.
    - It's still important to know what are the proper technologies required for such kinds of projects.
    - In general, it's undoubtedly that consultation of the users contributes to activate the role of scientific research in the development processes in general.
    - The time and effort that have been spent in the process of calculating indicators calls the specialists in geo-information systems fields to support this kind of studies using their experiences to make planners' life easier.
    - Based on what has been observed regarding the accuracy and clarity of the national statistics, by dealing with MON database, it's recommended to develop components of these kinds of data according to the requirements of its expected users.

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ANNEX 1: MOBILITY SURVEY IN THE NETHERLANDS MON

MON is Mobility Survey in Netherlands, which is organized by the Ministry of Transport and National Water Centre for Transport and Shipping. The purpose of MON research is getting information about continuous daily movement behaviour of the Dutch population. It is a national research, implemented through a written and telephone survey, based on a random sample of the population.

The implementation of the study consists of four processes. These are sampling, fieldwork, data entry and weighting and elevation. The sampling focused on collecting the addresses for the sending out letters and questionnaires. Then the fieldwork process to compose, send and receive survey material. Data entry is to find the coding and entering the data collected to prepare dataset can be provided. Finally found weighing and raising place, with data as representative as possible for the Netherlands.

During all these processes control and validation activities conducted to determine the quality of the processes where monitoring is necessary. The research processes result in the database and table book.

Sampling

The random sample drawn from Dutch addresses for the MON survey is of the population living in the Netherlands except for residents of institutions, facilities and homes (IIT2). This random selection is done monthly to ensure that the sample is as up-to-date as possible.

This file comes from the coupling between the KPN Telecom stock, the Consumer DMdata file of Cendris (DMC) and the code table. The latter applies to PO boxes of only residential addresses (only private addresses are drawn, Business ones are excluded)

The address obtained from the DMC include postcode, house number, house number and add a phone number if available. Then, the municipal personal records database (GBA) checked the validity of the address. Subsequently, additional information such as the function of an address (home address or letter) and the birth dates of the residents, at the addresses searched.

Addresses that do not occur or in the GBA there is no data available about the main resident, are removed. Between these steps by the addresses, Social Data checked for accuracy, completeness and distributions to phone ownership, degree of urbanization and province. Finally, random selection for the addresses, then a list is ready for use in the fieldwork process. The number of delivery addresses used for Basic Research MON 2009 was 21,900.

Fieldwork

The fieldwork process consists of three main activities: the sending and received the survey materials, processing response and perform the standard post-surveys.

Send and receive shipping materials: The standard study of MON is a written examination. A week before sending the main transmission (with the survey material) households received an announcement letter. This one is information about the study.

Response processing: All returned questionnaires will be administered immediately upon receipt. Then there is the process of validation of the response. Manually verified information is missing, unclear or inconsistent. In this case the households with telephone are contacted to complete the data. The telephone validation process is aimed all ambiguities and 'mistakes' to be solved, for getting questionnaire as good and as complete as possible.

Standard post-surveys: since the move consists of one or more transport modes, in the basic research hardly any information collected on trips because it is a load in filling such questionnaire which may reduces the number of response.

Obviously trip information is important for mobility research. Especially public transport movements often consist of multiple trips per shift. Prior to a trip by train is someone a few hundred meters to the bus stop and then go a few miles by bus. In basic research, these distances fall within the head rail transport, because it (generally) the greatest distance traveled. The same happens when a person first cycle to the station. This creates a distorted picture of the distance traveled by vehicles in the pre-and post often used, such as walking, cycling and bus / tram / metro. To better understand the distance travelled by these vehicles and the public transport modes, post-survey (by telephone) to all persons 14 years or older about the transport that have been used.

The fieldwork for the basic research is comprehensive, covering all months of the year and for each day of the week. Overall, the standard survey for the basic research 2009 to 21,900 addresses. Eventually, 20,141 addresses were rightly gross sample of the basic research group (this number is the adjusted gross sample).

Weighting and grossing

A sample is never perfect representative of the actual population regarding the distribution of variables that are important for the mobility behavior, such as age, gender, income, urbanization and so on. A small proportion of the differences already arise by chance during sampling, but most have differences in the response process because some groups are more likely to respond. By this weighting is corrected.

Every day of the year has the same weight for determining the average travel behavior, but not every day provides an equal amount of response. Households and individuals are therefore called "day response factor" that indicates how hard the household and the people of that day count in representing the national total for that day. In other words, one days with poor response to the households and individuals get high "day response factor" and vice versa.

The second weighting is applied to correct for differences in response due to differences in accessibility. Households that are available by phone call motivated and therefore have a higher response rate than households that are not available by phone. Both groups are respectively slightly lower and slightly higher weight, so the final ratio reached by telephone versus non-telephone line with the same ratio to the gross sample.

Finally, the two major end products of MON are the database and table book. The database contains all MON the results of the standard survey. The table book contains the most important and most consulted data summaries from 2009 MON (Mobiliteitsonderzoek Nederland 2009, Het onderzoek).

META DATA OF MON (2004, 2005, 2006, 2007, 2008, 2009)

MON	2004	2005	2006	2007	2008	2009
Number of variables / columns	116	129	129	129	129	129
Number of records / rows	231,899	221,986	187,589	180,656	138,296	140,904
Households	29,221	28,436	23,695	23,240	18,102	18,158
People	66,482	64,052	53,545	52,218	40,125	40,836
Persons with zero transport	10,618	10,597	9,012	8,713	6,551	6,647
Movement	206,499	196,075	165,521	159,637	121,107	123,870

ANNEX 2: META DATA OF MON (2004, 2005, 2006, 2007, 2008, 2009)

Number of Observations per PC4 - Year 2005

PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #
7411	17	7531	33	7623	10	7797	1	8261	15
7412	27	7532	18	7625	2	7946	5	8262	18
7413	21	7533	12	7627	4	7951	29	8263	9
7414	12	7534	17	7631	12	7954	5	8264	5
7415	30	7535	14	7638	2	7955	1	8265	55
7416	11	7541	8	7641	48	8011	11	8266	2
7417	12	7542	42	7642	17	8012	30	8271	42
7418	1	7543	24	7645	3	8013	6	8274	8
7419	5	7544	47	7651	18	8014	27	8276	3
7421	28	7545	29	7661	2	8015	13	8277	5
7422	3	7546	15	7662	5	8016	41	8278	1
7423	28	7548	11	7665	12	8017	29	8281	18
7424	13	7551	4	7666	7	8019	8	8325	20
7425	19	7552	24	7667	8	8021	11	8326	2
7428	3	7553	21	7671	53	8022	10	8331	21
7429	4	7554	3	7672	7	8023	24	8332	15
7431	18	7555	32	7676	8	8024	5	8334	3
7433	14	7556	23	7678	12	8025	6	8335	2
7434	4	7557	36	7679	17	8026	2	8338	3
7437	21	7558	65	7681	42	8031	25	8341	6
7441	5	7559	36	7683	17	8032	35	8343	6
7442	36	7561	11	7688	5	8033	30	8344	3
7443	24	7571	4	7691	16	8034	7	8347	4
7447	19	7572	15	7692	5	8035	7	8355	6
7448	2	7573	3	7693	6	8041	4	8356	2
7451	44	7574	27	7694	4	8042	16	8363	2
7461	28	7575	1	7695	9	8043	29	8371	2
7462	52	7576	45	7696	2	8055	6	8372	2
7463	12	7577	40	7701	37	8061	21	8375	6
7467	4	7581	27	7702	4	8064	16	8376	1
7468	19	7582	19	7707	11	8071	2		
7471	40	7586	10	7711	40	8101	14		
7475	15	7587	17	7721	15	8102	22		
7478	16	7591	18	7722	23	8103	16		
7481	42	7595	5	7731	37	8105	4		
7482	50	7596	8	7734	3	8106	5		
7483	12	7601	16	7735	3	8107	8		
7491	22	7602	33	7738	9	8111	11		
7495	5	7603	14	7761	2	8112	8		
7496	2	7604	15	7771	16	8121	34		
7497	8	7605	6	7772	49	8131	26		
7511	14	7606	18	7775	4	8141	22		
7512	14	7607	16	7776	4	8146	3		
7513	6	7608	30	7782	5	8147	5		
7514	2	7609	47	7783	24	8148	3		
7521	33	7611	7	7784	3	8151	4		
7522	19	7615	9	7791	8	8152	8		
7523	12	7621	17	7792	3	8161	4		
7524	14	7622	31	7793	3	8181	3		

Number of Observations per PC4 - Year 2006

PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #
7411	21	7535	7	7634	5	7946	13	8251	1
7412	31	7541	8	7635	3	7951	30	8261	11
7413	13	7542	28	7637	1	7954	18	8262	35
7414	14	7543	23	7641	32	7955	1	8264	2
7415	26	7544	25	7642	5	8011	23	8265	49
7417	12	7545	21	7651	18	8012	6	8266	19
7418	4	7546	27	7661	4	8013	1	8271	22
7419	9	7548	4	7665	6	8014	36	8275	1
7421	12	7551	16	7666	2	8015	9	8276	14
7422	7	7552	23	7668	2	8016	26	8278	7
7423	9	7553	25	7671	39	8017	17	8281	31
7424	18	7554	1	7672	6	8019	9	8316	4
7425	24	7555	31	7675	5	8021	11	8325	6
7429	2	7556	27	7676	8	8022	5	8331	28
7431	18	7557	21	7678	1	8023	9	8332	27
7433	8	7558	43	7679	2	8024	24	8334	4
7434	7	7559	12	7681	36	8025	1	8338	3
7437	19	7561	5	7683	7	8026	2	8341	4
7441	37	7571	4	7687	2	8031	26	8344	3
7442	29	7572	21	7688	6	8032	20	8347	1
7443	42	7573	7	7691	8	8033	13	8355	4
7447	21	7574	12	7693	2	8034	4	8356	11
7448	12	7576	17	7694	7	8035	1	8363	2
7451	16	7577	31	7695	11	8041	2	8373	1
7461	32	7581	21	7696	4	8042	20	8374	10
7462	70	7582	24	7701	33	8043	59	8375	6
7463	11	7585	2	7702	2	8061	13	8376	4
7468	14	7586	6	7707	1	8064	26	8377	5
7471	40	7587	2	7711	26	8081	1	8378	3
7475	19	7591	27	7715	6	8101	30		
7478	12	7595	11	7721	18	8102	28		
7481	18	7596	4	7722	19	8103	15		
7482	30	7597	11	7731	44	8105	6		
7483	6	7601	11	7734	4	8106	7		
7491	15	7602	8	7735	1	8107	3		
7495	2	7603	11	7737	4	8111	10		
7496	4	7604	14	7738	4	8112	3		
7511	13	7605	7	7739	1	8121	30		
7512	12	7606	9	7771	22	8124	4		
7513	4	7607	35	7772	32	8131	28		
7514	19	7608	22	7773	5	8141	13		
7521	33	7609	28	7775	9	8144	1		
7522	26	7611	9	7776	11	8146	5		
7523	33	7615	6	7777	8	8148	1		
7524	1	7621	11	7782	11	8151	3		
7531	18	7622	10	7783	12	8152	9		
7532	12	7623	11	7794	4	8154	2		
7533	8	7625	12	7795	2	8181	1		
7534	40	7631	15	7797	6	8196	2		

Number of Observations per PC4 - Year 2007

PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #
7411	4	7534	26	7623	15	7796	1	8166	2
7412	31	7535	11	7625	3	7798	1	8196	2
7413	16	7541	3	7626	5	7811	1	8261	9
7414	8	7542	23	7627	4	7812	1	8262	17
7415	33	7543	15	7631	17	7822	1	8263	1
7416	14	7544	25	7634	2	7873	1	8264	13
7418	1	7545	30	7636	2	7902	2	8265	43
7419	11	7546	34	7641	33	7946	4	8266	14
7421	18	7547	1	7642	9	7951	55	8267	2
7422	5	7548	14	7645	4	7954	15	8271	40
7423	26	7551	15	7651	11	7955	1	8274	2
7424	8	7552	18	7661	1	8011	5	8275	1
7425	23	7553	31	7664	3	8012	19	8277	10
7429	2	7554	6	7665	7	8013	4	8278	5
7431	19	7555	28	7667	2	8014	54	8281	23
7433	5	7556	61	7668	2	8015	6	8325	11
7434	2	7557	26	7671	43	8016	37	8326	12
7437	22	7558	47	7672	5	8017	9	8331	36
7441	13	7559	35	7676	13	8019	5	8332	11
7442	39	7561	5	7678	5	8021	17	8334	10
7443	42	7571	5	7679	5	8022	5	8335	7
7447	28	7572	9	7681	20	8023	12	8338	4
7448	2	7573	20	7683	11	8024	13	8341	5
7451	19	7574	4	7685	2	8025	2	8342	1
7461	19	7576	27	7688	5	8026	2	8343	4
7462	39	7577	28	7691	5	8031	20	8344	1
7463	8	7581	14	7693	5	8032	12	8355	4
7468	26	7582	21	7694	13	8033	18	8356	2
7471	25	7585	2	7695	2	8041	2	8363	2
7475	25	7586	22	7701	52	8042	20	8371	1
7478	12	7587	4	7702	5	8043	45	8374	1
7481	18	7591	20	7707	6	8055	1	8375	7
7482	31	7595	6	7711	31	8061	39	8376	4
7491	26	7596	2	7715	5	8064	12		
7495	3	7597	1	7721	17	8101	28		
7496	7	7601	11	7722	14	8102	13		
7497	1	7602	21	7731	37	8103	21		
7511	12	7603	3	7734	3	8105	9		
7512	10	7604	18	7771	24	8106	2		
7513	13	7605	4	7772	32	8107	5		
7514	12	7606	16	7773	17	8111	22		
7521	24	7607	10	7775	10	8121	21		
7522	9	7608	29	7776	7	8124	3		
7523	29	7609	32	7777	3	8131	17		
7524	9	7611	1	7778	3	8141	19		
7525	4	7614	5	7782	9	8144	1		
7531	10	7615	3	7783	11	8148	1		
7532	11	7621	27	7791	4	8151	6		
7533	7	7622	20	7794	2	8152	18		

Number of Observations per PC4 - Year 2008

PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #
7411	10	7534	34	7642	7	8021	15	8347	1
7412	13	7535	7	7645	4	8022	5	8351	1
7413	8	7541	6	7651	12	8023	11	8355	11
7414	10	7542	14	7661	2	8024	5	8356	3
7415	15	7543	22	7665	12	8026	7	8374	1
7416	3	7544	11	7667	4	8031	16	8375	8
7417	5	7545	27	7671	17	8032	16	8376	1
7419	1	7546	10	7672	12	8033	3		
7421	10	7548	7	7676	7	8041	1		
7422	4	7551	3	7678	5	8042	11		
7423	11	7552	25	7679	2	8043	30		
7424	4	7553	17	7681	40	8061	19		
7425	8	7555	30	7683	31	8064	6		
7429	2	7556	30	7685	3	8077	2		
7431	10	7557	31	7687	5	8101	18		
7433	8	7558	39	7691	7	8102	22		
7435	3	7559	27	7693	10	8103	20		
7437	24	7571	9	7694	6	8105	5		
7441	2	7572	17	7696	3	8106	7		
7442	23	7573	7	7701	28	8111	15		
7443	15	7574	7	7702	2	8112	4		
7447	12	7576	29	7707	15	8121	13		
7448	2	7577	19	7711	12	8124	4		
7451	16	7581	17	7715	1	8131	19		
7461	24	7582	17	7721	26	8141	7		
7462	50	7585	2	7722	31	8151	6		
7463	1	7586	14	7731	24	8152	2		
7468	3	7587	11	7734	3	8261	3		
7471	23	7591	39	7735	1	8262	4		
7475	16	7595	7	7771	10	8263	4		
7478	2	7596	5	7772	24	8264	3		
7481	8	7601	13	7773	4	8265	23		
7482	26	7602	3	7775	3	8266	17		
7483	10	7603	10	7776	7	8267	1		
7491	18	7604	8	7777	1	8271	37		
7495	2	7605	2	7782	13	8274	3		
7496	7	7606	3	7783	8	8277	5		
7497	2	7607	14	7784	2	8278	5		
7511	10	7608	34	7811	1	8281	40		
7512	6	7609	20	7951	23	8325	5		
7513	8	7615	1	7954	5	8326	6		
7514	1	7621	15	8011	6	8331	12		
7521	21	7622	7	8012	4	8332	28		
7522	5	7623	9	8013	3	8334	4		
7523	12	7626	2	8014	24	8336	2		
7524	5	7627	3	8015	7	8338	2		
7531	18	7631	11	8016	13	8342	2		
7532	9	7634	2	8017	7	8343	4		
7533	7	7641	23	8019	6	8345	1		

Number of Observations per PC4 - Year 2009

PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #
7411	15	7541	10	7642	23	8031	11
7412	7	7542	13	7651	11	8032	28
7413	6	7543	14	7661	3	8033	2
7414	2	7544	19	7665	6	8042	10
7415	6	7545	16	7666	4	8043	32
7417	2	7546	22	7667	3	8055	3
7418	1	7547	5	7671	18	8061	16
7419	3	7548	8	7672	13	8064	8
7421	11	7551	5	7676	7	8081	2
7422	4	7552	8	7678	13	8101	12
7423	5	7553	13	7679	2	8102	4
7425	11	7555	11	7681	28	8103	5
7428	5	7556	14	7683	19	8105	9
7429	2	7557	15	7685	1	8111	2
7431	4	7558	22	7692	3	8121	23
7433	21	7559	21	7694	9	8124	4
7435	2	7561	4	7701	10	8131	8
7437	15	7571	3	7707	13	8141	10
7441	16	7572	12	7711	9	8148	2
7442	25	7573	6	7715	1	8151	9
7443	19	7574	3	7721	2	8152	6
7447	13	7576	19	7722	21	8261	8
7448	4	7577	22	7731	22	8262	1
7451	22	7581	10	7739	2	8265	22
7461	12	7582	7	7741	1	8266	4
7462	43	7586	4	7751	2	8271	21
7467	1	7587	17	7771	3	8276	3
7468	3	7588	1	7772	15	8277	2
7471	26	7591	16	7776	3	8281	16
7475	18	7595	2	7781	2	8294	1
7478	8	7596	4	7782	5	8325	2
7481	23	7601	5	7783	7	8326	1
7482	20	7602	7	7786	2	8331	15
7483	4	7603	9	7797	6	8332	13
7491	14	7604	4	7946	2	8334	7
7497	2	7607	12	7951	26	8338	2
7511	4	7608	19	7954	13	8341	12
7512	9	7609	16	8011	4	8342	5
7513	4	7611	2	8012	8	8355	4
7514	7	7615	4	8013	3	8356	1
7521	4	7621	8	8014	12	8375	8
7522	12	7622	24	8015	8		
7523	7	7623	8	8016	13		
7524	3	7625	4	8017	8		
7531	15	7626	2	8021	7		
7532	6	7631	15	8022	2		
7533	1	7634	8	8023	7		
7534	18	7636	1	8024	7		
7535	8	7641	23	8026	2		

Number of Observations per Year

Year	Observations #
2005	3490
2006	3121
2007	3101
2008	2262
2009	1775
Total	**13749**

PC4 available in the spatial data, but with Null value in MON data

PC4 Spatial Data	PC4 MON
7426	<Null>
7427	<Null>
7466	<Null>
7472	<Null>
7536	<Null>
7562	<Null>
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7736	<Null>
7779	<Null>
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8153	<Null>
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8291	<Null>
8293	<Null>
8337	<Null>
8339	<Null>
8346	<Null>
8361	<Null>
8362	<Null>

Number of Observations per PC4 – All Years

PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #	PC4	Observations #
7411	67	7524	32	7608	134	7715	13	8021	61	8266	56
7412	109	7525	4	7609	143	7721	78	8022	27	8267	3
7413	64	7531	94	7611	19	7722	108	8023	63	8271	162
7414	46	7532	56	7614	5	7731	164	8024	54	8274	13
7415	110	7533	35	7615	23	7734	13	8025	9	8275	2
7416	28	7534	135	7621	78	7735	5	8026	15	8276	20
7417	31	7535	47	7622	92	7737	4	8031	98	8277	22
7418	7	7541	35	7623	53	7738	13	8032	111	8278	18
7419	29	7542	120	7625	21	7739	3	8033	66	8281	128
7421	79	7543	98	7626	9	7741	1	8034	11	8294	1
7422	23	7544	127	7627	11	7751	2	8035	8	8316	4
7423	79	7545	123	7631	70	7761	2	8041	9	8325	44
7424	43	7546	108	7634	17	7771	75	8042	77	8326	21
7425	85	7547	6	7635	3	7772	152	8043	195	8331	112
7428	8	7548	44	7636	3	7773	26	8055	10	8332	94
7429	12	7551	43	7637	1	7775	26	8061	108	8334	28
7431	69	7552	98	7638	2	7776	32	8064	68	8335	9
7433	56	7553	107	7641	159	7777	12	8071	2	8336	2
7434	13	7554	10	7642	61	7778	3	8077	2	8338	14
7435	5	7555	132	7645	11	7781	2	8081	3	8341	27
7437	101	7556	155	7651	70	7782	43	8101	102	8342	8
7441	73	7557	129	7661	12	7783	62	8102	89	8343	14
7442	152	7558	216	7662	5	7784	5	8103	77	8344	7
7443	142	7559	131	7664	3	7786	2	8105	33	8345	1
7447	93	7561	25	7665	43	7791	12	8106	21	8347	6
7448	22	7571	25	7666	13	7792	3	8107	16	8351	1
7451	117	7572	74	7667	17	7793	3	8111	60	8355	29
7461	115	7573	43	7668	4	7794	6	8112	15	8356	19
7462	254	7574	53	7671	170	7795	2	8121	121	8363	6
7463	32	7575	1	7672	43	7796	1	8124	15	8371	3
7467	5	7576	137	7675	5	7797	13	8131	98	8372	2
7468	65	7577	140	7676	43	7798	1	8141	71	8373	1
7471	154	7581	89	7678	36	7811	2	8144	2	8374	12
7475	93	7582	88	7679	28	7812	1	8146	8	8375	35
7478	50	7585	6	7681	166	7822	1	8147	5	8376	10
7481	109	7586	56	7683	85	7873	1	8148	7	8377	5
7482	157	7587	51	7685	6	7902	2	8151	28	8378	3
7483	32	7588	1	7687	7	7946	24	8152	43		
7491	95	7591	120	7688	16	7951	163	8154	2		
7495	12	7595	31	7691	36	7954	56	8161	4		
7496	20	7596	23	7692	8	7955	3	8166	2		
7497	13	7597	12	7693	23	8011	49	8181	4		
7511	53	7601	56	7694	39	8012	67	8196	4		
7512	51	7602	72	7695	22	8013	17	8251	1		
7513	35	7603	47	7696	9	8014	153	8261	46		
7514	41	7604	59	7701	160	8015	43	8262	75		
7521	115	7605	19	7702	13	8016	130	8263	14		
7522	71	7606	46	7707	46	8017	70	8264	23		
7523	93	7607	87	7711	118	8019	28	8265	192		