HOW SUSTAINABLE IS ROUTE NAVIGATION? A COMPARISON BETWEEN COMMERCIAL ROUTE PLANNERS AND THE POLICY PRINCIPLES OF ROAD CATEGORIZATIONS

Koen De Baets
Institute for Sustainable Mobility (IDM);
Department of Geography – Ghent University, Belgium
koen.debaets@ugent.be

Sven Vlassenroot
Department of Telecommunication and Information Processing (TELIN);
Department of Geography;
Department of Mobility and Spatial Planning (AMRP) – Ghent University, Belgium
sven.vlassenroot@ugent.be

Dirk Lauwers
Institute for Sustainable Mobility (IDM) – Ghent University, Belgium
Department of Infrastructure, Space and Traffic, ARCADIS
dirk.lauwers@ugent.be

Georges Allaert
Department of Mobility and Spatial Planning (AMRP) – Ghent University, Belgium
georges.allaert@ugent.be

Philippe De Maeyer
Department of Geography – Ghent University, Belgium
philippe.demaeyer@ugent.be

ABSTRACT

In-Vehicle route planning is used to support a driver's route choice and to guide a driver to his/her destination. The suggested route takes less account of environmental aspects, which also could lead to cut-through traffic. Nonetheless, route-guiding systems may provide opportunities to stimulate a sustainable usage of the road network wherefore an integration of route planning and measures to improve traffic livability and safety is essential. The Flanders Spatial Structure plan describes certain categories of roads for the optimization of the road network based on selectively prioritizing either accessibility or livability. The aim of this paper is to examine to what extent route planners apply the principles of this (policy-made) road categorization while calculating a proposed route.

To achieve this, relevant origins and destination are selected in the study area, to the south-east of Antwerp. Several route planners are used to calculate routes between each

origin/destination relation. Between each origin and destination exists a ‘desired’ route which follows the principles of the Flemish Spatial Structure plan. The routes suggested by route planners are then compared with the corresponding desired route, after which the road classification usage of route planners can be evaluated. This paper will describe the in-depth analysis of this research.

First results of the research show that different route planners may suggest different routes. These routes can also differ from the desired route based on the Flanders Spatial Structure plan. By comparing planned routes with the corresponding desired routes, differences in road usage are apparent. These deviations are mostly found in the use of low and/or high categorized roads. Especially roads of the lowest category - which should only be used to give access to adjacent parcels - are frequently used by route planners to guide through-traffic without considering the lower function of these roads. For some of these suggested routes, the desired route is a feasible alternative. The desired routes do not necessarily deviate from suggested routes in the matter of time or distance, but will prevent the use of local roads for through-traffic. It is concluded that the implementation of the Flemish road categorization in routing algorithms has the potential to stimulate more sustainable driving behavior with more sustainable route choices.

INTRODUCTION

Recently, the use of navigation systems and route planners has increased. These systems are capable of guiding travelers to their destination by presenting the most appropriate route to the user, and even information to avoid traffic can be included (Cohn, 2009). However, if the navigation system suggests roads that are not intended to be used by through-traffic, they might put at risk the viability and safety of the environment. It is not clear to what extent the available route planners (e.g. Mappy) take into account the traffic annoyance they may cause by their suggested routes.

In the Flanders Spatial Structure Plan (RSV)(Afdeling Ruimtelijke Planning, 2004) a functional road categorization is introduced. The basic principle is to selectively prioritize the roads by ‘giving access’ or ‘livability’(Lauwers & Gillis, 2010). By applying this policy-made road categorization, a routing methodology that is preferred by policy makers can be developed. In addition, the livability of neighborhoods can be protected, since quality of the environment is one of the basic assumptions of the RSV road categorization (Lauwers, 2008a).

However, digital maps suppliers use a different, usually private road categorization based on functional importance and road characteristics (Bradt, 2008). The categorization of roads into several levels differs between various map makers, and deviates from the RSV road categorization. Additionally, route planners do not necessarily make effective use of all the available road categories (as offered by the map suppliers) and other relevant map information. A comparison between the preferred (RSV) routes (as indicated by the policy makers) and the (fastest) route from route planners seems necessary. This study examines to which extent route planners take into consideration the principles of the RSV road categorization to determine a route choice. This is done by examining the categories of roads that are used to travel from origin to destination by using route planners and by using a preferred RSV-based route. Attention is given to the use of the lowest road categories, namely the Type III local roads. The RSV road categorization is not available as a single digital map. Because of data availability, the study area is located in the southeastern part of Antwerp, where origin and destination zones were selected to calculate the relevant test routes. The chosen route planners are Google Maps, Mappy and TomTom Route planner.

This paper will explain first the principles of route planning and the road categorization according to the RSV. Secondly, the study describes and elaborates on the choice of origin-destination points and the methodology used for comparing routes. Finally, the results of all routes, and one route in particular, are examined in detail.

A ROUTE PREFERRED BY DRIVERS AND POLICY MAKERS

Route planners, in particular in-vehicle navigation systems, are developed to guide a driver as fast as possible to a destination. This has led to negative effects on the liveability of village centres due to increased traffic. Although map makers are aware of undesirable situations, they will not prohibit drivers to use routes that are legally available. Map makers seek after a correct representation of real situations and legislation in their digital maps. This implies that the suggested routes are most likely to be permitted routes, but possibly undesired from a policy maker's point of view. Policy-makers use spatial structure and mobility plans to attempt to limit the choices of road users, by guiding traffic along the most appropriate routes based on the functions of the roads (Deknudt et al., 2011). This section illustrates how route planning works and which policy principles apply to route guidance.

Route planning

Route planning allows calculating an optimal route between two locations, depending on the available data. To generate these routes, two aspects are indispensible: the data including the road network with additional information to guide vehicles efficiently through the road network, and a process or algorithm to calculate a suitable route based on the available data.

Map database

The data needed for route planning are structured as a digital map. These maps are geospatial databases (Güting, 1994) and are optimized to store and query spatial data such as road networks. Map makers collect and receive geospatial information, store and process it in a local database, and provide their maps to the end users, i.e. the navigation system vendors. The delivery of spatial data from source to end user is referred to as a 'data (update) delivery chain'.

The databases of map makers hold the geometry of the road network, the road classification, characteristics of roads such as direction, etc… Map makers construct this database by collecting their own data or receive data from third parties (ROSATTE, 2008). Data can be derived from topographic maps, aerial photographs or satellite images. Additional data is collected by fieldwork (Chen et al., 2009; Tao, 2000). This fieldwork enables to verify parameters, such as narrow passages, one-way streets, street names, signage, number of lanes, geometry of roads, physical barriers, obscure locations, inaccessible roads, etc… Other data are obtained from various institutions, mostly governments such as the Flemish government or municipalities. For example, a municipality can inform a map maker of a (physical) modification in the road network or the addition of a new traffic sign. The data is transferred to the map makers, and processed and stored in the databases.

The next step in the data provision chain is to deliver the maps to the navigation system developers and route planners. The map maker's databases have never been intended to be used directly by applications. These databases are organized for efficient storage and management of digital map data, but are not compact enough for use in navigation devices and not suitable for fast calculation of routes. Therefore, suppliers of navigation systems will compile the database to obtain a file system which meets the needs of a navigation device. These custom map databases are defined as a physical storage format (PSF), and may differ among each vendor of navigation devices.

Algorithm

Planning the routes is the task of the navigation systems' software. In addition to having up to date road network data supplied by the map maker, there is a need for a process to efficiently calculate a route on the bases of the available source data. This process is the routing algorithm. Depending on the source data, a wide variety of criteria can be taken into consideration while calculating a route. The quality of the route depends on several factors such as distance, travel time, number of turns, traffic lights, dynamic traffic information and even aspects that may ensure traffic liveability. Together these factors make a total trip cost. The routing algorithm will attempt to minimize this travel cost.

One of the most important algorithms to calculate routes is the Dijkstra's **shortest path** algorithm (E. W. Dijkstra, 1959). The algorithm searches for the lowest cost path between a node and every other node in the network. This process is labour-intensive and delivers lots of redundant results. While planning a route, the general direction of the route is known in advance (**heuristics**). This knowledge allows searching for results in a limited area and can be used to accelerate the search process. A* is an algorithm (Koenig, Likhachev, Liu, & Furcy, 2004) that applies this principle, and is a widely used algorithm for route planners and navigation systems. The calculation can be further accelerated by applying a **bidirectional** search (Fu, Sun, & Rilett, 2006), in which case the algorithm searches from origin towards destination, and from destination towards the origin. The two searches will meet somewhere in between. Furthermore, a road network often has a **hierarchical** structure. This has led to the idea of an efficient, hierarchical search algorithm for road networks. The basic idea is to search first in an abstract area, rather than the total area. Such an abstract area can be created for each hierarchical level. This allows an incomplete first route search at a high hierarchical level. Next details can be added using roads from a lower level. In a large road network it is advisable to apply a heuristic, bidirectional and hierarchical search method for route planning (Zhao, 1997).

Navigation systems and route planners offer various routing options to select a route depending on the preferences of the user. Changing the preferred routing options will affect the usage of different parameters while calculating a route. This allows route planners to have the possibility to suggest multiple routes between two locations. The most common option is the fastest route, but alternatives are available such as the shortest route, the most fuel efficient route (Ericsson, Larsson, & Brundellfreij, 2006), the safest route,… possibly depending on the time of day (e.g. school hours) (Schäfer, 2009). It is up to the end user to make the choice.

Policy

Map makers aim to create a digital map as a true representation of the road network. This includes all legal restrictions to avoid traffic violations. Within these limits, navigation systems have complete freedom of actions to plan a route. Policymakers however try to limit the route choices of road users and guide them to particular roads and directions, to preserve the liveability of residential areas (Deknudt et al., 2011). This strategy is specified in spatial structure plans and mobility plans, which state that certain relations between certain destinations should run via certain routes. The key policy principle which applies to route choice is the road categorization. The extent to which policy strategies are taken into account by route planners while generating routes, may affect the problem of cut-through traffic, safety and annoyance.

Road categorization

Road categorization is used to assign different functions or hierarchies to roads. It allows to define and subdivide complex road networks, and clarifies the structure of the road network for both road users and road administrators. Generally there are three methods to assign roads to road categories; the hierarchical categorization, the functional categorization and the categorization by road types (Matena et al., 2006).

Hierarchical categorization (Lauwers, 2008b) is mainly a result of responsibilities for providing, regulating and operating public roads at different levels of road authorities due to legislative aspects. A hierarchical categorization does not necessarily depend on functions or traffic importance of roads. The **functional road categorization** is based on the management of traffic (Allaert, Gillis, & Lauwers, 2009). Roads are categorized according to their function in the road network, which in general is either ‘high mobility’ or ‘giving access’. The goal of the functional categorization is to develop road networks adapted to the conflictive needs of road users and residents. The **categorization by road types** is based on the major geometric or operational features or the bearing of the road. This categorization could be hierarchical or functional, but will consider more factors such as importance of destinations, trip lengths, traffic characteristics, etc…

The existing road categorization of the Flanders Spatial Structure Plan is based on selectively prioritizing either accessibility or liveability and has been a milestone in the development of the basic concepts of hierarchy in the road network and a functional road categorization. The road network in Flanders distinguishes four categories of roads: the *main road* network, the *primary roads,* the *secondary roads* and the *local roads*. Three main functions are distinguished on functionality: the *connection* function, the *collection* function and the function of *giving access* (Afdeling Ruimtelijke Planning, 2004). A main function and a complementary function are assigned to each category. In addition a distinction is made between three hierarchical levels (International, Flemish, (super-)local) depending on the relation between origin and destination. On the highest level, the road network must be consistent. Roads of Flemish and (supra-)local level do not need to form a coherent network. They do have to form a coherent road network with the higher level network on which they are connected via links. This creates a tree-like structure with branches to lower levelled roads. The underlying idea of the tree (Lauwers, 2008a) is to avoid connections within a mesh, which would start to function on a higher level. The traffic flow at various levels must be in proportion so that the lower levelled road network does not get overloaded by through-traffic (‘cut-through traffic ‘) and that the road network of higher level is not loaded with traffic at a subordinate relationship (‘illegitimate use’).

ROUTE FROM ORIGIN TO DESTINATION

The aim of this study is to determine to which extent the routes - calculated by existing route planners - take into account the policy-made categorization based on the principles of the RSV. For this purpose several different routes generated by route planners are compared with corresponding ‘preferred’ routes, which will take into account the RSV-principles. This section first discusses the choice of the origin and destination points and next the calculation of routes between these point. Finally the method for comparison of these routes is explained in more detail.

Choice of origin and destination zones

In the choice of origin and destination zones for the test routes the focus will be on relevant trips, based on daily trips between traffic-producing regions and based on relations between settlement structures. Although car navigation system are used primarily (95 percent) for trips to unknown destinations (van Rooijen, Vonk, Hogema, & Feenstra, 2008), this study will focus on the selection of frequently used routes to evaluate the route planners. The construction of the road classification is based on relationships between areas on three levels. These are the international level, the Flemish level and the provincial level. These relationships can serve as a starting point for selecting appropriate routes. Due to the limited size of study area, the focus will be on the connections at the provincial level. The selection of origin and destination of the test routes is based on the settlement structure of a location and on the extent to which a location serves as a traffic generating or attracting area.

A **settlement structure** is defined as the residential precinct in urban areas and in the countryside. This categorization is a hierarchical partitioning of Flemish cities and villages. An origin-destination matrix illustrates the relationships between different settlement structures. At the Flemish level, relations between metropolitan areas, between regional urban areas, and between metropolitan and regional urban areas are the most important. At the lower provincial level, the focus is on relationships between small urban and regional urban/metropolitan areas, and among small urban areas themselves. Table 1 is an example of such a matrix, and the relations in the study area.

Table 1
Origin-destination matrix

Settlement Structure	Metropolitan area	Regional Urban area	Subregional level	Small Urban area on provincial level	Main Village type I	Main Village type II	Main Village type III	Small village
Metropolitan area	x							
Regional Urban area	x	x						
Subregional level	Antwerpen - Lier	Mechelen - Lier	x					
Small Urban area on provincial level	Antwerpen - Boom	Mechelen - Boom	Lier - Boom	x				
Main Village type I	Antwerpen - Duffel	x	x	x	x			
Main Village type II	Antwerpen - Ranst	Mechelen - Ranst	Lier - Ranst	Boom - Ranst	x	Ranst - Berlaar		
Main Village type III	Antwerpen - Zandhoven	Zandhoven - Mechelen	Lier - Zandhoven	x	x	Ranst - Zandhoven	x	
Small village	Antwerpen - Hove	x	Lier - Aartselaar	Boom - Wijnegem	x	Ranst - Wilrijk	Zandhoven - Wijnegem	Aartselaar - Kontich

x = relation not available in study area

Besides the relationships between settlement structures, **attraction centres** are chosen for the selection of test routes. This mainly involves economic centres, recreation areas, multi-modal transfer points, train stations, Park & Ride -facilities and event centres in relation to their hinterland. The attraction poles with functions of regional importance are most often industrial parks with lots of commuter and truck traffic. In the study area, areas with traffic generating functions of regional importance are selected.

In addition to the selection of areas and attraction centers, the production of traffic in the area will influence the choice of test routes. These commuter trips show mainly radial connections to Antwerp, but also non-negligible tangential trips.

Finally, the selection of test routes is also based on trip distance. According to the OVG survey on travel behaviour (Cools, Declercq, Janssens, & Wets, 2009), the average commuting distance is 19 kilometres. This measure is used as a guideline while selecting the test routes. Furthermore, shorter trips are included in the study, in particular trips between main cities and their surrounding municipalities. By applying the above stated principles, a total of 11 origin/destination pairs within the study area were selected for the calculation of test routes. These routes represent commuter trips and trips to locations of regional importance, and between several levels of settlement structures.

Calculation of routes

Route planners

The study uses three route planners to calculate routes between origin and destination points. These route planners are Google Maps, Mappy and TomTom Route Planner. For each planner the basic car navigation settings are used. Highways and toll roads are not avoided. Although Google Maps route navigation suggested several alternatives, the first proposed route is used in this study. Mappy Route Planner presents a choice between fastest and shortest route. In this case the fastest route is selected. The TomTom route planner can include the departure time and actual traffic information. These functions to reduce delays and a specific time of departure are unchecked for this research. It should also be noted that small changes (no more than 10 meters) in origin or destination can greatly alter the calculated route.

A complete road network with data of the Flemish road categorisation is not available, so the necessary road data was added to the network. The next step (Fig 1) is to link the calculated routes to this network, which allows the identification of the subjacent road categories. Routes are exported from Google Maps using the online tool GMapToGPX, and then imported into a GIS (Geographic Information System) and matched to the network for further analysis. Routes from other route planners are exported by the same tool after manually reconstructing them in Google Maps. At this point the imported routes consist of adjacent road segments, which do not form a single route with start and end point. Using the Network Analyst tool in ESRI ArcMap GIS software it is possible to select a start and end point of a route and connect the line segments to form a route. This allows further analyses of the usage of road categories along the routes.

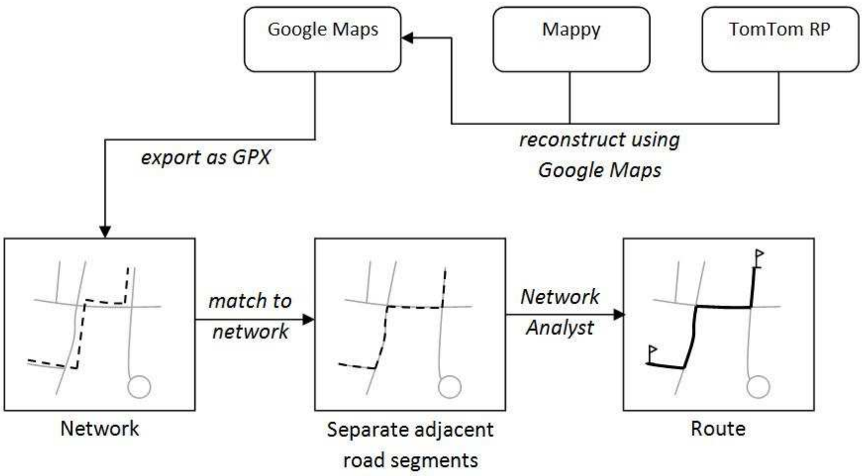

Fig 1: processing of routes from route planner to GIS

RSV route

The routes calculated by the route planners will be compared with a ‘preferred’ route that takes into account the roads categorization according to the principles of the RSV. A distinction is made between four hierarchical levels according to the importance of the road infrastructure: the international level, the Flemish level, the regional level and the (supra)local level. In a node, roads of the same level join and the possibility of changing road exists. In a linking point, roads of different levels join with the possibility of changing levels while changing roads. This type of network follows a tree-like structure. By applying these principles, a routing process based on the RSV can be developed which follows a fixed progressing of road use (A. Dijkstra, 2010); the route departs from the starting point on a road with a low category and moves gradually to the nearest road with a higher category until the highest categorized road for the route is reached. While approaching the endpoint, the category of the used roads gradually decreases until the destination is reached. The profile of a standard RSV route will therefore be represented by the pattern shown in Fig 2, with the origin at the left and destination at the right.

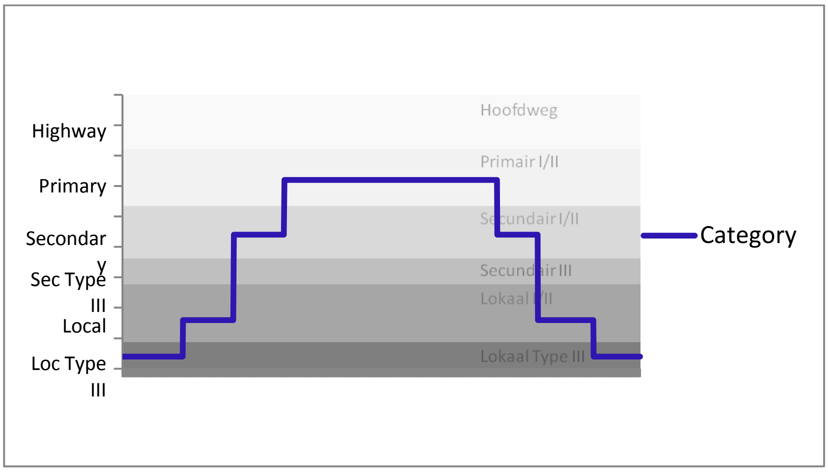

Fig 2: Profile of RSV route

This algorithm calculates a shortest pad between two locations in a network. A ‘shortest path’ can be defined as a path with the lowest resistance. This can be the shortest time, shortest distance or any other value assigned to the network. To calculate a RSV route, the ‘shortest path’ is defined as the route with the shortest distance dependant on the used road categories and the function of the trip, e.g. travelling on international, Flemish, supra-local or local level. To do so, the distance of each road is multiplied by a weight factor. Each road category has a corresponding weight factor, and for each origin/destination relationship, different weight factors are assigned to the categories. This means that different sets of weights are used for different travel functions. Higher weights on a stretch of road will cause higher resistance on that road, so the use of this road for route planning will become less favorable. This implies that low categories should have high weights, and vice-versa. However, (supra-) local trips should not make use of high level roads, whose functions are to connect and/or collect on an international/Flemish level (Afdeling Ruimtelijke Planning, 2004), and which would result in illegitimate use of those roads. In this study area with few primary roads, a strict implementation of different weights by trip function leads to unrealistic results. For example, travelling from Wijnegem to Zandhoven uses the secondary road N116, while the highway A13 should be a much more realistic choice. Therefore, only two sets of weights were used. One for International, Flemish and Supra-local trips, and one for Local trips.

Comparison of routes

It is possible to plan different routes between two locations. The underlying algorithms and used source data determine the route choice a route planner will make. Although the route planners in this study all rely on Tele Atlas data, the results suggest a different implementation of the available data used by these route planners. Due to a different approach of data use and alternative algorithms, it is not surprising that route planners suggest routes that are not always equal. This research focuses on determining the conformity of these routes with a corresponding desired RSV-route.

Routes between each origin and destination are calculated using all the three route planners. The routes may or may not meet the profile of a standard RSV route (like Fig 2). The profile indicates where routes use roads of lower categories (legitimate or not) and can visualize possible cut-through traffic.

For each origin-destination pair a RSV route is calculated. Next the three routes of the route planners are compared with the corresponding RSV route regarding distance (calculated in GIS) and time (calculated using Google Maps). Both total distance and distance by category are taken into consideration. The distance of RSV-routes should remain within acceptable margin and shouldn't cause a major detour. The tree-like structure of the road network and the road categorization is defined in such way that policy-based 'preferred routes' (RSV-routes) should never result in major detours. The acceptability of a detour can be easily calculated using the following formula: *[shortest route] x [detour factor]*. This detour-factor is 1.4 (Engels, Korsmit, & Lauwers, 1998).

RESULTS

While discussing the results, route planners will be referred to as RP A, RP B and RP C as this study does not intend to evaluate route planners individually.

Shortest or fastest route?

The study shows that the average distance of routes generated by the three route planners is 17.6 km long and the in-between distance deviates on average 10.4%. The routes calculated according to RSV principles are on average 6.5% longer than routes from route planners, which corresponds to approximately 1.1 km over a distance of 17.6 km. This shows that in most cases the RSV-routes do not exceed the maximum acceptable detour (shortest distance x 1.4), as was expected due to the structure of the road network.

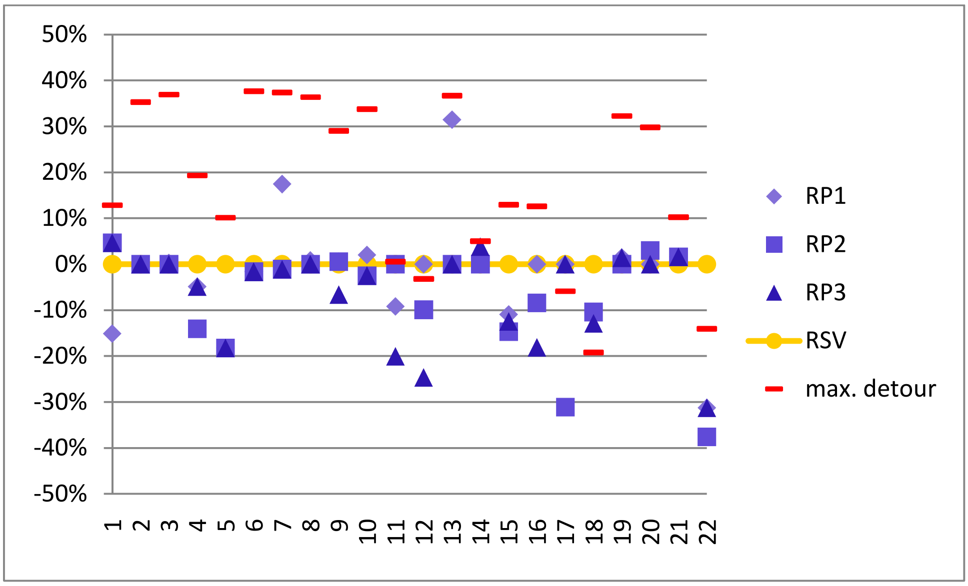

Fig 3: Deviation of distance of 'routes from route planners' vs. 'RSV route'

Figure 3 shows the percentage of deviation between the routes (1 to 22) calculated by the route planners (RP 1, 2 and 3) compared with the corresponding RSV route. The values are calculated as follows: $\frac{Distance\ RP - Distance\ RSV}{Distance\ RSV} \times 100\%$

Positive values imply that the route is longer than the RSV route. The appearance of a majority of RP-markers (blue) below the RSV line (yellow) in the plot confirms that most routes calculated by the route planners are shorter than their RSV-counterpart. The values show that the deviation of 9 routes is smaller than 4% compared to the RSV route. This implies that for 13 out of 22 routes at least one route planner will suggest a route with a deviation in distance more than 4%. Out of 22 RSV-routes, 4 of them exceed the maximum allowed detour distance and therefore could be considered to be unsuitable as alternative routes. However, in some cases the route planners exceed these limits too (routes 12, 17, 18), which could indicate a deficiency of the road network.

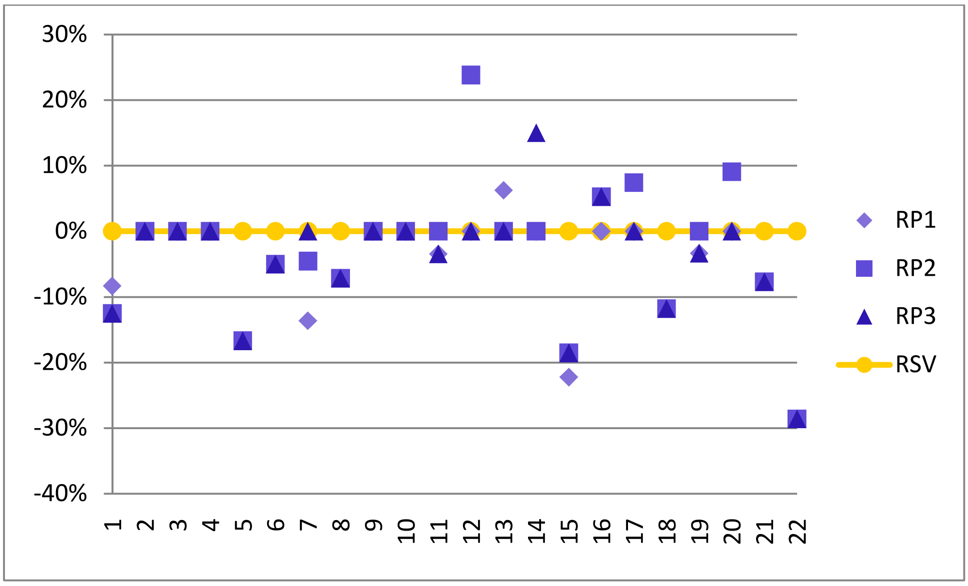

Fig 4: Time difference between 'routes from route planners' and 'RSV route'

The time difference between the routes is acceptable. Fig 4 shows the deviation of the routes (1 to 22) calculated by the route planners (RP 1, 2 and 3) compared to the corresponding RSV route, regarding trip duration (in %). The average time to cover a route using route planners is 19.9 minutes, and 20.9 minutes using RSV guidance. The average deviation of time is 9.7%. Most RSV routes in this study have a longer trip duration, with a maximum additional time of 6 minutes (29%) over a total time of 15 minutes (route 22).

Usage of road categories

The structure of road categorization and the resulting preferred routing aims at reducing the use of lower categorized routes. This is reflected in the results. RSV routes make less use of local roads (21%) than the routes proposed by the route planners (27%). The use of secondary roads (20% for Route Planners and 23% for RSV routes) and primary roads (23% for Route Planners and 21% for RSV routes) presents the least variance. RSV routes will use more main roads (36%) than route planners (29%). These results are shown in Fig 5.

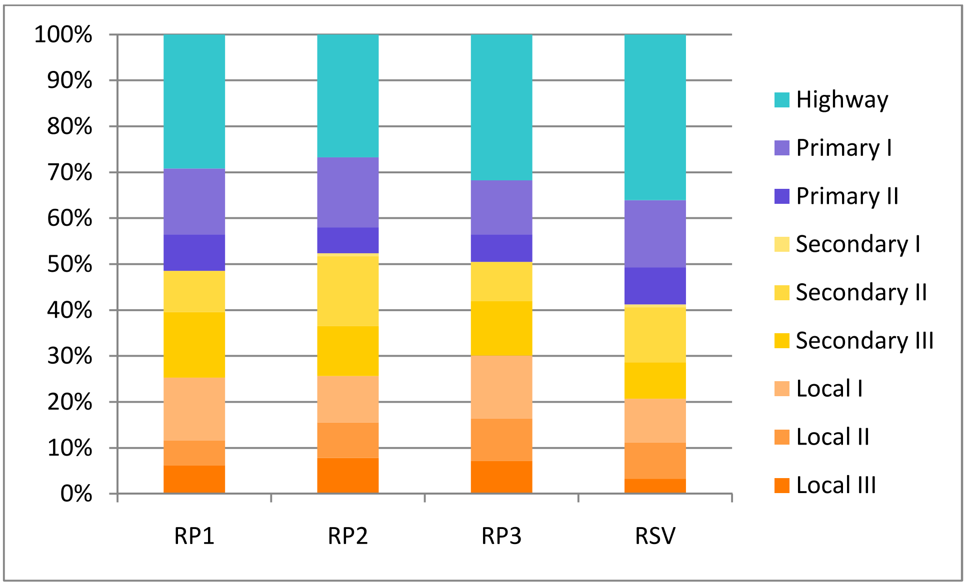

Fig 5: Percentage of road use by category

Special attention is given to the Local roads Type III. This is the lowest category and the roads included in this category are only intended to provide access at the local level, and should be avoided by through-traffic. Local roads type III include residential roads, shopping streets, agricultural roads, and other roads with the function to give access. Fig 6 shows the percentage of routes using the local roads Type III. A distinction is made between the road use at the origin or destination of the trip, and the road use during the trip. The use of local roads type III at the start or end of a trip is in accordance with the function of these roads. However, during the trip this can be considered as cut-through traffic (the *hatched* part of the column). The routes of route planners will send road users on trips of which (on average) 7.0% of the used roads will be along roads of the category ‘local road type III’. More than half of this road use takes place during the trip (4.5%). Trips along RSV routes minimize the total use of this category of roads to 3.3%, of which 1.6% takes place during the trip.

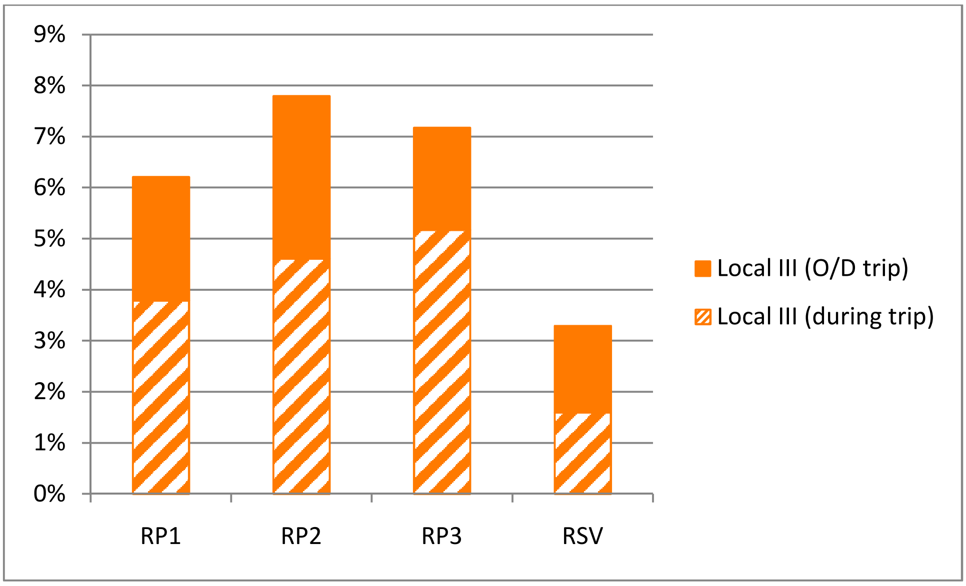

Fig 6: Percentage of road use of the category ‘Local Road type III’

Example route

The desired route according to RSV, using the policy-made categorization, starts and ends for the most part at a local road using higher classed roads in between, as represented by the profile in Fig 2. As an example, a closer look will be taken on a route with origin in Lier and destination in Aartselaar. The route planners all propose a different route. One of these routes corresponds to the RSV route. The routes are shown in Fig 7. The map also indicates the residential areas. The RSV route attempts to avoid these areas by minimizing the use of local roads.

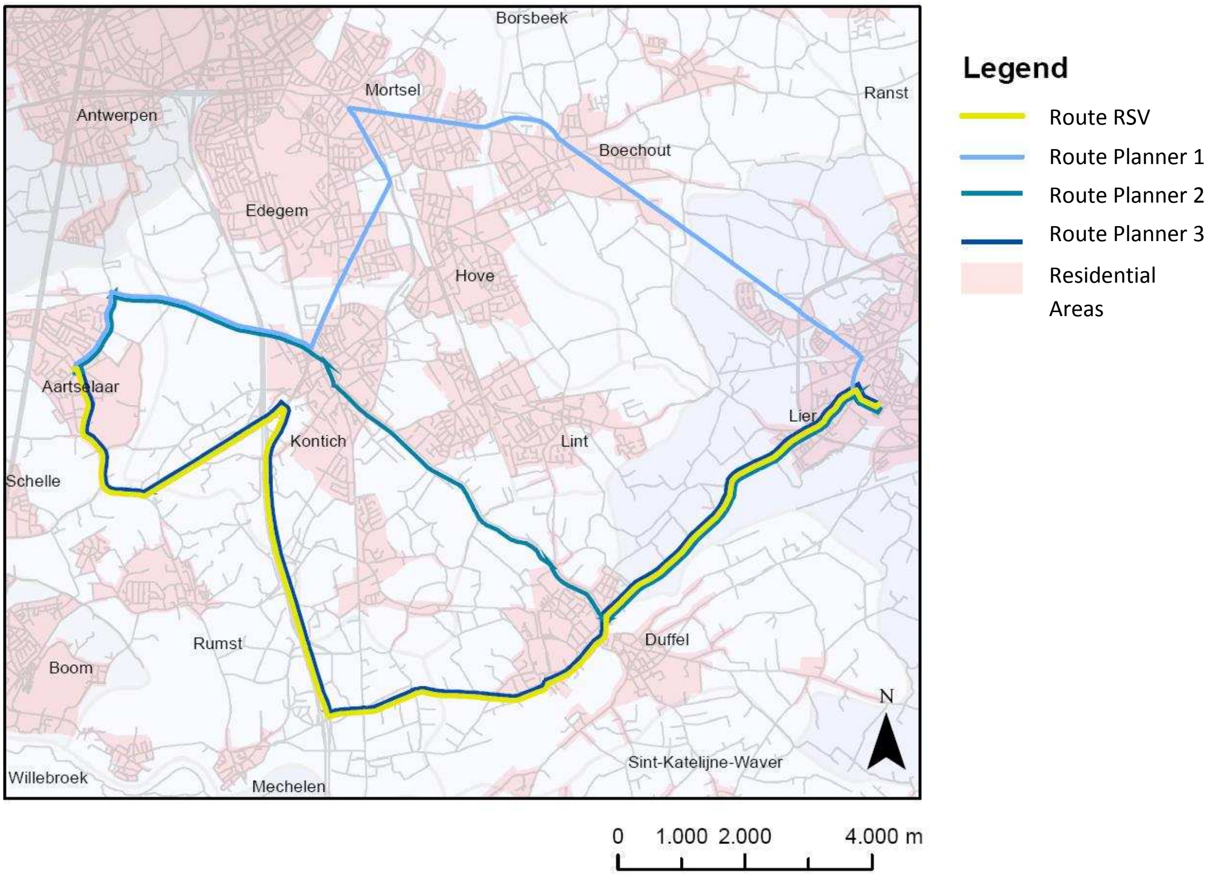

Fig 7: Trip Lier-Aartselaar according to different route planners

The profile of a route for each of the route planners is shown in Fig 8. The RSV route and Route C are identical and present a profile at which the use of local roads only occurs at the start and end of the trip (19.5% of the trip on local roads). Route B applies a limited use of the Secondary roads (26.2%), and proposes a route which uses primarily local roads Type I and Type II (70.1%). The profile of route A shows that Local roads Type III are used during the trip, but not to give access to the destination point. This route differs from the RSV-principles. This route also goes through residential areas in Mortstel and Edegem.

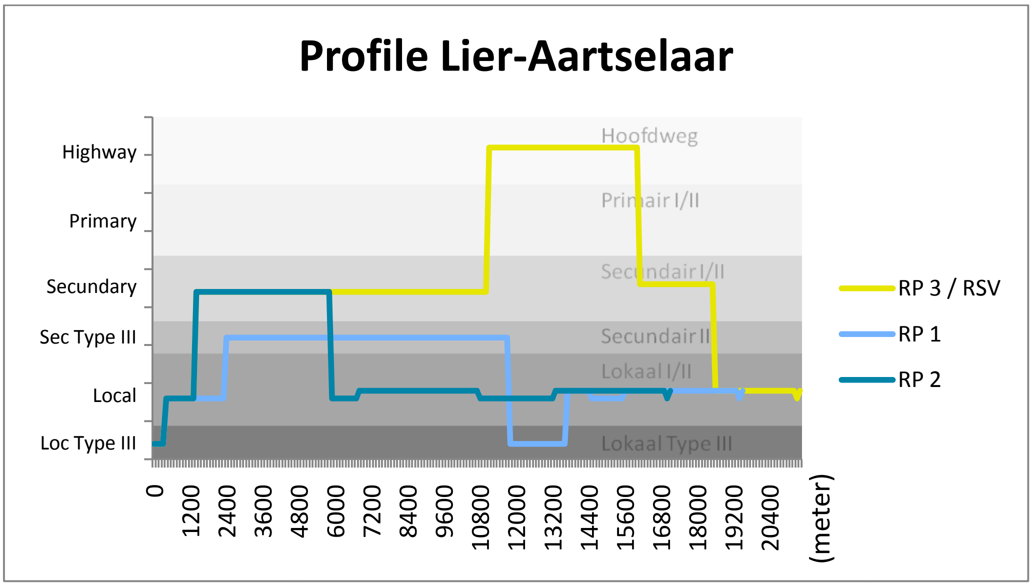

Fig 8: Profile of trip Lier-Aartselaar according to different route planners

Route B has the shortest total distance (17.1 km), followed by route A (19.5 km). The RSV-route and route C are 21.4 km long. The difference in trip duration, 28 minutes for route A and B and 29 minutes for route C and RSV-route, is minimal.

CONCLUSION

The aim of this study is to demonstrate to what extent the existing policy-made road categorization, based on the principles of the Flanders Spatial Structure Plan, is implemented by route planners, and whether these principles may contribute to a more sustainable route navigation. Particular attention is given to the use of local roads by through-traffic. The methodology used in this study analyzes the used road categories along routes generated by route planners. A comparison of these routes with 'preferred' RSV-routes illustrates a difference in road use and highlights the possible excessive use of local roads by through-traffic due to the use of route planners.

The findings of this study show that the routes calculated according to the RSV principles are on average 6.5% longer than routes suggested by route planners. The duration of a trip along a RSV route is slightly longer than trip duration of route planners, but limited to an increase of 6 minutes. This implies that, taking a limited detour and loss of time into account, routing algorithms could take into account the RSV road categorization while calculating a route. Routes based on the RSV make less use of local roads (average 21%) than routes proposed by route planners (on average 27%), and make more use the highways (36%) than route planners (29%). By applying RSV routes, the use of local roads Type III can be reduced from 7.0% to 3.3%, and it can limit the use of this low level roads during the trip from 4.5% to 1.6%, to only give access at the beginning and end of the trip. This illustrates that route planners make more use of local roads. A reduced use of local roads could decrease the amount of traffic in residential areas and may contribute to the livability of the area.

For the calculation of RSV routes in this study, the existing policy-made road categorization is used. New interpretations of the road categorization in Flanders are possible, with enhanced attention to road safety, multimodal use, multiple functions of highways in urban areas, etc… This may influence the 'preferred' route due to addition of other features and parameters to the routing algorithm. In addition, strict appliance of the functions of the various categories can lead to implausible routes, for example, by avoiding a main road for travelling on a local level although this main road is the most appropriate route choice.

A routing based on road classification is static. If an incident or congestion occurs along a 'preferred' route, an alternative route will be sought on the local road network. But can a routing method, based on the principles of the RSV, make the adjacent road network available? The study "Cut-through traffic in the South-East of Antwerp (Keppens, Lauwers, Rottiers, & Dotremont, 2007) shows that RSV road categorization is unable to form a solid basis to deal with traffic in congested networks. Further research is needed to - in addition to normal traffic situations - include dynamic routing options.

This study serves as a starting point to examine if sustainable route navigation is feasible, and if the existing policy-made road categorization and other environmental parameters (e.g. presence of schools) can offer added value. After all, route planning straight through villages and residential areas leads to increased problems of cut-through traffic (Keppens et al., 2007).

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