

“TOOLS FOR EFFICIENT AND SUSTAINABLE MANAGEMENT OF THE ROAD NETWORK IN SMOLYAN BY GIS TECHNOLOGY”

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ABSTRACT

The main priority is capacity building in the field of mobility and transport planning and monitoring. Therefore the project also aims at working on four different themes: monitoring of both parking and road traffic organization, developing a proposal for improving traffic organization for Smolyan in relation to the territorial development plans of the city and the region, capacity building in the field of methodological tools and instruments. The interest to the technologies for permanent monitoring of the republican road network traffic is growing. The data for the traffic have specific characters as geographic position, linear segmentation, dynamic variables values and volume as function of the time. The necessity from the technology that permits easy and fast presentation and utilization of these characters is appearing. Contemporary GIS technology for traffic modeling and visualization act in concert with cartographic methods can suggest a way for automated mapping of such data.

TRAFFIC MODELLING

Traffic models are computer models, which are used to describe and analyse different aspects of transportation and traffic flows. The complex reality of traffic is simplified in such a way, that it can be described using mathematical algorithms. These simplifications can deal with the area and the time period which are covered by the model, or concern which aspects of traffic (traffic patterns, traffic flows, traffic noise, traffic emissions, ...) are (and are not) studied in the model.

Typically the model building has to find a compromise between three restrictions:

- the size of the model area;
- the level of detail;
- available resources (computer capacity, availability of input data, personnel, ...).

The resources for model building a model will generally come down to the financial resources, which are mostly determined by the project budget, and therefore cannot be influenced.

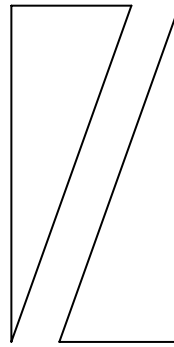
This means that in practice, equilibrium should be found between the size of the model area and the level of detail: it is not possible to study a much extended area into the smallest details.

MODEL AREA

MACRO MODELS

MESO MODELS

MICRO MODELS



LEVEL OF DETAIL

Figure 1: Different types of traffic models

This has led to different types of models, depending on the size of the modelled area:

- macro-models aim at modelling larger areas, implying a lower level of detail. This means that these traffic models focus on the general traffic patterns and traffic flows in a region. Starting from social and economical data (inhabitants, employment, ...), these models calculate the amount of generated traffic and the resulting traffic intensities per link.
- micro-models aim at modelling traffic at a very detailed level, which means that these models deal with very restricted study areas. These models allow analysis on the design of road infrastructure, junction design and the programming of traffic lights. This is done by simulating the driving behaviour of each individual vehicle, taking into account the characteristics of the road infrastructure, the vehicle and the driver.
- meso-models fill the gap between macro- and micro-models. These models analyse traffic in an intermediate model size at an intermediate level of detail.

The following picture shows a typical view of a macro-model. For each road in the model network, the estimated amount of traffic is visualised by the color: yellow links have a small amount of traffic, light and dark green links have more, orange and red links carry the heaviest traffic flows. In this case, for example the Ring road and the incoming highways are clearly recognised by the red colors.

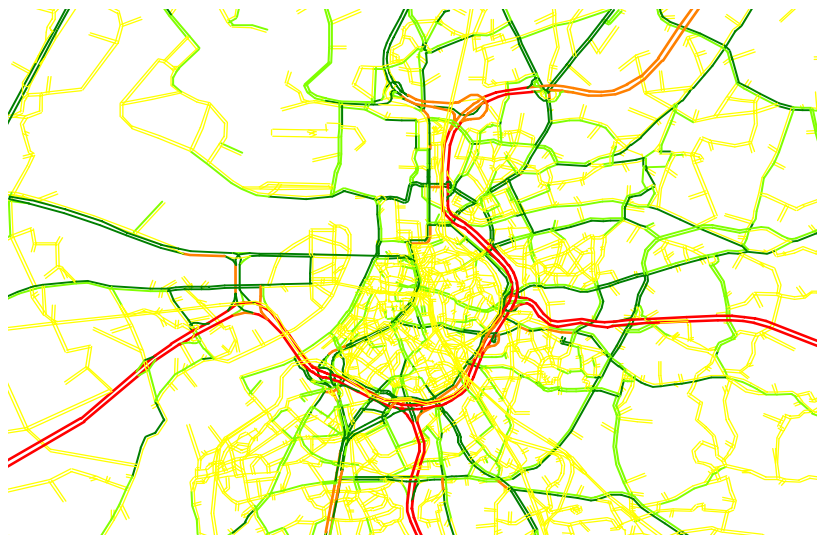


Figure 2: Example of a macro model output

A micromodel on the other hand, give a much more detailed view of the traffic behaviour, queue lengths, time loss, etcetera. An example is shown in the following picture. It is clear that this type of models is very useful to visualise traffic designs and evaluate the capacity of roads and junctions.

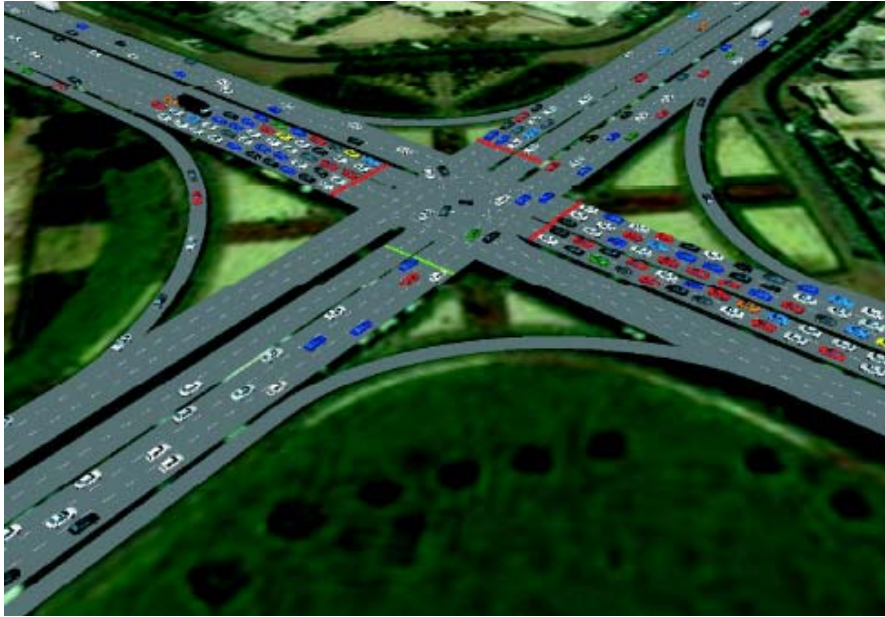


Figure 3: Example of a micro model output

BACKGROUND ON MACRO-MODELS

The classical traffic model consists of four consecutive steps, calculating traffic production, traffic distribution, modal split and route choice or assignment. For this reason, they are often referred to as ‘four-step-models’.

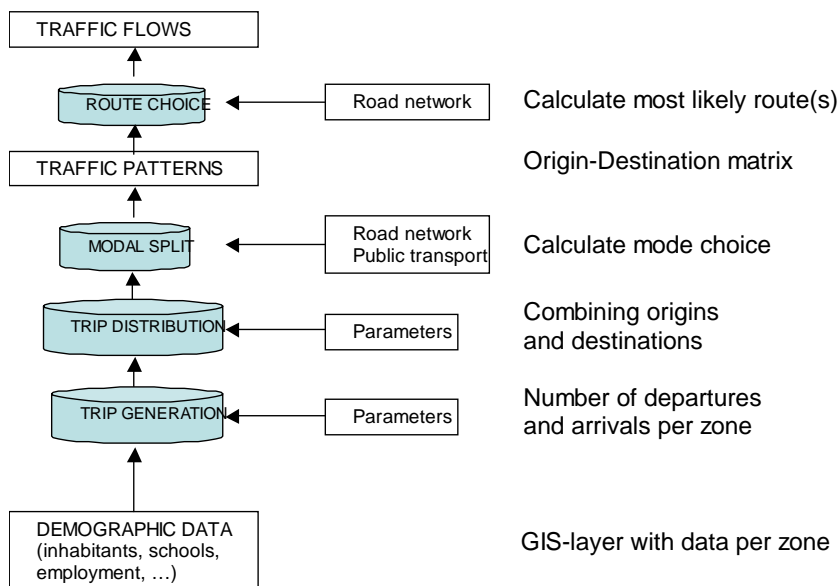


Figure 4: Structure of a Four-Step Model

The most vital part of the traffic model is the estimation of an “origin-destination-matrix” (OD-matrix) for the modelled area. This is a matrix with all model zones in its rows and columns, with the matrix cells showing the estimated amount of trips between each pair of origin and destination zones.

The calculation of this OD-matrix is mainly based on a set of demographic data. The model area is divided into traffic zones, each linked with a set of attributes, describing the different functions within the zone: inhabitants, employment,

shops, schools, industry, ... The quality of these data (accurateness, level of detail, ...) will of course determine the quality of the model.

Figure 5: The Origin-Destination matrix (OD-matrix), core of the macro model

The first step of the macro model calculates the expected traffic production and attraction per zone. Starting from the demographic data, this step estimates the amount of trips starting from each zone and the amount of trips arriving in each zones. These amounts correspond to the row and column totals of the OD-matrix.

Now that we know how much trip leave each zone, the next question is where these trips are heading to. In a mathematical way, this means that the matrix cells are estimated, for a given set of row and column totals. This is what happens in the second step of the model, the distribution phase.

The third step is the calculation of the model split. The amount of trips in each matrix cell is now split into the amount of car trips, bicycle trips, public transport (PT) trips, etcetera. The OD-matrix is now split into a car matrix, bicycle matrix, PT-matrix, and so on.

The fourth and final step is the called the matrix assignment. For each pair of origin and destination zones, the optimal route is determined. Different techniques are available, for example depending on whether the restricted link capacity is taken into account.

For each pair of zones, we now know the amount of traffic between them, and we know what route(s) is (are) used. For each link in the model network we can total the amount of (car) trips that is expected to use this link. This total gives an estimation of the expected traffic flows.

BUILDING THE SMOLYAN TRAFFIC MODEL

The Smolyan traffic problems mainly deal with the regional traffic: different types of traffic streams pass through Smolyan and the main challenge is to make each kind of traffic use the roads that are meant for this traffic: the central Bulgaria Boulevard is an urban axis, supposed for urban traffic, while the Magistrale ringroad is constructed as a by-pass for regional and long-distance traffic.

For the building of a macro traffic model, the following data is required:

- demographic data for the estimation of the OD-matrix;
- a traffic network for the route calculation;
- traffic surveys for the model calibration and validation. These can be classic traffic counts, but also origin-destination data or even speed data are very useful.

It is logical that the quality of these input data will largely determine the quality of the traffic model. The “quality” incorporates the accuracy of the model network and the link attributes, the reliability and level of detail of the demographic data and the amount and representativity of the traffic surveys.

To build the traffic model of the city of Smolyan, the following input data has been used:

- traffic network was based on existing with existing GIS-layers, checked and completed using road maps of the town;
- demographic data for the town of Smolyan were collected by the municipality. The center of Smolyan and the surrounding area were divided into logical zones. For each zone demographic data were collected or estimated.

- Traffic counts were based on two sources:
 - For the national roads, count data from the Road Agency were used. These data have the advantage that there is a set of fixed count locations, which allows an evaluation of the historic traffic growth over the last years, and which increases the reliability of the counts, as these locations are counted during several days.
 - For the municipality roads however, these data are insufficient. Therefore additional traffic counts were carried out. These counts consisted of about 10 cross-section traffic counts (counting the total amount of traffic in each direction) and three junction traffic counts distinguishing between the different turns (traffic going left – right – straight on).

APPLICATIONS OF THE SMOLYAN TRAFFIC MODEL

In this chapter we will demonstrate some of the possible applications of the Smolyan model. In general we distinguish the following applications:

- analysis of the current traffic patterns in the modelled area;
- estimation of the traffic flows in different scenarios;
- further analysis of the traffic patterns in these scenarios.

Analysis of the current traffic patterns

The model is developed for the current traffic situation. This means that it is calibrated in such way that it gives a reliable representation of the actual traffic. The model structure, the input data, the parameter settings are chosen so that the model results reflect what happens in real life. Hence the importance of good traffic data, as these data is the base to determine how good the model meets reality.

The following picture gives an impression of the model results: the amount of traffic on each link is represented by its colour and its width. Yellow and green links have less traffic, orange and red links have more traffic.



Figure 6: The Smolyan model: traffic flows in the current situation

Although traffic counts are available for only a few roads in the network, the model allows a reasonable estimation of traffic on the entire network. We see that the busiest axis is the historic road through the town center, while the “Magistrale” Ringroad carries relatively little traffic. From this picture it is clear that this ringroad does not fulfil its original purpose, as it should be the main connection for long distance through traffic. As a consequence most traffic passes through the center, where it has a lot of negative impact on the living quality of the town.

The traffic model allows some additional possibilities for evaluation of the traffic situation. For example, by comparing the traffic flow on each link to the road capacity, we get an idea of the bottlenecks in the network. This is represented by the I/C-ratio (Intensity / Capacity – ratio). The picture below shows the spare capacity on each link. Green links are links with spare capacity to draw more traffic. The wider the green link, the more reserve there is for additional traffic. Orange links are links where traffic flow exceeds the road capacity.

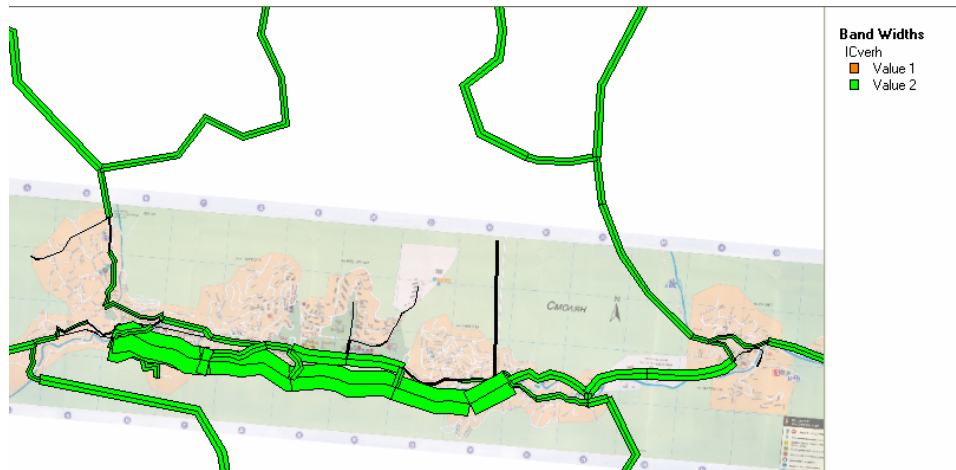


Figure 7: The Smolyan model: free capacity in the current situation

From this picture we learn the roads in the center are very near to capacity. Certainly in the center of a (quiet and touristic) town, this is a very uninteresting situation.

Another application is the traffic model is the 'selected link analysis' (SLA). This means that the origins and destinations are visualised for one specific link in the network. In the following picture we made such an analysis for the red link. For all traffic using this link, the yellow bands show how much traffic uses the other roads. The further we go away from the red link, the less traffic uses the red link. We also see that a large part of the traffic on the red link is local traffic with an origin or destination within the center of Smolyan. The share of long distance traffic driving out of Smolyan is rather low.

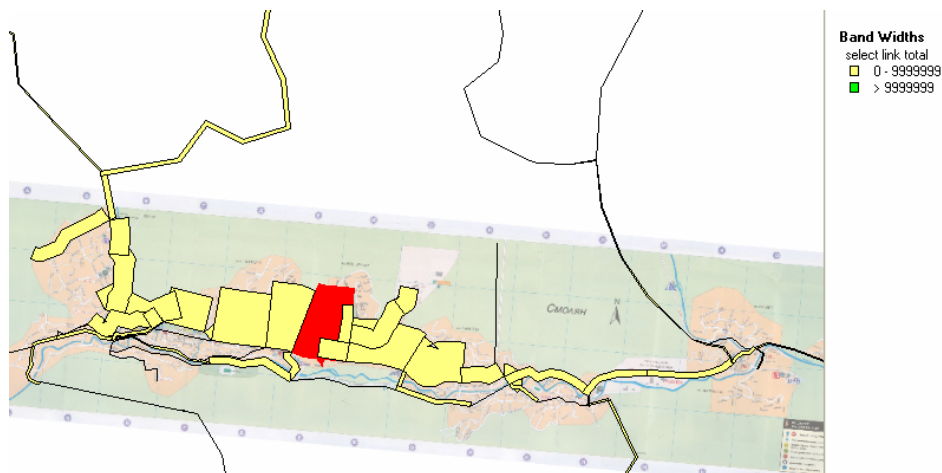


Figure 8: The Smolyan model: selected link analysis (SLA) on Bulgaria Boulevard

Traffic flows in different scenarios

Starting from the base model, we can now calculate different traffic scenarios. By changing the input data of the model, we can evaluate the according changes of the traffic flows. These changes can affect different topics:

- demographic changes: traffic generated by new spatial developments (new urban area, industrial zone, ...), by population growth, ...
- changes of the Origin-Destination patterns: effect of a general traffic growth (annual growth rate);
- network changes: these can be changes in the road network: construction of a new road, adding an extra lane to an existing road (or deleting a lane in favour of a bus lane...), changing the maximum speed, ...

Scenario 2015

For example, in the Smolyan model, a scenario for the 2015 situation was elaborated. Using an estimation of the annual traffic growth and of the additional traffic generated by the new border crossings towards Greece, the model calculates the expected amount of traffic in the year 2015.

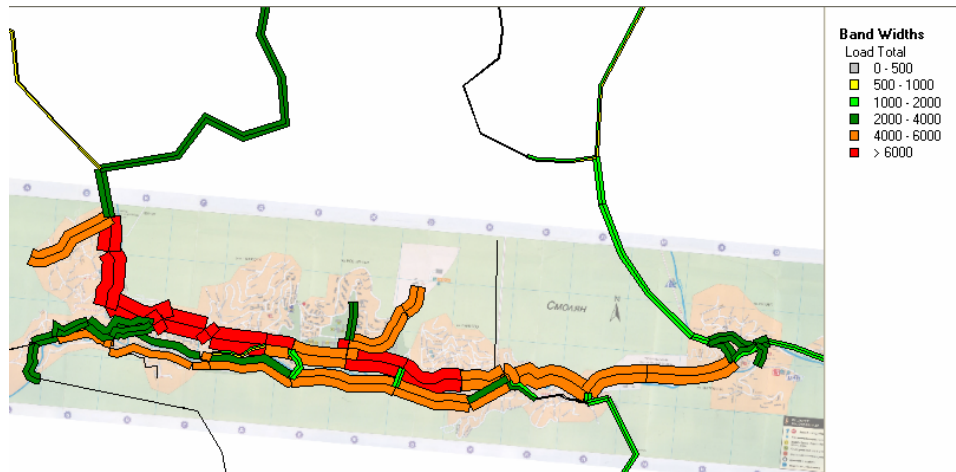


Figure 9: The Smolyan model: expected traffic flows in the 2015 scenario

From this picture, we see that the general situation looks similar to the current situation: most traffic uses the road through the city center, while the amount of traffic on the ringroad is lower. Both in the center as on the ringroad, there is more traffic than nowadays. Nevertheless it is hard to draw clear conclusions from this view: on which links does traffic grow? And how strong is the growth? On which links does it decrease?

Therefore scenarios are often represented using a 'difference plot' in order to compare different scenarios: roads with a traffic growth are shown in orange, roads with a traffic decrease are shown in green. The width of the link shown the size of the increase or decrease.



Figure 10: The Smolyan model: difference plot of scenario 2015 compared to the current situation

In the Smolyan case, we see that the largest traffic growth is in the city center. Furthermore we recognise an increase from the traffic to and from the new border crossings with Greece. This traffic enters Smolyan from the South (car traffic) and East (freight traffic).

As there is hardly any free capacity to capture more traffic on the Bulgaria Boulevard, the congestion in the city center gets even worse. As a consequence the additional traffic is forced to start using the ringroad. The increase of traffic on the ringroad is a positive effect, but this scenario is not preferable, as no solution is offered for the problems in the center.

Scenario 2015 with extension of the ringroad

It is clear that, in order to improve the living conditions in the center of Smolyan, traffic should be diverted from the central Boulevard towards the ringroad. A possible scenario could be the extension of the existing ringroad. One of the main reasons for the low traffic flows is the poor connection to the other National roads. For example at the west end, the ringroad ends on a local road in order to connect further on to Plovdiv. Therefore a solution could be the construction of an additional part of the Ringroad, leading traffic from Plovdiv around the center towards the Ringroad. This scenario was calculated in the model:

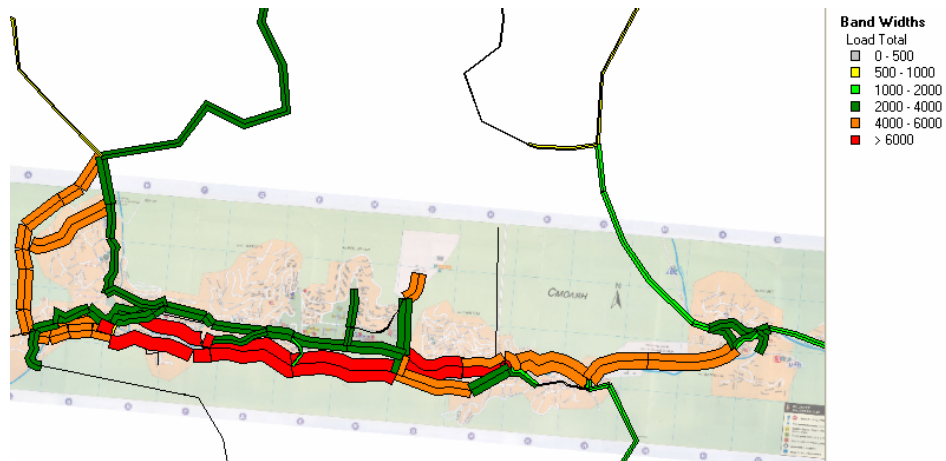


Figure 11: The Smolyan model: expected traffic flows after extension of the ringroad

It is clear that the new ringroad attracts an important amount of traffic. The traffic on the Boulevard drops down to the green level, which is a clear decrease in comparison, the situation without the extended ringroad. This can also be seen on the following difference plot:

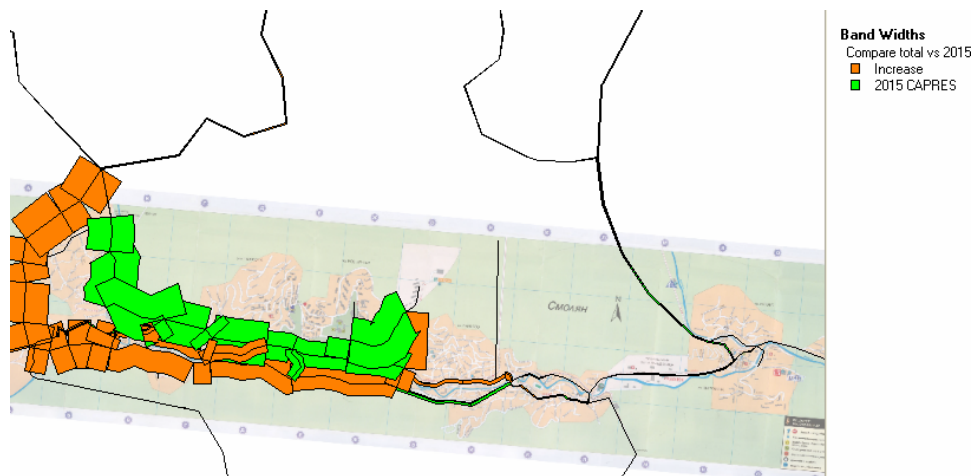


Figure 12: The Smolyan model: difference plot: situation with the ringroad extension compared to the situation without the extension

This plot shows the differences between the situations with and without the extension of the ring road. Orange links will have more traffic after the construction, green links will have less traffic. In this case we clearly see how a considerable amount of traffic changes its driving behaviour, and will start using the ringroad, instead of using the Boulevard, as they do nowadays.

Of course one should remark that this traffic model only shows the traffic effects, and therefore decisions can never be based purely on the traffic model. In this case, the clear traffic advantages should be evaluated to e.g. the construction costs and the environmental impacts.

Analysis of the traffic patterns in the scenarios

The same evaluations as we described in chapter 0, can also be applied for the scenarios.

Scenario 2015

For example, we can look at the I/C-ratios in the 2015 situation. Here we see that on most sections of the Boulevard, traffic has reached capacity, and roads are completely full, resulting in congestion problems, queues, noise and emission problems, poor living conditions, ... On the ringroad, there still is plenty of free capacity.

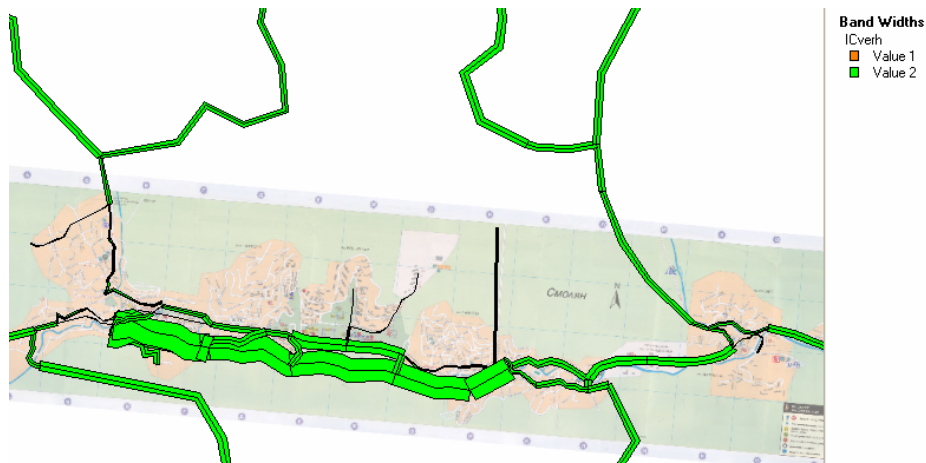


Figure 13: The Smolyan model: free capacity in the 2015 scenario
Scenario 2015 with extension of the ringroad

After constructing the new part of the ringroad, traffic in the center decreases, and shifts towards the ringroads. This means that traffic congestion within the center of Smolyan decreases. This can be seen in the plot of I/C-ratios. In this case there is some free capacity on the central Boulevard (even though the section near the shopping area is still very full).

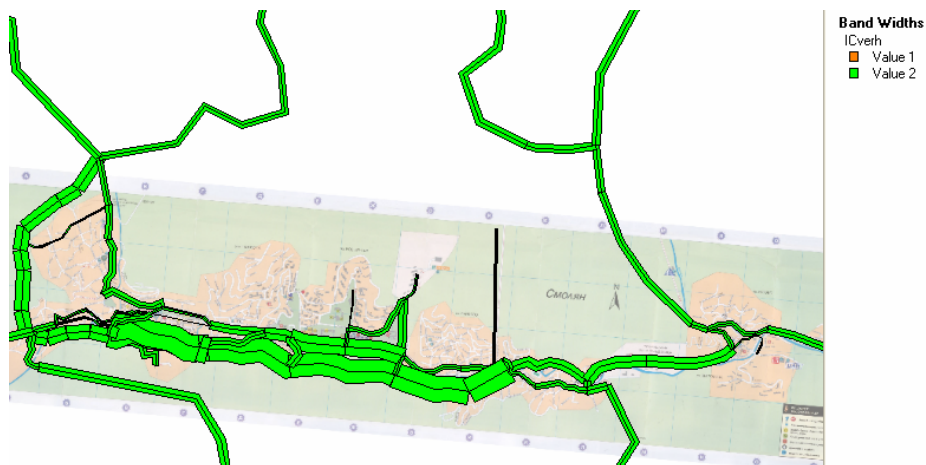


Figure 14: The Smolyan model: free capacity in the situation after extension of the ringroad

Further traffic analysis for this scenario is possible. For example, using selected link analysis, we can evaluate what type of traffic is using the different roads in the network. The following picture shows such an analysis for the traffic entering Smolyan from the North (the red road coming from Plovdiv – Pamprovo):

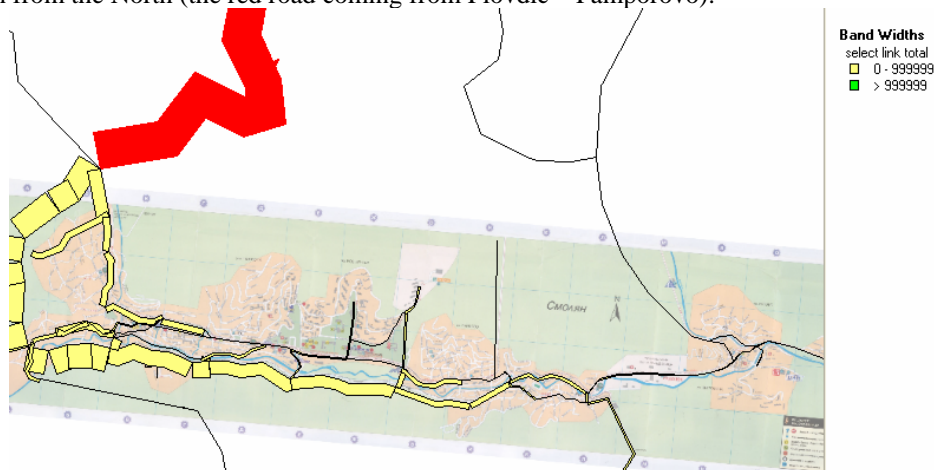


Figure 15: The Smolyan model: selected link analysis of the traffic coming in from Pamprovo

We now see that the major part of this traffic prefers to use the new ringroad. Only the traffic towards the very north-western part of town and a part of the traffic to the historic center prefer to use the current roads. Traffic towards the administrative center of Smolyan or beyond, prefer to use the ringroad and enter town at a further junction. It can be concluded that, purely from a traffic engineering view, this is a much better situation than nowadays, and the living conditions in Smolyan would benefit a lot from such a traffic reorganization.

FUTURE DIRECTIONS

There are several directions in which the traffic modeling and visualization could be expanded. As we already mentioned, adding the **timestamp (hour, date, day of the week)**, improving urban GIS data (demographic and social) and the direction of traffic as part of the data then the efficiency of the system would increase significantly. This will allow to visualize one of the results of traffic, namely – congestions in real-time with the capability to do comparative analysis with prior periods of time including the possibility of adding more attractive cartographic visualization methods such as animation. The **sign system** could be further developed improving the artistic appearance of the visual features (shape, color, orientation, texture, etc), work in different scales, including user preferences. Adding **diagrams** that represent summarized and processed statistical data for the traffic flow, and etc. The system must necessarily be adjusted for **Internet** use, **GPS and mobile communications** – data transfer in on-line mode and mapping in real-time. The dynamic nature of the data need not be manifested only in the geographic position, but also in the generation time, transfer, processing and mapping that is possible thanks to these technologies.