Towards simulation-based sketch planning, part II: Some results concerning a freeway extension in Berlin[1]

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1 Introduction

VSP working paper number 08-22 (see www.vsp.tu-berlin.de/publications) was a study of how to use MATSim (see www.matsim.org) for a version of planning that would allow fast turn-around of results and thus possible rapid interaction with stakeholders. Similar work is now presented here for the A100 extension in Berlin.

The A100 extension is politically sensitive terrain. The results here are meant as input to a discussion. As such, they will hopefully be used to facilitate informed decision-making.

2 Inputs

The results presented here are based on a model. Any model needs inputs. They will be described here. The description here will not be complete; it is meant as a first sketch. More information can, for example, be gained through our publications, see the link above, or through the matsim web page, also see the link above.

2.1 Network

Transport simulation models need digital road data as input. The input data for the current study is extracted and converted from www.openstreetmap.org („OSM"). The precise procedure that was used for Berlin is not yet documented; a description of the mechanics can be found under matsim.org/node/608.[2] Critical elements are

- the translation of the OSM street types into flow volumes, i.e. how many cars per hour the link can maximally process. Although this sounds very critical, in our experience this has less influence on the congestion structure than one may think since traffic v mflows adjust so that the traffic jam patterns are equilibrated. That is, flows may be wrong, but travel times and thus congestion patterns are usually still correct. Clearly, one needs to be careful with cost-benefit-analasysis for such links since the number of affected travelers is wrong.
- Public transit is not simulated in detail although MATSim is capable of this (see matsim.org/docs/tutorials/transit). Adding detailed public transit makes the simulation system much more complicated, which is against the intention here.

Since the OSM network was extracted in 2010, it roughly reflects the network status in 2010.

2.2 Demand

Transport simulation models need some information about the demand for travel. The demand for the current study is derived from a so-called „BVG household survey" from 1994. That survey contains, for 2% of the population, trip diary information about what a person did on a specific day. A trip diary normally contains a sequence of activities – such as „home", „work", „shop", etc. –, their locations, their start and end times. Importantly, the trip diary also contains how the person moved from each location to the next, i.e. the mode or modes that were used. The actual paths are

[1] A typo in the title was removed on 6-jul-12. Apart from that, the paper is from 30-sep-11.

[2] That URL is probably not very stable. If it does not exist any more, go to matsim.org/docs/tutorials, search for a "recent" tutorial, and go to the "network" section of the tutorial. Alternatively, search for "osm" under matsim.org.

normally not contained in the (German) surveys and are thus generated by MATSim. Little „official" information seems to be available about this data set although it is used in several studies.

Overall, this means that the demand is from 1994 while the road network is from 2010. As we will show below, a comparison to real world counts (from 2008) implies that the simulations are still useful. Unfortunately, there was already a significant construction measure (the A113) exactly in the area of interest, implying that specifically in the area of interest demand may have changed significantly between 1994 and 2010. It would be better to use the results of the SrV'2008 (http://tu-dresden.de/die_tu_dresden/fakultaeten/vkw/ivs/srv).

2.3 The traffic simulation model

Also the traffic simulation model itself can be considered input, since the underlying program code is also just a text file. MATSim (Multi-Agent Transport Simulation, once more see www.matsim.org) is based on 20 years of experience with traffic simulations; the current code base started around 2005. Any computer code can contain errors. The following is done in order to increase the quality of MATSim:

- The source code is available from the web. We believe that this is helpful to encourage everybody to go through the code, since no documentation will ever be able to document every last wrinkle of a computational model.
- Numerous scientific publications use MATSim as their computational engine. This means that there is a quality management process through peer review and through peers reading (and criticizing) our publications. This also helps ensuring that MATSim uses state-of-the-art methodology that is accepted by the scientific community.
- The project uses an automatic build server with regular regression tests (see www.matsim.org/tests and ci.matsim.org:8080). Although it is well known that it is impossible to write regression tests that cover all possible execution paths of a software, this is still helpful to ensure that at least the functionality covered by the test cases will not be removed accidentally. There are more than 1000 test cases that run after every modification of the code.

Clearly, in spite of all our efforts, MATSim may contain errors, both conceptual and programming errors. We are working hard to make the number and significance of these errors small.

Additional remarks:

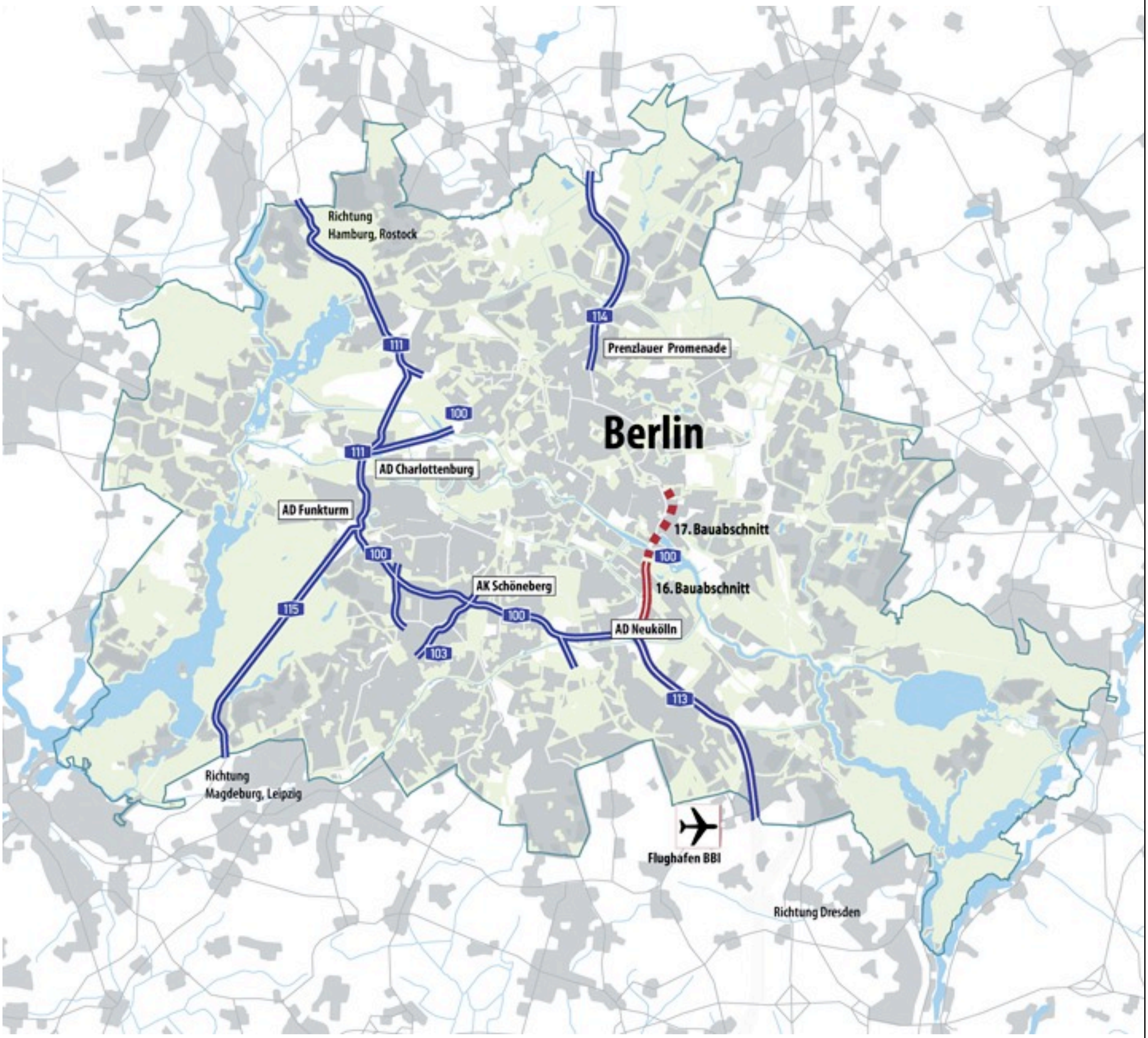
- The simulation model is stochastic. That is, running the same scenario twice can lead to different congestion patterns. „Typical" congestion patterns are usually stable between such stochastic runs, but there are often additional fluctuations on top. As a result, the so-called signal-to-noise ratio needs to be strong enough before policy-relevant statements can be made. The research is currently not far enough to automatically differentiate between signal and noise, and in consequence intuition is needed.

2.4 2% sample

The household survey contains a 2% sample of the Berlin population. The simulation is directly run with the demand from this 2% sample. This speeds up the computer running times quite considerably. More realistic results, however, can be obtained by expanding the demand to, say, 10%. Since this work was about an approach to fast turn-around, this option was not used in the present investigation. All simulation results are scaled up to 100% before presentation.

2.5 The construction measure

The construction measure that is to be considered is the 16th construction section ("16. Bauabschnitt") of the A100 ring. There is also a possible 17th construction section, which is not considered in the present investigation. See the following figure.



(Source: http://www.stadtentwicklung.berlin.de/bauen/strassenbau/a100_16_ba/de/verkehrsnetz.shtml in Sep'11)

Figure 1

3 Base case

At first, we just look at the base case, i.e. at simulation results *without* the freeway extension.

3.1 Comparison with reality

As a plausibility test, we compare our simulation results to real world counts. The counts available and used here are from 2008. They were obtained from a variety of sources, including the so-called VMZ (Verkehrsmanagementzentrale, www.vmz-berlin.de).

The results of this comparison are illustrated in the appendix (Sec. 9.1).

It is quite difficult for the non-expert to judge the realism of the simulation from such comparisons. We would argue that there are few if any models that are better than this model when compared on the basis of hourly counts. Unfortunately, such comparisons are typically not published so it is difficult to find comparable results (this statement refers to hourly counts, not, say, daily or annual counts). Also, one needs to be careful to not be too demanding: It is possible to bring the error much closer to zero with corresponding calibration methods; in such situations, however, one typically loses predictive power.

These are results which should also be obtainable from other models, for example from the planning models that the city administration is using. It would be interesting and useful to compare those results to our results.

3.2 Spider analysis

The following contains results of a so-called spider analysis. For such an analysis, one

- determines a certain link
- determines all trips that are using the link during a certain period (here: a full day)
- plots the paths of all those trips on top of each other

Details are shown in the appendix (Sec. 9.2).

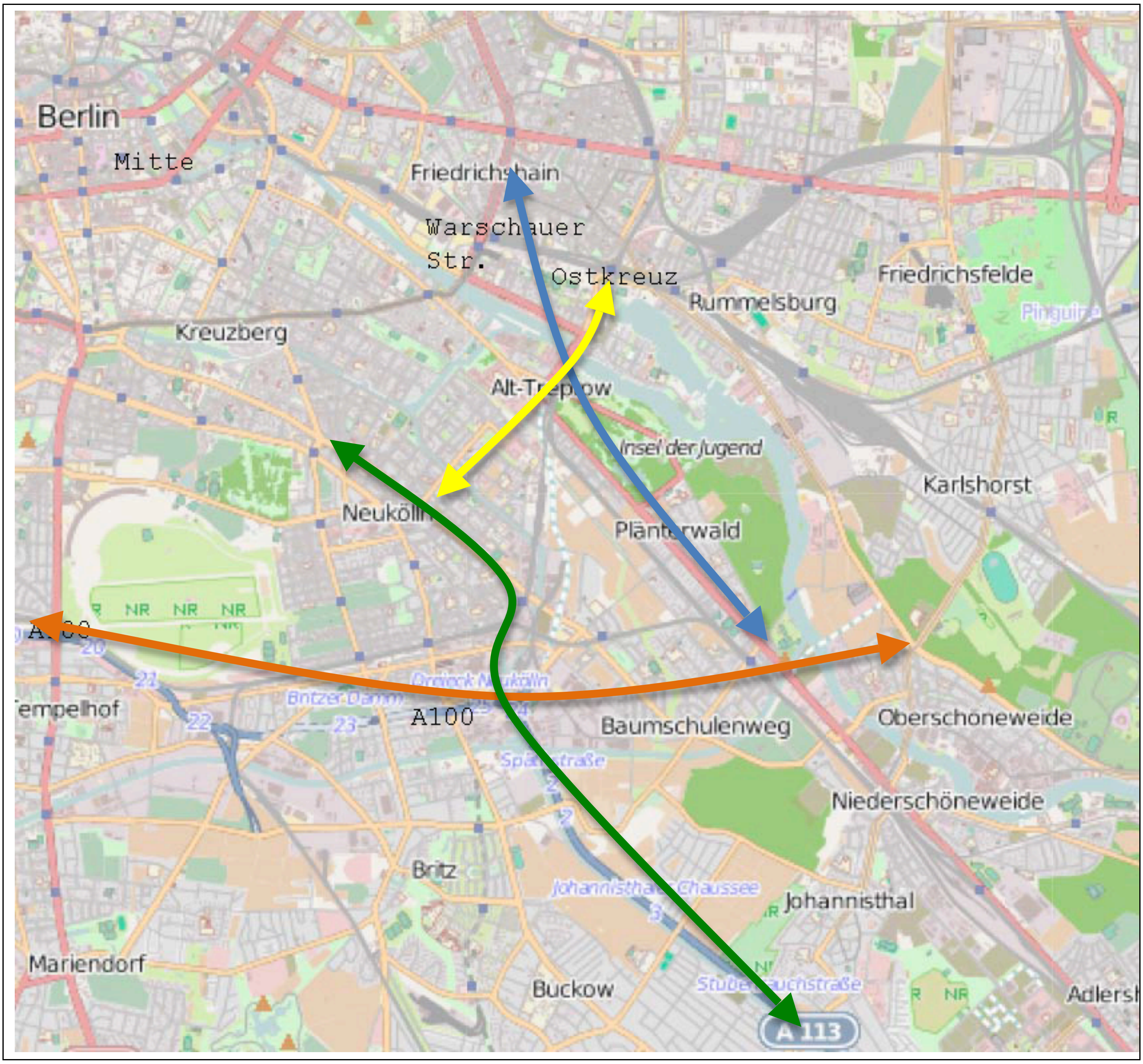


Figure 2

Overall, one seems to have the following distinct to/from relations going through the area of interest:

- green: A113 (southeast) ↔ Berlin Mitte
- orange: A110 (west) ↔ direction Karlshorst
- blue: Plänterwald/Adlershof ↔ Warschauer Str.[3]
- yellow: Neukölln ↔ Ostkreuz area

It seems noteworthy that there seems to be little demand in terms of the "ring" (i.e.between A100 in the west and "Ostkreuz").

[3] This text attempts to use geographical names which are also in the maps. Those names may not always be the same that a native would use.

One could, however, argue that a function of a ring is not only along the ring, but also to distribute incoming traffic tangentially before it enters into the city area. In that sense, the traffic coming from the southeast and going towards the city centre could be seen as traffic that should first take a radial freeway (A113) and then a ring road before it makes it final push into the city centre.

These are results which should also be obtainable from other models, for example from the planning models that the city administration is using. It would be interesting and useful to compare those results to our results.

4 With BA 16 without mode choice

The 16th construction section was now added into the simulation model. Since this is a regional simulation model, details of the connection into the secondary network are not modelled with a high level of detail. In the simulations done here, it was simply assumed that those connections would have enough capacity. It is in our opinion it is nearly always possible to construct such connections, even with limited funds. (One only needs to make the connections wide enough.) It is important to note, however, that sufficient capacity of the connection itself does not ensure enough capacity further down into the secondary network.

Initially, travellers could react to the new road facility by re-routing only, i.e. they could not change their mode of transport (but see Sec. 5).

4.1 Congestion patterns

It would be nice to look at congestion patterns, in particular since those are rather intuitive. In the present case, however, the combination of stochasticity (Sec. 2.3), 2%-sample (Sec. 2.4), and the mismatch between the demand and the network (Sec. 2.2) make a straightforward interpretation difficult. They are thus not presented in this investigation. We hope that a more consistent demand will eventually enable us to present such results.

4.2 Spider analysis

Traffic that connected A100 (west) and Karlshorst in the base case now uses the new freeway.

If the goal was to keep additional traffic away from the center of the city, this may go against this intention.

These are results which should also be obtainable from other models, for example from the planning models that the city administration is using. It would be interesting and useful to compare those results to our results. Although the simulation methods are different, I would expect structurally similar results.

4.3 Average car travel times

The following table contains information about average car trip times in the simulation:

Average car trip time "before"	30min 55sec
Average car trip time "after"	30min 19sec
Change	–36sec
Number of car trips in simulation (scaled to full population)	4’584’600
Time gain per day	45’846h

Notes:

- These gains are not distributed uniformly across the population; rather, some travellers will gain much more wil most others will gain nothing.
- These values alone can possibly justify the cost-benefit result of the BVWP (German assessment exercise). At a value of 3.83Eu/h[4] and assuming 300 days per year at which

[4] BVWP’2003 assumes at least 3.83Eu/h for private traffic, and a lot more for commercial traffic. Let us assume the 3.83Eu/h.

these benefits can be reaped, one obtains gains of more than 52 millions of Eu per year from this component alone. This is a lot.[5]

These are results which should also be obtainable from other models, for example from the planning models that the city administration is using. It would be interesting and useful to compare those results to our results. In this case, the different simulation methods may lead to quite considerably different results.

4.4 Scores

MATSim generates scores, that correspond to units of utility. Those values can be converted to monetary units. This is heading in the direction of cost-benefit-analysis but, for a variety of reasons, this is not yet advanced enough to be used in practice. Since the numbers coming out here seem to point into the right direction, they are presented anyway.

The scores improve about 0.32 in the average, i.e. every agent in the simulation gains 0.32 units of utility. **Every score point ("util") corresponds to 2.45min of reduced travel time.**[6]

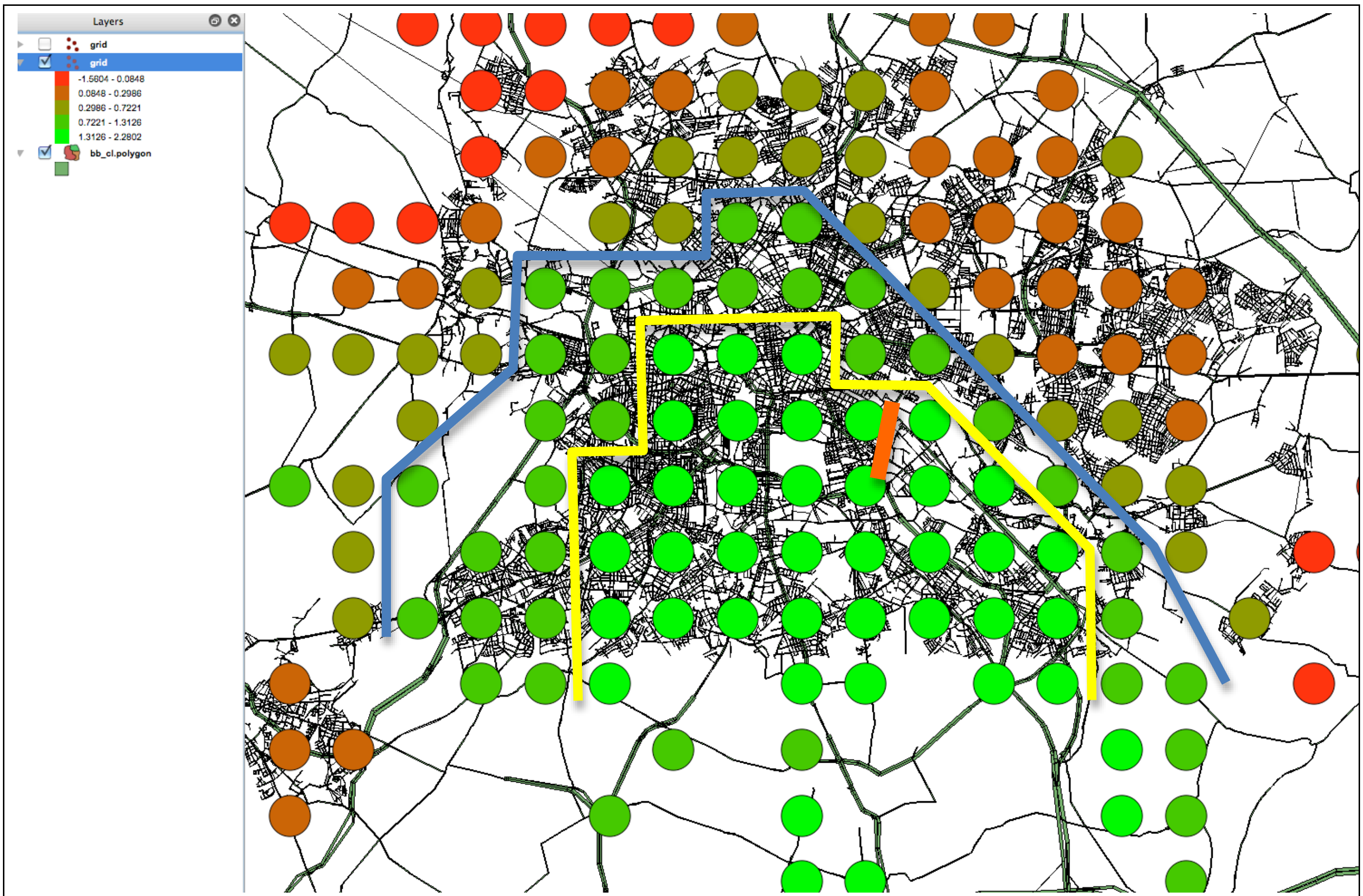
This is an analysis that cannot be performed with traditional models. It is also a result that is not useful for itself: It serves as preparation for the following sections.

4.5 Winner-loser-analysis

The MATSim approach, since it traces full daily plans instead of the conventional trip-based analysis, allows to reflect economic gains (and losses) to the originating households. When aggregating those household-based gains and losses into square grids and color-coding them, one obtains the following plot. Red dots correspond to grid cells where households sustain, in the average, economic losses. Green dots correspond to grid cells where households reap, in the average, economic gains.

[5] Update (30-sep-11): Found BVWP'03 values. They state 2.774 mio h gained per year on workdays. Compare this to our 45'846 x 300 = 13.754 mio h. On the other hand, our annual gain goes down to 3.821 mio h when mode choice is switched on (see below).

[6] 0.32utils x 3.5mio inhabitants = 1'120'000utils.
1'120'000 utils / 45'846 h = 24.43 uilts/h or 0.041 h / util = 2.45 min / util.



23jul-ba16ext-vs-23jul-base (i.e. w/o mode choice but consistent scoring fct). Quantiles. Households in all cells except those with the brightest red gain in the average. The yellow/blue lines demark the 20%/40% top gainers. The short orange line demarks the approximate location of the construction measure.

Figure 3

One finds that the main beneficiaries of the 16th construction section of A100 are located towards the south of the city. The logic seems to be that those households that already have easy access to the A110/A113 system can use the extension of the freeway system best. In this plot, however, nearly everybody gains; compare to Sec. 5 below.

This result cannot be compared to traditional models, since they lack the capability to connect trips to home locations. What *could* be done is to look at commuting trips only (since most of them start at home).

5 BA 16 with mode choice (and discussion of "induced" traffic)

There is much discussion about induced traffic. The term means additional traffic that is generated by improving the transportation system. Induced traffic is important, but we believe that it is sometimes disctracting from elements that are equally important but earlier in the logical hierarchy. The element that is to be considered here is **mode choice**. Recall that so far we have simulated without mode choice. Improving an urban freeway will incite people to move from other modes of transport to car.

When mode choice is switched on in the simulation, first the base case needs to be run again. This is because, without simulated mode choice, the mode choice is taken from the survey both for the base case and for the construction measure case. With simulated mode choice, the base case first needs to find its own mode choice before it can be compared to anything. For this, behavioral parameters were calibrated such that the simulation-generated mode choice in the base case is, in the average, consistent with the original mode choice in the survey. That model is then used to investigate the construction measure.

5.1 Comparison to real world counts

Clearly, this new base case is different from the previous base case. When comparing this newly generated base case, the comparison to the real world counts (not shown) implies that this new base case is actually *more* realistic than the previous base case. This makes us confident that the results are useful. As stated multiple times, a demand consistent with the network would remove this inconsistency.

5.2 Scores

Switching mode choice on reduces the average score improvement due to the construction measure from 0.32 to 0.1. That is, adding mode choice to the simulation logic reduces the (travel time component of the) economic benefits to a third. This is also a lot.

It is quite difficult to put this into perspective. It is, unfortunately, unclear if the German assessment exercise ("BVWP") in 2003 includes the congestion effects caused by this effect; the documentation (BVU/IVV/PLANCO 2003, pages 170ff) implies that the effect is simulated, but not included into those assessment components that include congestion ("NB2" and "NE").[7]

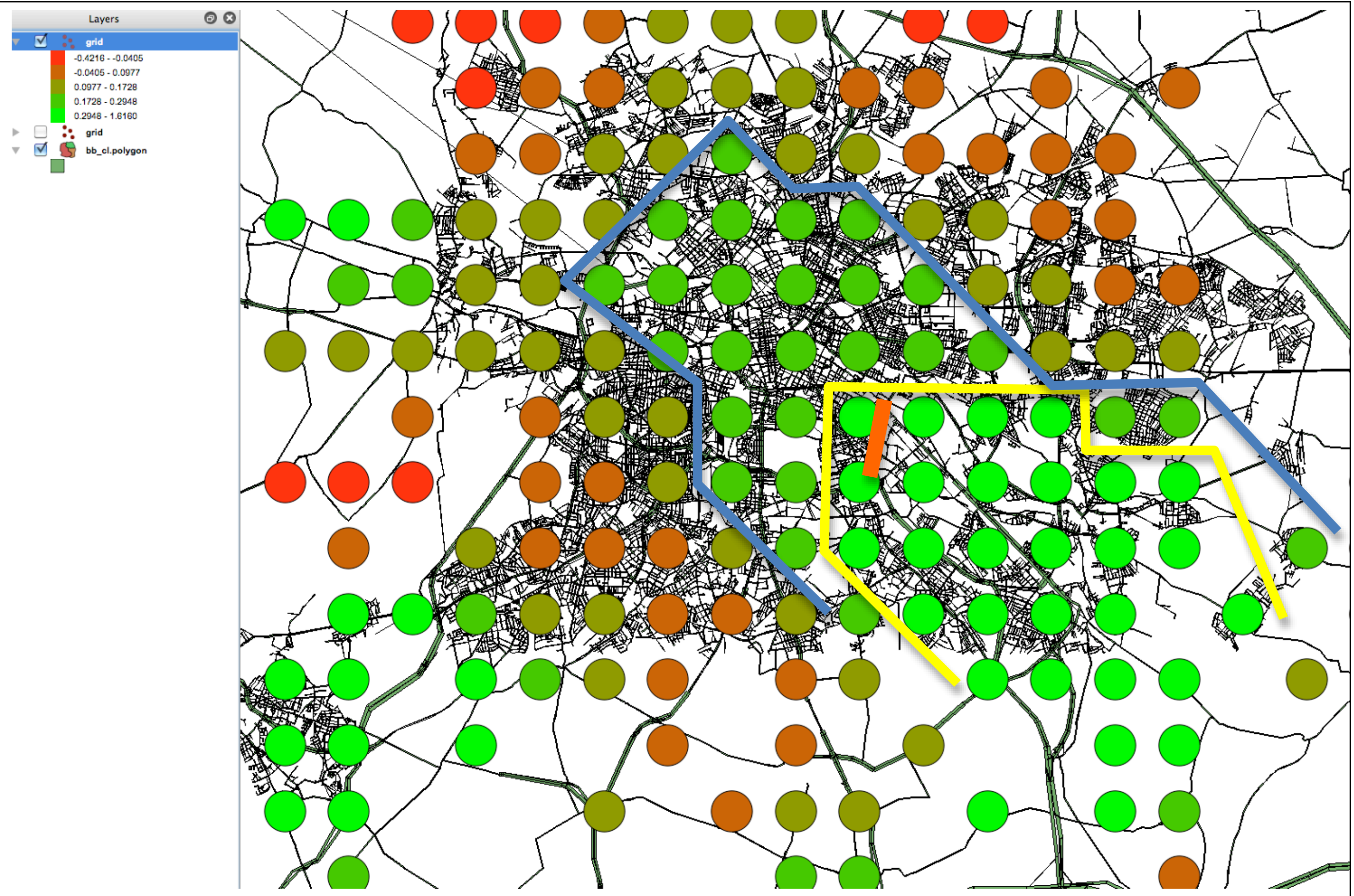
At any rate it points to the necessity to significantly improve the methodology for the assessment of transport measures in urban areas. Minimally, mode choice, time choice, and short-term destination choice should be included consistently.

It should be possible to compare this result to more traditional model, assuming that mode choice was allowed as a reaction to the construction measure.

5.3 Winner/loser analysis

The following plot shows the winner/loser analysis, for the simulation where mode choice was switched on. I was, unfortunately, unable to find a color coding that is both meaningful *and* comparable to the winner/loser plot in Sec. 4.5. The locations of the winners of the measure have shifted to the southeast, along the A113 corridor. This supports the analysis that the 16th construction section mostly helps those households that gain a better connection to the center of the city. Households in all other parts of the city do not gain or may even lose. This is due to increased congestion elsewhere, caused by additional car traffic on its way to the new 16th construction section.

[7] Update (30-sep-11): The fact that the travel time gains are much more in line between our work and BVWP'03 when mode choice is switched on implies that BVWP'03 in fact also has mode choice switched on From a technical perspective, that would make sense, it is just not consistent with how I understand the documentation.



Long-ba16ext-vs-long-base (i.e. with mode choice). Quantiles. The bottom 20% lose, the next 20% are indifferent, the top 60% gain. The yellow/blue lines demark the 20%/40% top gainers. The short orange line demarks the approximate location of the construction measure.

Figure 4

This result cannot be compared to traditional models, since they lack the capability to connect trips to home locations. What *could* be done is to look at commuting trips only (since most of them will start at home). For such a comparison, one would need a model where mode choice was allowed as a reaction to the construction measure.

6 Discussion

Recall that all results were obtained with a demand from 1994. Comparison to real world counts (Secs. 3.1 & 5.1) encourages us to believe that the demand can still be used. Clearly, using a more recent demand would be useful. Data would be available from SrV'2008, but permission would need to be granted that it can be used.

There is also a 17th construction section under discussion. Some people argue that the 16th construction section is useful by itself, but that it would be particularly useful when the 17th construction section becomes added. This is not investigated here.

7 Conclusions

- The 16th construction section of the A100 mostly serves the function to improve access to the city for cars coming from the south-east via the A113. In doing so, it presumably moves traffic away from the parallel arterial ("Adlergestell").

- In contrast, the 16th construction section does *not* serve as an extension of the A100 ring. Cars driving along the ring will use the extension once constructed, but the demand really goes to "Karlshorst", not to "Friedrichshain". In that sense, the measure would move additional traffic towards the city centre.
- The economic gains in the conventional analysis are quite large. However, already switching on mode choice reduces them by a factor of three, since switchers from other modes of transport fill up the new capacity. This points to the necessity of an improved prognosis methodology for urban transport measures.
- Overall, it was shown that the model can be used, with relatively little effort, to perform useful (in our view) policy studies. All simulations were run on a standard laptop, and typically ran over night. The reduction of the sample size to 2% makes the results a bit unstable, but not useless. It was useful that the demand data was already converted to the MATSim format through a different project.

8 References

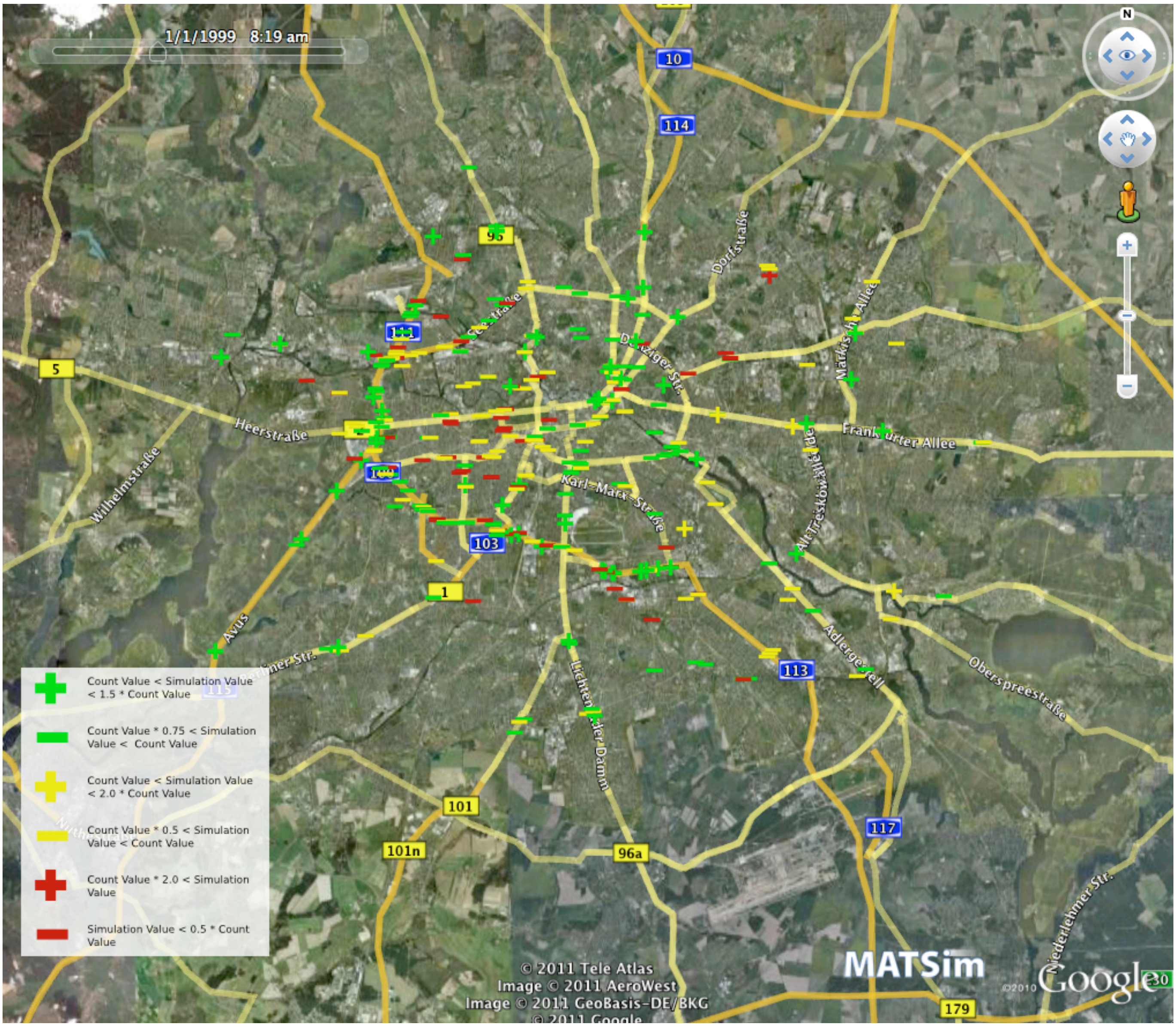
This document mostly refers to web pages; hyperlinks were given in the text. The hyperlinks often lead to additional references.

BVU/IVV/PLANCO 2003, "Bundesverkehrswegeplan 2003 – Die gesamtwirtschaftliche Bewertungs-methodik", siehe http://www.bmvbs.de/SharedDocs/DE/Artikel/UI/bundesverkehrswegeplan-2003-die-gesamtwirtschaftliche-bewertungsmethodik.html, pdf files near bottom of page

9 Appendix

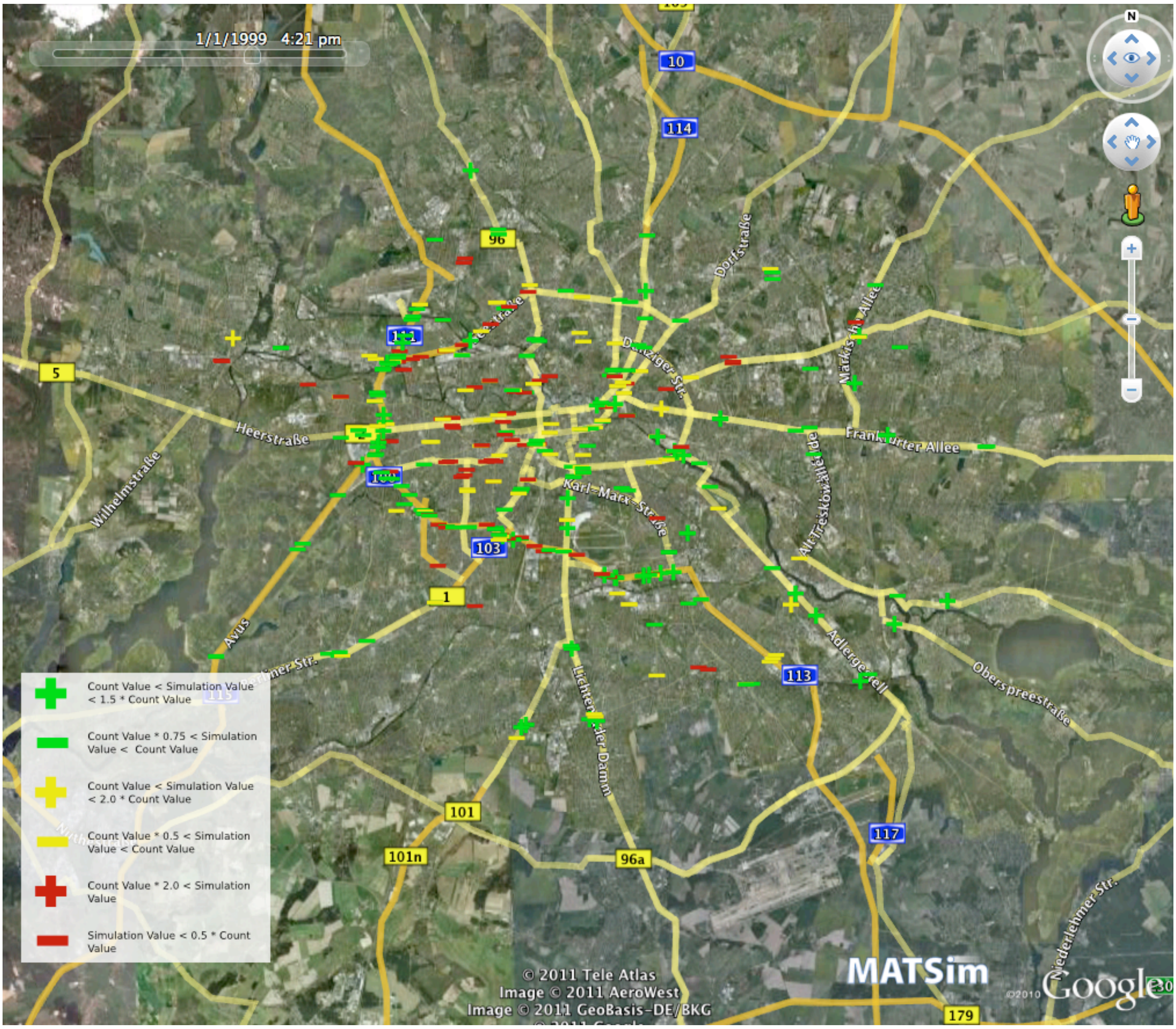
9.1 Details of the comparison with reality of the base case

The next two plots show, for the hour between 8am and 9am and for the hour between 4pm and 5pm, a comparison between the simulation and reality. For every counting station, its position marked by a symbol in the map, both in the simulation and in reality the vehicles passing by the counting station are counted. If the count in the simulation is below the count in reality, the counting station is marked by a „minus", else by a „plus" sign. Symbols in green mark counting stations where the error is less than a factor or 1.5. Symbols in yellow mark counting stations where the error is less than a factor of 2. Symbols in red mark counting stations where the error is larger than a factor of 2.



Comparison between simulation and reality for the hour between 8am and 9am. Source: google earth for background map, own simulation with MATSim for simulation results.

Figure 5



Comparison between simulation and reality for the hour between 4pm and 5pm. Source: see above.

Figure 6

The following plots show the same information as so-called scatter plots. Every plot represents an hour of the day, every point represents a counting station, the x-value is given by the count in reality, the y-value is given by the count in the simulation. Ideally, all points would be aligned along the diagonal; a point above the diagonal means that the simulation lies above reality; a point below the diagonal mans that the simulation lies below reality.

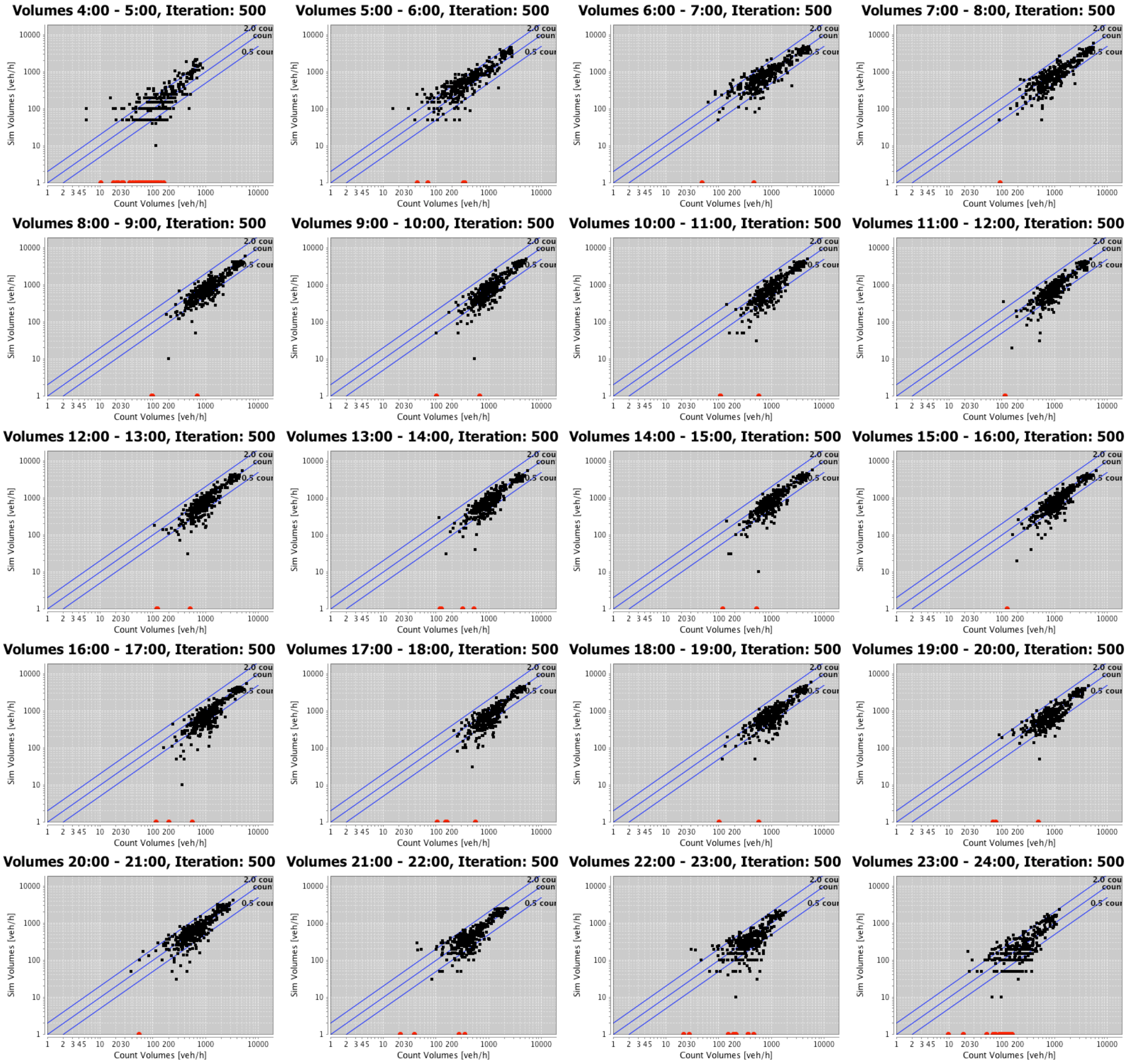


Figure 7

The following plot shows a two aggregated error measures over the time-of-day. The red line is the mean of the unsigned relative error; somewhat intuitively one can say that the simulation is, in the average, 30% off during daytime hours. The blue line is the mean bias in absolute terms (= vehicle counts). When it is below zero, this means that the simulation in the average under-estimates the vehiclar flow.

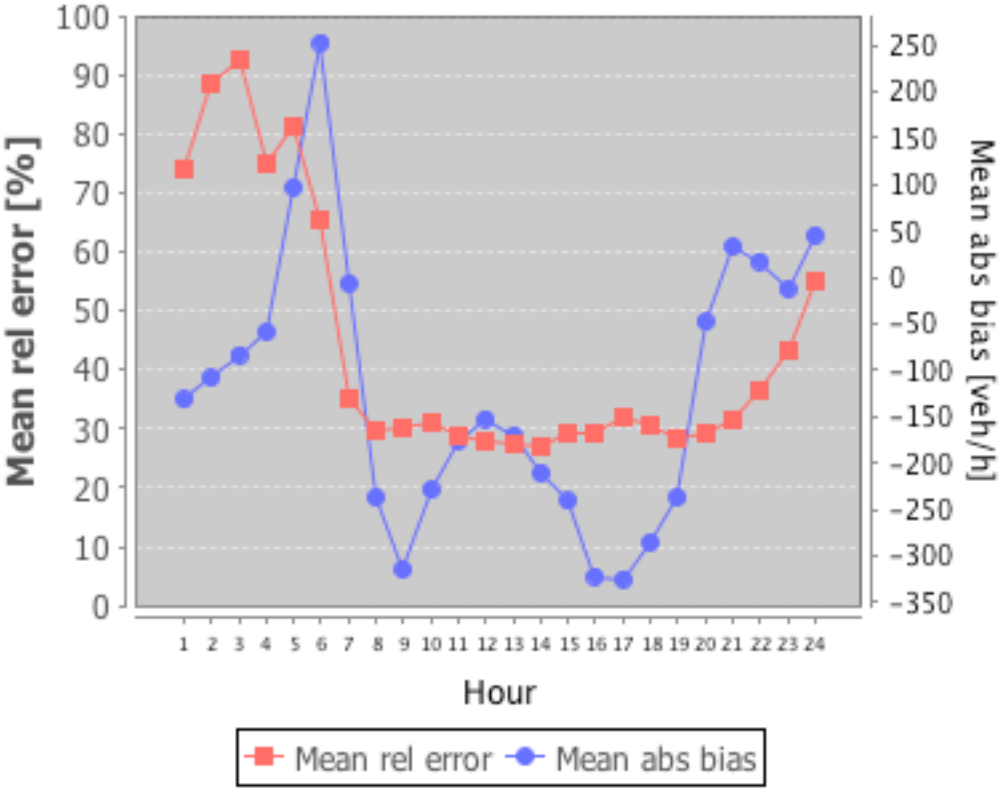


Figure 8

9.2 Details of the spider analysis of the base case

This section contains the details of the so-called spider analysis of the base case. The figures in the following aways contain:

- top left a schematic illustration of the result, top right a textual description
- bottom row the screen shots from the simulation that contain the evidence

In the screen shots, the spiders are in blue. Dark blue means that there are many paths on top of each other, light blue means that there are few paths on top of each other. It is rather intuitive and maybe best understood by directly looking at the following examples.

Since only single links can be selected, it is not possible to look at specific turns. This could, in principle, also be analysed, but the programming has not yet been done. Nevertheless, in some cases turning movements can be analysed – when there are separate turning lanes. This explains why in the following certain turns can be investigated while others cannot.

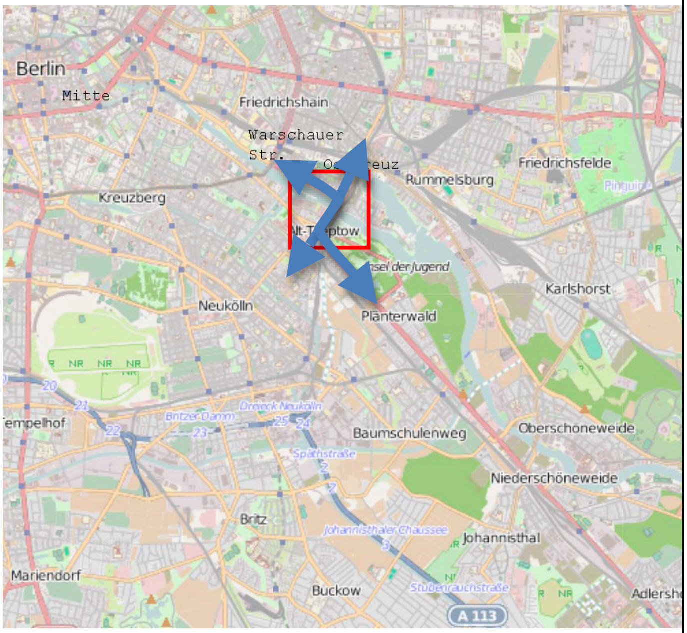
9.2.1 Elsenbrücke

We will first look at a bridge called "Elsenbrücke". This is located where the 16th construction section would end. It is interesting because

- it is a bottleneck in the present situation

- it might be even more of a bottleneck if the 16th construction section would be built since it would end *before* Elsenbrücke
- it should contain a large portion of the traffic that would be, perspectively, moved onto the A100 extension especially after finishing construction of the 17th construction section

9.2.1.1 *All (car) users of Elsenbrücke*

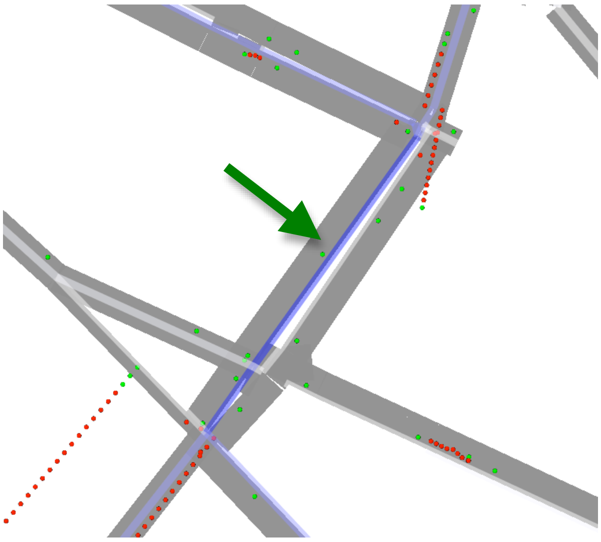


Source of this and all other background images: openstreetmap (www.osm.org) .

Users of „Elsenbrücke" north-to-south (left picture):

- ~ 50% coming from „Warschauer Str."
- ~ 50% coming from „Ostkreuz"
- ~ 50% going to „Plänterwald"
- ~ 50% going into the direction of „Neukölln"

Opposite direction similar (right picture)



Source of this and all other simulation snapshots: own work, performed with the open source software MATSim (www.matsim.org).

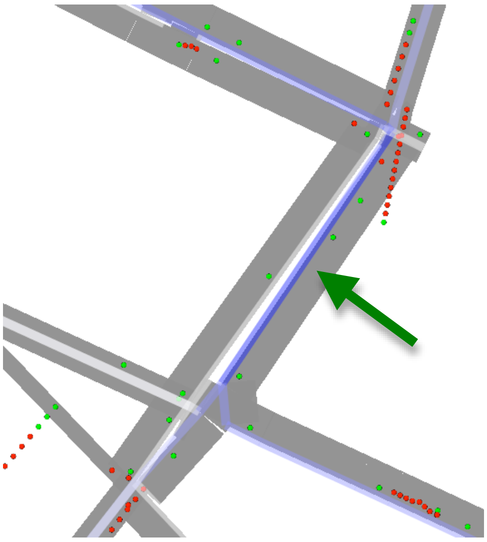


Figure 9

This implies that there are four distinct streams of traffic:

- coming from and going to the Neukölln area
- coming from and going to the Plänterwald area
- coming from and going to the Ostkreuz area
- coming from and going to the Warschauer Str. area

In the following, it will be attempted to look at those four streams separately.

9.2.1.2 Elsenbrücke (car) users coming from/going to Neukölln area

<table>
<tr>
<td>
</td>
<td>Elsenbrücke users coming from Neukölln area:

many from Sonnenallee
some from A100 (via Sonnenallee)
going to Ostkreuz/Warschauer Str. (approx. half/half)

Opposite direction not selectable in model without additional programming effort</td>
</tr>
<tr>
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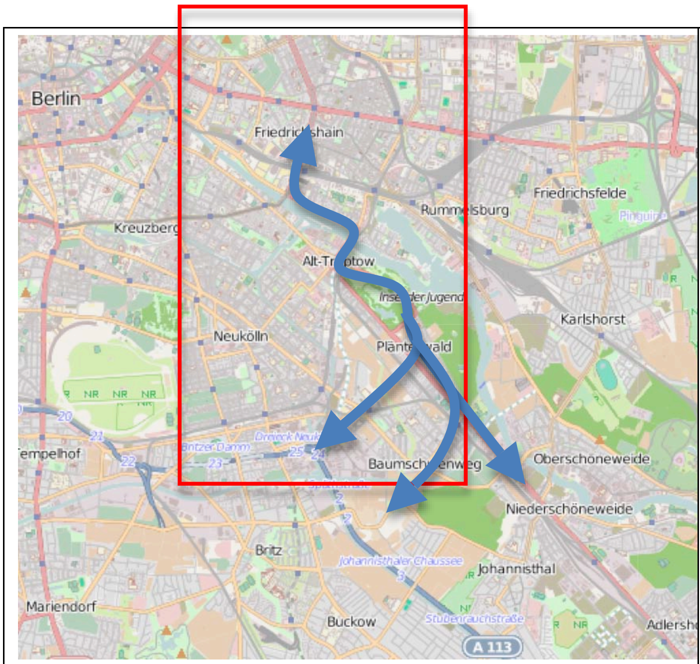
</table>

Figure 10

9.2.1.3 Elsenbrücke (car) users coming from/going to Plänterwald area



Elsenbrücke users coming from Plänterwald area (this can be separately selected since there is a right turning road segment):

- many from Adlershof area
- some (but minority) from A113

Opposite direction not selectable in model without additional programming effort

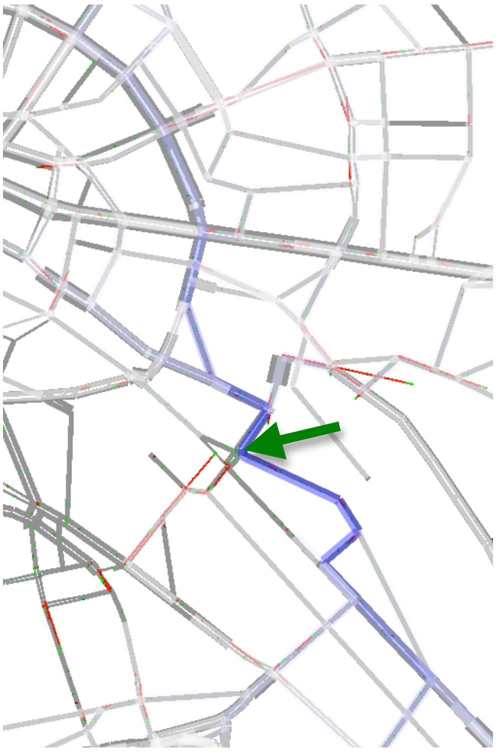


Figure 11

9.2.1.4 Elsenbrücke (car) users coming from/going to Ostkreuz area

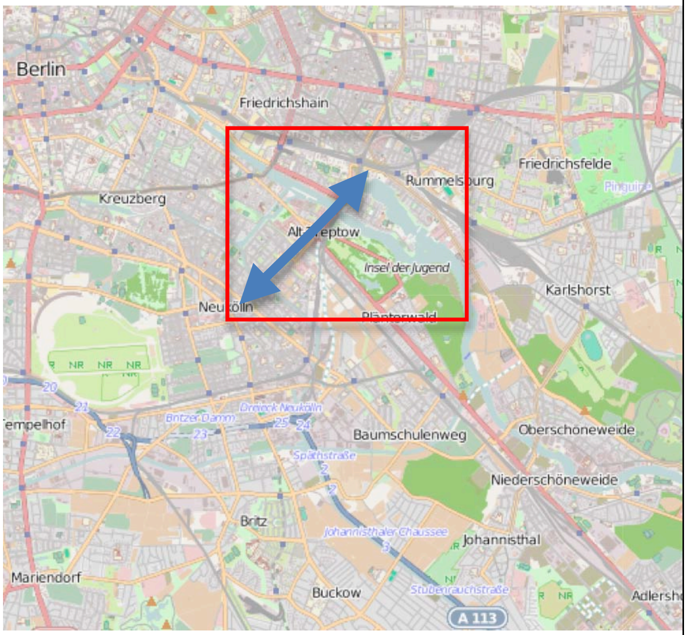
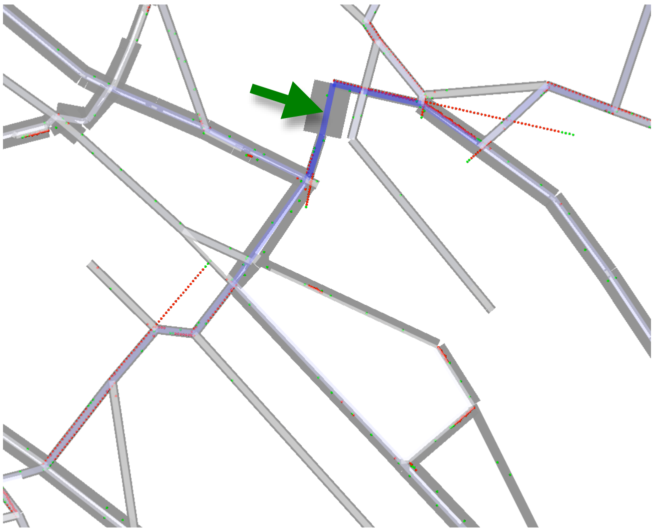
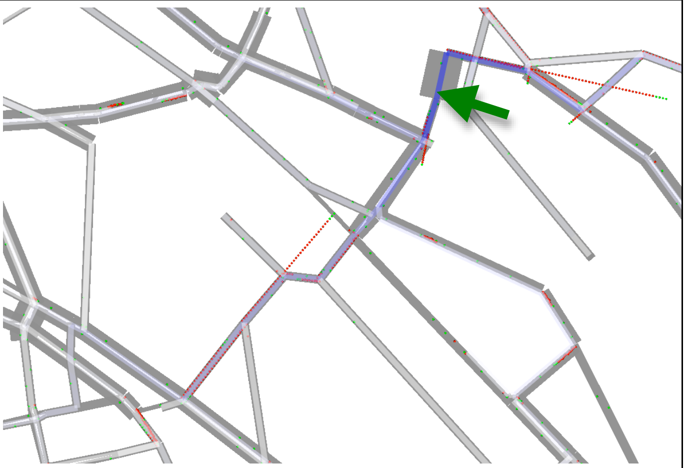
	Elsenbrücke users going to Ostkreuz direction • mostly coming from Neukölln Opposite direction similar
	

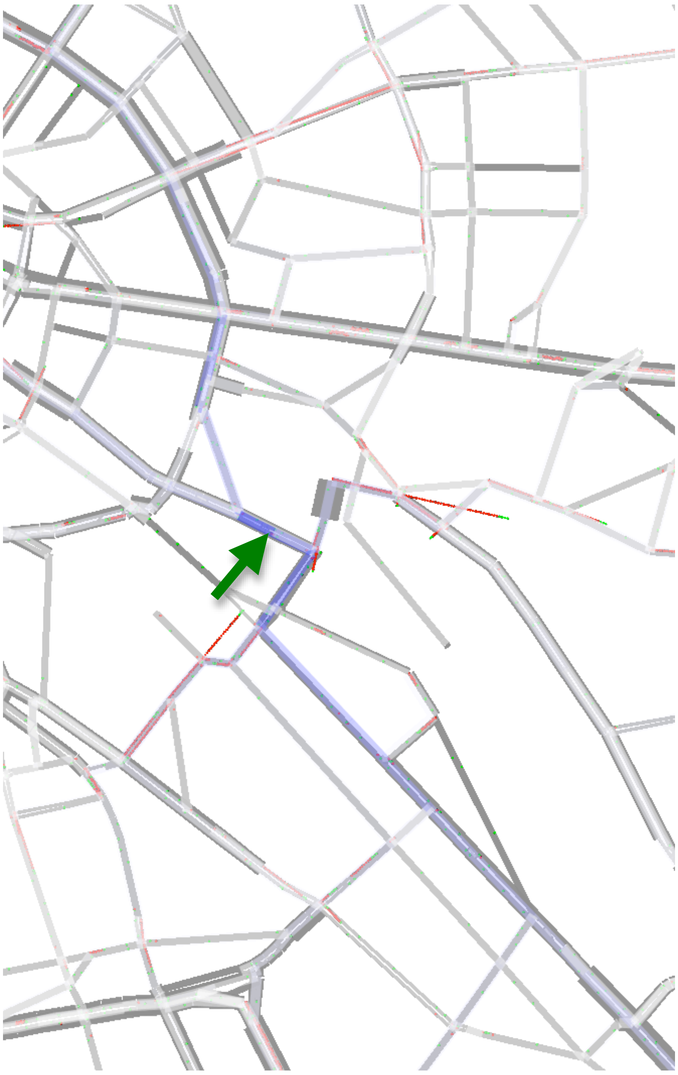
Figure 12

9.2.1.5 Elsenbrücke (car) users coming from/going to Warschauer Str. area

Elsenbrücke users coming from Mitte:

- many coming from inner ring (Warschauer Str.)
- many going to Plänterwald area

Opposite direction similar



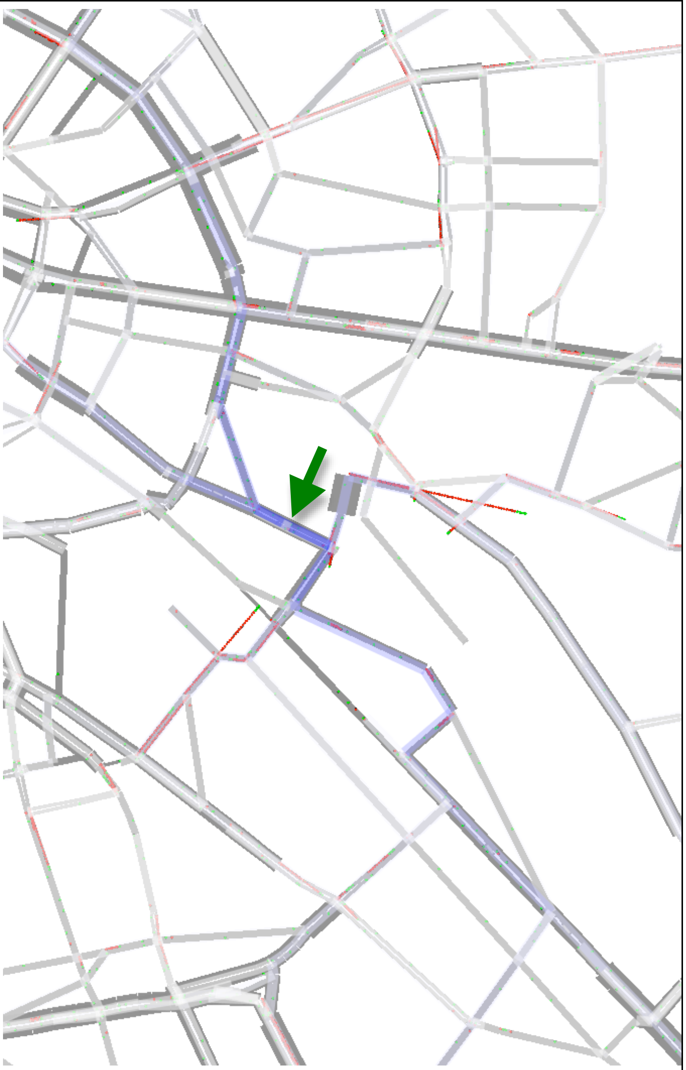


Figure 13

9.2.1.6 Elsenbrücke (car) users summary

The last two selections ("to/from Ostkreuz", "to/from Warschauer Str.") show that there are essentially two separate streams of traffic:

- one to/from the Plänterwald area, going to/from the Warschauer Str. area
- one to/from the Neukölln are, going to/from the Ostkreuz area

This is depicted in the following:

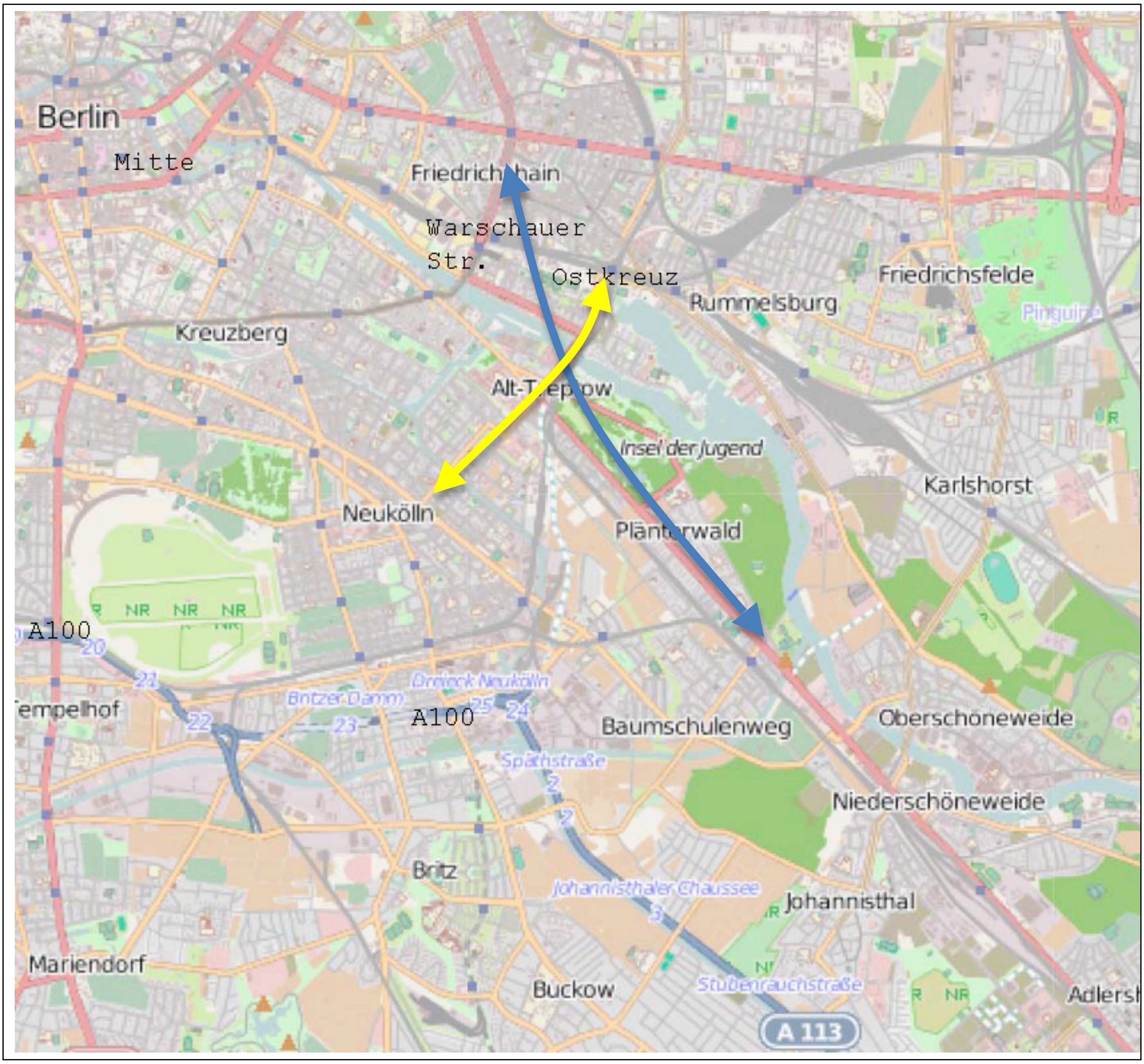


Figure 14

This states that there is little demand coming from/going to A100 that traverses Elsenbrücke.

The following plots check this, by specifically selecting traffic on the A100 or A113.

9.2.2 Autobahndreieck Neukölln

9.2.2.1 From A100 (west) exiting at "Dreieck Neukölln"

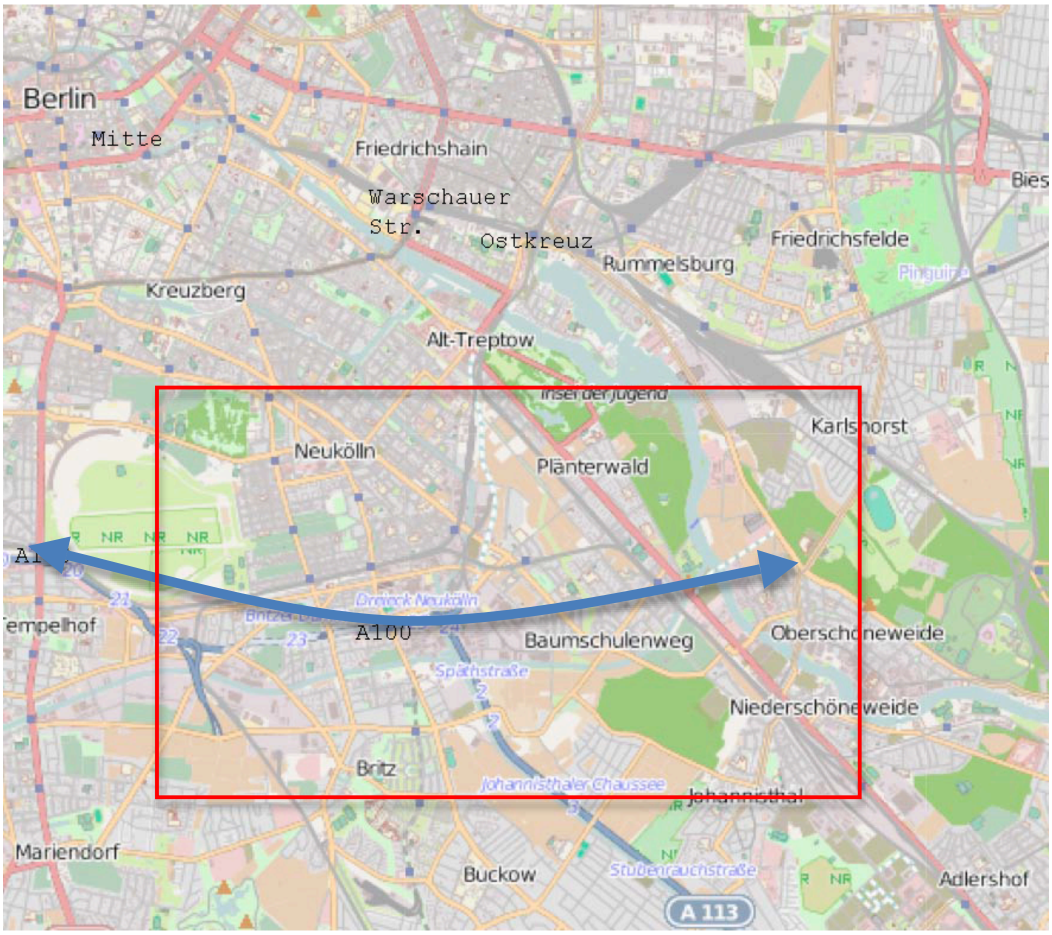
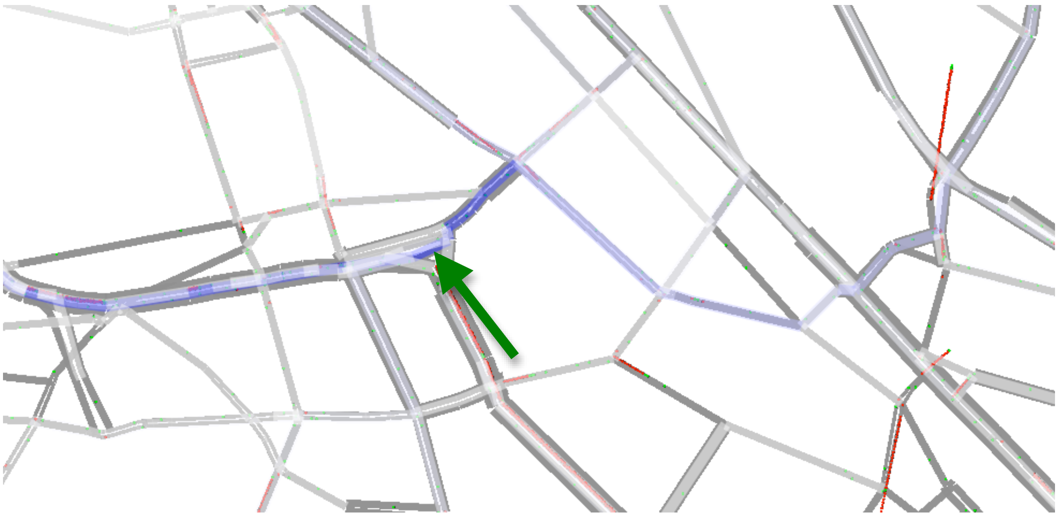
	Cars coming from A100 (west) and exiting at „Dreieck Neukölln" to a large extent head towards the (south)west.
	

Figure 15

The following is a zoomed-out version of the same situation, i.e. selecting traffic coming on A100 from the west and exiting at "Dreieck Neukölln"

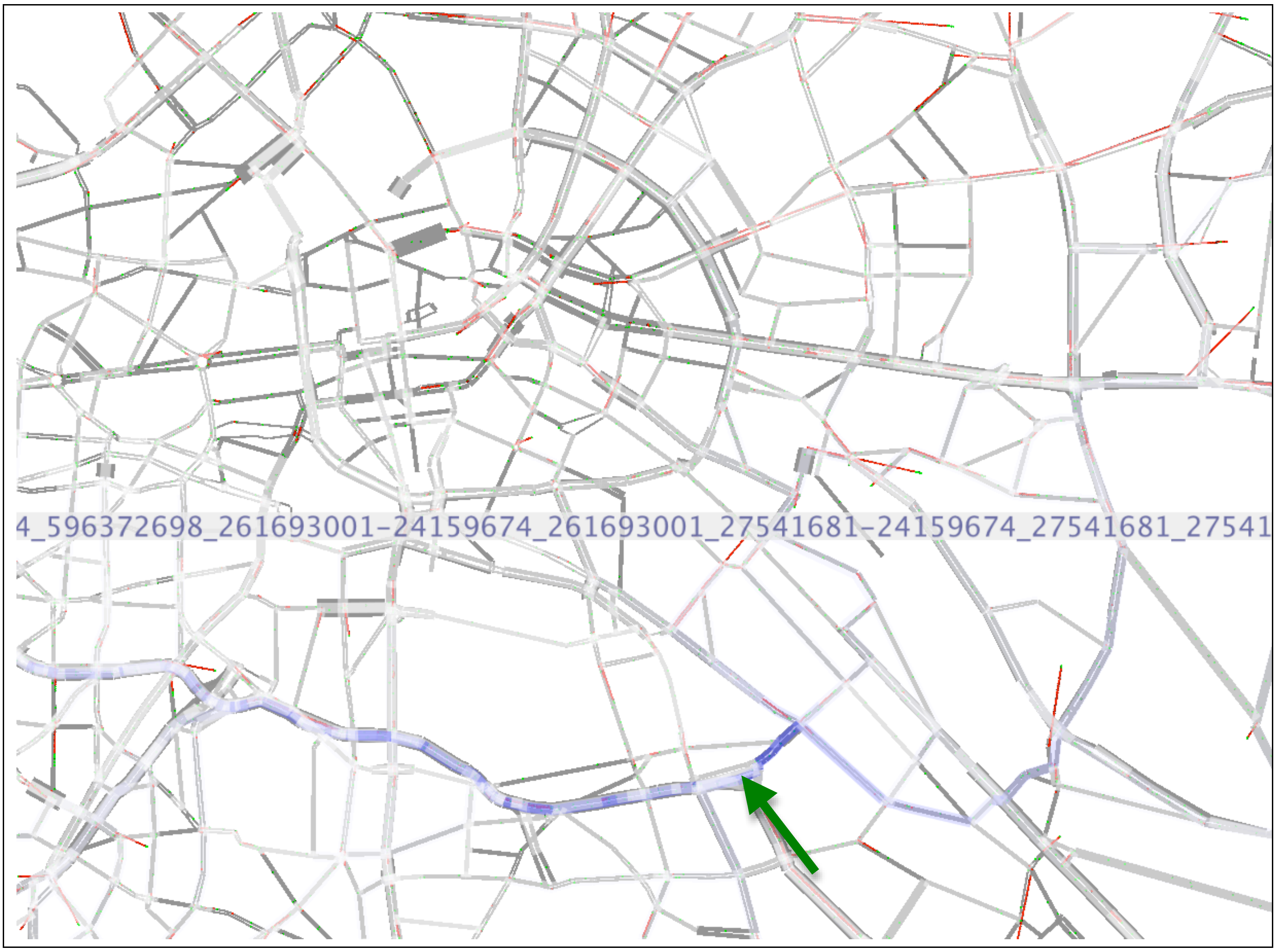


Figure 16

One finds that there is indeed a considerable amount of traffic travelling along A100 and existing at "Dreieck Neukölln". The majority of this traffic is interested continuing towards the west. At this point, that traffic is not using the Elsenbrücke.

9.2.2.2 From A113 (southeast) exiting at “Dreieck Neukölln”

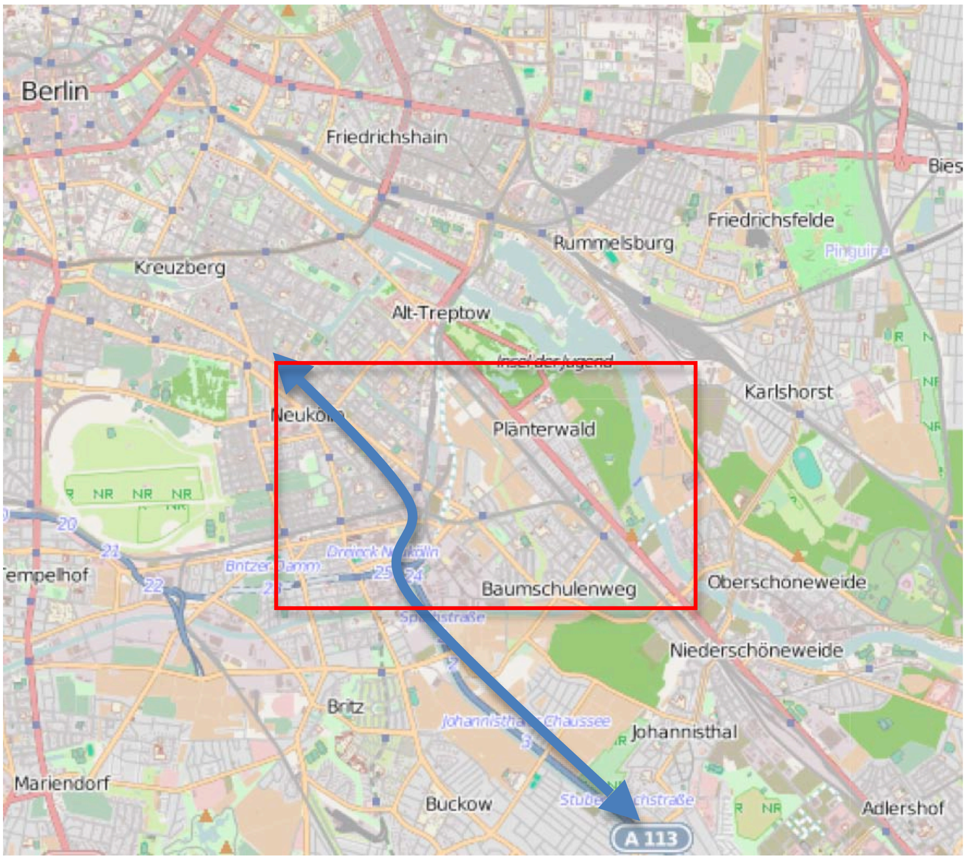
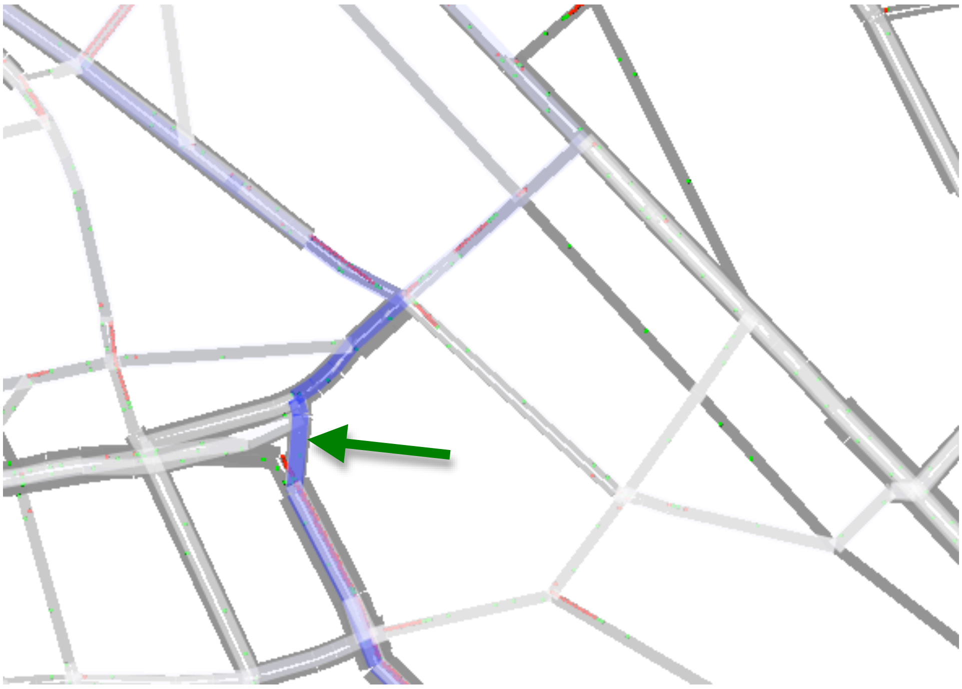
	Cars coming from A113 (southeast) and exiting at „Dreieck Neukölln“ to a large extent head towards the northwest.
	

Figure 17