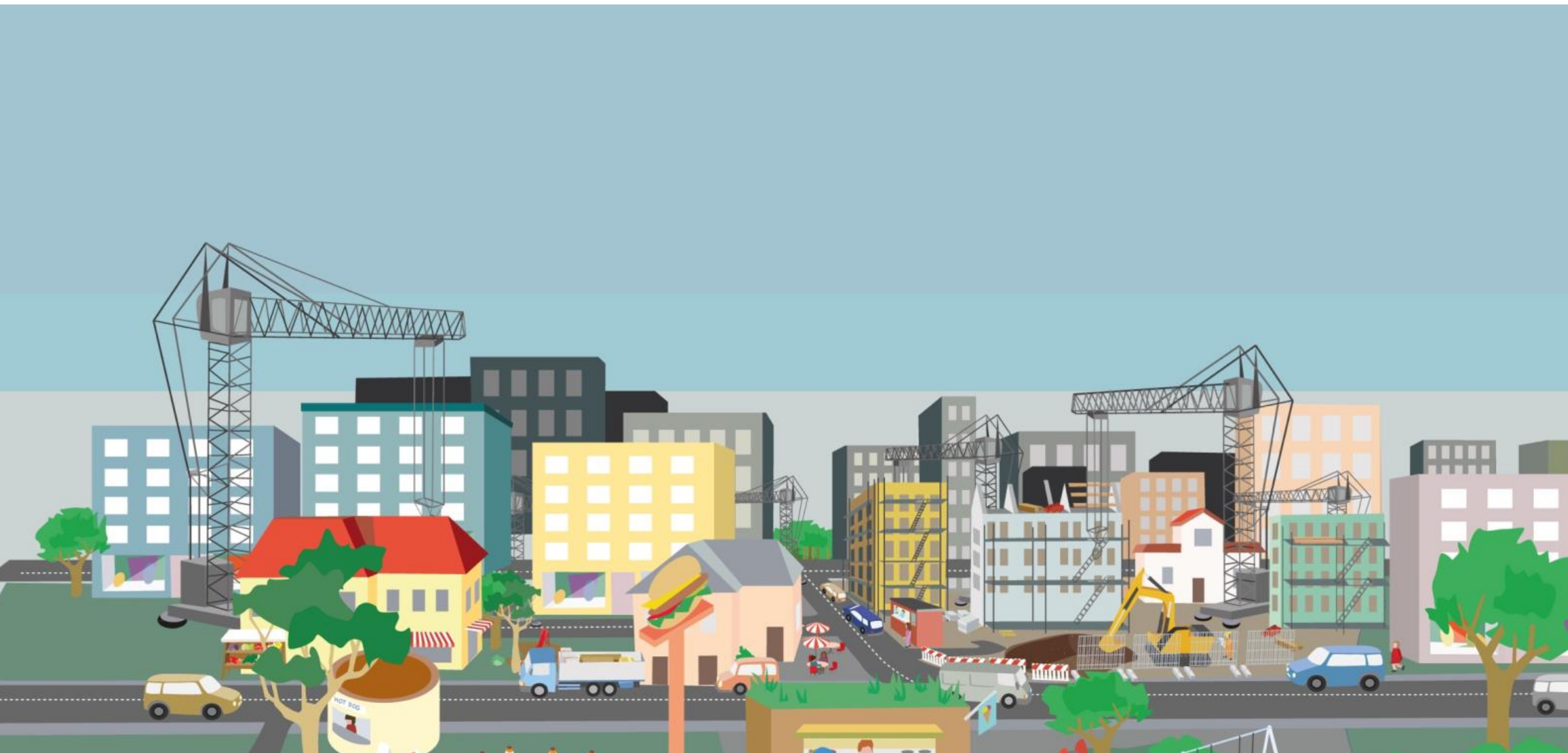
WP3: Impact assessment

Deliverable 3.1: Impact of construction logistics on city traffic

December 2020



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MIMIC Deliverable 3.1

Impact of construction logistics on city traffic

Version: 1.0

Date: December 2020

Responsible partner: AIT Austrian Institute of Technology (AIT)

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Executive summary

Urban construction projects are essential in reducing the housing deficit of the latest urbanization trend (UN, 2015 & 2018). As such, construction projects contribute to more attractive, sustainable and economically viable urban areas once they are finished. However, construction work and construction material flow activities cause severe negative impacts on the surrounding community during the construction process. The MIMIC project focuses on the social, economic and environmental sustainability problems that arise from urban construction, and especially the logistics activities to, from, around and on urban construction sites.

This deliverable is part of Work Package 3 of the MIMIC project (Minimizing impact of construction material flows in cities: Innovative Co-Creation), a JPI Europe funded research project with demonstration cases in Brussels, Vienna, Oslo and Sweden. The objective of WP3 is to evaluate real-world construction site impact on city traffic using a data-driven approach and to evaluate construction work scenarios under different logistics optimization approaches.

Using cellular signaling data and algorithms developed in MIMIC for the reconstruction of travel routes, it is possible to estimate traffic flow volumes in the urban transportation network based on a large sample of the population. Comparisons between periods before, during and after construction works provide direct insights into the influence of the construction works on urban traffic. This method was demonstrated using the case of a major construction project at a subway line in Vienna in July 2019. Using a MATSim simulation model the transport related effects of large construction sites with lane closures due to storage areas were evaluated under different scenarios. The results show that construction sites clearly obstruct car traffic and shift some traffic to different routes, often not large enough to handle the added traffic. The increase in congestions as well as decreases in speed and increases of congestions in the surroundings implies the need to carefully plan both the sites as well as traffic restrictions in the surroundings and a well-organized campaign to shift people from their cars to other means of transport.

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1. Introduction

There is an ongoing urbanization trend, making municipalities focus on densifying cities, hence stimulating construction and renovation works in urban areas. Urban construction intrinsically strongly relies on logistics activities, and these in turn are the source of environmental nuisances. These nuisances are referred to as external costs, a cost that "*arises, when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group*" (Bickel et al., 2005: 10).

For transport to and from the construction site (off-site construction logistics), they come in the form of i.a. air pollution, greenhouse gas emissions, noise pollution, congestion, accidents etc. The order of magnitude of external costs of transport in the EU equals approximately 1,000 billion euro per year, which represents about 7% of the EU28's GDP (EC, 2018). The construction sector represents a share of about 20-35% of total freight traffic in urban areas, depending on the cases and calculation methods and variables (Brusselaers et al., 2020). However, to perform accurate external cost calculations, there is a need for accurate data to enable the consideration of significant calculation-variables, like vehicle-type, road type, traffic situation, number of receptors, etc., which are often not considered in construction logistics impact assessments so far (Brusselaers et al., 2020).

For on-site work, the nuisance and vibrations from construction work and waste generation, as well as greenhouse gas emissions and air pollution from construction machinery, are some examples of the considerable negative impact from construction sites. The on-site construction site activities alone, are estimated to represent around 5-10 % of the total GHG emissions from cities (DNV.GL. 2019).

Fossil free and emission free construction activities in Norway are good examples, where the construction industry aims to reduce impact from construction site in order to contribute towards reaching emission reduction targets on the international (e.g. the Paris agreement), national (for example, 50% emission reduction by 2030 and becoming a low-emission society in 2050) and regional level (e.g. 95% direct emission reduction before 2030 in Oslo). The market has developed rapidly since public building owners started to develop requirements for emission free construction sites. In the Norwegian construction industry, the plan is to develop these sites in a stepwise approach to reach the ambition of an emission free construction site (Fufa et al., 2019b). This stepwise approach starts with requirements of a fossil free construction site. Next, ambitions can be raised to an 'on-site emission free' construction site which covers no direct GHG emissions from construction activities taking place on-site (e.g. from internal transport, operation of construction machinery and on-site energy use). The next step involves adding emission free transport to and from the construction site, whilst the final step covers all construction site activities. In addition, there is also a parallel initiative which investigates the 'waste free' construction site. To reach these ambitions, considering all construction activities, the construction logistics itself have to change to become smarter, more efficient and sustainable.

Despite the fact that construction sites have a positive economic impact in the long run, they bear a vast amount of external costs during the site duration. Improved control and coordination of logistics flows to, from and on construction sites can decrease such negative environmental and social impacts. However, the full picture of the environmental impacts from construction sites is not known, and there is an increased need for environmental (and social) evaluations of construction logistics.

For cities, there is a great potential to reduce negative impacts through stronger requirements on construction logistics. However, today there is a lack of knowledge within cities on how to set such demands and how to involve and manage stakeholders in these processes. The purpose of the MIMIC project is therefore to demonstrate how SMART Governance concepts can be used as an aid in the construction and city planning processes to facilitate and support construction logistics.

1.1 About MIMIC

"Minimizing impact of construction material flows in cities: Innovative co-creation" (MIMIC) is a JPI Urban Europe project that aims to demonstrate how SMART Governance concepts can be used as an aid in the construction and city planning processes. The SMART Governance concepts aims to facilitate and support logistics to, from and on urban construction sites to improve mobility and reduce congestion within cities and thereby reduce the negative impact of construction sites on the surrounding community. This is done by:

(1) The analysis and identification of construction logistics scenarios (both on- and off-site) highlighting the relation between projects context and logistics solutions;
(2) Stakeholder involvement and management throughout the different project phases, through identification of stakeholders and stakeholder objectives in a participatory MAMCA and gaming;
(3) The implementation of a sustainability impact assessment framework to evaluate the economic, social and environmental performance of the construction logistics scenarios (which is the main focus of this report);
(4) Enhanced data collection and optimization of construction logistics processes to evaluate and visualize the different construction logistics scenarios, using dynamic data technologies;
(5) Combining 1-4 into a SMART Governance Concept 2.0;
(6) The deployment of the SMART Governance Concept 2.0 to eliminate functional barriers for implementation and;

(7) The transferability and scalability of construction logistics scenarios and the SMART Governance concept 2.0 across European cities.

The activities within the MIMIC project are divided in six work packages (WP). The overall structure of the work packages and the connection between them is presented in Figure 1. This report mainly focusses on the impact assessment framework under WP2.

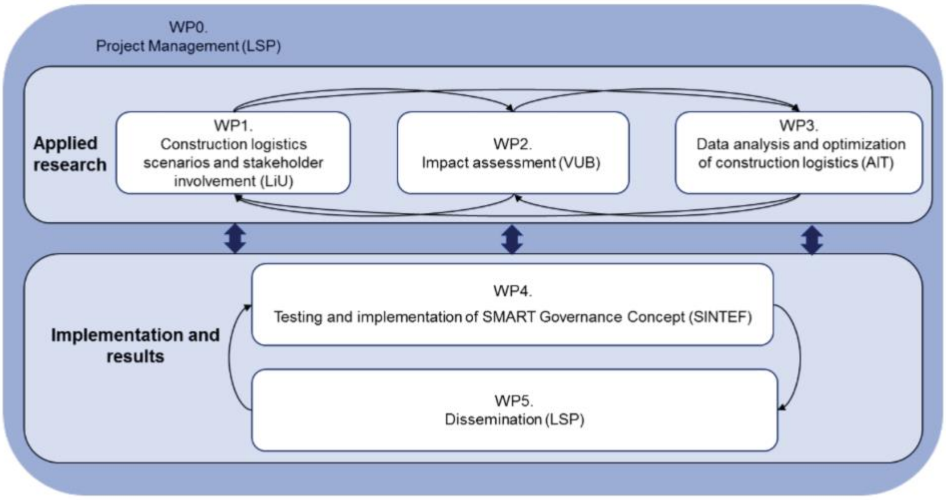

Figure 1. Structure of the different work packages within the MIMIC project

The MIMIC project integrates construction logistics, construction management, city logistics, sustainability and optimization of flows research, with the goal of developing the SMART Governance Concept 2.0. This concept provides the implementation partners (Cities and companies in the construction process and supply chain) with a structure of tools organized into a supportive platform for construction logistics issues in the urban development decision and procurement processes (D4.2 and D4.3). The tools help to increase the knowledge of construction logistics (D1.3), collecting stakeholder needs and criteria of construction logistics scenarios (D1.1, D1.2 and D1.4), and to evaluate the impact of construction logistics solutions on different stakeholders (D2.2, D2.3, D3.1, D3.2 and D3.3).

1.2 Description of demonstration pilot

Norway: Omsorgsbygg Oslo KF in collaboration with Arkitema Architects will build the world's first energy-positive nursing home for elderly (Tåsenhjemmet) with low greenhouse gas emissions. The pilot building in massive wood will enable the best indoor environment for the residents and be the new meeting venue in the neighbourhood of Tåsen. A main goal is to use the most simple and passive measures that enables to

Tåsen nursing home project, Oslo (Norway) meet the requirements for low emission energy-plus houses. Another high ambition for the project is to be certified as BREEAM-NOR Outstanding.

Sweden: Two of the large development projects in Sweden are the Stockholm Royal Seaport and Väsjön projects. Together, these projects will amount to approximately 18 500 new residences and some 770 000 m2 of commercial areas.

Stockholm Royal Seaport and Väsjön project (Sweden)

Belgium: A first goal in Brussels is to gain better insight in the share of construction logistics related transport in the total transport flows per type of project, as there is currently a large gap in accurate data on these flows. The data collection on construction logistics related transport movements will be attempted by using i.e. OBU (on-board unit) data of +3,5 T trucks as well as traffic counts for a selection of (larger) construction sites, providing a better understanding on the amount and type of flows generated in practice by construction works. A second goal is to better understand the impact of these flows on urban sustainability. Therefore, VUB-MOBI will contribute to the development of tools to assess and evaluate the sustainability impact of construction logistics solutions on different stakeholders. In association with owner and city development agency CityDev and main building contractor Van Roey Vastgoed, the application of the sustainability impact assessment framework will be tested on the City Campus project, a 17.600 m² site bringing together light industrial activities and housing facilities. This will allow to assess the impact on economic, social and environmental sustainability (with specific focus on congestion, emissions and safety) of construction freight flows from origin to destination.

City Campus project, Brussels (Belgium)

Austria**:** To enable efficient logistics for urban construction processes, we combine optimization, traffic simulation, and novel data science approaches. Our construction logistics optimization deals with coordinating workers, material delivery, and storage to optimize resource efficiency and reduce road traffic. We develop heuristic solution methods to approach real-world uncertainties and dynamic changes in construction processes. To evaluate the optimized solutions with respect to real-world conditions, we perform a traffic simulation. The simulation assesses the impact of construction traffic in terms of congestion, travel times, etc. based on realistic traffic volumes over times of the day.

Vienna project, Austria

1.3 The present report

This report is a deliverable (D3.1) under work package 3 *“Data analysis and optimization of construction logistics”* and is primarily targeted towards the MIMIC consortium partners directly involved in data analysis and development of the Impact Assessment framework.

The objectives of WP3 are to

- evaluate real-world construction site impact on city traffic using a data-driven approach (Task 3.1)

- evaluate construction work scenarios under different logistics optimization approaches (Task 3.2+3.3)

Deliverable 3.1 describes the procedure for mobility data collection and analysis of constructions site impacts on city traffic.

- Development and implementation of a novel robust method to efficiently detect inter-modal trips from mobile network data, i.e., including changes in traffic mode along the way. Our approach is based on an efficient spatial search algorithm (map matching) using multi-modal transport network data.

- Integration of inter-modal trip chains in the generation of traffic demand estimation and resulting origin-destination matrices.

- Evaluation of traffic situations with and without ongoing construction works through analysis of traffic flows and used transport modes based on mobile signaling data.

The structure of this deliverable is as follows:

Chapter 2 provides an overview of mobility data collection, describing the data sources and information extraction.
Chapter 3 describes the methodology to analyze the impacts of construction sites on city traffic.

2. Mobility data collection

The methodologic approach in MIMIC is based on the collection and analysis of mobile phone data to analyse construction site impacts on city traffic.

For the Vienna demonstration pilot, MIMIC solutions will be used to evaluate how mobile phone-based movement data provided by the mobile network provider T-Mobile can be investigated to monitor the impacts of urban construction works on city traffic.

2.1 Measuring real-world construction site impact using mobile phone data analysis

Austrian mobile phone data is being investigated to detect the impact of real-world construction sites on urban mobility. The analyses are performed using anonymized mobile phone data, i.e. call detail record (CDR) datasets, of three disjunct time periods:

- Before construction work started: 17 days in March 2019
- During construction work:13 days in July 2019
- After construction work ended: 15 days in February and March 2020

The spatial resolution of the mobile phone data is governed by the antenna density and cell coverage of the mobile network (typically several hundred meters in urban areas). The temporal resolution varies greatly (from seconds to several hours) and depends on phone usage behaviour.

To determine whether impacts of construction activities can be measured using CDR, a major subway construction project has been chosen as example. During the summer holidays in 2019, infrastructure of the subway line U4 has been thoroughly renovated, necessitating temporary close-downs of several subway stops during July 2019 (corresponding to the period covered by the second dataset).

Figure 2 shows the locations of three subway stops directly affected by the constructions: subway line U4 did not operate between stops Längenfeldgasse and Karlsplatz (green diamonds), thus U4 stop Kettenbrückengasse (green star) was not serviced.

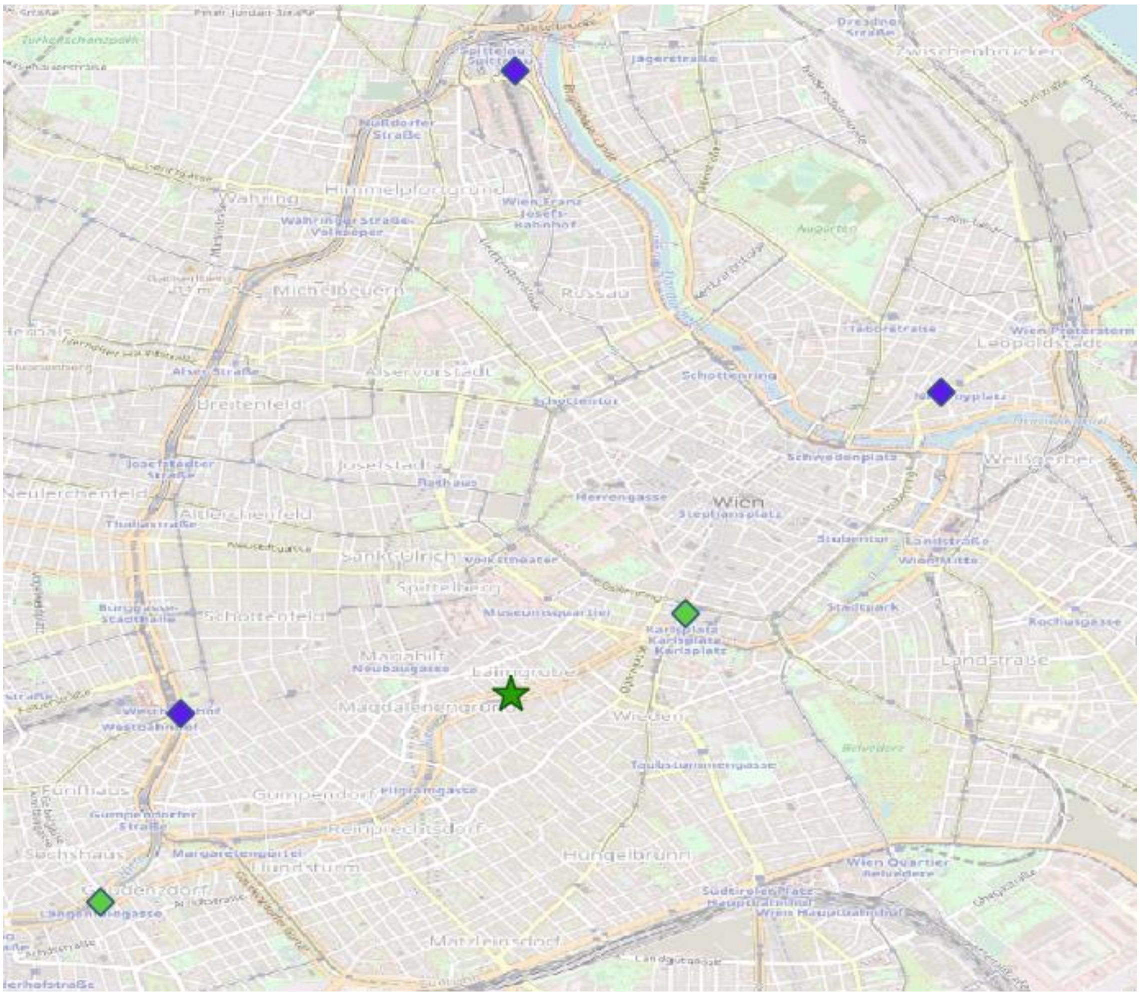

Figure 2: subway stops affected by the construction site (green) versus randomly chosen subway stops (blue) to serve as comparison data (base map: OpenStreetMap).

Three additional subway stops (Westbahnhof, Nestroyplatz and Spittelau; represented by blue diamonds) that were not directly affected by renovation activities but have otherwise similar properties (passenger throughput, function in the network) have been chosen to serve as control sample for the analyses.

CDR for the corresponding network cells from each of the six subway stops have been analysed. Figure 3 illustrates four different counts of CDR per subway stop, from left to right: total CDR count, count of unique device IDs registered at the network cells, avg. CDR count per day, and avg. count of unique device IDs per day. Each subplot shows how the respective counts developed throughout the three available time periods.

The three top-most rows indicate that mobility severely decreased during the renovation period in July 2019: the number of unique device IDs registered per day on average drops almost by half at the temporary endpoints of U4 at Karlsplatz and Längenfeldgasse, and plummets towards zero at the closed-down subway stop Kettenbrückengasse.

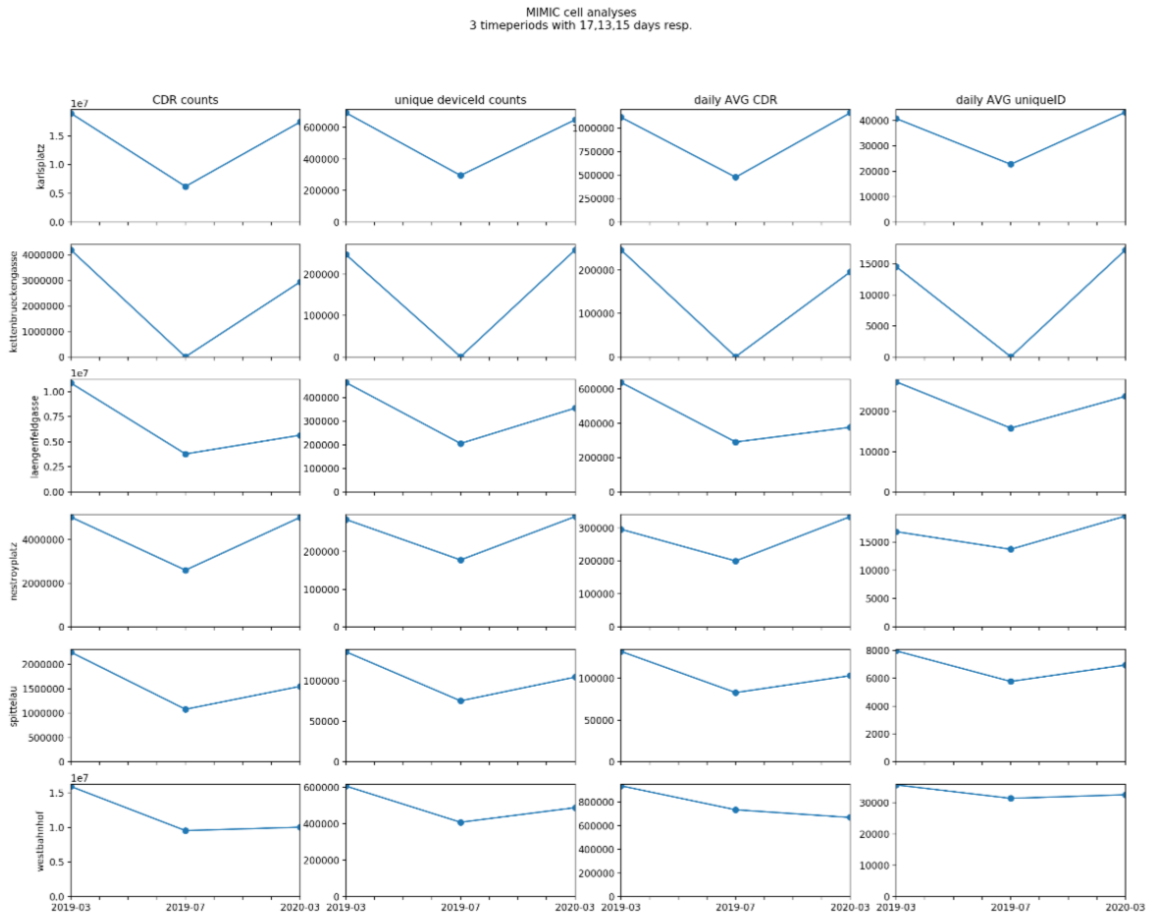

Figure 3: CDR count analyses for network cells at subway stops

In contrast, rows four to six, which illustrate CDR from subway stops unaffected by any construction work, show only a small decline during July 2019, which may be attributed to seasonal effects (summer holidays).

To perform more advanced analyses, it is necessary to look beyond individual CDR and investigate the mobility behaviour in more detail. Therefore, **an algorithm has been developed to reconstruct the mobility behaviour of users from CDR**: the mobile phone records of each observed mobile device are grouped together and enhanced with probabilistic location data derived from meta-information of the mobile network cells.

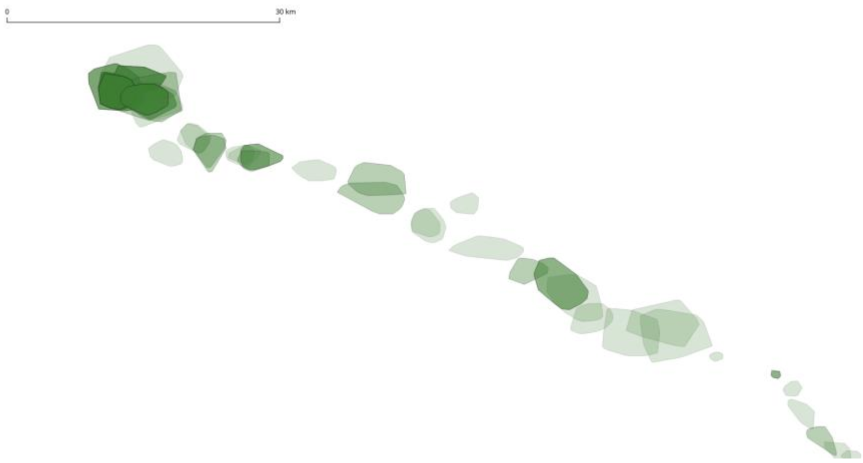

Figure 4 Raw cell phone data of a single device. (Due to the confidential nature of cell geometry information, this figure is provided without background map.)

Figure 4 shows the raw cell phone data of an example trajectory. The green areas represent the location information derived from the cell network. Clustering and stop detection algorithms are applied on the raw cell phone trajectory to create a plausible sequence of directed A-to-B Trips (a "trip chain").

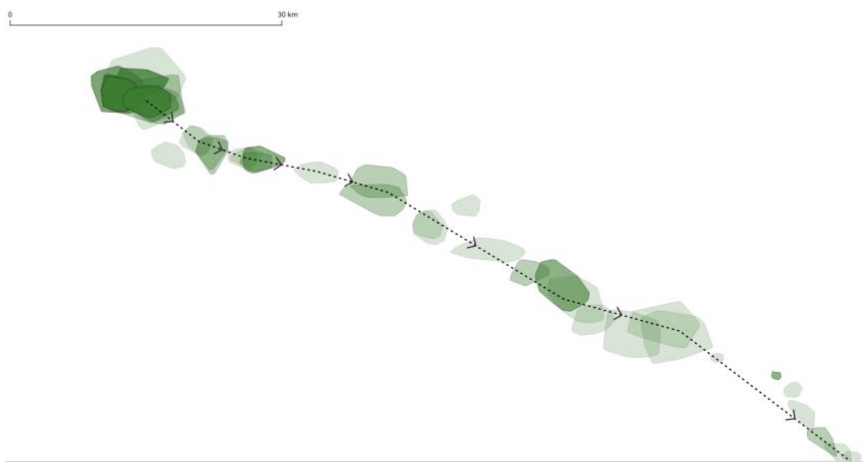

Figure 5 Detected TripChain (part)

Figure 5 shows part of a trip chain. The dashed black line indicates the most likely trajectory of the user. To determine the **most probable travel route and mode of transport** for this trajectory, a **route reconstruction algorithm** is applied. The route reconstruction algorithm matches the trajectory to an underlying road and public transit network (based on OpenStreetMap data). The state-of-the-art algorithm for this task is Hidden Markov Model-based map-matching (Newson, P., & Krumm, J. 2009). However, this algorithm involves a number of computationally costly shortest path routings, which grows quadratically with the position measurement error. For cellular data with position errors of several hundred meters this method quickly becomes computationally infeasible. In MIMIC the route reconstruction problem has been formulated as a graph search in a multi-layer graph. To perform this operation efficiently, A modified version of the A* algorithm was used to solve this graph-search problem and determine the most likely travel route.

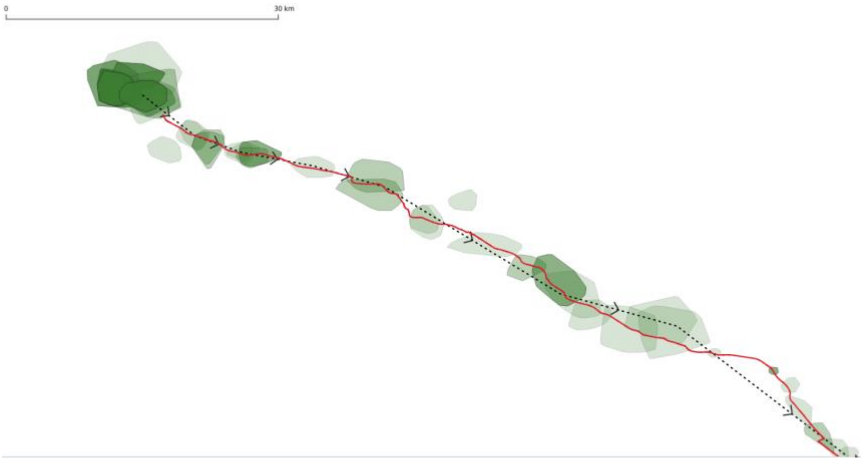

Figure 6 Reconstructed Route

Figure 7 Reconstructed Route (detail view)

Figure 6 shows the reconstructed route on the road network in blue. Figure 7 shows a part of the reconstructed route in detail. Note that while the input trajectory (black) is just a straight line, the reconstructed route (blue) closely follows the road network.

The algorithm has been validated experimentally on a small sample of the available test data from volunteers. In addition, the resulting link traffic volumes have been compared to the projection of a MATSim simulation model of Vienna (see Chapter 3), which has been calibrated to the latest national mobility survey (Österreich Unterwegs) and cross-sectional traffic count data (Figure 8). The two estimates are in good agreement, with the exception, however, of the motorways, which can be explained by the fact that the trips from the cellular data did not include commuting trips.

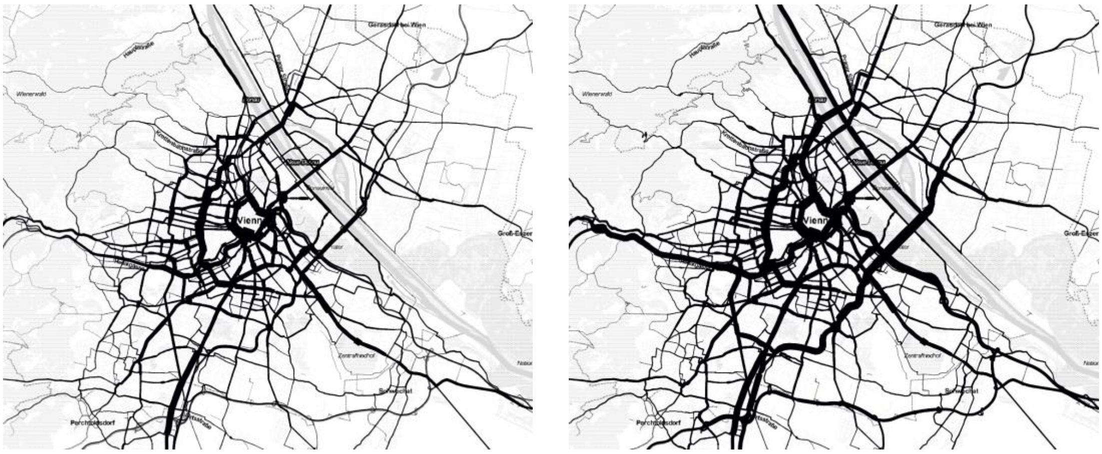

Figure 8 Link flow volumes estimated with the cellular data (left) and a MATSim simulation model (right).

A comparison of the estimated traffic volumes in public transport (Figure 9) shows a clear shift from the affected section of the U4 subway line to the parallel section of the U3 line. Less than half of the former U4 journeys have shifted to rail replacement services (dark red line). It can also be seen that not only the closed section of the U4 line is affected by the construction work, but that the sections before and after also show a decline in passengers. On the other hand, during the construction work in July, the number of U3 trips to the recreation area around the Danube river ("Donauinsel") increased, which certainly cannot be attributed to the construction site, but rather to the warm season of the year.

Figure 9 Estimated link flow volumes in the public transportation network in March 2019 (before the construction works) and significant increase (red) and decrease (blue) during the construction work in July 2019.

During the construction work there was also a decrease in car traffic along the streets ("Wienzeile") running parallel to the closed subway section. This can be explained by the fact that some lanes were closed for the time of the construction work. However, it cannot be ruled out that this observation is caused by inadequacies in the measurement method using cell phone data. Subway traffic cannot always be clearly distinguished from nearby and parallel car traffic. The apparent decrease in traffic volumes on the road could therefore be (at least partially) due to the elimination of subway journeys. There is no discernible shift of subway traffic to car traffic. However, as in public transport, there is an increased number of car trips to the recreational areas “Donauinsel” and “Alte Donau”.

Figure 10 Estimated link flow volumes in the road network in March 2019 (before the construction work) and significant increase (red) and decrease (blue) during the construction work in July 2019.

3. Construction site impacts on city traffic

The goals of WP3 are to evaluate real-world construction site impact on city traffic using a data-driven approach and to evaluate construction work scenarios under different logistics optimization approaches. The approach applied for this analysis is depicted in Figure 11.

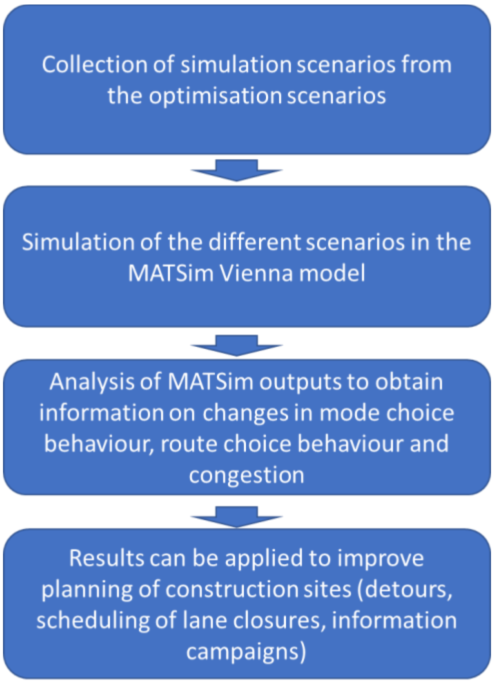

Figure 11 Approach to apply an agent based MATSim model for the planning of construction sites.

The construction logistics case for Sweden has been optimized and presented to the Swedish traffic administration and concerned decision makers (Fredriksson 2021). The Austrian case has been optimized as well and integration of the traffic simulation into the optimization procedure is currently being set up. A step towards the integration was the setup of the Vienna MATSim model to evaluate the influence of lane closure on traffic and modal split. Scenarios were developed, and first analysis were run on the MATSim simulation output.

3.1 Agent Based Transport Simulation

To evaluate the transport related effects of large construction sites with lane closures due to storage areas, three scenarios were initially simulated in the AIT's MATSim Model Vienna (Müller 2021) which is also available as an open source model[1].

Below, the main characteristics of the MATSim Vienna Model. For more detail refer to Müller et aL 2021.

- **Simulation Area:** Vienna and surroundings in a 30km radius (total population: 2.33 million, area: 4170 km², Figure 12)
- **Network**: 156k links and 71k nodes extracted from OpenStreetMap with pt2matsim
- **Facilities:** 435k locations extracted from OpenStreetMap and the geostat population density grid (2011)
- **Population synthesis**: based on the Austrian mobility survey *Österreich Unterwegs 2013/14*[2]
- **Population**: 200k agents represent 12.5% of the mobile population older than 17 years. The agents use the MATSim modes walk, bike, pt, car.
- **Routing**:
  - open access model: MATSim car routing and teleporting for all other modes
  - full model: *Ariadne* intermodal routing framework calculating exact travel times for all modes and also allowing for intermodal trips such as park and ride
- **Mode choice model:** based on travel survey from WU/BOKU Vienna (Hössinger 2020) 10 subpopulations with different utility functions. Assignment of an agent to a subpopulation depends on socio-economic characteristics.
- **Calibration:** 180 count stations for traffic volumes, normalized error for peak hours:
  - open access model: 0.4
  - full model: 0.33

[1] https://github.com/ait-energy/matsim-model-vienna
[2] https://www.bmk.gv.at/themen/verkehrsplanung/statistik/oesterreich_unterwegs/berichte.html

- **Freight Traffic** is not included directly in the simulation directly. Instead, the capacity of the network is reduced by 15% according to average delivery traffic[3].

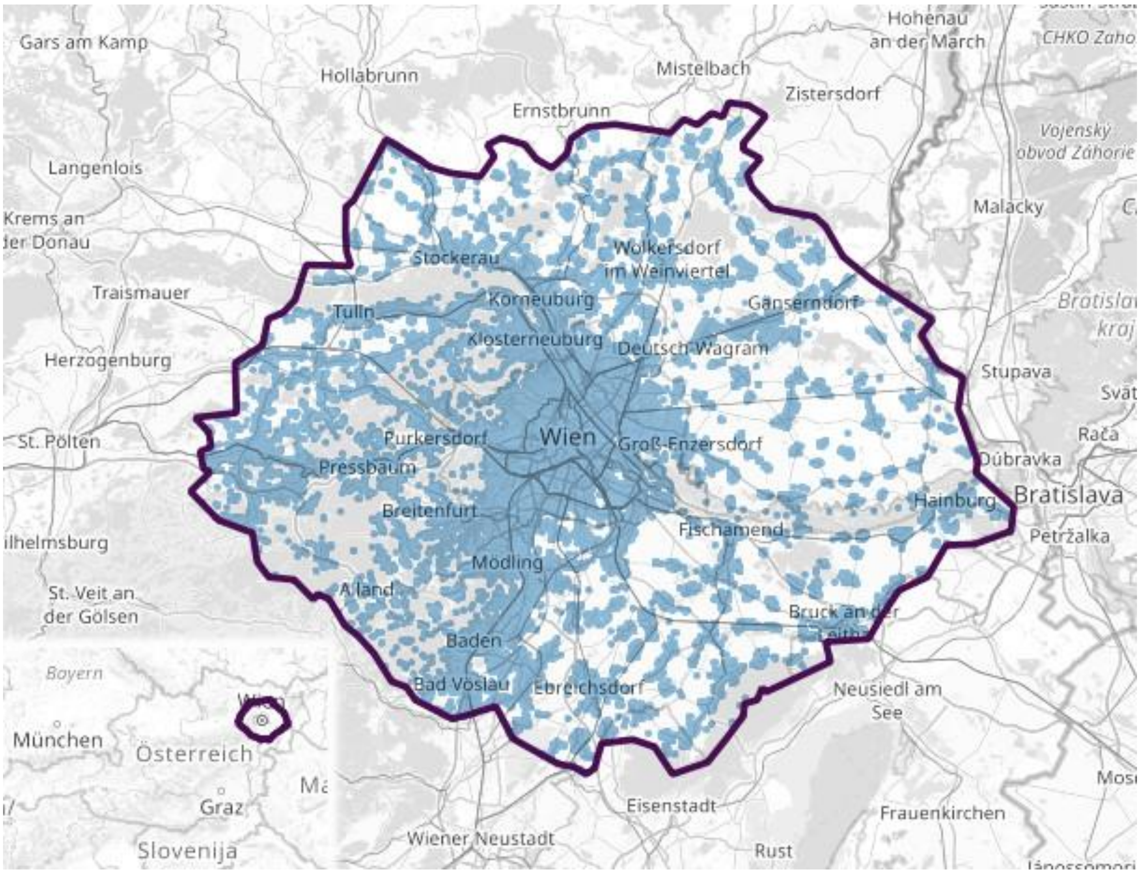

Figure 12 Simulation region of the MATSim Vienna model

The MATSim Model Vienna is intermodal through usage of the Ariadne routing framework, i.e. allows for park and ride or combining cycling with demand responsive transport on a single leg.

In the full model we follow the same approach as described by Hörl et al (2019), where the classic MATSim cycle of trial and error with random changes to plans is discarded as it would take too much time to fully explore all intermodal possibilities. This leads to much faster convergence towards a state of equilibrium.

Instead of random changes to the agents' plans we use Ariadne to only generate plausible intermodal plans. To further increase the simulation time all plausible plans are pre-calculated and cached for the whole population. This cache can then be used for all simulation runs.

[3]http://www.bestufs.net/download/BESTUFS_II/national_seminar/Abgesagter_Termin/BESTUFS_Lieferverkehr.pdf

For each of the scenarios one business day is simulated. The baseline scenario simulates a working day in Vienna without obstructions due to construction sites. In Scenario 1 minimal restrictions were introduced for two sites along the subway under construction in Vienna and one at a site of a subway renovation project that happened in 2019. Two of the sites are main arteries into and out of the city (Triester Strasse and Wienzeile at Pilgramgasse) and one is one of the main streets close to the Vienna city center (Rathausplatz). At each of the sites, one lane was closed on the full length of the site (capacity was reduced accordingly). In Scenario 2 at the same sites, only one lane was kept open on all the links between two intersections. The details of the scenarios can be seen in Table 1.

Table 1 Closed lanes in the two MATSim scenarios

Location	Scenario 1	Scenario 2
Pilgramgasse (Two lanes on 89 m and three lanes on 52m)	One lane open 89 meters, two lanes open for 52m	Only one lane open for 141m
Rathausplatz (Two lanes for 107m and three lanes for 112m)	Two lanes open for 219m	Only one lane open for 219m
Triester Straße (3 lanes for 189m, 4 lanes for 105m)	Two lanes open for 189m and three lanes open for 105m	Only one lane open for 294m

The MATSim simulation produces several output files including one, that contains all trips as a chain of used links with entry and exit times to these links. These files are analysed in the MATSim analysis Tool Via[4]. In addition, information of mode usage per trip is generated by MATSim for all users, allowing a detailed mode choice analysis in the scenarios.

First analysis results show that there is no real effect on the overall modal split for the complete study area with less than 0.1% of reduction of car journeys for Scenario 2. When only the agents that travel over the restricted links by car in the baseline scenario are taken into consideration, the modal split of these agents changes considerably. When looking at all the trips of the respective agents on the day, the modal split of car for those agents drops from around 95% car trips on the day to between 74% car trips for the Triester Straße agents to 65% for those agents travelling over the Rathausplatz links.

In addition, car counts and average speeds around the three building sites were analysed. In Figure 13 the difference between the number of cars travelling on each link over the cause of the day in the base line scenario and in scenario 2 can be seen. One can see that the number of cars at the building sites is reduced for all three sites. There are also some apparent detours that travelers take by car but the increased number of cars on these detours appears small in comparison to the reductions on the surrounding links.

4 https://simunto.com/via/

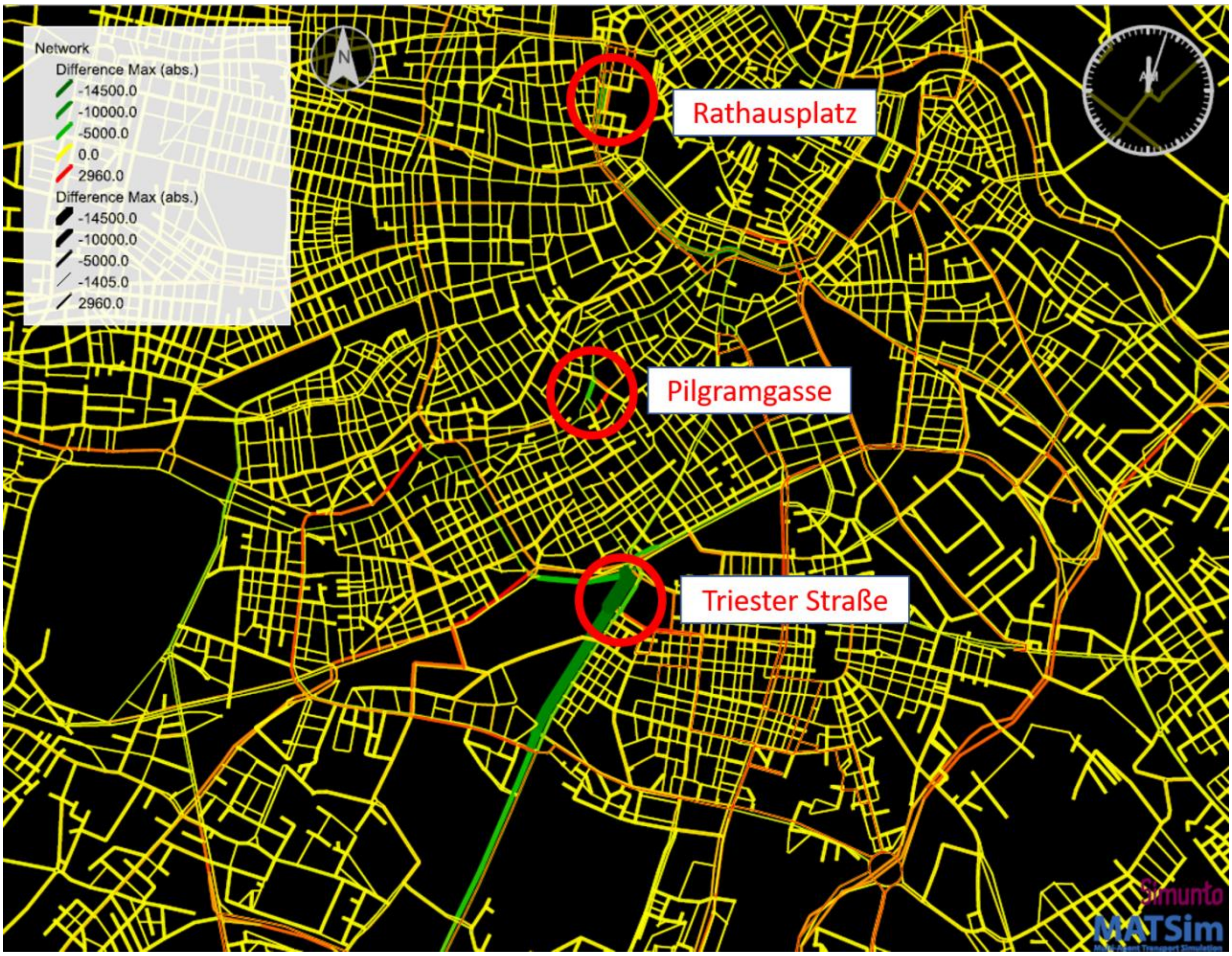

Figure 13 Difference in car counts on the links between the base line scenario and scenario 2.

Similarly, when looking at the average speeds on the links extracted from the trips data in Via one can see the following: The speeds are dropping considerably on the restricted links. In addition, there are reductions in speed on the surrounding links (see Figure 14). For the Pilgramgasse case, this is only clear for one detour where parts of the traffic are shifted to. For the Triester Straße case, the small links surrounding the site are adversely affected due to the relatively large number of cars shifted into the small side streets. However, one can see that the reduction in traffic actually improves congestion on the feeder lines at the top of the map.

Figure 14 Differences in average speeds on the restricted and surrounding links between the base line scenario and scenario 2 for the two sites at Pilgramgasse and Triester Straße.

The results show that construction sites clearly obstruct car traffic and shift some traffic to different routes, often not large enough to handle the added traffic. Some of these effects are difficult to avoid, but there might be useful countermeasures that can be planned during the planning of the construction sites The increase in congestions as well as decreases in speed and increases of congestions in the surroundings implies the need to carefully plan both the sites as well as traffic restrictions in the surroundings, e.g. limit restrictions to times with less traffic demand (summer months, off-peak times) if possible, signpost allowed detours on roads with enough and restrict detours on other routes to avoid unwanted increases in traffic in smaller, residential streets. In addition, a well-organized campaign to shift people from their cars to other means of transport. The simulation results suggest that there is a considerable increase in public transport usage by people that usually use the roads along the construction sites. However, the construction sites may pose the chance to increase the share of public transport users even further, if travelers are informed about alternatives like P&R, high level bike routes or public transport alternatives in advance.

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