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1. Reading guide

The structure of this deliverable is based on the guidelines of Deliverable 4.1 that i) describes an assessment framework for a methodology process, used to systematically assess progress and valorize results of the demonstrations and provide valuable feedback to the different methodological frameworks developed in WP 1, 2 and 3, and ii) describes an assessment framework for the demonstration’s progress and results to identify cost-effective strategies, measures and tools to improve the sustainability of construction related urban logistic activities.

As the Vienna demonstration deals with development of a data-driven prediction model, some sections of the Demonstration Deliverable template as conceived in D4.1 are not relevant, such as “Recommendations and lessons learned from previous demonstrations”. For reasons of consistency, we kept the structure as foreseen, but indicated which parts were not relevant for this first demonstration deliverable.
2. Introduction

2.1 Background CIVIC

Construction is required to create more attractive, sustainable and economically viable cities. This includes the expansion of infrastructure, development of new residential areas and renovation of buildings. However, construction-related transport has a negative impact on people who live, work and/or travel in the vicinity of construction sites (Gilchrist 2005; Quak et al. 2011).

CIVIC (Construction In Vicinities: Innovative Co-creation) supports transport to, from and around urban construction sites that minimizes disruptions in the surrounding community and optimizes energy efficiency. This is done by 1) evaluation of alternative measures in a multi-actor participatory setting; 2) optimization of models for planning and impact assessment using smart data; and 3) development of smart governance concepts for successful and efficient implementation of these tools. This deliverable focuses on the optimization of models for planning.

Over the last five years, strategic research has led to increased understanding on potential energy efficient measures for construction related transport. However, practical improvements are barely implemented in the field, mainly due to the sensitive, multi-actor environment in which decision-makers work. By combining innovation and implementation with applied research, CIVIC will support the movement from “research to market” through experiences from the four European cities that will host demonstration sites for the project: Brussels, Vienna, Amsterdam and Stockholm.

All demonstrations will also implement innovative impact assessment methodologies, in order to gain a more detailed insight into actual effects of construction logistics on stakeholders and the environment. The specific ambition for implementation in CIVIC is that the first actual impact takes place before the end of the project. This is achieved through the involvement of stakeholders of local construction projects planned for 2016-2018, both within the consortium and as implementation partner with a letter of intent. These partners are real estate, logistics and transport companies, including their clients and suppliers.

The results of the two and a half-year project are the identification of energy efficient transport solutions to, from and around construction projects, by implementation of participatory analysis; increased understanding among all stakeholders of the impacts of improved logistics and mobility; and recommendations for smart governance concepts, which go beyond urban construction as they create a supportive platform for all urban development decision processes.

2.2 Background demonstration

The aim of Task 4.3: Demonstration and assessment Vienna is to support the movement from research to implementation by demonstrating and assessing the methods and concepts as developed in WP1, 2 and 3.

Project-history is shown in document “asperm-project-history”
Details concerning governance at Seestadt Aspern can be found in the document “20170308_Task 3 1 Current governance structures data collection 161121_answer-SEESTADT”:

Wien3420 development AG tasked BL&UM in January 2013 (commissioning) through tendering procedure with the overall site organization, transport logistic and way data acquisition as well as environmental assistance for the urban development project “Seestadt Aspern”. Then, the building construction phase started in May 2013. The logistic area (unpainted provision by Wien 3420 development AG) is prepared and managed by BL&UM. Furthermore BL&UM develop, coordinate and check the primary guidelines and objectives by regular meetings and site visits (in coordination with Wien3420 development AG). Based on current contractual regulations each building lot arranges their internal responsibility on its own (as usual for building sites).

The demonstration is focused on the first main construction phase (Mid 2013 – Mid 2015) with overlapping building construction and construction of technical infrastructure (surface, water supply & disposal, power supply, district heating, telecommunication, ...)

In the Austrian context of CIVIC, novel dynamic optimization methods are implemented and evaluated considering Seestadt Aspern in the city of Vienna. Figure 1 shows the development phases of Seestadt Aspern. Data collected in the first phase was provided by the demonstration partner Bernard Engineers and analysed by researchers at AIT. Data included size and schedule of construction sites, as well as truck trip data. Findings are considered for the planning of construction tasks for the second development phase. The movement from research to implementation was supported by regular demonstration and assessment of the methods and concepts developed in WP2, together with Bernard Engineers. In this way, adaptations could be performed to create realistic settings and valuable insights.

Figure 1: Development phases of Seestadt Aspern

This demonstration builds on real-life data (of construction sites and corresponding truck trips) from demonstration partners collected within Task 2.1. Based on the initial data analysis
performed in Task 2.1, this task deals with integrating the collected data as well as further feedback from the demonstration partners into an enhanced prediction model that will be used to evaluate future construction scenarios.

Construction site data for Seestadt Aspern includes plans of individual construction site location (see Figure 2 for an example) and time schedules that provide details about which construction phase (earth works, cellar, core building, and façade) took part during which period. The time schedule was converted from planning-focused MS Projects format to a consistent analysis-focused schedule for all sites. The construction site maps (starting from summer 2014) also provided information about the location of the gates that were used to count incoming and outgoing trucks (circles marked B, C, and D in Figure 2). These gates are mobile and have been moved to different locations several times in the past years depending on the progress of the construction activities. In parallel, the road network was developed as well and this means that different construction sites were accessible via different streets and counting gates at different times during the construction process. The mapping of gates to construction sites provided by these maps was converted into a schedule for analysis as well. This enables us to match truck trip data to a set of construction sites.

- Wien3420 development AG tasked BL&UM through tendering procedure with the overall site organization, overarching construction logistic, transport logistic and way data acquisition as well as environmental assistance for the urban development project “Seestadt Aspern”
- BL&UM fulfill the superordinate site logistics by them self as well as by delegating subsidiary parts to the individual building lots
- BL&UM coordinate and check the primary guidelines and objectives by regular meetings and site visits
- Based on current contractual regulations each building lot arranges their internal responsibility on its own (as usual for building sites). Before starting construction phase each building lot have to give information concerning internal responsibility (organizational structure, standard procedures, contact data, …) to BL&UM
- Each project participant is responsible to organize and invest for necessary equipment. There is no superordinate organized equipment for rental.
- Overall Coordination (BL&UM) as well as the Ombudsman and other over all investments (construction roads, noise monitoring …) are paid by the development company (Wien3420 Development AG). Following a defined payment schedule each Investor (building lot) has to pay proportionate costs (per m² gross floor area) to finance the payment of the development company.

Truck trip data is collected at gates using RFID in order to count incoming and outgoing trucks for the whole Seestadt construction area. Each gate consists of three RFID antennas (as illustrated in Figure 3). This setup makes it possible to distinguish incoming from outgoing trucks. Trucks need a specific RFID tag to open these gates and access the area. Each tag has a unique identifier. These identifiers are stored together with information about the activated RFID antennas and timestamps and provide the basis for analysis of construction site traffic. Due to the nature of the RFID technology, this data is very noisy since antennas can pick up tags from quite far away and do so multiple times even if the respective truck is not actually passing the gate. This raw data has been cleaned and processed to derive the daily actual and accurate incoming and outgoing traffic.
Figure 2: Layout of the individual construction sites with information about the gates for counting in and out going trucks

Figure 3: Setup of the truck trip data collection system using RFID gates
2.3 Structure of deliverable

The evaluation activities within CIVIC serve two major objectives: (i) facilitate the implementation of the methodological frameworks within CIVIC (Act/Decide), and (ii) identify cost-effective strategies, measures and tools to improve the sustainability of construction related urban logistic activities (Compare).

The assessment of a demonstration will therefore have two main components:

1. Assessment framework for the methodological progress
2. Assessment framework for the demonstration’s progress and results

The structure of the overall CIVIC Assessment framework is given in Figure 4. The different evaluation frameworks need to be linked to allow feedback from one framework to be used as input in the other framework over each cycle.

![Assessment Framework](image)

*Figure 4 Assessment framework structure*

The final goal is to embed the participatory setting (e.g. participatory MAMCA) and dynamic logistics optimization methodologies within the smart governance concept. This deliverable will primarily focus on the challenges to develop reliable prediction models for construction-related truck traffic.

The second assessment framework needs to monitor the progress of the CIVIC demonstration both with regards to timing as with regards to performance indicators. The demonstration needs to be assessed on three dimensions:
1. Impact on stakeholders' criteria
2. Impact on citizens' participation
3. Impact on energy efficiency

The structure of this deliverable is based on the necessary steps towards development of the prediction model in Vienna.

2.4 Recommendations and lessons learned from previous demonstrations

As this deliverable focuses on data-driven development, previous lessons learned in the Brussels demonstration do not apply here, hence this section is not applicable. However, to maintain the same structure over the different demonstration deliverables, this section number is maintained as lessons learned from this demonstration will be used in further deliverables.
3. Roles and responsibilities

3.1 Description of roles and responsibilities

3.1.1 Demonstration coordinator

The demonstration coordinator for the Vienna demonstration is the research group Dynamic Transportation Systems at the AIT Austrian Institute of Technology. The person appointed for coordination was project leader Pamela Nolz.

3.1.2 Demonstration stakeholders

The demonstration stakeholders are a group of organizations that need to be involved in the organization and implementation of the demonstration. Stakeholders are usually involved in the strategic and practical governance and implementation of the demonstration.

AIT works closely together with the BauLogistik und Umweltmanagement (BLUM) by Bernard Engineers in Seestadt Aspern.

3.1.3 Users

The users are the organisations that are involved in testing the proposed innovation or solution in real life. Depending on the solution, users can be organisations or a specific group within organizations.

Results of the developed prediction model have been evaluated by the experts at BLUM. Further tests involving other stakeholders are planned for the future.

3.2 Overview

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<th>Task description</th>
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<tr>
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<td>AIT</td>
<td>Pamela Nolz</td>
<td>Coordinator of the Vienna demonstration</td>
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<tr>
<td>Demonstration stakeholders</td>
<td>BLUM / Bernard Engineers</td>
<td>Thomas Holaus</td>
<td>Coordinator at BLUM, the BauLogistik und Umweltmanagement, Seestadt Aspern.</td>
</tr>
<tr>
<td>Costumers</td>
<td>Consortium</td>
<td>Susanne Balm</td>
<td>Management of the learning loops around the different demonstrations</td>
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<td>Contractors</td>
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<td>Participation</td>
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4. Process: methodological assessment

4.1 Introduction

The prediction model integrates both construction site and truck trip data in order to predict the number of trips generated by a particular future building project. This model provides an objective basis for public discourse. The developed prediction model is the basis for a visualization tool that can be used in citizen communication to demonstrate impact of future construction sites to a citizen audience. Furthermore, the information could also be used for local traffic management and road safety actions.

We designed a mathematical model for each phase of the building process. Specifically, the models use a linear kernel estimator with a quadratic kernel. As the number of trips per day is highly volatile and depends on many external factors, such a model is bound to be limited to only give a qualitative approximation to the number of trips per day.

4.2 Implementation

4.2.1 3-Phase Model

Based on an initial analysis of the available real-world data, the 3-phase model distinguishes three building phases: earthwork, construction underground, and construction over ground, in order to avoid over fitting. To estimate the model parameters, the dataset was split into a training set and a test set. The training set consisted of 30% of the days, sampled at random. Model estimation was performed for concrete delivery and earthwork, the two types of trips with the most available data. The computed parameter values for each building phase are depicted in Figure 5. They both show similar characteristics, but with an expected stronger influence of earth transportation during the earthwork building phase.

The trained 3-phase model was used to compute the estimated trips for each building site. To this end, we extracted the building phase starting dates and the building size for each site from the provided documentation. We then summed the resulting trips for each day to arrive at the estimate for trips per day. The results for each trip type as well as the measured number of trips can be seen in Figure 6.

Figure 5: Computed parameters of trips for each phase of the 3-phase model for concrete and earthwork
As expected, only the general shape of the trip numbers can be reconstructed by the model and the fit still leaves some room for improvements. These issues have been examined further and – together with feedback from our demonstration partner – provided the basis for the refined model.

*Figure 6: 3-phase model prediction versus observed trips per day for concrete and earthwork*
Based on the results from the previous step a refined model was implemented. In order to reduce input data noise, the input data was cleaned (removed weekends, holidays and time periods with inconsistent data) and aggregated to time-slices of 1 week. A new phase model was created based on expert feedback: building phases are no longer aggregated but kept as separate input variables. In addition, the “earthwork” phase was split into two separate parts: “earthwork main” and “earthwork last”. This strategy allows the model to better capture the transition from earthwork to concrete trips that happens at the end of the earthwork building phase. While there are no concrete trips during the main earthwork phase, there are already first concrete deliveries during the earthwork last phase. As a result, the refined model uses the following building phases as separate input variables: Earthwork_main, Earthwork_last, Concrete, Facade, and Interior.

The refined model was trained on a random sample of the available data (60% of the days used for training, 40% used for testing/validation). Example model predictions for a typical construction site with 1000m² are shown in Figure 7. The figure shows the model prediction (red line) with a 50% confidence interval (grey area) for earthwork and concrete trips. It can be observed, that in contrast to the 3-phase model, the refined model predicts concrete trips only during the concrete building phase and during the last few days of the earthwork phase (in the beginning of March 2017). The number of predicted concrete trips is slightly higher during this transition period. However, the confidence interval during this period is large, as the number of concrete trips during the Earthwork last phase varied greatly in the available training data.

Based on expert feedback, the predicted phase durations are: 69 days for earthwork, 69 days for the cellar, 160 days for the building shell, 181 days for the facade, and 120 days for the interior.
The model predictions for all available data are shown in Figure 8. The figure shows the original data (blue line), the predictions (red line) and a 50% confidence interval for the predictions (grey area). The lines are discontinuous in several places, where whole weeks of data had to be removed in data pre-processing (e.g. seasonal holidays). Given the high noise of the original input data an overall satisfactory fit can be observed. Detailed evaluation results are discussed in the next section.

*Figure 8 Predictions for earthwork, concrete, and total trips of the Refined Model (training and test data)*
4.3 Evaluation

The model performance was evaluated with a random sample of 40% of the available data (note that this test data was not used for model training). Figure 10 shows the model predictions for the test data.
Figure 10 - Model predictions on test data

The deviations between the actual values and the model predictions are shown in the scatter plots of Figure 11. It can be seen in Figure 10 and Figure 11 that both models capture the general shape of the trip numbers, but are not able to predict the variations well (as indicated by the RMSE\textsuperscript{1} values for both models). Besides the high natural day-to-day variation of trips, this is most likely due to the noisy input data and deviations between the available building schedule and reality. A related artefact can be, for example, observed in the predictions for concrete trips: starting in October 2014, the number of predicted concrete trips is generally too low. This is caused by an inconsistency between the planned building phases and reality: according to the available time schedules, almost no building sites were in the “concrete” building phase after October 2014 (as illustrated in Figure 9). The model thus predicts a very low (almost zero) number of concrete trips, which contradicts the measured number of such trips.

\textsuperscript{1} The root-mean-square error (RMSE) is a frequently used measure of the differences between values (sample and population values) predicted by a model or an estimator and the values actually observed.
A systematic analysis of the model error distribution is presented in Figure 12. The boxplots show, that the average estimation error for both earthwork and concrete trips is close to zero, thus indicating a small model bias. The results show a much larger interquartile-range for the Earthwork model errors. This is due to the higher number of earthwork trips and their more unpredictable nature (which is in part caused by their spread across all building phases).
Given the high noise of the available input data, the refined model shows a satisfactory overall performance within a 50% confidence interval (see Figure 8). A lot of potential for further model improvement exists: this includes distinguishing between additional trip types, including diurnal variations in the prediction model, utilizing more fine-grained building schedules, explicitly modeling inter-building-site dependencies and using more sophisticated prediction algorithms. However, to make such improvements viable, more and higher quality training data would be required. Future research efforts will therefore have to deal with finding economically feasible ways to collect appropriate data.

4.4 Act/Decision

The Act/decision phase takes the results of the evaluation phase and use these to decide on the continuation or not of the implementation case and CIVIC methodological frameworks. This will result in important feedback towards the methodological framework and lessons learned towards subsequent demonstrations. This is an essential part in order to develop the learning cycle. In order to be able to perform this step, it is crucial to identify the recipients of the tools.

4.4.1 Making Decision

The Vienna demonstration has shown great opportunities to provide predictions of truck traffic incurred by construction projects.

4.4.2 Acting on decision

We envision the following actions taking advantage of the predictions provided by our model:

- Prediction based planning for future construction projects in a way that balances truck traffic over time
- Prediction based public discourse and citizen communication to demonstrate impact of future construction sites to a citizen audience
- Prediction based local traffic management and road safety actions

4.5 Conclusions

The Vienna demonstration was able to advance the data basis for construction logistics planning.

Improvements/developments

- How was the methodological framework improved during this demonstration cycle? What are major and minor improvements?
  - Development of a prediction model for truck trips based on historic truck trip data
- Which developments are specific for this case and which ones are beneficial from a more general viewpoint (transferability)
  - Since the number of required transports is not location-specific, it is expected that the developed prediction model can be transferred to other sites where similar constructions projects are planned.
  - Similarly, if historical data from other sites can be obtained, the developed model can be retrained accordingly.
- How did the methodological framework aid in achieving the demonstration goals (link with demonstration assessment)?
  - Not applicable

Learning cycle: Lessons learned & attention points.
• Describe how lessons learned and attention points from previous demonstrations have been taken into account.
  o As this is a data-driven development, previous lessons learned in the Brussels demonstration did not apply here.
• List the most important lessons learned and attention points for further development and implementation in subsequent demonstrations (as main items to be taken into account by subsequent demonstration coordinators).
  o Our prediction model makes it easier to plan future construction projects in a way that balances truck traffic over time. Furthermore, the model provides an objective basis for public discourse and citizen communication to demonstrate impact of future construction sites. The information could also be used for local traffic management and road safety actions.
  o There is significant potential for prediction model improvements if more detailed truck data can be obtained. For example, it might be feasible to expand the current setup by installing additional RFID readers at construction sites. This would enable us to determine the actual destination of truck deliveries with more detail. Similarly, information about truck loading rates could provide the basis to determine the potential of bundling deliveries.
5. Impact: demonstration assessment

How did the demonstration perform on the three dimensions?

1. Impact on stakeholders' criteria:
   One criterion in the environmental impact assessment (EIA) for the Seestadt Aspern area is the maximum number of allowed truck trips per day. To proof compliance with this requirement, incoming and outgoing trucks had to be monitored and counted. In our demonstration, we used this historical data to develop the prediction model for future number of trips. Our prediction model therefore should make it easier to plan future construction projects in a way that balances truck traffic over time.

2. Impact on citizens' participation
   An important goal within CIVIC is aimed at finding ways to increase the participation of citizens in creating more sustainable urban environments. The analysis of historical truck movement data provides an objective basis for public discourse. Beyond providing quantitative information, the developed prediction model and visualization tool can be used in citizen communication to demonstrate impact of future construction sites to a citizen audience. The information could also be used for local traffic management and road safety actions.

3. Impact on energy efficiency
   The developed prediction model does not directly influence energy efficiency since the overall number of truck trips is not affected. If the model is used to balance truck traffic over time, there is potential to improve energy efficiency by reducing congestion in peak times.

What are lessons learned for transferability of demonstration measures?
   o Since the number of required transports is not location-specific, it is expected that the developed prediction model can be transferred to other sites where similar constructions projects are planned. Similarly, if historical data from other sites can be obtained, the developed model can be retrained accordingly.

What are general or more case-specific attention points?
   o It is worth noting that data-driven methods strongly depend on the quality of the available training data. Consequently, gaps and uncertainties in the training data make it more difficult to develop reliable prediction model.

   o In this specific case, training data was collected before the start of CIVIC for the purpose of proofing compliance with EIA requirements. The data collection goal therefore wasn’t aligned with our goal of developing a prediction model. As a result, we had to deal with uncertainties about the final destination of trucks entering the construction area since we could only observe when trucks passed a gate but we could not determine exactly which construction site was their destination.

How can subsequent demonstrations be improved?
   o As described in the previous section, there is significant potential for prediction model improvements if more detailed truck data can be obtained. For example, it might be feasible to expand the current setup by installing additional RFID readers at construction sites. This would enable us to determine the actual destination of truck deliveries with more detail. Another interesting aspect would be the analysis of truck loading rates in order to determine the potential for bundling of deliveries.

What were barriers and facilitators for the demonstration measures?
   o Development of the prediction model was facilitated by the fact that truck movement data had already been collected for the purpose of the EIA. If this would not have been the case,
the organizational and financial effort might well have been too high to justify for the sole purpose of developing a data-driven prediction model.

- In general, it is challenging to gain access to comparable information since there are few incentives for carriers to cooperate in data collection campaigns. In some countries, truck data is already collected centrally for the purpose of km charging but this data falls is subject to strict privacy laws and therefore generally inaccessible for researchers. For this very reason, it seems unlikely that more comprehensive data, for example, including GPS tracks will be available at other sites.