



Eberswalde Use Case set up Report

Pillar A

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SUMMARY SHEET

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Abstract	<p>D2.10.1 describes the set-up of the Eberswalde use case. The objective of this use case is a feasibility study on the operation of the diesel bus line 910 into the existing trolleybus system using trolleybuses that are retrofitted with energy storages.</p> <p>Furthermore, automatic wiring systems will be tested and evaluated.</p>		
Keywords	trolley buses, buses with partial catenary free operation, batteries		
Critical risks	<p>The inclusion of the existing diesel bus line 910 into the trolleybus system is not possible.</p> <p>Insufficient battery range.</p> <p>Systems for automatic wiring not available.</p>		

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CONTRIBUTING PARTNERS

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UITP	Yannick Bousse	International Association of Public Transport

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1. Executive Summary

D2.10.1 describes the set-up of the Eberswalde use case. Within a feasibility study the possibilities of including the diesel bus line 910 between Finowfurt and Eberswalde into the existing trolley bus system are to be evaluated. Within Eberswalde, buses of line 910 already run along the existing catenaries. After the inclusion of line 910 into the catenary network, approx. 60 % of the total length of line 910 would be under the catenaries. This requires the retrofitting of the already existing trolleybuses with a sufficiently large energy storage. They are to replace the currently installed autonomous diesel power units which weigh approx. one ton.

It is planned to recharge the energy storages while the buses run under the catenaries. As soon as the buses leave the catenary network, the entire electric energy and power are provided by the vehicle energy storage only. This leads to the necessity to minimize the energy storages and to avoid losses in passenger capacity. Furthermore, smaller energy storages will cause less energy consumption.

The feasibility study will also answer the question whether the existing catenary network will be able to provide enough charging power. Additionally, it will be assessed whether the energy storage can cover the remaining 40 % of line 910 without additional recharging. If this is not the case, additional charging opportunities must be installed at the terminal stops of line 910.

A necessary prerequisite for the operational concept described above is a fast wiring and unwiring of the pantographs. Therefore, different systems for automatic wiring of trolleybus pantographs will be tested within the Eberswalde use case.

The Eberswalde use case will serve as an example for the operation of so-called hybrid trolleybuses which can be driven with and without catenaries. Such operational concepts are an interesting alternative on bus lines that serve high passenger demand using articulated buses.

2. Partner Contribution

Company	Sections	Description of the partner contribution
BBG	3	input
Fraunhofer	all	Text
UITP	All	Review of document

3. Context conditions

3.1. Economic, geographical and urban context of the Use Case

In 2015, the city of Eberswalde has a population of approx. 39,000 inhabitants who live on a total area of about 94 square kilometers. Eberswalde is the administrative centre of the district Barnim.

Eberswalde features a T-like city structure with major linear traffic demand. This leads to a concentration of passenger demand for public transport on the major trunk road Eberswalder Straße - Hegermühler Straße - Eisenbahnstraße.

As with all East German cities Eberswalde has been undergoing a major economic transformation during the last 25 years. In September 2015, the official unemployment rate was approx. 10 %. However, as with many regions around Berlin, a significant number of inhabitants work in the city of Berlin, which leads to significant commuter traffic to and from Berlin.

3.2. PT service context

The Barnimer Busgesellschaft mbH (BBG) offers public transport services on 57 bus lines in the districts of Barnim and Märkisch-Oderland. Within the city of Eberswalde BBG transports about 3.9 million passengers per year on five bus lines. The total length of all bus lines in the city of Eberswalde is 97 km.

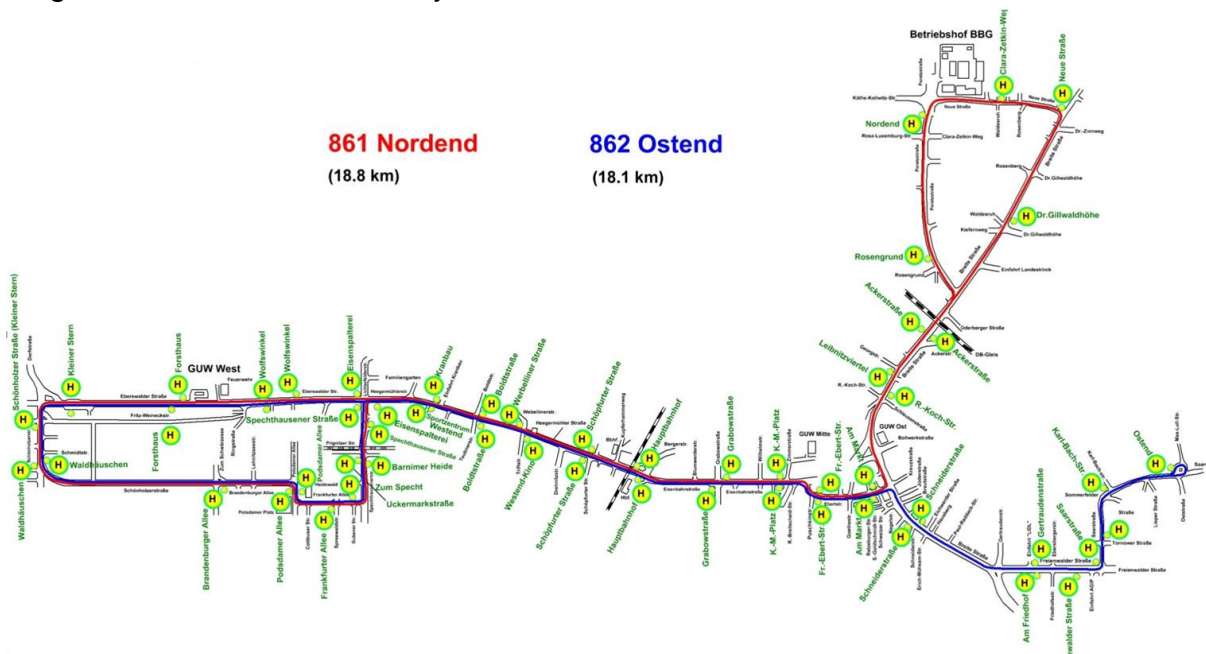


Figure 1: Trolleybus network of Eberswalde

The public transport in Eberswalde is dominated by two trolley bus lines, which annually transport approx. 3,551,000 passengers with 12 trolley buses.

The BBG bus fleet is composed of

- 12 articulated trolley buses,
- 26 articulated diesel buses,
- 72 standard diesel buses, and
- 6 mini diesel buses

with an average age of 8,8 years.

Within the modal split in Eberswalde public transport has a share of approx. 10 %. One trolleybus is equipped with a battery instead of an auxiliary power unit. The nominal energy content of the installed battery is 70.4 kWh. All other trolleybuses are preconfigured for the installation of batteries as well.

3.3. Information about the Use Case

Within the ELIPTIC project the possibilities for using the existing catenary network for the fully electric operation of regional transport buses are to be evaluated exemplarily. For that purpose bus line 910 between Finowfurt and Eberswalde has been selected. Approx. 70 % of the route of this line is already equipped with a catenary (see Figure 2).

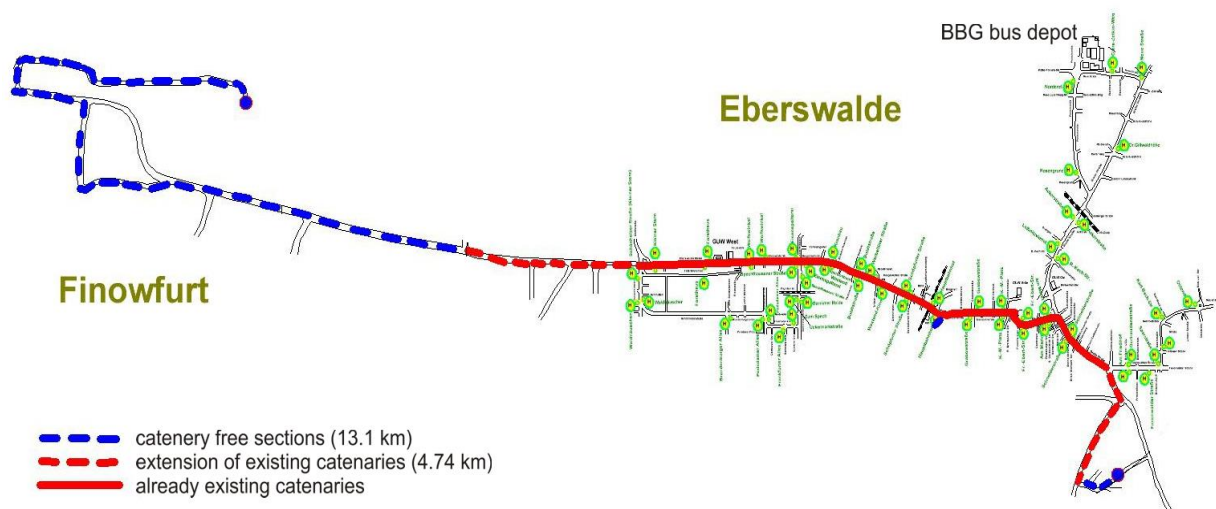


Figure 2: Bus line 910 - existing configuration

In the future this line is to be served with trolleybuses equipped with batteries instead of auxiliary power units.

Trolleybuses already procured in 2010 and 2012 will form the basis for the new operational concept. (Figure 3) Currently, 11 out of the 12 trolleybuses are equipped with auxiliary power units which are not suitable for regular bus services. It is planned

to retrofit some of the buses with suitable electric energy storages in order to replace conventional diesel buses on bus line 910, subject to the results of the feasibility study.



Figure 3: Solaris trolleybus currently operated in Eberswalde

Within a feasibility study the following aspects are to be evaluated:

- an efficient and passenger friendly operational concept in which line 910 is to be merged with the two trolleybus lines in order to minimize the number of additional trolleybuses
- elaboration of a concept which describes the electrical implications such as necessary energy content of the onboard storage unit, recharging possibilities within the existing catenary network and necessary retrofitting of the existing catenary network to cover the additional charging power
- test of a system for automated wiring of the pantographs

The results of the feasibility study will be the basis for strategic decisions on the future bus network in and around the city of Eberswalde.

The feasibility study consists of two major iterative steps. Step 1 is the elaboration of an adapted operational concept which considers the future passenger demand. The major results will be a new alignment of the line, especially in the neighboring town Finowfurt, public schedules, and the according bus operation schedules. The technical feasibility of this new concept will be evaluated within the second step. The questions to be answered are

1. Can the new operational concept be served with trolleybuses that are equipped with batteries that do not cause any losses in passenger capacity and do not exceed the gross axle weight ratings?
2. Can the batteries be recharged while driving beneath the catenaries?
3. Are catenary extensions necessary or useful?
4. Are additional charging stations at the terminal stops necessary or useful?

5. What nominal and usable energy contents must the batteries have?

The analysis will be carried out using the so-called energy balance calculation method implemented in the Fraunhofer software tool *IVision*. The method has been used for the evaluation of many bus lines and whole bus networks in the past. It uses the existing or planned bus operation schedules and duty rosters as the operation of trolleybuses without catenaries shall not lead to any changes in the bus schedules or especially the labor requirements.

The so-called energy balance calculation method compares the available energy in the vehicle energy storage with the consumed energy and the necessary energy reserve at any time throughout a day of operation. The use of trolleybuses with partial catenary-free operation on a certain line is deemed to be possible if

$$E_{bat} + \sum E_{ch} > \sum E_{con} + E_{res} \quad (3-1)$$

with

E_{bat} energy content of the battery after leaving the bus depot [kWh]

E_{ch} energy charged during operation [kWh]

E_{con} consumed energy [kWh]

E_{res} energy reserve [kWh]

is given at any time throughout a day of operation.

First tests with a trolleybus which is already equipped with a battery will be used to evaluate the simulation results.

Systems for automated wiring of pantographs are necessary if trolleybuses are to be operated on bus lines that partially have no catenaries. They provide a higher flexibility and lower the threshold for partially catenary-free operation, as neither manual wiring nor the use of so-called wiring funnels are necessary. The outcome of the tests is still open. The feasibility study as such assumes that there is a system that is quick and flexible enough. However, it also assumes that wiring is possible at bus stops only.

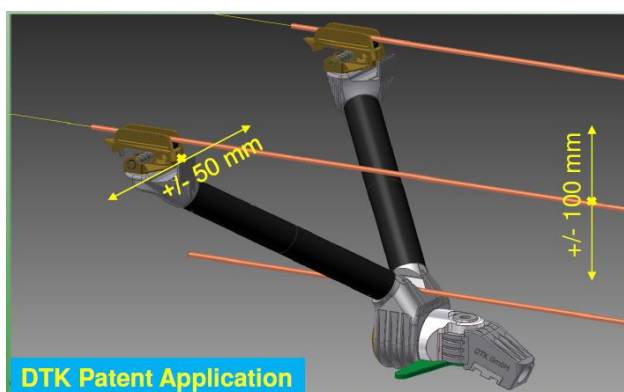


Figure 4: Automatic wiring system from Deutzer

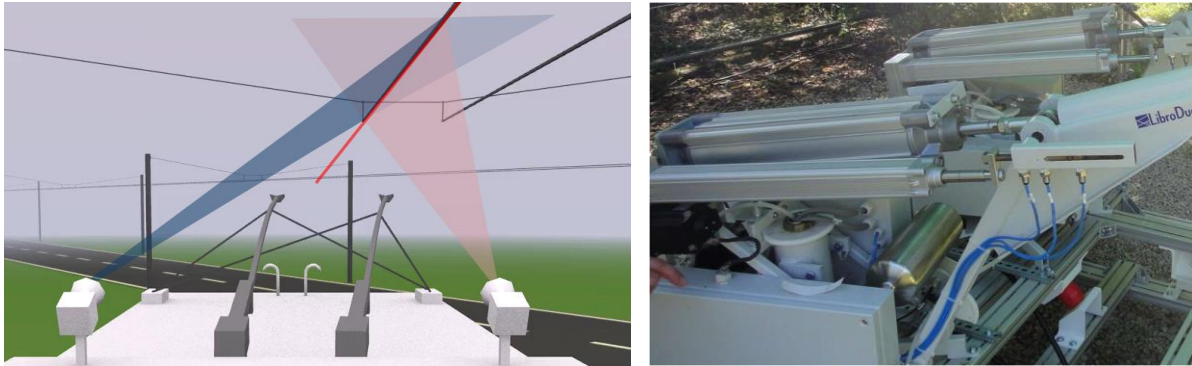


Figure 5: Automatic wiring system from Kummler + Matter / Dialogica

Until now the companies Kummler + Matter and Deutzer have expressed their willingness to carry out tests of their automatic wiring systems in Eberswalde.

4. Objectives

4.1. Objectives of the Use Case

The main objective of the Eberswalde use case is to prove that the partially catenary-free operation of trolleybuses on bus line 910 between Finowfurt and Eberswalde Südend is possible with retrofitted vehicles. This operation is planned as interaction with the existing trolleybus lines 861 and 862, aiming at a minimum of necessary trolleybuses. For that, additional trolleybuses must be equipped with a battery, but ideally no additional trolleybuses are necessary. The new operational concept for all three lines will also take future passenger demands into consideration. Furthermore, the feasibility study will determine

- the energy content, the charging power and the discharging power of the batteries
- the length of necessary or useful catenary extensions, and
- the necessity of additional charging stations at the terminal stops of bus line 910.

Tests of automatic wiring systems will show to which extent such systems will facilitate the concept of partially catenary-free operation.

The widely technical feasibility study will be backed-up by a financial evaluation.

Finally, the results of the feasibility study will be the basis for strategic decisions on the future bus network in and around the city of Eberswalde.

4.2. Expected impacts

The survey will give the local operator and the authorities of Eberswalde and the district a blue print for the conversion of a diesel bus line into a line with electric buses, and with that a sound basis for the necessary decisions and fund raising.

It will also show the environmental impact of the operation of battery buses in comparison to conventional diesel buses, namely savings in CO₂, NO₂, NO_x and PM₁₀. However, savings in greenhouse gases and air pollutants will not be included into the financial evaluation.

The Eberswalde use case will also provide useful information on trolleybus line extensions using modern energy storage systems.

4.3. Use Case KPIs

The KPIs for the Eberswalde use case are listed in Table 1. Practical measurements will only be from tests with one trolleybus which is already equipped with a battery.

KPI definition
Ose1 - Commercial speed
Ose2 - Bus frequency
Ose7 - Round trip time
Ose8 - Operation time
Ode1 - Passenger demand
Eco6 - Vehicle capital costs - diesel buses
Eco7 - Vehicle capital costs without battery
Eco8 - Battery capital cost
Eco22 - Recharging infrastructure
Eco23 - Electricity costs for vehicles
Eco24 - Electricity costs for traction
Eco25 - Electricity costs for non-traction
Eco26 - Electricity costs for facilities
Eco27 - Fuel costs

Ecn9 - Electricity consumption
Esu5 - Recharging capacity
Eem1 - CO ₂ emissions

Table 1: KPIs for the Eberswalde use case

5. Risks

The Eberswalde use-case mainly focusses on a feasibility study and tests of automatic wiring systems. The feasibility study will be backed-up by first tests with an existing trolley bus. All necessary data is available.

The so-called energy balance calculation method has been used in many projects before. Both the methodology and the software tool to be used are ripe and tested. Fraunhofer IVI employs several engineers who can carry out the analysis.

In total, there is no major risk for reaching the set objectives.

6. Detailed description of the Use Case

6.1. Description of expected use case features, establishing the link among use case conditions, objectives and background

As already mentioned in section 3 the very content of the Eberswalde use case is a feasibility study on the partial catenary-free operation of trolley buses with batteries on bus line 910 between Finowfurt and Eberswalde Südend.

Additionally, automatic wiring systems that connect the pantograph with the catenaries without physical intervention of the drivers will be tested.

6.2. Use Case constraints

Based on operational data and a comprehensive data base, the feasibility study will remain a simulation-based analysis. By their very nature such analyses are characterized by a remaining error.

6.3. Use Case monitoring criteria

The use case monitoring will be carried out using the completion of work steps and the fulfilment of milestones as described in chapter 7.

7. Use case work plan

7.1. Use Case development logic

Figure 6 shows the use case development logic using a flow chart that describes the single work steps, their sequential arrangement and their interdependencies.

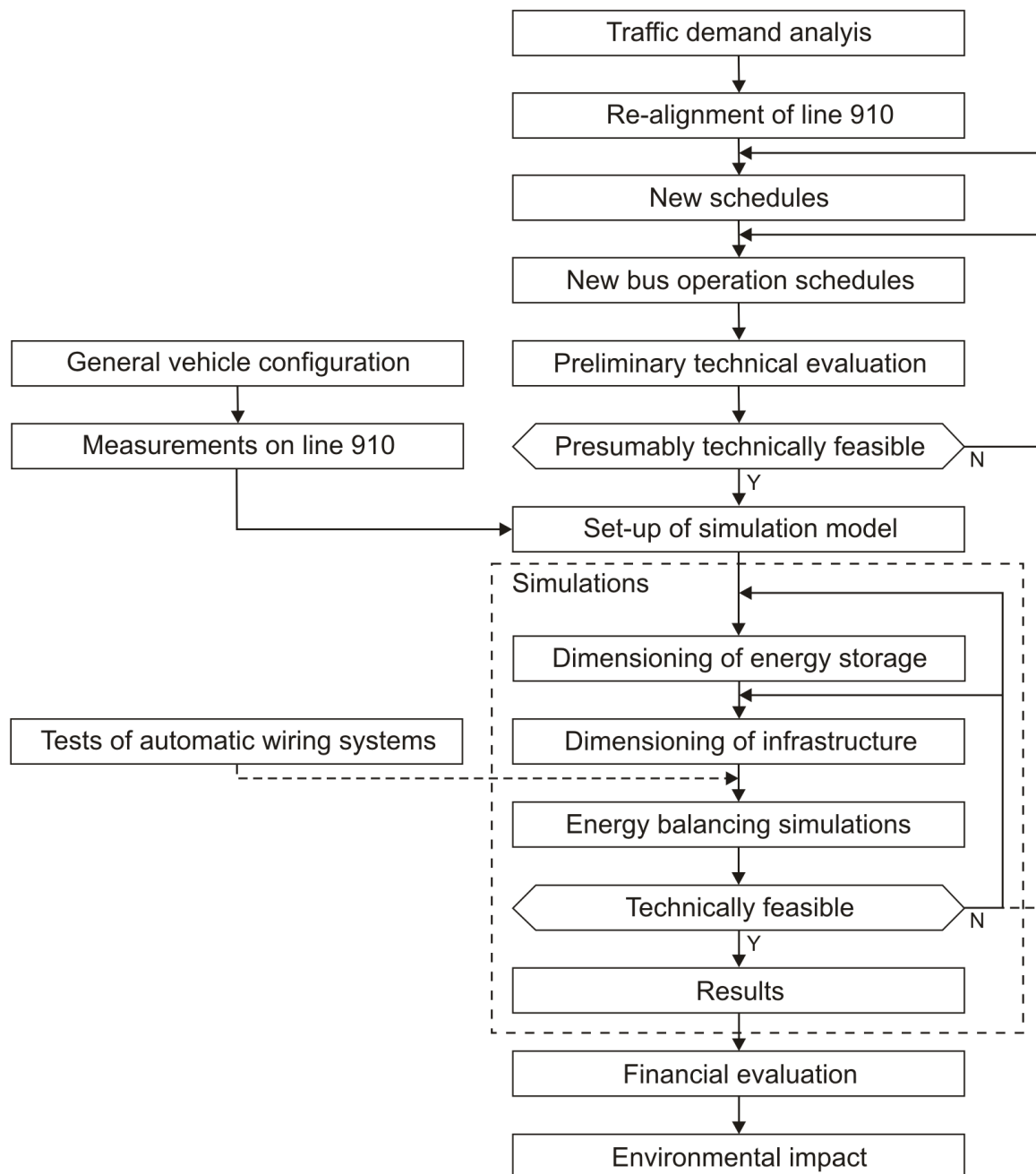


Figure 6: Development logic of the Eberswalde use case

WS 1 – Traffic demand analysis and realignment of line 910

The analysis of the new traffic demand has been subcontracted to Dresden University of Technology. The analysis of the future traffic demand and relations will perhaps lead to a new alignment of line 910 in connection with the existing trolleybus lines 861 and 862. This new alignment will most likely be focussed on new terminal stops only. The main route alignment will presumably not be changed.

WS 2 – Set-up of new schedules

Based on the traffic demand analysis and the new alignment new schedules will be elaborated. It is planned to keep the service frequency on the major trunk road Eberswalder Straße - Hegermühler Straße - Eisenbahnstraße the same.

WS 3 – Set-up of new bus operation schedules

The bus operation schedules will describe all tasks to be performed by the single buses that service bus line 910. The objectives are to not procure additional trolleybuses and to minimise the number of buses to be retrofitted with an energy storage. WS 2 and WS 3 will also be carried out by Dresden University of Technology.

WS 4 – Preliminary technical evaluation

The general technical feasibility of the new bus operation schedules will be evaluated prior to detailed energy balancing simulations. This procedure is to ensure that the simulations must be carried out for a feasible operational concept only. This preliminary technical evaluation will be carried out using specific consumption and recharging parameters. Furthermore, the maximum catenary extensions and the maximum energy storage content will be looked at as mere configurations. It is possible that WS 2 - 4 will be carried out in iterative steps.

WS 5 – General vehicle configuration

Within this work step all vehicle parameters, the HVAC concept etc. will be defined and the simulation model of the basic vehicle will be set-up. The only parameters that are still open are all storage-related data and the net weight of the vehicle.

WS 6 – Measurements on line 910

Necessary prerequisites for vehicle simulations with IVision are speed-distance-patterns that represent normal operation. Therefore, a bus on the existing line 910 will be equipped with measuring devices to get information on the speed patterns during regular passenger service. Additionally, the number of passengers will be counted as this is important input data for the vehicle simulations. To this day, it remains open whether a diesel bus or the trolleybus that is equipped with a battery will be used.

Data from BBG trolleybuses will be used for the validation of the vehicle model in any case.

WS 7 – Set-up of simulation model

During the set-up all necessary information are merged into one simulation model. This includes information on the alignment, corresponding speed-distance-patterns, passenger numbers, bus operation schedules for school days and the basic vehicle data. All storage related data and the net weight of the vehicle will be varied. This also applies to additional catenaries or rather unlikely charging stations at the terminal stops.

WS 8 – Simulations

The vehicle simulations are an iterative process which includes the dimensioning of the vehicle energy storage, the definition of the charging infrastructure, especially the catenary extensions and the simulations as such including the energy balancing simulations, which combine vehicle simulations with energy balancing calculations as explained in chapter 3.3.

Assuming that the maximum energy storage and maximum catenary extension will lead to a technically feasible solution, it will most likely not be necessary to return to work step 2 or work step 3. Therefore, the iterative processes will be focussed on variations of the catenary length and the energy storage to find an optimum solution.

WS 9 – Financial evaluation

The financial evaluation will compare the new total costs for operating line 910 in combination with line 861 and line 862 with the costs of the existing operation.

WS 10 – Environmental impact

The environmental impact of the operation of battery buses in comparison to conventional diesel buses, namely savings in CO₂, NO₂, NO_x and PM₁₀ will be calculated. However, savings in greenhouse gases and air pollutants will not be included into the financial evaluation in WS 9.

WS 11 – Test of automatic wiring systems

Different prototype wiring systems will be tested using BBG catenary infrastructure. The results will be used for the future equipment of the BBG trolley buses in order to ease the wiring at bus stops.

The automatic wiring process should not last longer than 10 - 20 s. This time will be used as default value for the vehicle simulations. The default value will be adapted if the tests show significantly higher wiring times.

7.2. Work plan

The expected action plan including the respective involved partner's staff effort and time-line is described in the following table. The work plan is subdivided into 11 work steps.

#	Action	PM ¹⁾	Staff BBG	Staff Fraunh.	Start-month	End-month
WS 1	Traffic demand analysis and realignment of line 910	1.0 / -	SE	-	3	9
WS 2	Set-up of new schedules	1,0 / -	SE	-	9	11
WS 3	Set-up of new bus operation schedules	1,0 / -	SE	-	11	12
WS 4	Preliminary technical evaluation	0.1 / 0.1	SE	SE	5	8
WS 5	General vehicle configuration	/ 0.1	-	SE	7	7
WS 6	Measurements on line 910	0.5 / 0.5	JE	JE	8	9
WS 7	Set-up of simulation model	/ 0.5	-	SE	9	10
WS 8	Simulations	/ 2.0	-	SE	10	12
WS 9	Financial evaluation	0,5 / 0.1	SE	SE	12	12
WS 10	Environmental impact	/ 0.1	-	SE	12	12
WS 11	Test of automatic wiring systems	2.0 / -	SE / JE	-	10	17

¹⁾ BBG / Fraunhofer
 JE junior engineer SE senior engineer

Table 2: Work plan of the Eberswalde use case

7.3. Detailed timeline

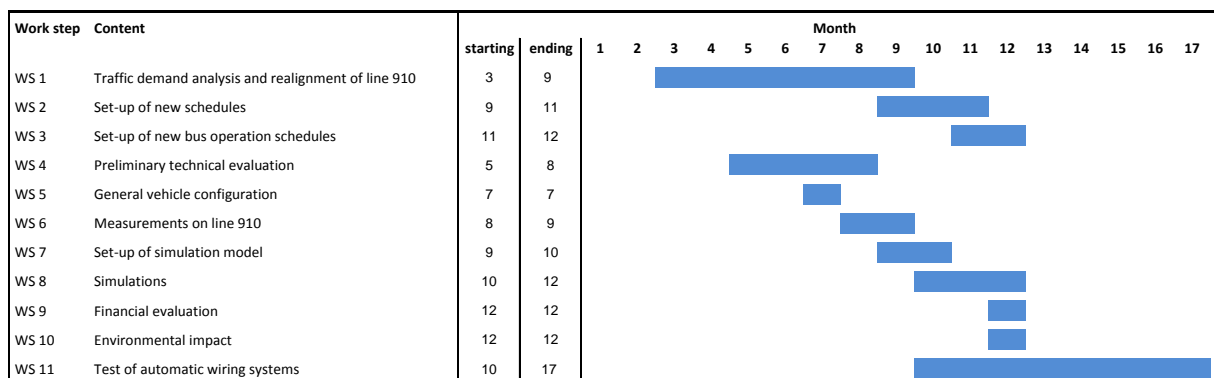


Figure 7: Detailed time line of the Eberswalde use case

The following milestones have been defined:

- M1 New bus operation schedules set-up Month 8
- M2 Measurements on line 910 completed Month 9
- M3 Simulations completed Month 12

8. Expected results

Beyond a technical and financial evaluation the feasibility study will also identify the climate and environmental impacts of the trolleybus operation on line 910. Although the savings in CO₂, NO_x, NO₂ and PM₁₀ will not be included into the financial evaluation, they make a substantial contribution to the air quality improvement plan of the city of Eberswalde.