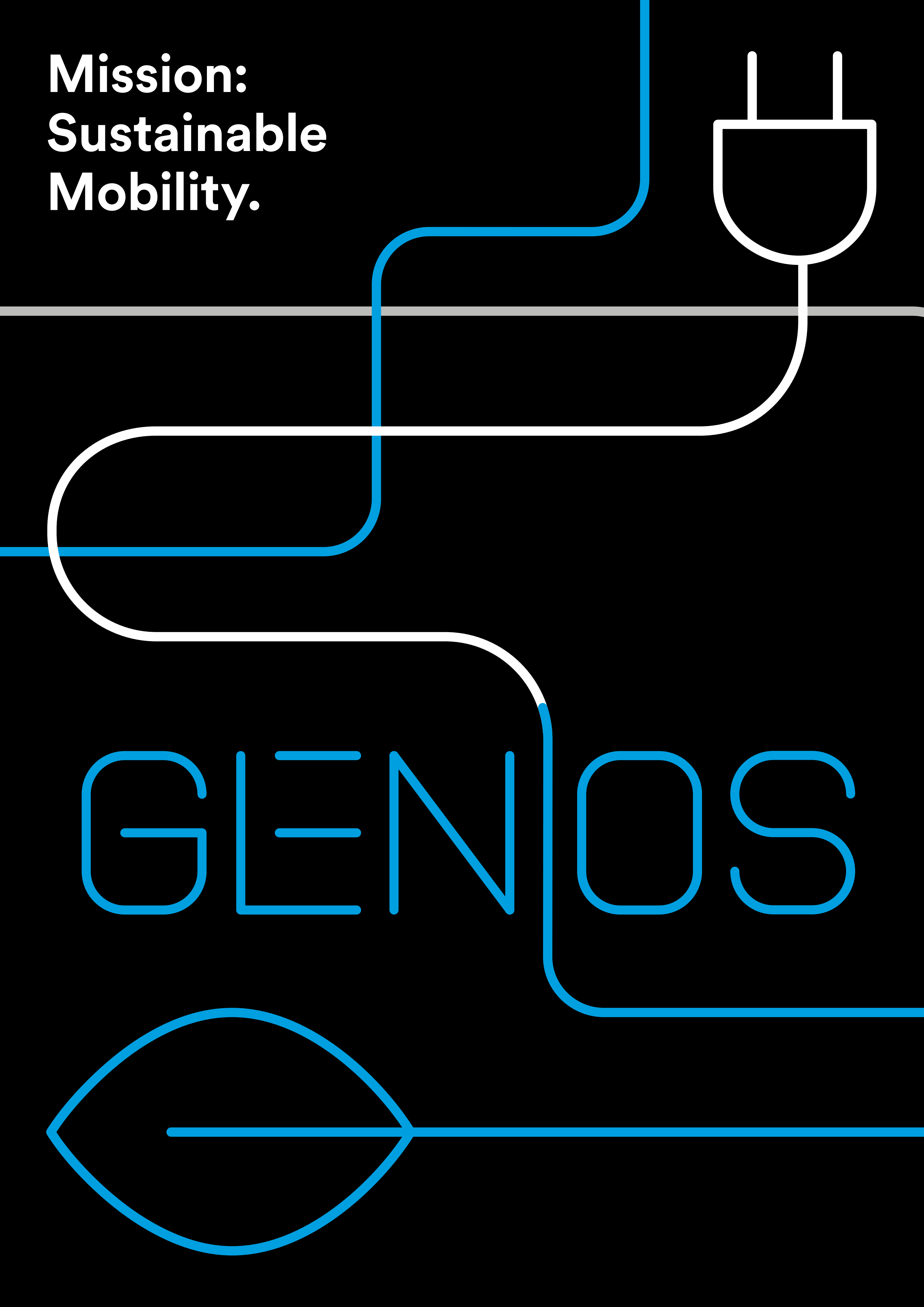
Mission: Sustainable Mobility.



GENIOS Computes the Basis for an E-Bus Study in Austria

How can the use of e-buses be simulated in a specific region in detail and how might the use of hydrogen buses compare? Using GENIOS by MENTZ, the Austrian "Low Carb Mobility" study was able to provide a few important answers.

Topic
E-bus studies in the VOR Region of Austria

Product
GENIOS

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The Study

As part of Interreg Project ATHU114 "Low Carb Mobility," the Austrian Transport Authority for the Eastern Region (VOR) GmbH and other project partners requested proposals for a study on the topic of "energy sector requirements for alternative drive systems in public transport." The idea behind the study was to gain knowledge and serve as a basis for approaches to differentiated usage of vehicles with alternative drive systems in bus and rail transport. Special attention was given to resolving issues concerned with usage of vehicles with alternative drive systems, like battery electric vehicles and vehicles with hydrogen fuel cells, in the border region between Austria and Hungary. The increased usage of energy-intensive vehicles in public transport poses challenges for the energy sector and charging grids.

In collaboration with energy and mobility experts from the Austrian Institute of Technology (AIT), MENTZ GmbH was asked to perform analyses and contribute calculations of vehicle schedules. Software solutions DIVA 4 R19 and GENIOS were used for the study.

Developed in-house, GENIOS is an optimization software solution that is based on MENTZ employee Dr. Roland Hesse's dissertation. The results represent close cooperation between EFA and DIVA developers. Led by another MENTZ employee, Dr. Markus-Ludwig Wermer, the GENIOS development team released the fourth generation of the software last year. The software can also be used to solve issues beyond public transport, but the focus of this article is on the plug-in for electric vehicles that was used in the current study.

Areas of Study

Calculations were performed in two areas. First, conversion to full battery-electric operation was analyzed for routes in Greater Schwechat.

And second, routes in Northern Burgenland were also investigated. To initiate the study, customers provided timetables and variants prepared as route groups using MENTZ's DIVA 4 Release 19 software. At the time of the study, services in the areas under investigation had yet to be designed in terms of policy and planning. The suppositions that were made for the study are thus theoretical, and do not reflect future precise service offerings or real-world locations in the charging infrastructure.

For each route group, a draft timetable was defined with the following day types: Monday to Friday school day, Monday to Friday school holidays, and Saturday-Sunday-Public holiday. The school holiday rules for Lower Austria and Burgenland and public holidays were entered into the database and accounted for while creating day types for the timetables. A property labelled “ordered vehicle type” indicated which trips should use electric vehicles and which should use diesel vehicles. → (Figure 1)

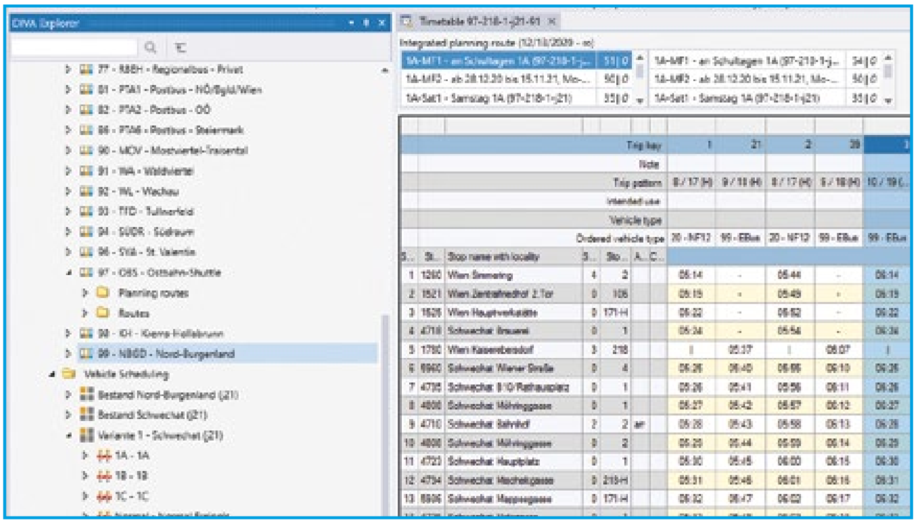
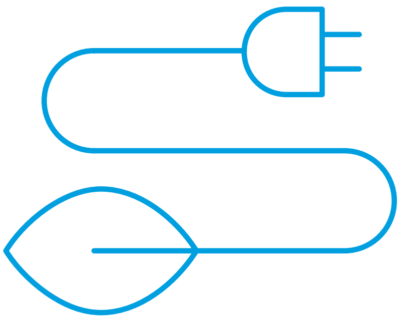


Figure 1
Timetable in Diva Client is synchronously edited to enter a draft timetable for day types Mon-Fri school days, Mon–Fri school holidays, and Saturday-Sunday-public holiday. These day types build a foundation for further vehicle schedule optimization.



In Schwechat, variants were defined that stipulated different amounts of electric vehicle use: services were added that used and did not use electric buses; short trips were considered first, then longer route options. Variants with partial and full use of electric buses were compared. In Northern Burgenland, operation of public bus services with other drive forms was studied. Similarly, day types and events were represented with additional timetable variants. The modeled routes were depicted and georeferenced on the road network of the graph integration platform (GIP). The GIP is a digital transport network of Austria that is open to the public in a standardized form. In this way, route options could be reliably created and their lengths more precisely determined. The DIVA Georef service was used to identify the number of empty trips required for vehicle scheduling. → (Figure 2)

After defining the timetables and determining which trips were to be operated with electric buses, well-situated depots were selected for the study areas. Because the operator was still unknown, a depot was selected based on a centrally located point that served as a node for many routes and services. For tender planning, the number and length of empty trip kilometers can be estimated downwards rather than upwards. During actual operation, significantly longer distances to the first passenger stop may occur. Using GIS-based routing in DIVA (Georef Service), for example, additional planning scenarios can be used to quickly find a different location for a new depot. The use of aerial images can be particularly beneficial to quickly assess whether parking space is available. Such aerial images can be directly accessed and displayed in DIVA Web.

Charging stations were defined at selected stop points with user-defined attributes, which can be “switched on” and “switched off” for subsequent calculations directly in GENIOS. For Schwechat, the stations were in Laxenburg and Himberg. In Northern Burgenland, charging stations were located in Zurnberg, Mönchhof, Frauenkirchen and Pamhagen. Using this common data, a vehicle schedule was optimized for electric vehicle requirements.

Route group in Nothern Burgenland with georeferences route options. The area extends north of Hainburg an der Donau to south of Pamhagen and from Eisenstadt to Andau.

Abb. 2

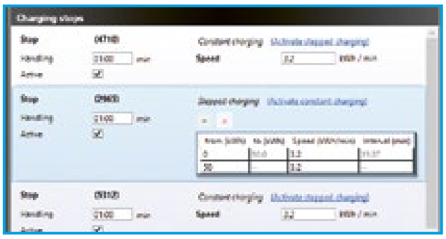


Figure 3
Modeling of constant vs. tiered charging. Charging stations can be switched on and off so that different levels of the charging infrastructure can be considered for tender planning, and so that results and key data can be compared. The initial operation for each charging station is considered additive.

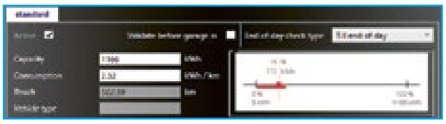


Figure 4
Parametrization of GENIOS's e-bus optimization module. The parameter can be adjusted on-the-fly and allow for comparison of different scenarios.

Parameterization of the Optimization Software GENIOS

During vehicle schedule optimization with GENIOS, a number of key data can be taken into account like depot capacities, planning requirements for vehicle types, and other technical conditions or constraints such as charging capacities, charging times for electric buses, and many others.

GENIOS automatically calculates a plan for a specific number of vehicle trips, which is created and validated in terms of selected key data. Users can still override existing directives using costs by deactivating previously defined directives before automatic scheduling, or by defining their limits with a different value.

By request, a tolerance criterion was also implemented to prevent full use of batteries when creating vehicle blocks.

GENIOS has two ways of modeling this:

1) the battery capacity transferred to GENIOS can be set lower so that 20 percent remains in reserve.
2) In addition, the optimization software allows for a capacity threshold to be specified, including a permitted tolerance (specified in absolute figures), which must be reached either at the end of an operating day or on the following operating day. These values result in different vehicle schedule scenarios. → (Figures 4 and 5)

Next, vehicle usage was examined with differing battery capacities and charging requirements. The geographical conditions of the study area were determined to have significantly influenced the determined values. In Schwechat, fully electric operation was without issue for the estimates made in various scenarios. In contrast, no cost-effective solution could be found for Northern Burgenland with the same parameterization. In some of these solutions, vehicles had to park along the route because a better result could not be rendered. A scenario that included a "central depot charging" was deemed ineffective and the charging stations that

Created scenarios were then evaluated by energy sector experts from AIT. The following table shows the results for the parameter set as defined in Figure 4:

Number	Blocks	Electric vehicles	Diesel vehicles	Connecting trips	Depot trips	Length of empty trips	Block time	Total electric	Productive electric	Total diesel	Productive diesel
1a	25	08	17	133	100	1320	250	250	966	3370	2420
1b	28	10	18	83	104	986	239	239	893	3320	2500
1c	25	16	09	60	106	1050	227	227	2180	1760	1210
2a	22	04	18	61	60	820	207	207	430	3650	2850
2b	23	07	16	66	74	853	222	222	973	3100	2310
2c	23	14	09	63	88	901	213	213	2080	1750	

Figure 5
Five routes with a workload of 270 trips were planned and various forms of operation using diesel and electric drive were investigated. In a base variant, all routes were calculated using diesel vehicles. Variant 1 involved long-distance routes with a) two fully electrically operated routes b) more trips of an additional three routes that were operated by electric vehicles and c) all routes operated by electric vehicles. For variants 2a–2c, similar calculations were made on shorter routes.

Figure 6
Creating blocks for Northern Burgenland: it quickly became apparent that meaningful operation is only plausible with stronger batteries and intermittent charging. Vehicles must attain a range of 300 - 350 km in order to fulfill the preset schedule with as few vehicles as possible.

had been entered in the network were switched on to simulate bus operation with occasional charging. As a result, solutions were identified for Northern Burgenland.
→ (Figure 6)

A last scenario examined the use of hydrogen-powered vehicles. The calculated energy policy observations show the advantages and disadvantages of the two different drive systems, battery-electric and hydrogen. It should be emphasized that battery electric drive is better than hydrogen drive in many ways. Battery electric (BE) buses are about 1.5 times cheaper to purchase than H2 buses. The investment and operating costs for their charging infrastructure are less expensive than for H2 refueling infrastructure. What's more, battery electric drive is far more energy efficient because less energy is lost during charging and operation than in H2 generation and in the H2 fuel cell. This latter aspect is one of the most important cost factors because electricity costs represent a significant share of the total costs.

The only two ways in which the H2 buses are better than the BE buses are their range and their ability to quickly refuel (ten minutes). For these reasons and in contrast to the BE buses, H2 buses can also be used on longer routes (Northern Burgenland) in similar fashion to diesel buses. It follows that switching to H2-powered buses is more advantageous than use of BE-powered buses in such cases. That said, any cost savings are eliminated when factors like the required infrastructure for H2 refueling and electricity costs associated with their operation are considered.

The case study in Northern Burgenland also reveals that several usage limits still exist for bus operation with alternative drive systems. For one, the range of BE buses is limited in rural areas. Two, the energy efficiency of H2 generation and fuel cells is comparatively low. And three, the costs of switching over to either BE or H2 buses remains high.

For simplicity's sake, more detailed results are not presented here, specifically, the energy policy observations on the charging infrastructure. This information will be publicly accessible at a later date when it is published as part of Interreg project ATHU114 "Low Carb Mobility" by the VOR. The link will be made available on MENTZ's website.

Due to time constraints, a selection had to be made for optimization calculation, which included the following parameters:

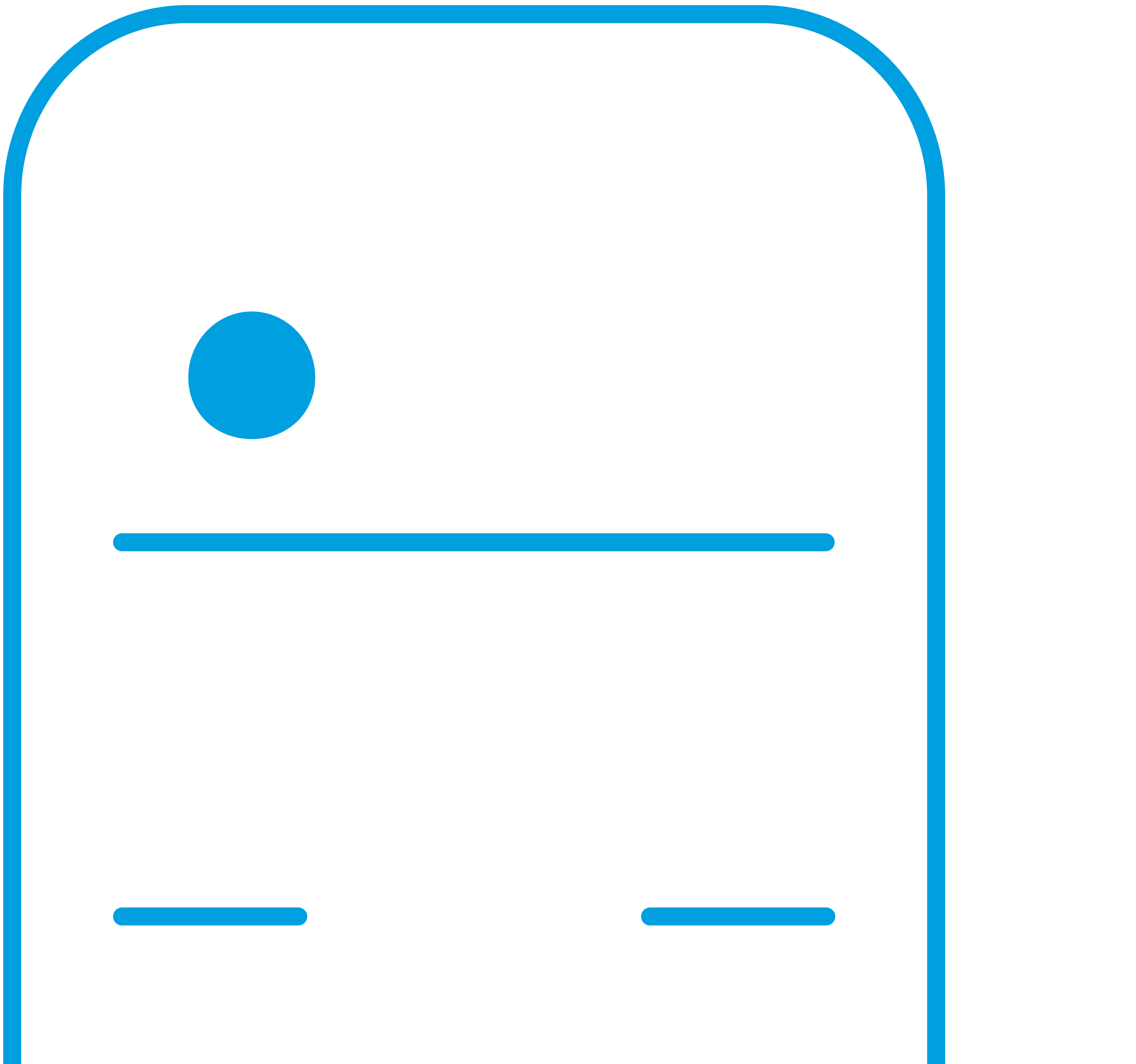
1) Vehicle battery capacity
2) Consumption kWh/km
3) Charging speed kWh/min

In joint research by AIT and MENTZ, battery capacities were identified for the following vehicle types:

Model	Capacity (kWh)
BYD	348
Mercedes eCitaro	292
Solaris Urbino	240
VOLVO	470
VOLVO	565

For subsequent calculations and after discussion, the following estimates were made for consumption and charging capacity:

1) Estimated consumption:
1,7 kWh/km
2) Charging capacity:
3,2 kWh/min or 192 kW



Conclusion

Close cooperation with the Austrian Institute of Technology GmbH and the Austrian Transport Authority for the Eastern Region (VOR) opened up completely new perspectives and MENTZ GmbH is grateful to have taken part in such an enriching experience. Other projects would certainly benefit from a study in the current or a similar form.

The calculation of vehicle schedules depends on various input parameters. In both scenarios presented above, Schwechat and Nordburgenland, a vehicle's range was shown to play an important role. In contrast to transport in an urban setting, an empty trip back to a depot in these areas can be significantly longer and therefore less cost effective. When vehicles with a lower range are used, the demand for vehicles increases. Intermediate charging stations can be beneficial when vehicles with lower battery capacity are used.

The method presented above uses predefined timetables and depots/charging stations whose definition directly effects vehicle deployment. In a future version of GENIOS, MENTZ will implement "trip shifting." This function will allow timetable trips to be shifted within certain thresholds to limit the need for additional vehicle blocks.