ebusplan
Solutions for Clean Transportation

Software-based planning of E-Bus Projects

TUMIVolt Charging Station webinar

06/05/2021

Philipp Sinhuber, ebusplan GmbH

Tel: +49 (0) 241 55 70 51 81
Mobile: +49 (0) 175 37 01 233
p.sinhuber@ebusplan.com

ebusplan GmbH
Your partner for planning and deployment of electric buses

ebusplan
Solutions for Clean Transportation

Compe-tencies

- Planning expertise in the field of battery and fuel cell buses for over 11 years
- Technical expertise
- Cutting edge in simulation and optimisation methods
- Tailor-made concepts for technology and operations

Portfolio

- Feasibility Studies
- Infrastructure Design
- Funding acquisition
- Specifications (tenders)
- Expert advice

IVU TRAFFIC TECHNOLOGIES
Mobilität Stadtwerke Offenbach
DSW21
MIVB STIB .brussels
VERKEHRSBETRIEBE KREIS PLÖN GMBH VKP
wupsi KRAFTVERKEHR WUPPER-SIEG AG
TfWM
WIENER LINIEN
DVG DUISBURGER VERKEHRSGESELLSCHAFT AG
STADT ST. INGBERT
west VERKEHR
eLIPTIC electrification of public transport in cities
Rheinbahn
Birmingham City Council
Foothill Transit
NVG Omnibus-Betriebsgesellschaft mbH
SALZBURG AG
BVG
Mülheim an der Ruhr Stadt am Fluss
RUHR BAHN
BREMEN ERLEBEN!
BSAG
VOR DER VERKEHRSVERBUND
ZeEUS Zero Emission Urban Bus System
SWBC StadtWerkeBiberach
movia

...and many more.

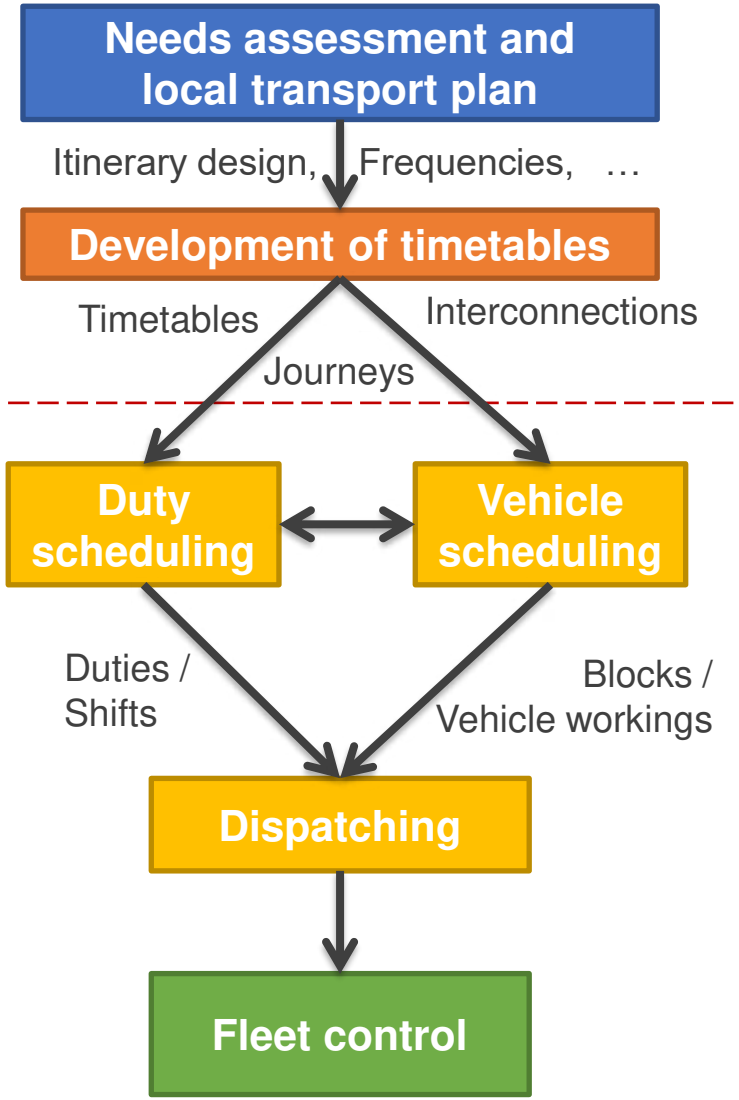
From Service Design to Implementation

ebusplan
Solutions for Clean Transportation

Service Design

Planning

Operations



Less affected by e-buses

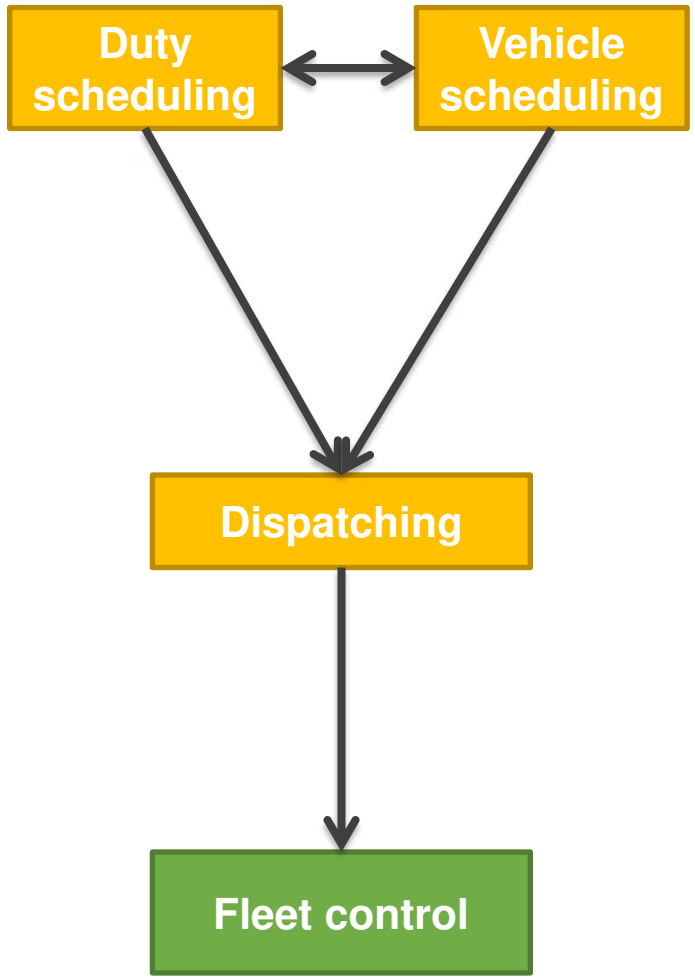
Strongly affected by e-buses

From Service Design to Implementation
Challenges posed using electric buses

ebusplan
Solutions for Clean Transportation

Planning

Operations



From Service Design to Implementation
Challenges posed using electric buses

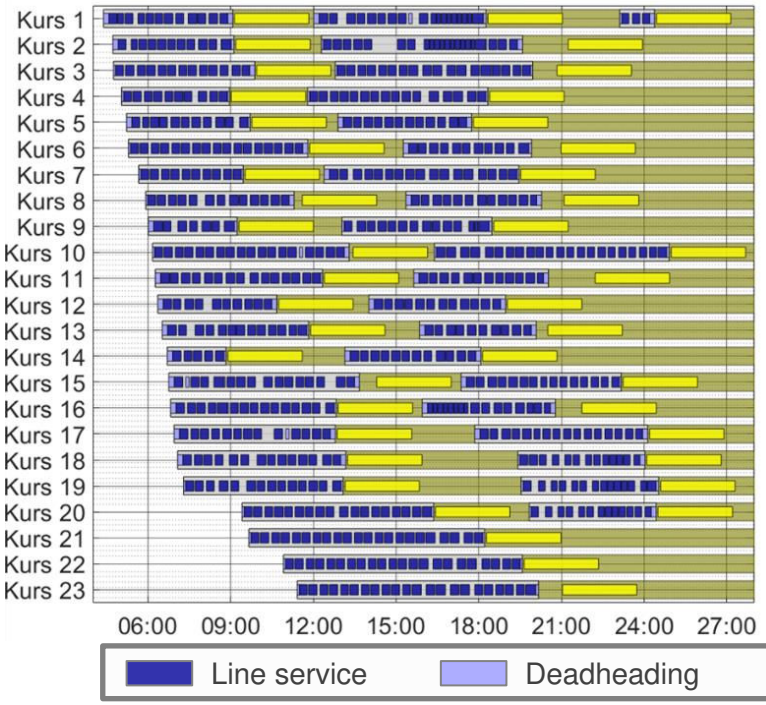
ebusplan
Solutions for Clean Transportation

Planning

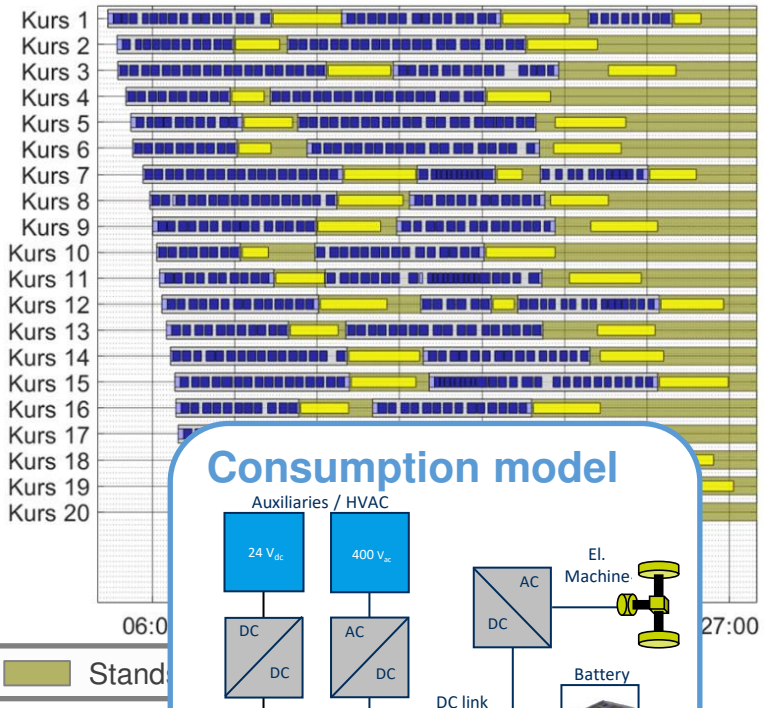
Vehicle scheduling

- Planning the deployment of buses by sequencing trips, minimizing
  - PVR
  - deadheading
  - driver costs

Simple vehicle scheduling



Energy-based scheduling

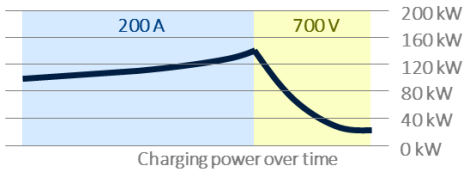


- Limitation to x kilometers
  - ➢ Blocks shorter than necessary
- Charging time assumed to y minutes
  - ➢ Reserved charging time often longer than necessary

- ➢ E… …ion
- ➢ C…

Consumption model

Charging model

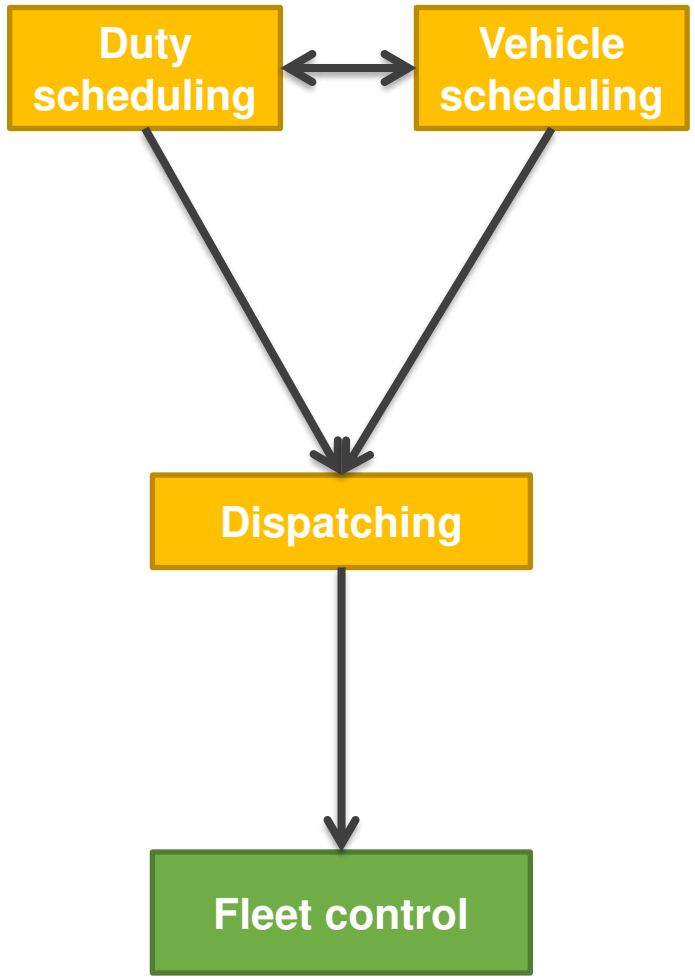


From Service Design to Implementation
Challenges posed using electric buses

ebusplan
Solutions for Clean Transportation

Planning

Operations

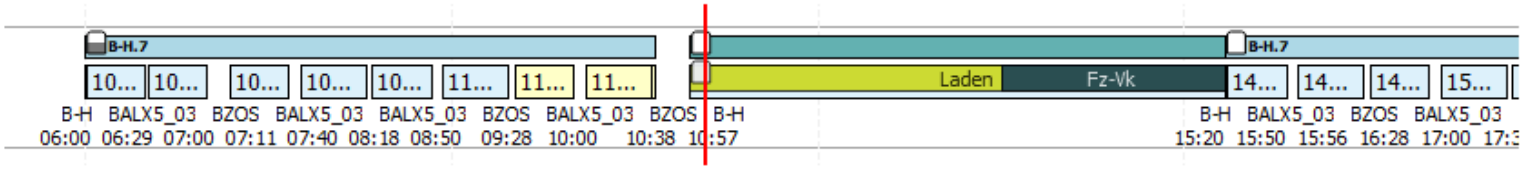


From Service Design to Implementation
Challenges posed using electric buses

ebusplan
Solutions for Clean Transportation

Operations

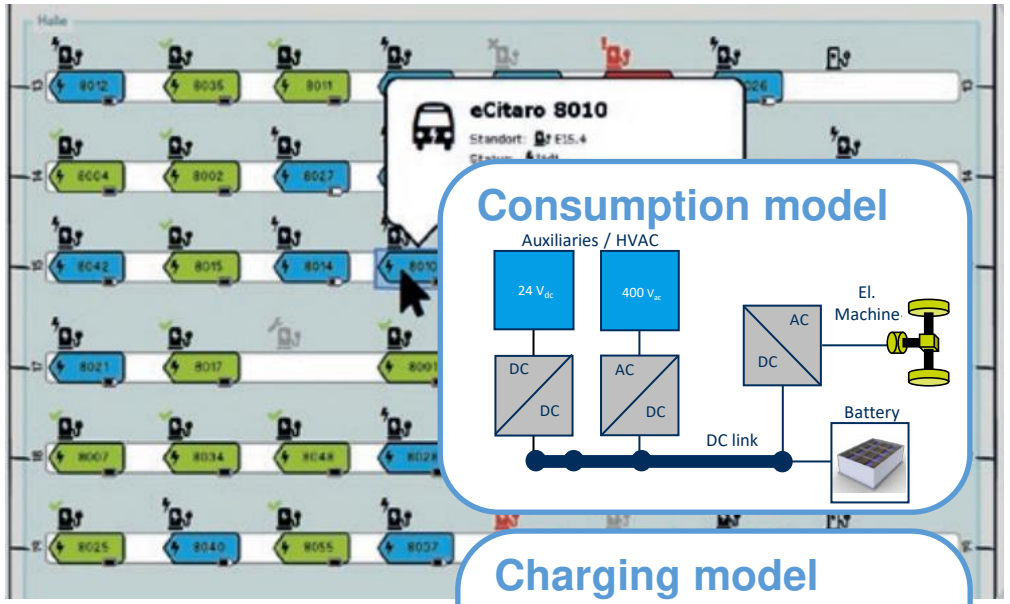
Dispatching



- Day-ahead:
  Assign the specific vehicles to
  - Specific parking positions
  - Specific blocks

- Intra-day:
  Monitor and readjust the assignment

- Charging station?
- Sufficient SOC for the next block?
- Sufficient time to recharge?



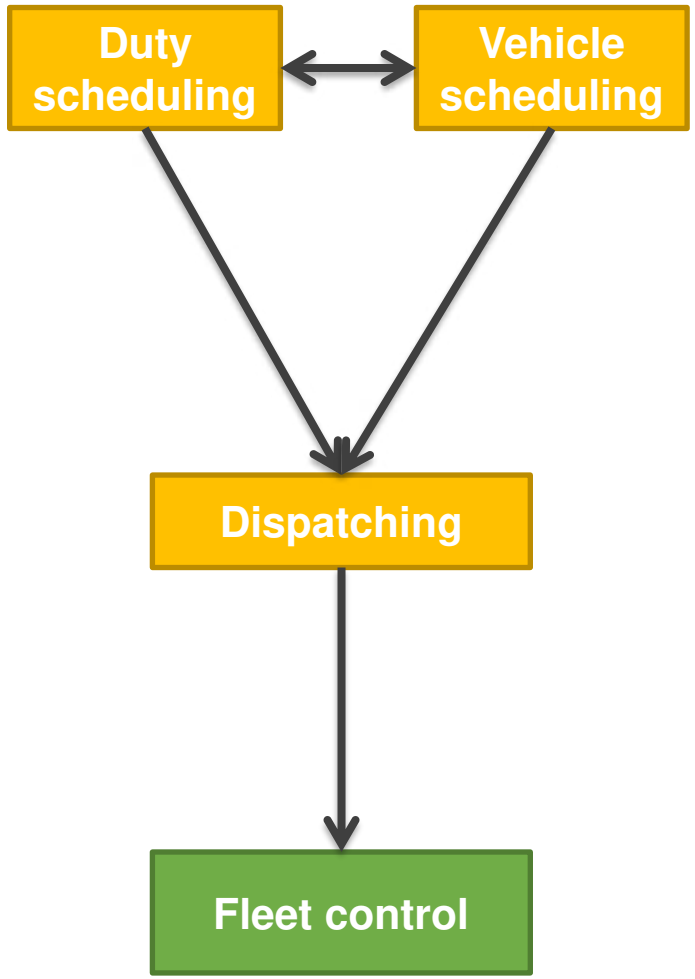
- Energy consum
- Charging time p

From Service Design to Implementation
Challenges posed using electric buses

ebusplan
Solutions for Clean Transportation

Planning

Operations



From Service Design to Implementation
Challenges posed using electric buses

ebusplan
Solutions for Clean Transportation

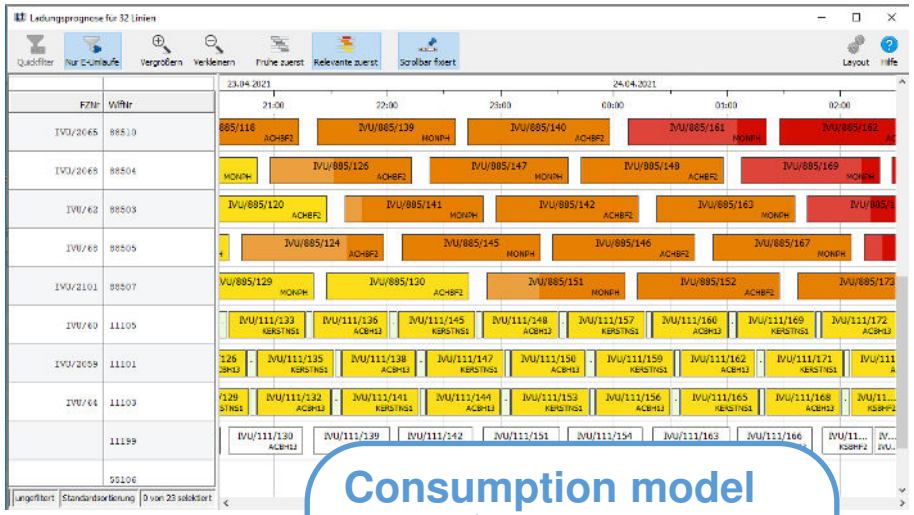
Operations

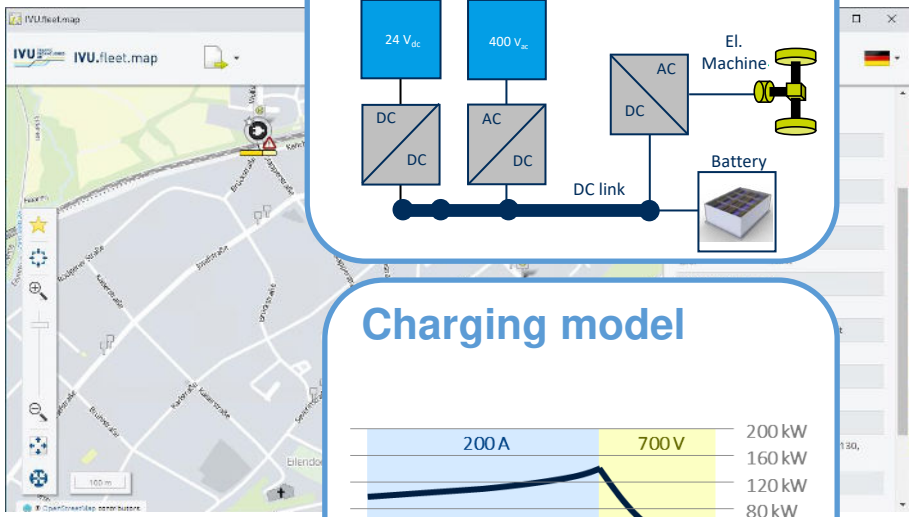
Fleet control

- Monitor operations
- Take certain measures to compensate for disruptions

- Monitor range
- Assess the consequences of dispositive measures

➢ Energy consumption prediction
➢ Charging time prediction (e.g. at terminal stops)



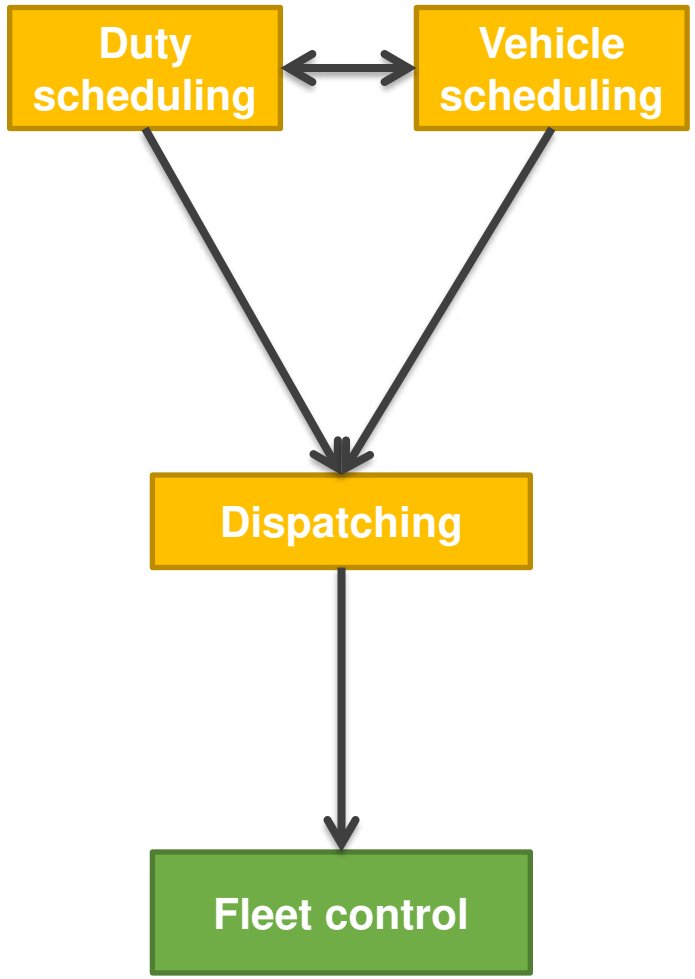


From Service Design to Implementation
Challenges posed using electric buses

ebusplan
Solutions for Clean Transportation

Planning

Operations

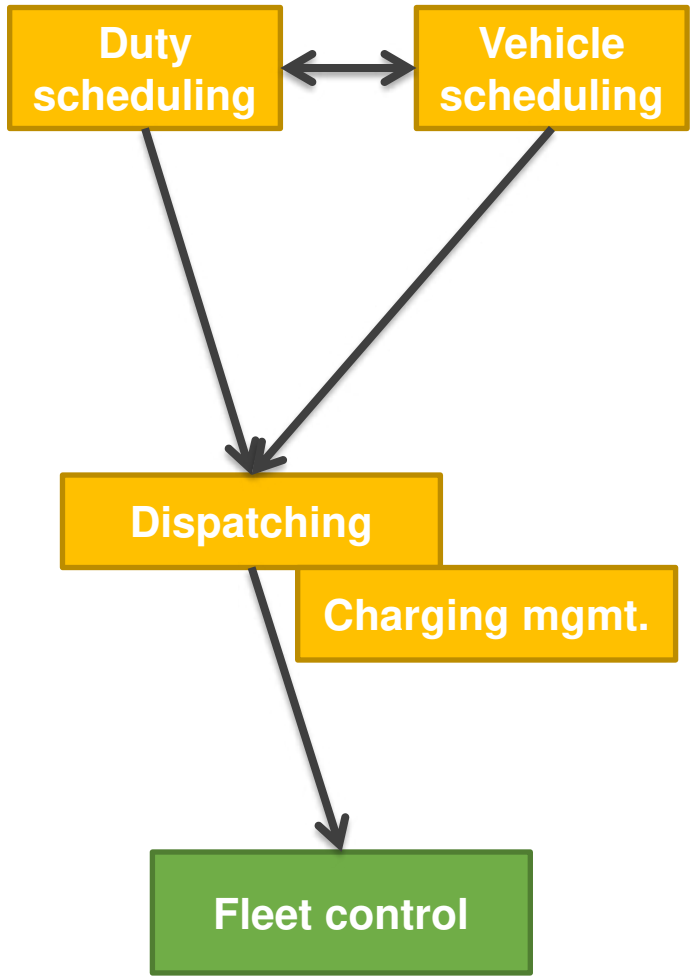


From Service Design to Implementation
Challenges posed using electric buses

ebusplan
Solutions for Clean Transportation

Planning

Operations

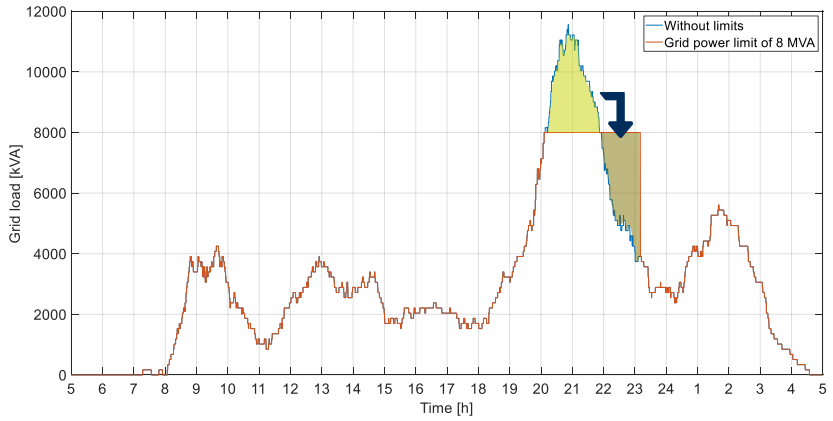


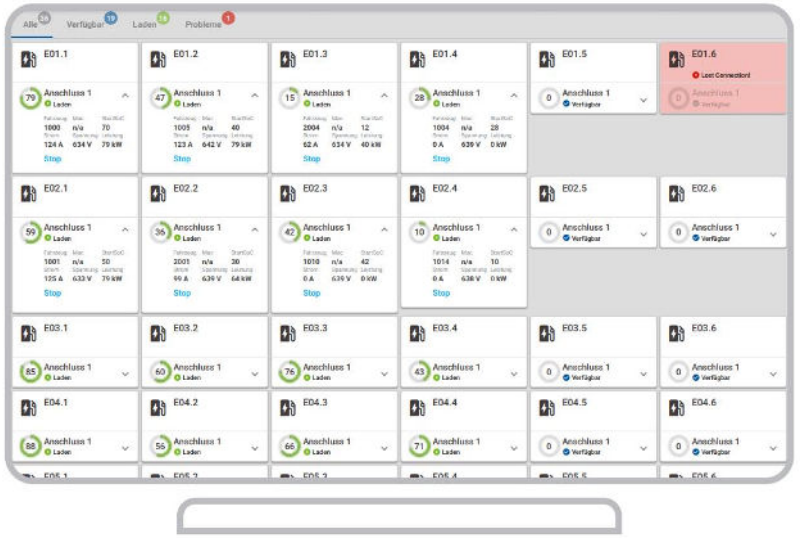
From Service Design to Implementation
Challenges posed using electric buses

ebusplan
Solutions for Clean Transportation

Operations

Charging mgmt.



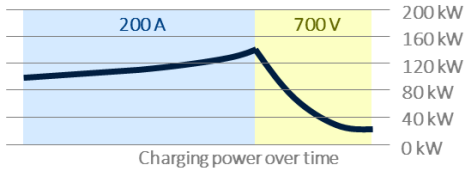


- Convert charging requests…
  - Vehicle x at charging station y to SOC z until departure time
- …into concrete power profiles for the charging stations

- (Energy consumption prediction)
- Charging time prediction

- Communicate with charging stations via OCPP
- Monitor charging progress and infrastructure availability

Charging model



From Service Design to Implementation
Challenges posed using electric buses

ebusplan
Solutions for Clean Transportation

Planning

Operations

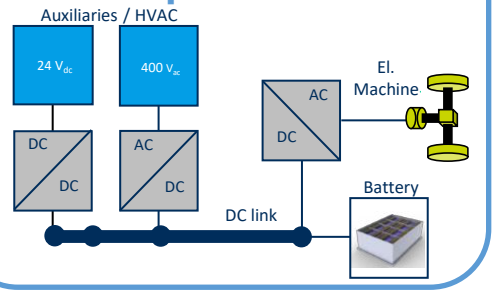
Duty scheduling ↔ **Vehicle scheduling**

Dispatching

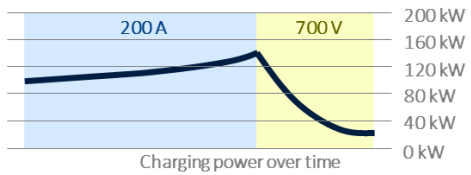
Charging mgmt.

Fleet control

Consumption model



Charging model



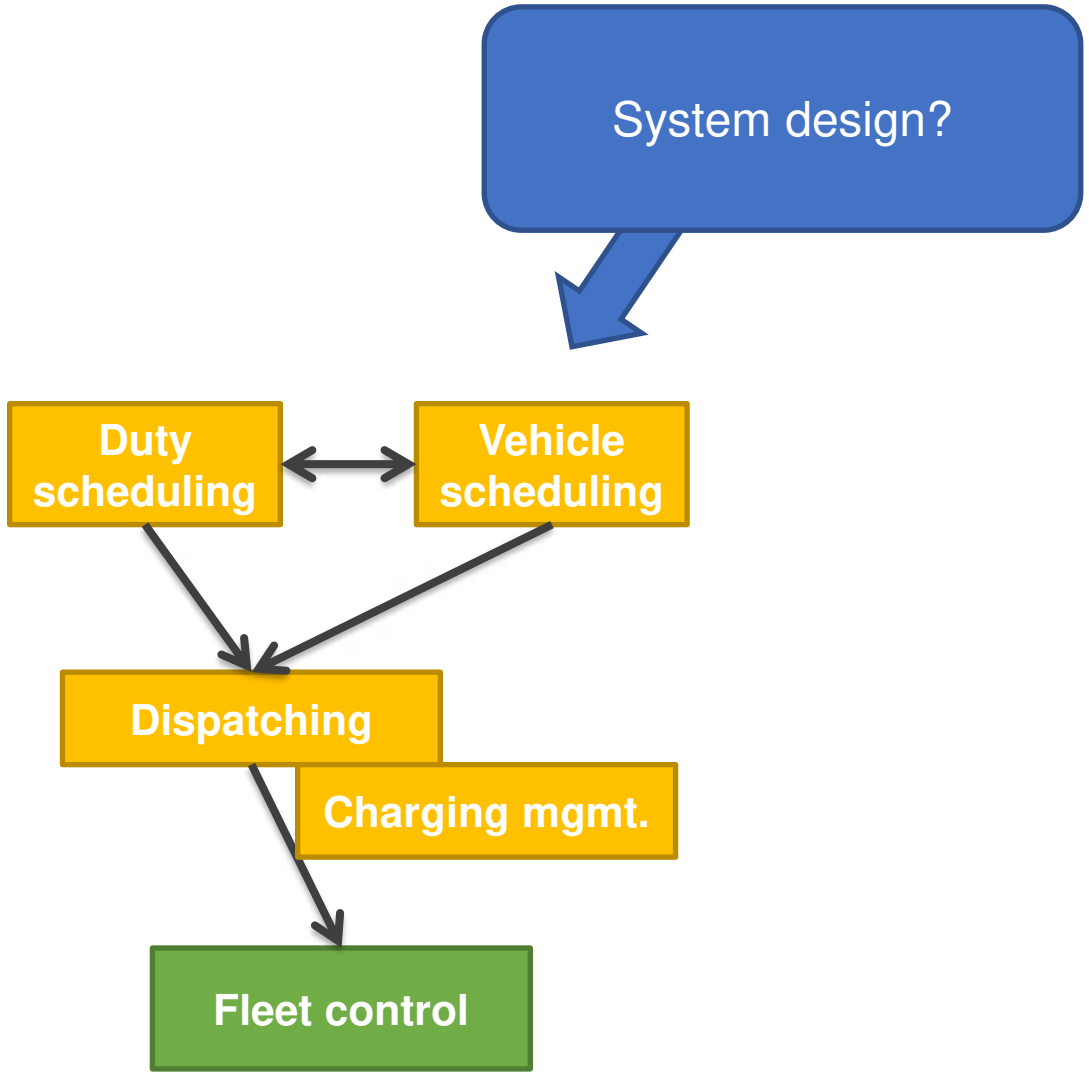
From Service Design to Implementation
Challenges posed using electric buses

ebusplan
Solutions for Clean Transportation

Conversion Strategy

Planning

Operations



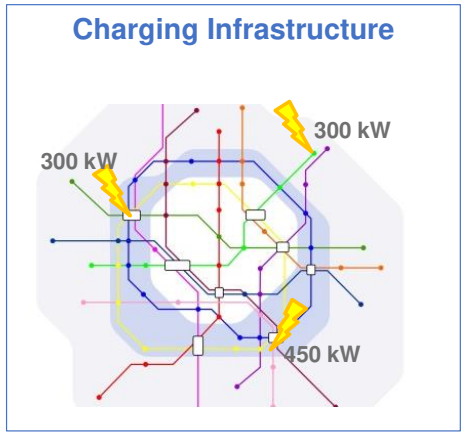
From Service Design to Implementation
Challenges posed using electric buses

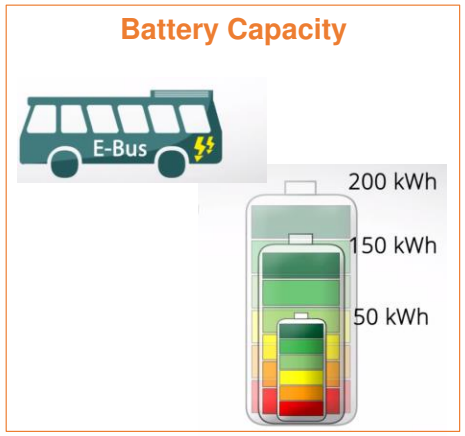
ebusplan
Solutions for Clean Transportation

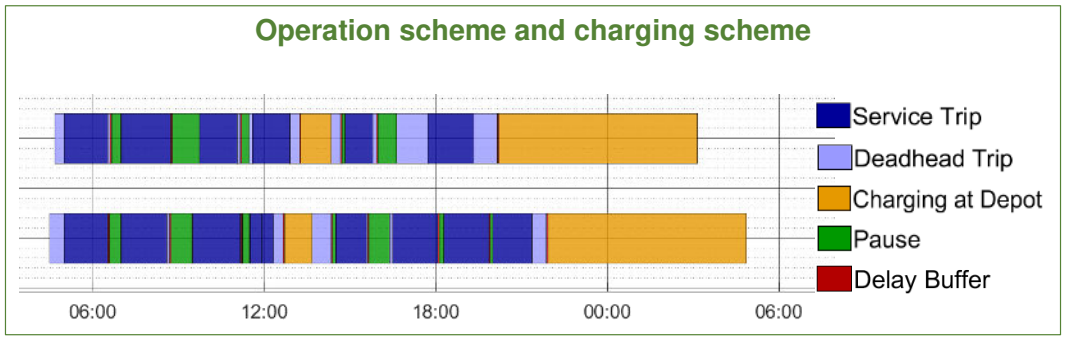
Conversion Strategy

System design?

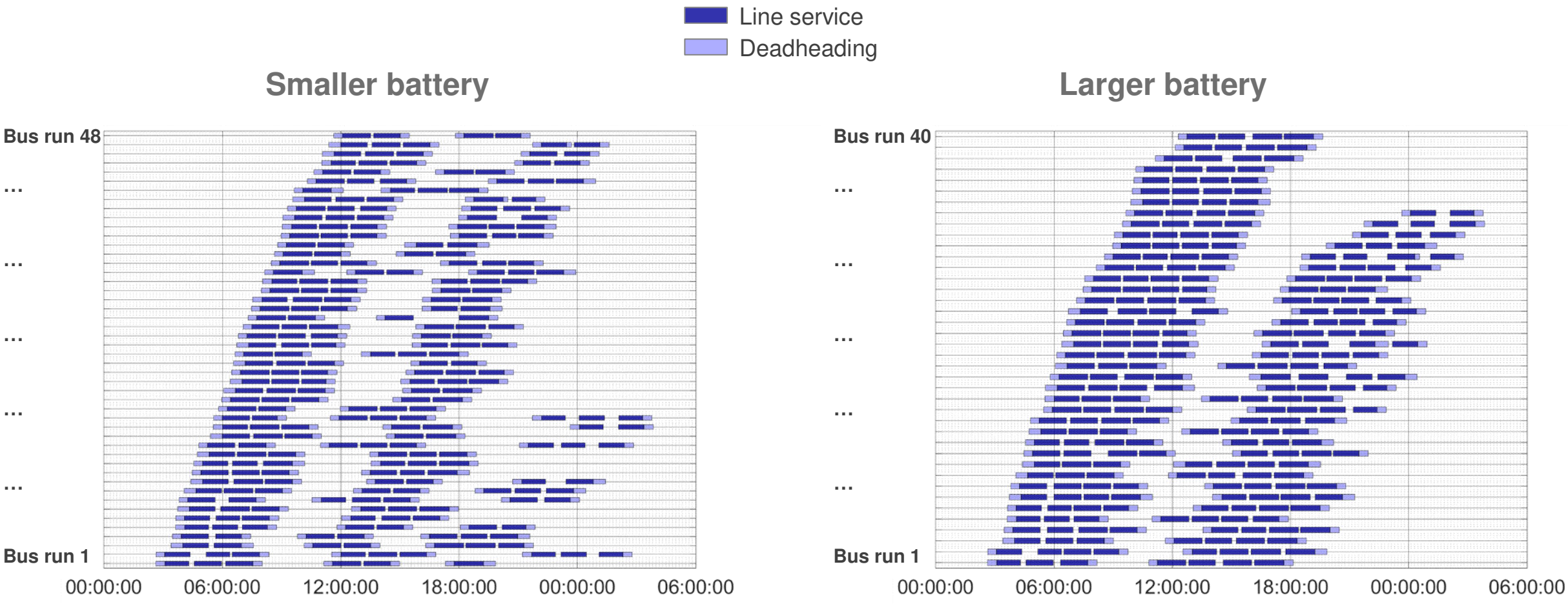
- What battery capacities do we need?
  - Technology? Capacity, weight, costs?
- Where do we need to recharge?
  - Depot charging? Charging at terminals? Charging hubs?
- What charging infrastructure do we need?
  - Charging power? Number of chargers?
- Efficiency of operations ←→ charging strategy?







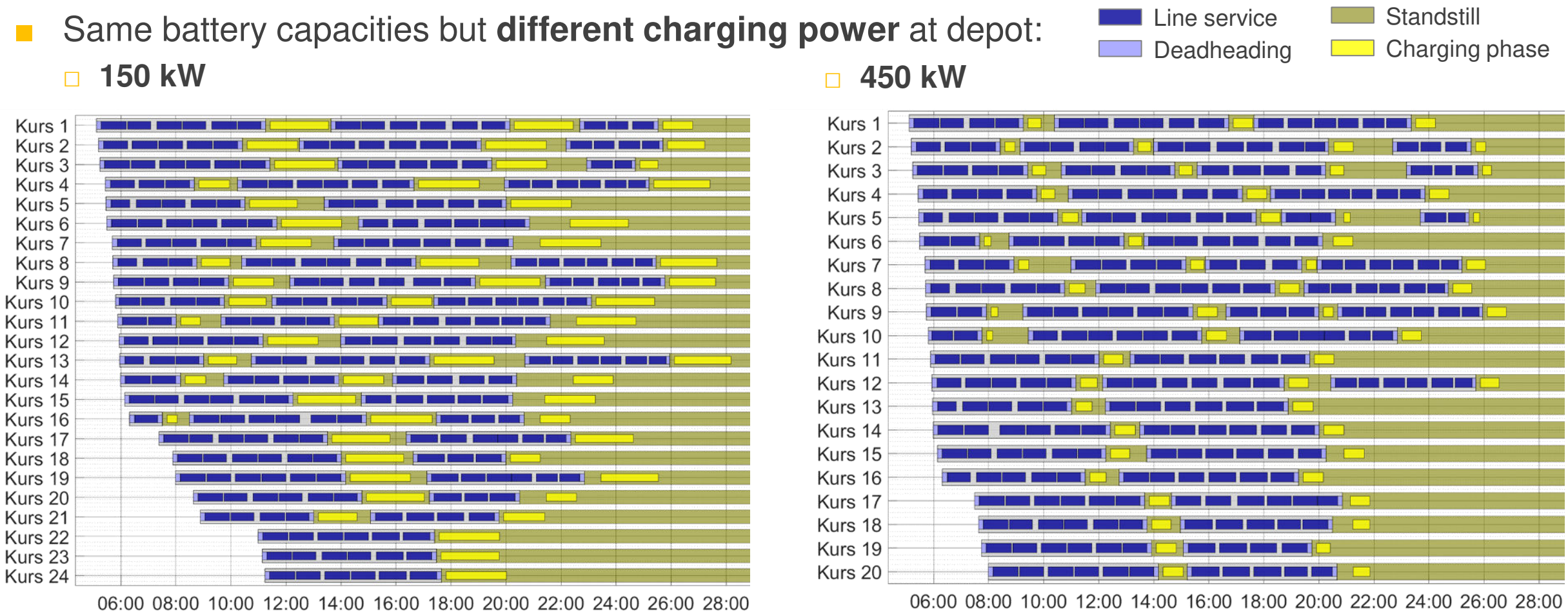
Effects of Technology Choice on Operations
Battery Size



Larger battery → Longer bus runs → Fewer vehicles required

Effects of Technology Choice on Operations
Charging Power in the Depot

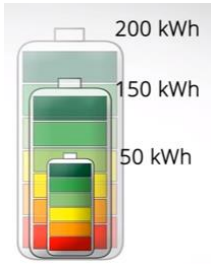
- Same battery capacities but **different charging power** at depot:
  - **150 kW**
  - **450 kW**

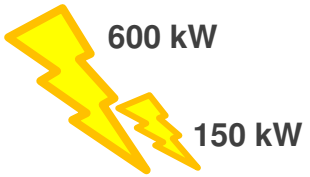


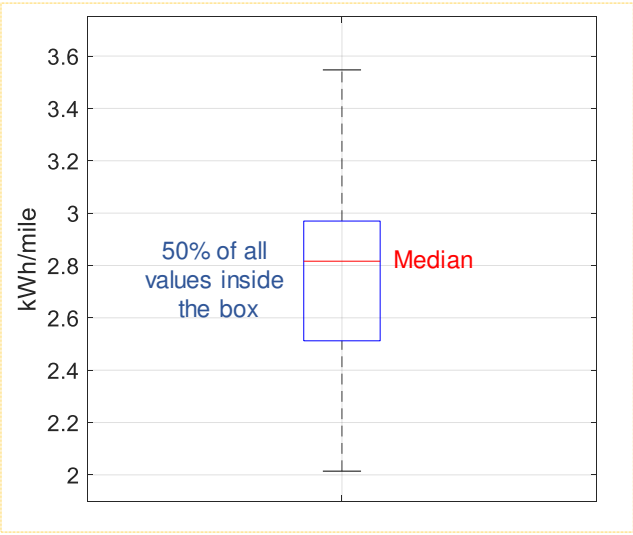
Higher charging power results in shorter charging times at depot → Fewer vehicles required

Effects of Technology Choice on Operations

- There are a variety of different configurations
  - Charging power (150 - 600 kW)
  - Battery concepts (in some cases over 800 kWh)
  - Heating / HVAC concepts (fossil heating, electric heating, heat pump, ...)
- To be answered differently for each configuration:
  - Energy demand?
  - Need for charging infrastructure? In the Depot? At terminal stops?
  - Required no. of vehicles?
  - Additional operating costs / efficiency of vehicle schedules?
  - Investment and follow-up costs? TCO?
- ➢ Experience shows that answers vary greatly from company to company.







➢ **Analysis and comparison of many scenarios necessary**

Required no. of vehicles

Driver time

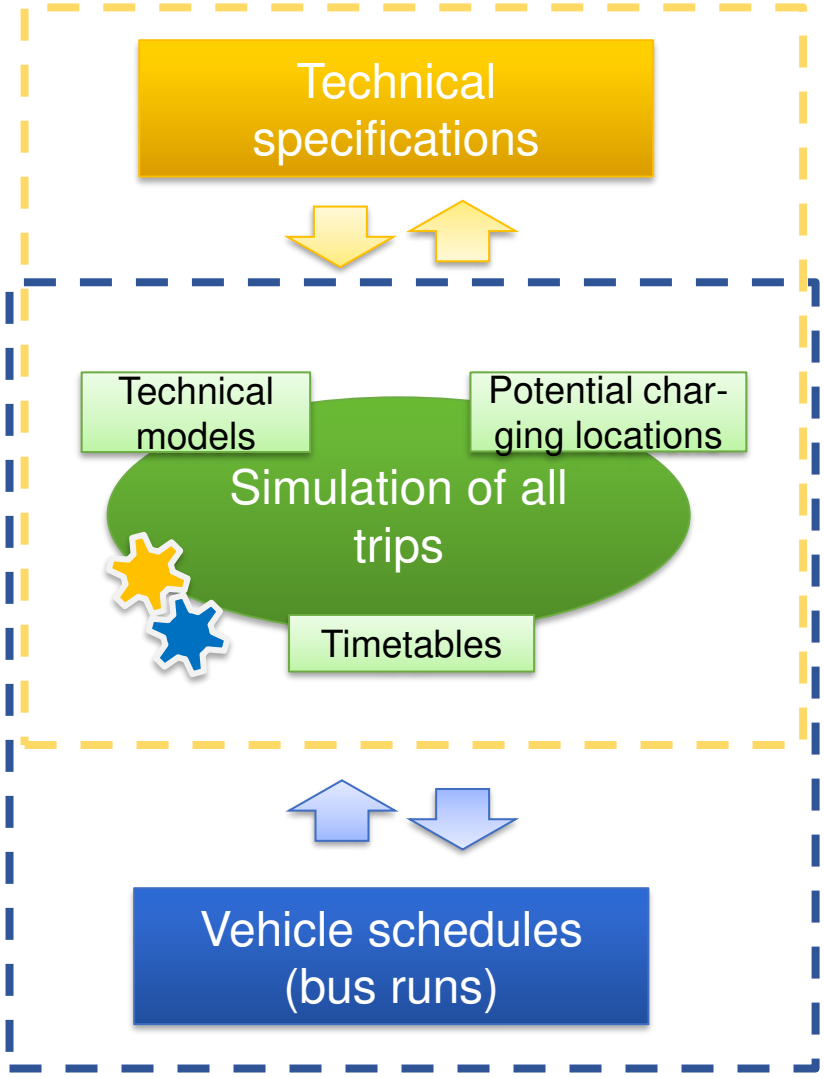
Dead-heading

Software-based Planning Process

Optimization of the technical specifications

+

Optimization of vehicle schedules (bus runs and charging schedules)



Technical specifications

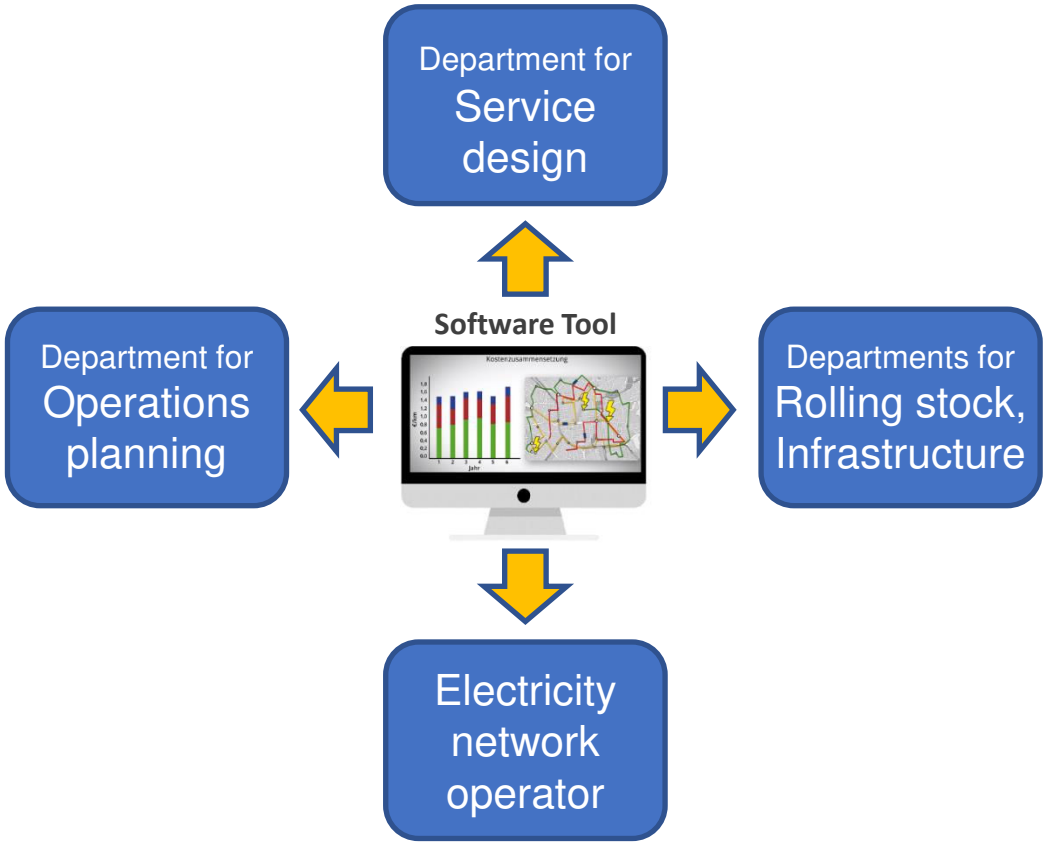
+

Operation concept

=

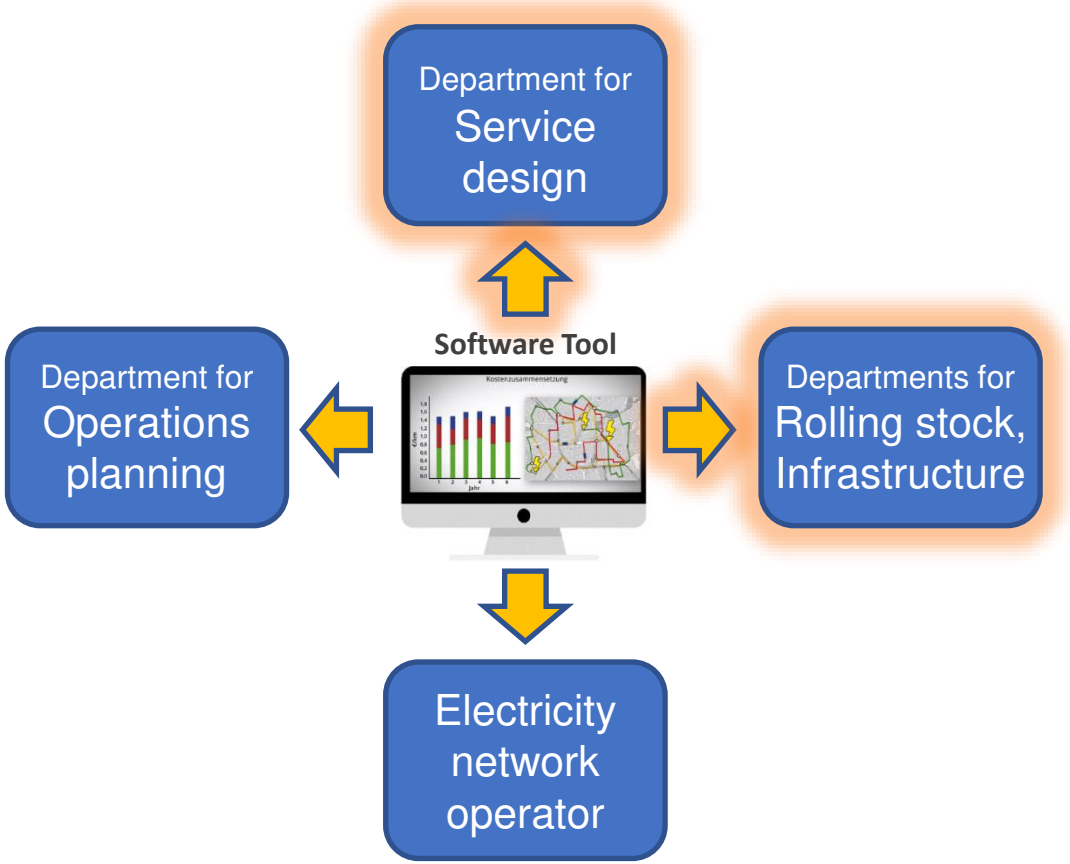
Implementation concept

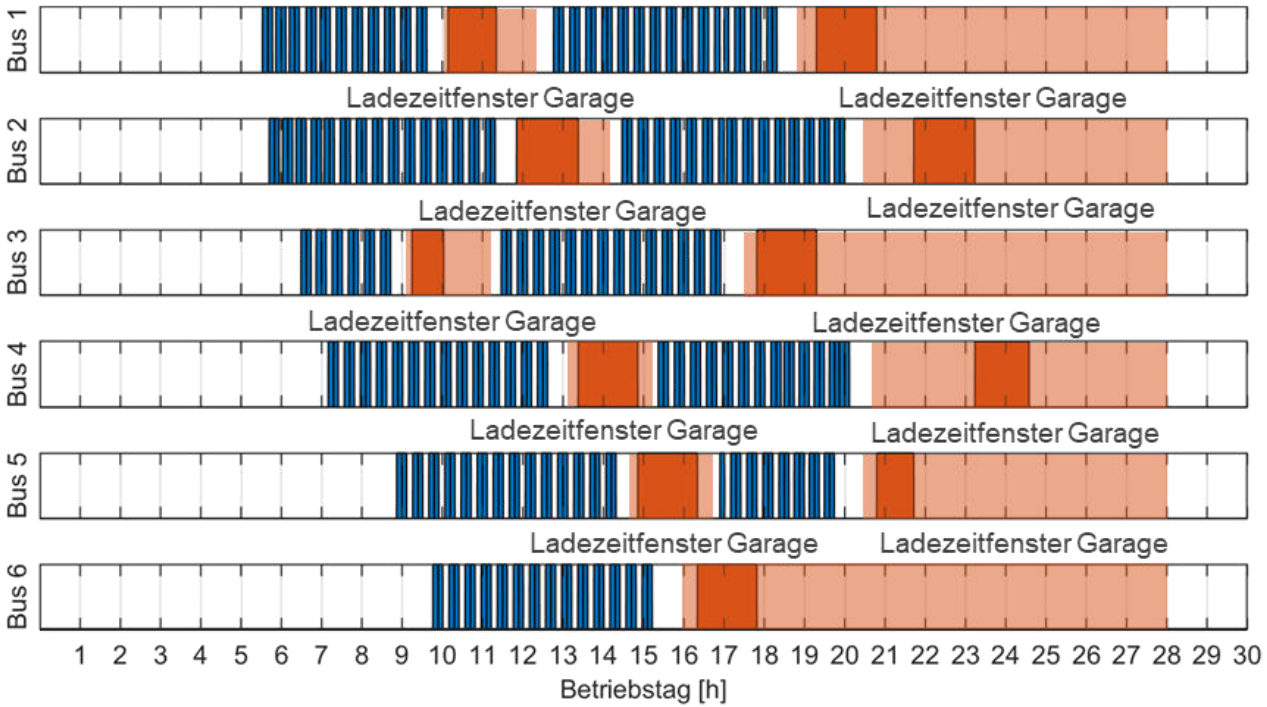
Use Cases of the Software Tool



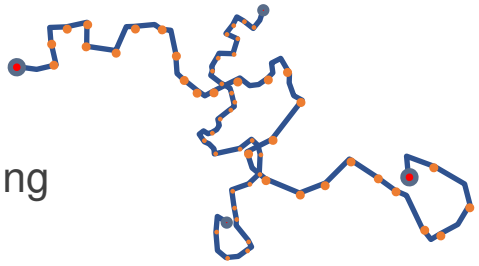
Use Cases of the Software Tool
System Design

- Selection of bus lines / line bundles to be electrified



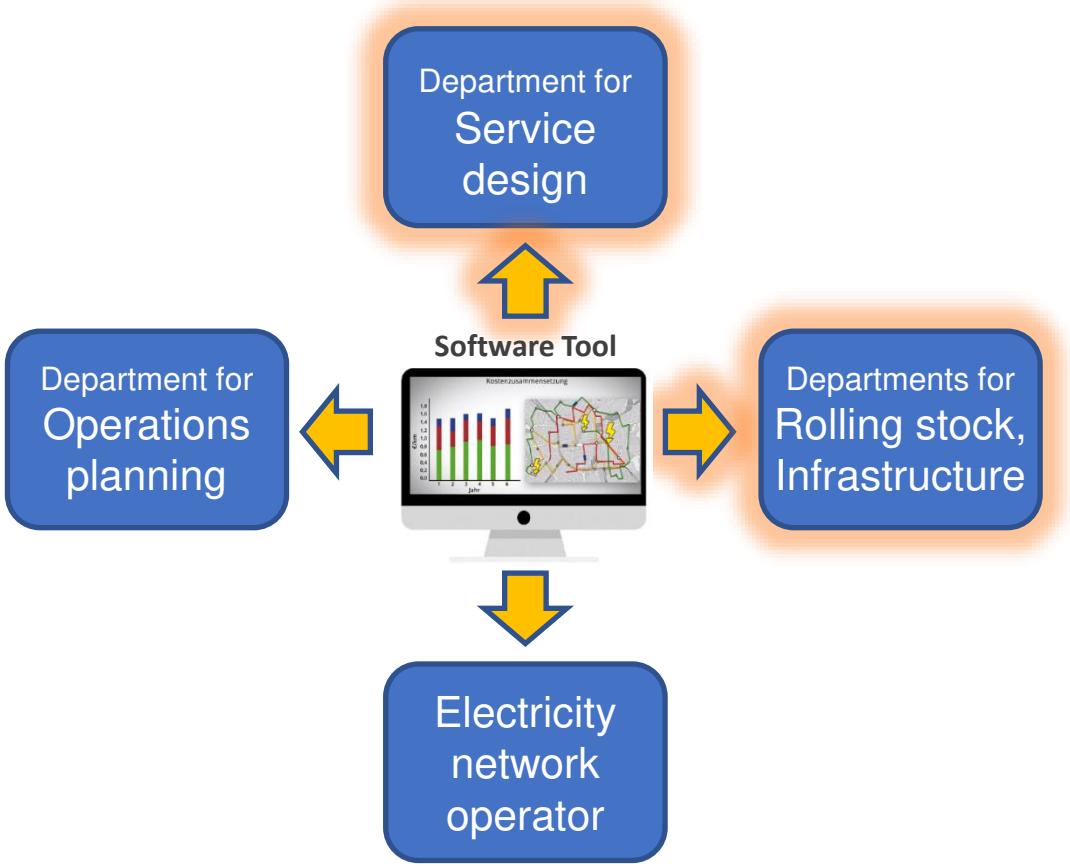


- For each line / line bundle
  - Required number of vehicles
  - Required number of chargers and charging locations



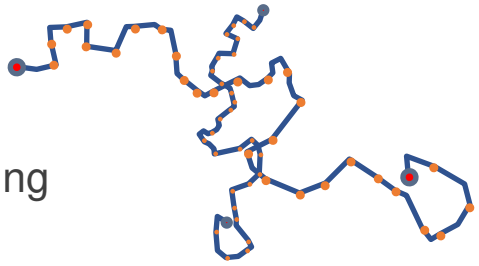
Use Cases of the Software Tool
System Design

- Selection of bus lines / line bundles to be electrified



Bus route	Bus type	No. of buses Conventional bus	Required no. of additional vehicles (scenario today)							
			Depot charger type 1		Depot charger type 2		Opportunity charger type 1		Opportunity charger type 2	
			A	B	A	B	A	B	A	B
***	Solo	7	2	0	1	0	3	2	3	2
***	Articulated	7	4	2	3	0	-	3	-	3
***	Solo	3	2	1	2	1	0	0	0	0
***	Solo	3	2	1	2	1	0	0	0	0
***	Solo	6	3	2	3	2	0	0	0	0
***	Solo	5	2	2	2	2	-	-	-	-
***	Articulated	6	5	3	4	2	-	-	-	-
***	Articulated	7	4	4	4	3	-	0	-	0
***	Articulated	7	4	4	4	3	-	0	-	0
***	Articulated	13	9	7	9	7	-	1	-	1
***	Articulated	3	3	2	2	1	-	-	-	-
***	Articulated	4	3	2	3	2	-	-	-	-
***	Articulated	7	6	4	5	3	-	-	-	-
***	Articulated	9	8	5	6	4	-	2	3	2
***	Articulated	9	8	5	6	4	-	1	-	1
***	Solo	5	3	2	3	2	-	-	-	-

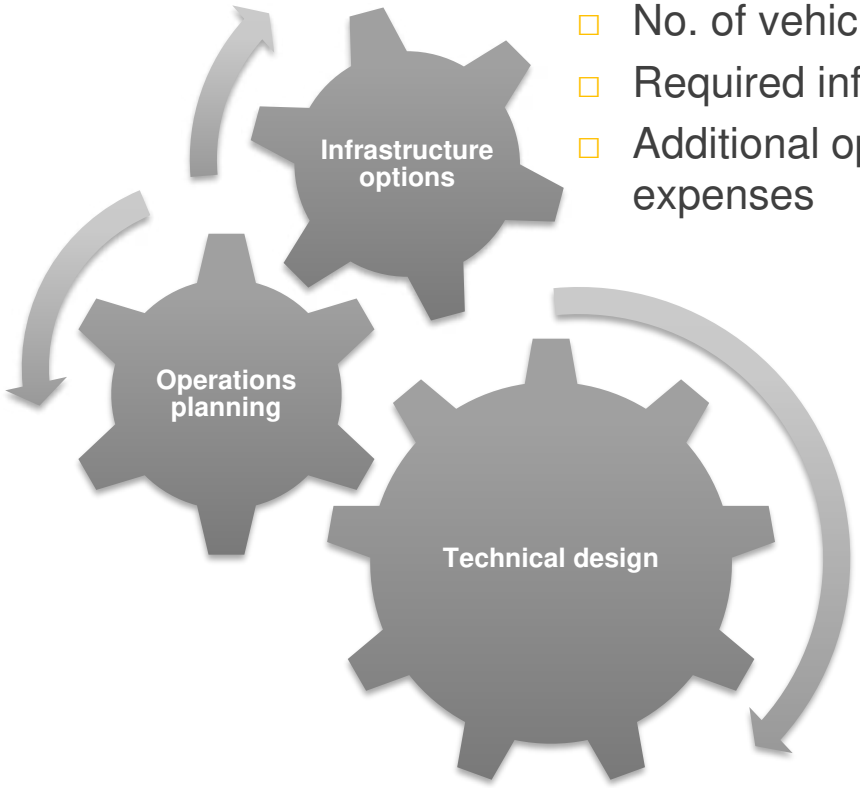
- For each line / line bundle
  - Required number of vehicles
  - Required number of chargers and charging locations



Use Cases of the Software Tool
System Design

ebusplan
Solutions for Clean Transportation

Analyse **technical** feasibility
including evaluation of **operational adjustments**



- No. of vehicles (PVR)
- Required infrastructure
- Additional operating expenses

Total cost of ownership (TCO)

- Vehicle procurement
- Infrastructure costs
- Operating costs
- Personnel costs

Emissions reduction potential

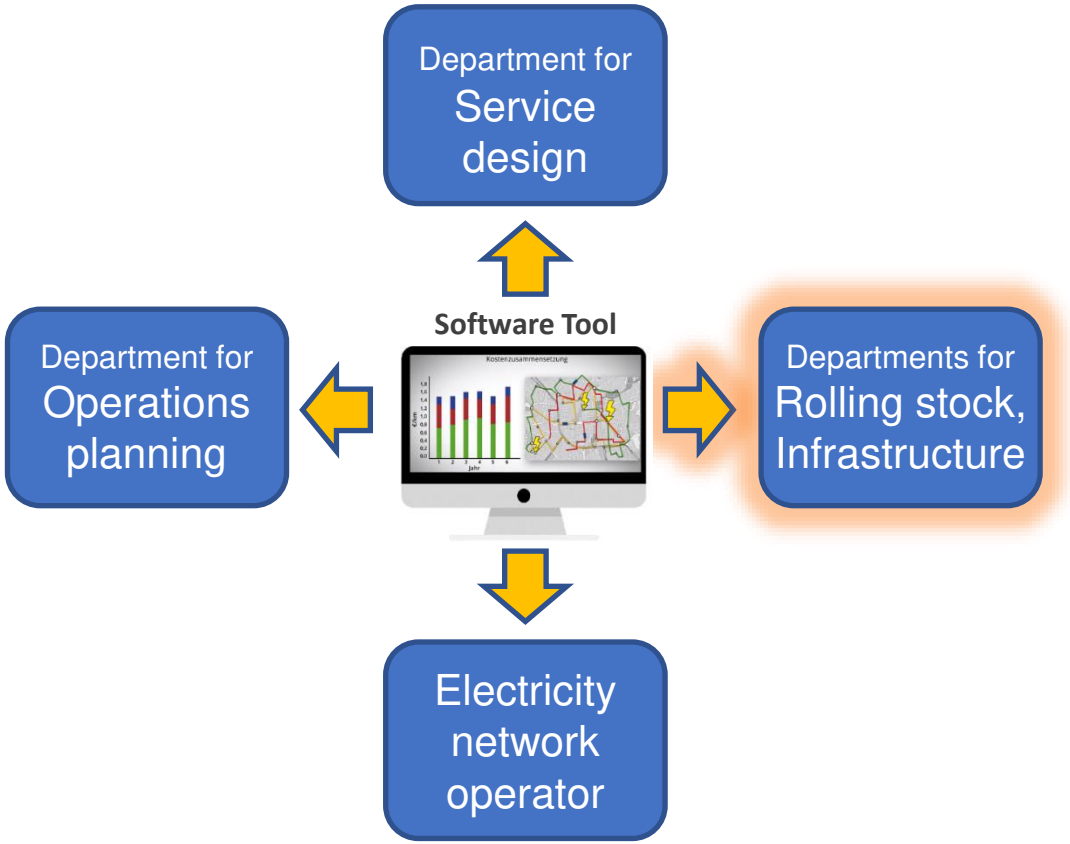
- CO_2
- PM
- NO_x

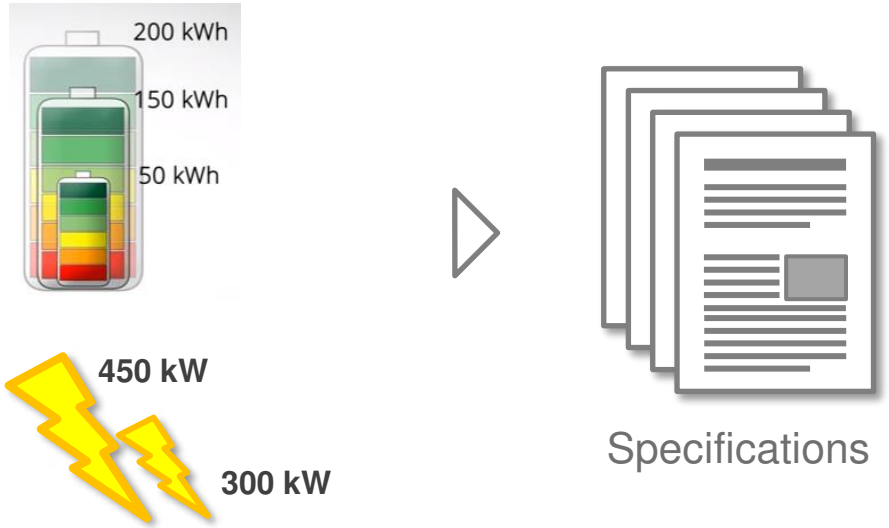
Cost / benefit evaluation of all config.s & options

Selection of technologies
and definition of build-out target ✓

Use Cases of the Software Tool
Procurement of Buses and Charging Infrastructure

- Preparation of technical specifications

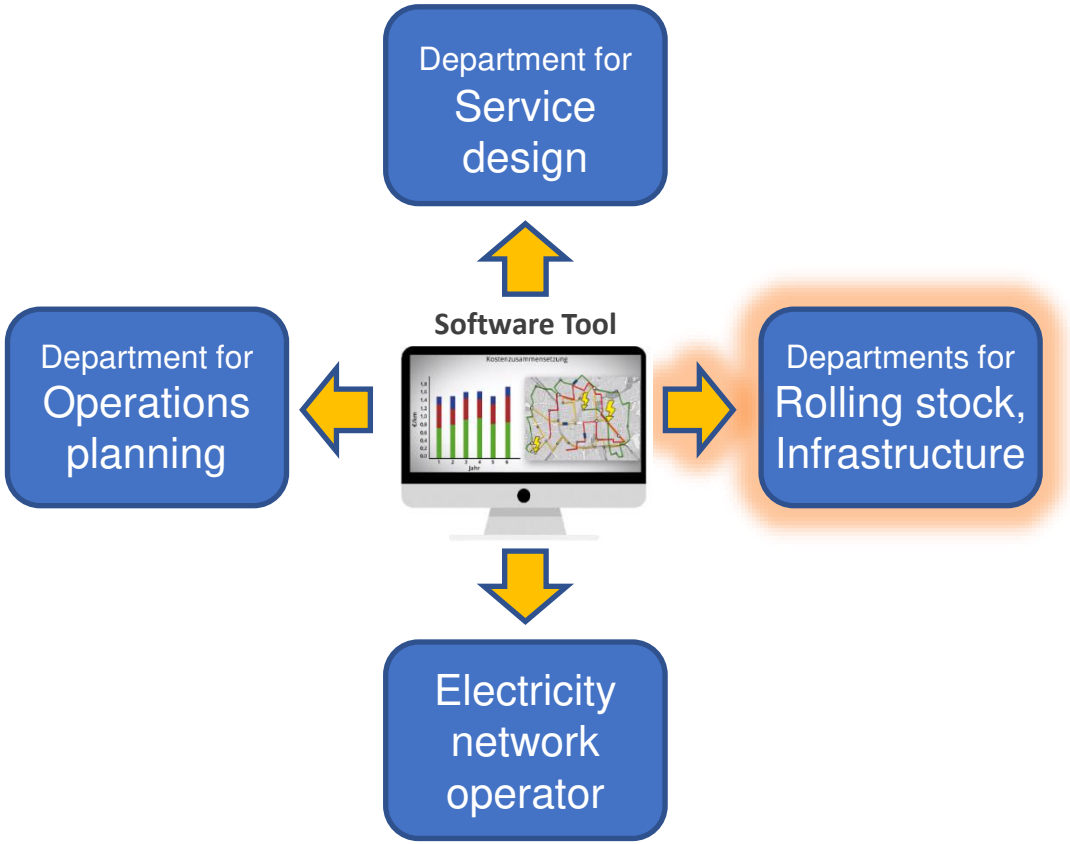




- Define concrete requirements for
  - Battery capacity in kWh
  - Charging power in kW

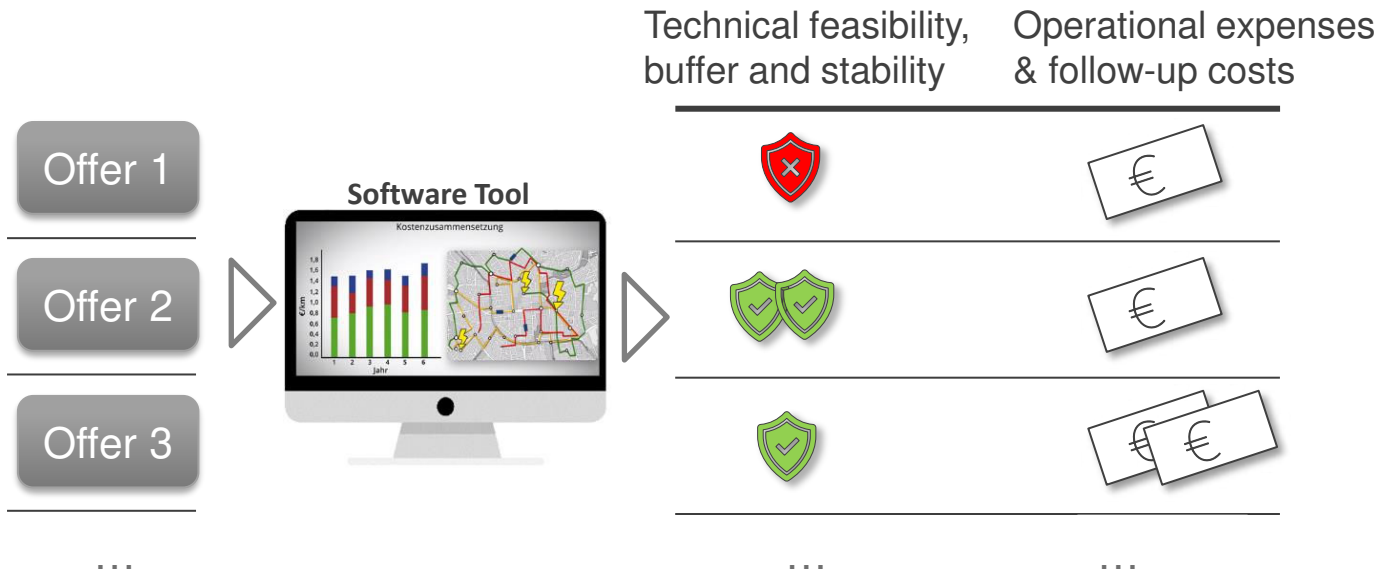
Use Cases of the Software Tool
Procurement of Buses and Charging Infrastructure

- Evaluating offers during tender call



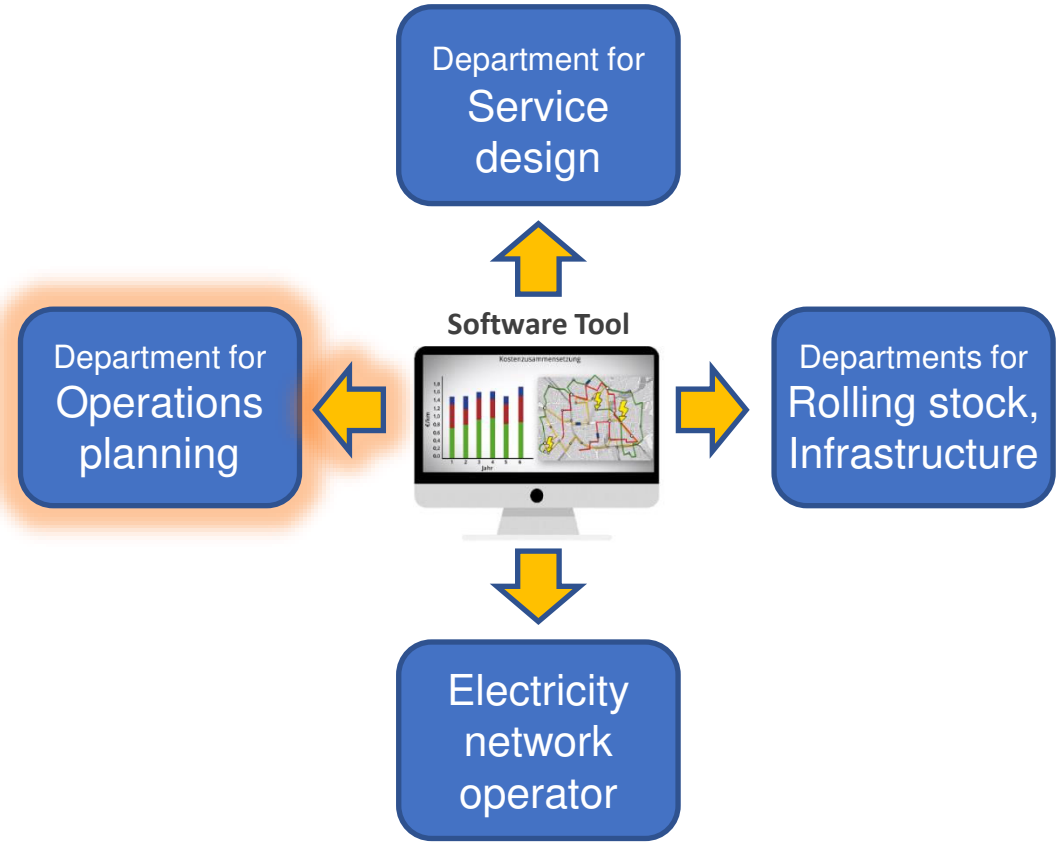
- Evaluate the different vehicles and charging infrastructure types offered by bidders

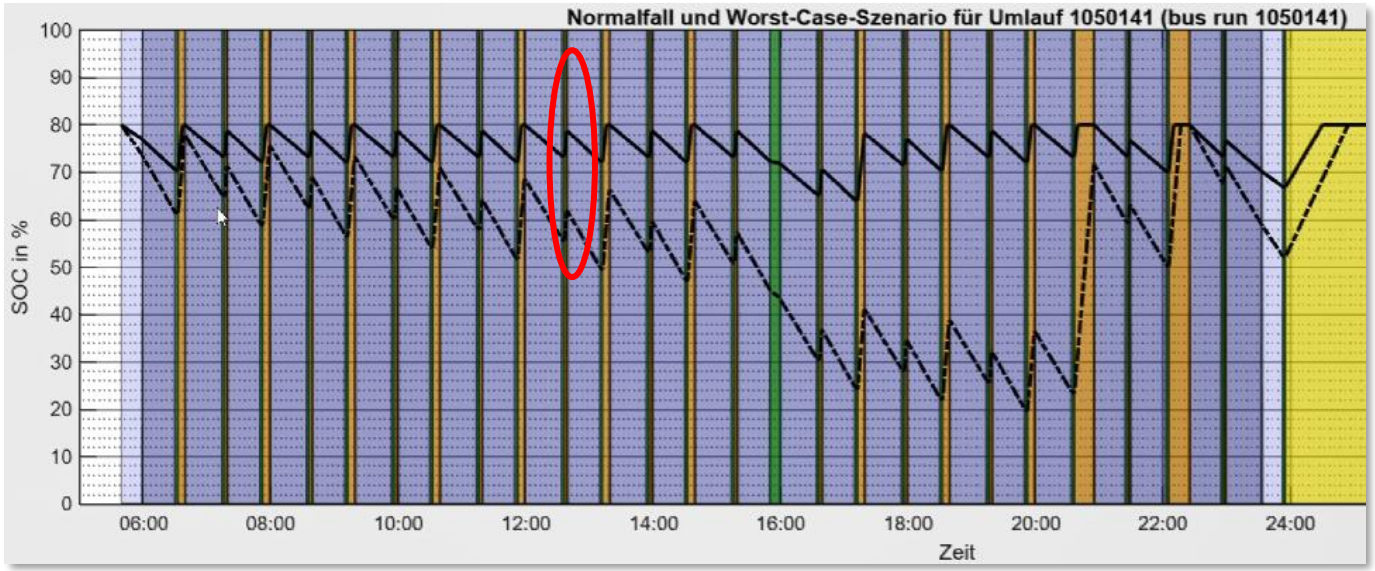
SOLARIS · VDL BUS & COACH · BYD · Irizar lighting the road · EvoBus



Use Cases of the Software Tool

- Define operational requirements for day-to-day vehicle scheduling

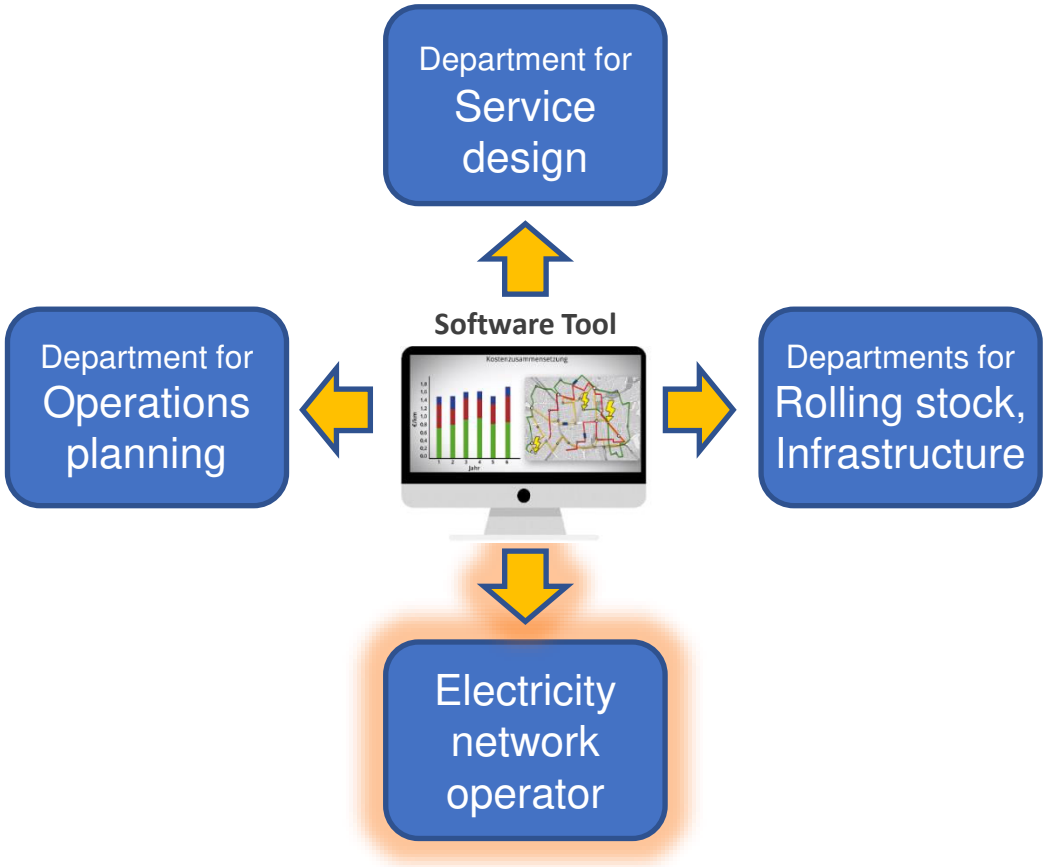


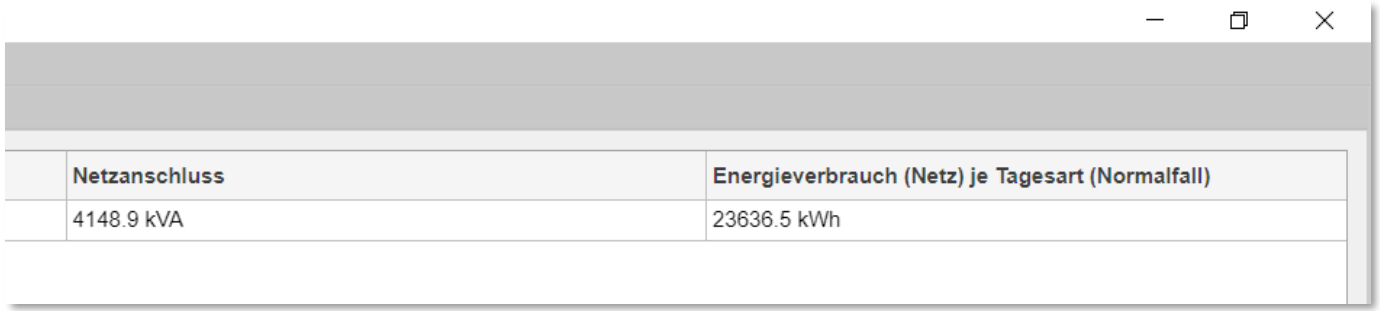


- Define parameterization of vehicle scheduling
  - Driving ranges
  - Charging duration
- Simulate failure scenarios and other special scenarios
- Dimensioning of buffers / redundancies
- Identify optimization potentials (“room for improvement”)

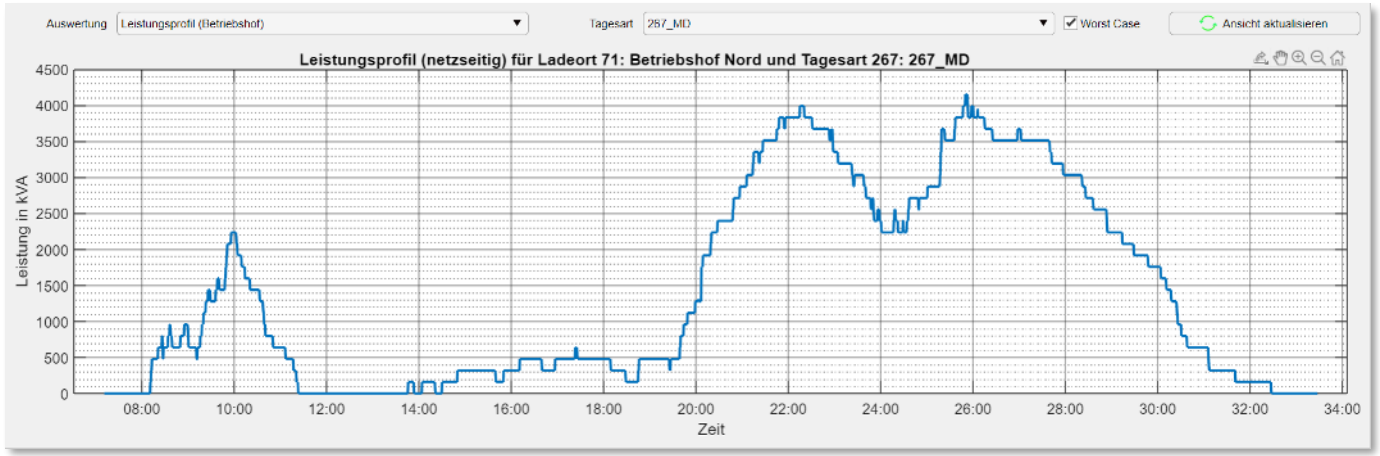
Use Cases of the Software Tool

- Negotiations with el. network operator
- Planning of energy procurement





	Netzanschluss	Energieverbrauch (Netz) je Tagesart (Normalfall)
	4148.9 kVA	23636.5 kWh



- Concrete load profiles and
- energy purchase quantities as a basis for planning and discussion

Wrap Up and Conclusion

- Electric buses bring along additional complexity for planning and implementation of bus services
  - Technical constraints: battery behaviour, energy consumption, charging technology
  - Entire chain is affected
- Software makes complexity manageable and optimizes efficiency (TCO reduction)
  - Models for energy consumption, battery behaviour and charging behaviour
- Strategic system design for optimized efficiency and TCO using dedicated software tool
  - Analyse and model operations, determine energy consumption and load profiles (e.g. battery strain)
  - Optimize vehicle schedules (PVR) for each electric bus concept and for different infrastructure scenarios
  - Optimize charging schedules (no. of chargers)
  - Calculate many different scenarios to make transparent the different interdependencies

- Expert advice
- Software

www.ebusplan.com

Project supported by:

Ministerium für Wirtschaft, Innovation, Digitalisierung und Energie des Landes Nordrhein-Westfalen

EFRE.NRW Investitionen in Wachstum und Beschäftigung

EUROPÄISCHE UNION Investition in unsere Zukunft Europäischer Fonds für regionale Entwicklung

strategieE ELEKTROBUSSE EINFACH PLANEN

ebusplan
Solutions for Clean Transportation

Software-based planning of E-Bus Projects

TUMIVolt Charging Station webinar

06/05/2021

Philipp Sinhuber, ebusplan GmbH

Tel: +49 (0) 241 55 70 51 81
Mobile: +49 (0) 175 37 01 233
p.sinhuber@ebusplan.com

Our Services

ebusplan
Solutions for Clean Transportation

Feasibility Studies

Choosing the right concept and suitable lines

- Analysis of the electrification potential of your bus line network
- Assessment of all available electric bus technologies (fuel cell bus, battery bus, diesel hybrid bus, trolleybus) for your bus route network incl. cost comparison (TCO)
- Quantification of environmental benefits
- Planning of the gradual transition to electric buses

Transition Planning

Complete planning of the individual transition phases

- Definition of the transition phases for the step-by-step electrification of the bus fleet
- Fleet planning for the transition period
- Planning the number of chargers, charging power and space requirements
- Determining the investment costs for the individual transition phases
- Identification of funding opportunities

Infrastructure Planning

Cost-optimized concepts ready for tender

- Planning of infrastructure deployment in the depot and at other charging locations
- Concepts for the installation and connection of the chargers
- Determination of the load profile for negotiation with the network operator
- Analysis of the possibilities of Smart Charging

Requirements Specification

Experienced support of tenders

- Identification of requirements and recording of the local situation
- Preparation of specifications for vehicles and infrastructure
- Advice on the tendering process
- Evaluation of offers and support in bidder discussions

Funding Advice

Extensive support in the acquisition of public funding

- Identification of funding opportunities for the procurement of vehicles and charging infrastructure
- Editing of funding applications
- Organizational support of application procedures

Project Support

Competent support of the electric bus implementation

- Review of planning bases and cost calculations
- Presentation of the electric bus strategy to supervisory boards and politicians
- Facilitation of internal workshops to involve all departments
- Specialist workshops and seminars on the topics of vehicle, battery technology, infrastructure and software