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Solutions for Clean Transportation

Software-based System Design of E-Buses

Session I: Decision-making: what bus system to go for?

- trolley 2.0 final conference -

12/11/2020

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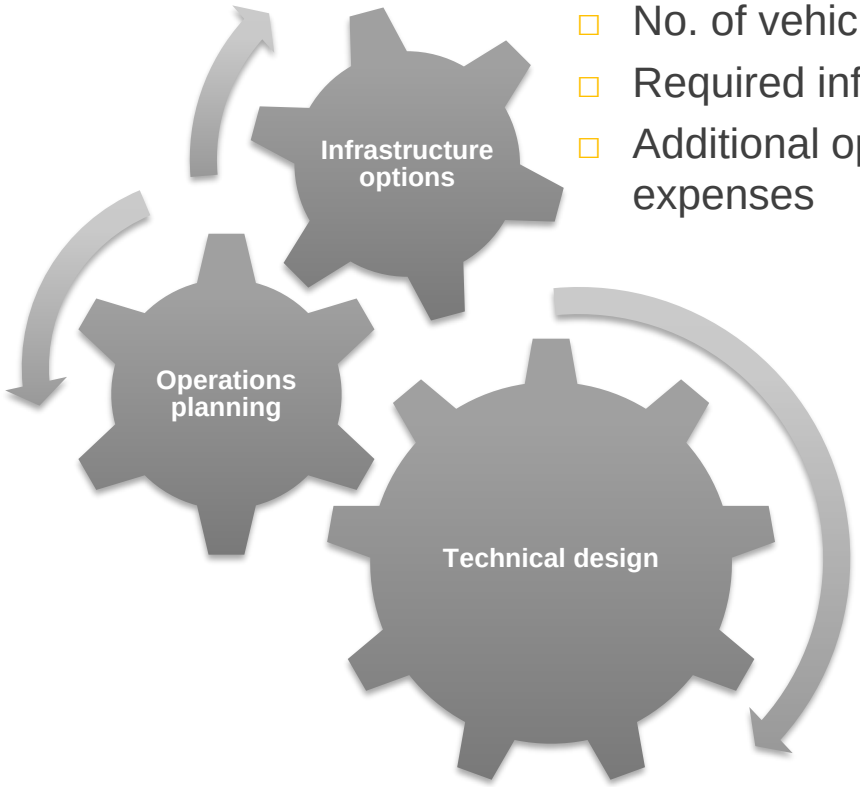
Decision-making: what bus system to go for?
Recommended Approach

Analyse **technical** feasibility
<u>including</u> 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

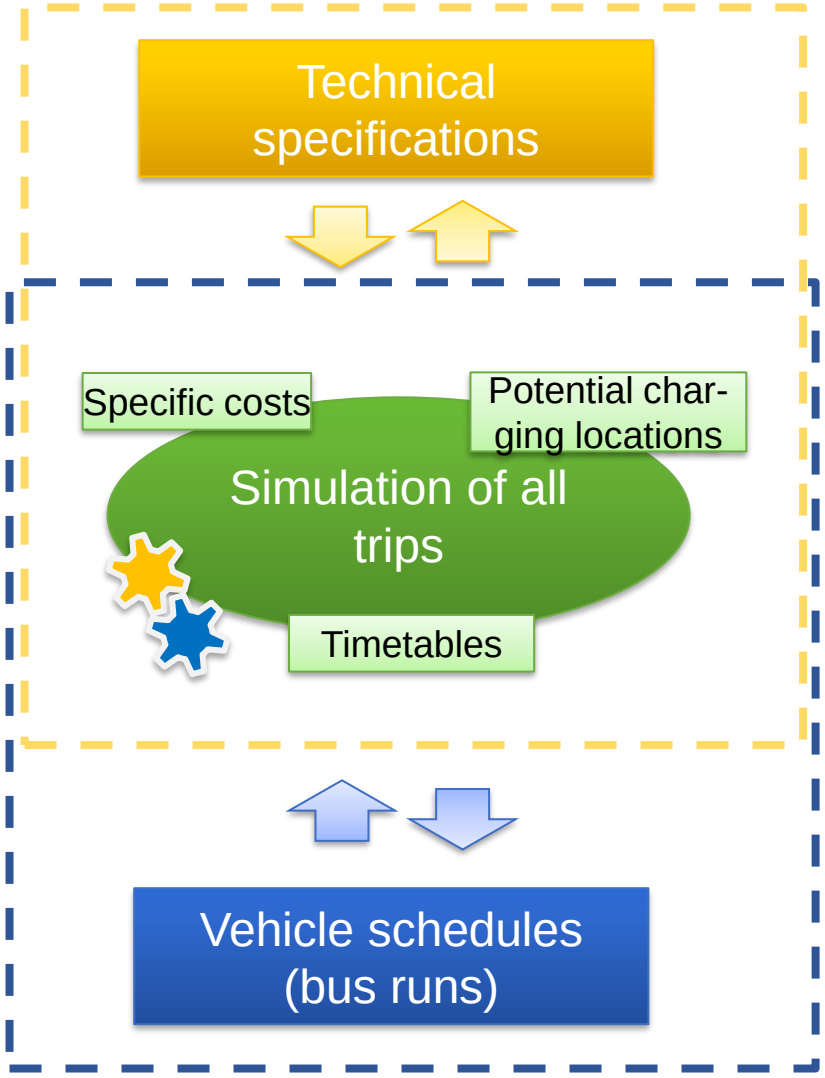
Selection of technologies
and definition of build-out target ✓

Software-based Planning Process

Optimization of the technical specifications

+

Optimization of vehicle schedules (bus runs and charging schedules)



Technical specifications

+

Operation concept

=

Implementation concept

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- R&D in the field of electric buses for more than 10 years
- Leader in simulation and optimization for system design and operations
- Customers in Europe and beyond:

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

...and many more

Agenda

- Aim of the software-based planning approach (consultancy + software):
  - Design electric bus systems concretely and specifically to the local requirements
  - Make transparent the consequences of technology choice for the person in charge and other stakeholders
  - Translate between technics and operations planning and bring both together to find the best solution

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- In the following, 2 aspects will be discussed:
  - What effects does technology choice have on operations?
    - Example: Efficiency of operations (bus runs, vehicle scheduling))

    Technology Choice → Operations

  - What effects do the requirements of operations have on technology?
    - Example 1: Existing catenary system → expand electric operation
    - Example 2: Greenfield site planning → Identify potential catenary lines

    Requirements of Operations → Technology

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Requirements of Operations → Technology

Effects of Technology Choice on Operations

Technology Choice → Operations

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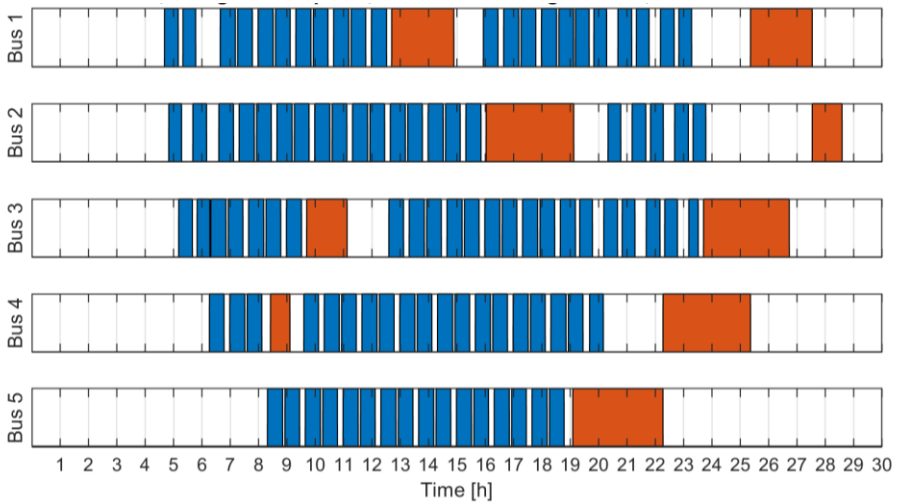
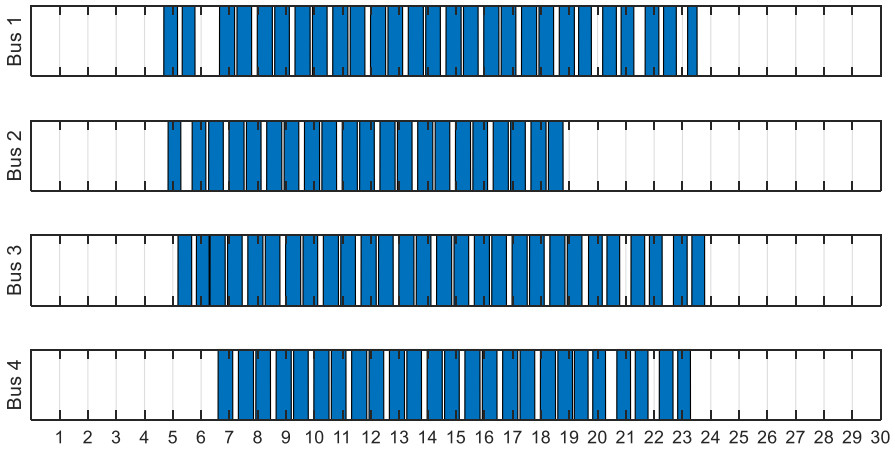
- Bus runs need to be planned according to technical constraints
  - Energy consumption
  - Available battery capacity (range)
  - Available charging power (charging duration)
  - Location of charging opportunities

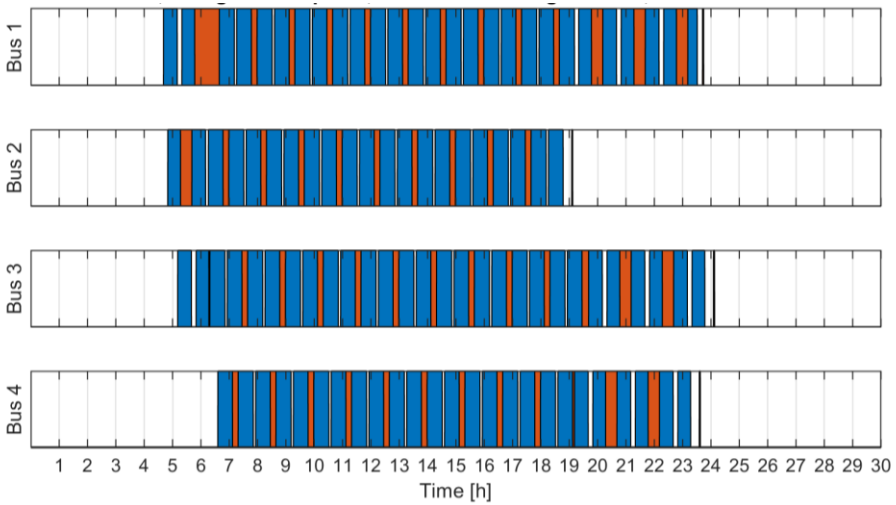
Depot charging



Diesel bus & fuel cell hybrid



Opportunity charging



Line service Charging phase

Effects of Technology Choice on Operations

Technology Choice → Operations

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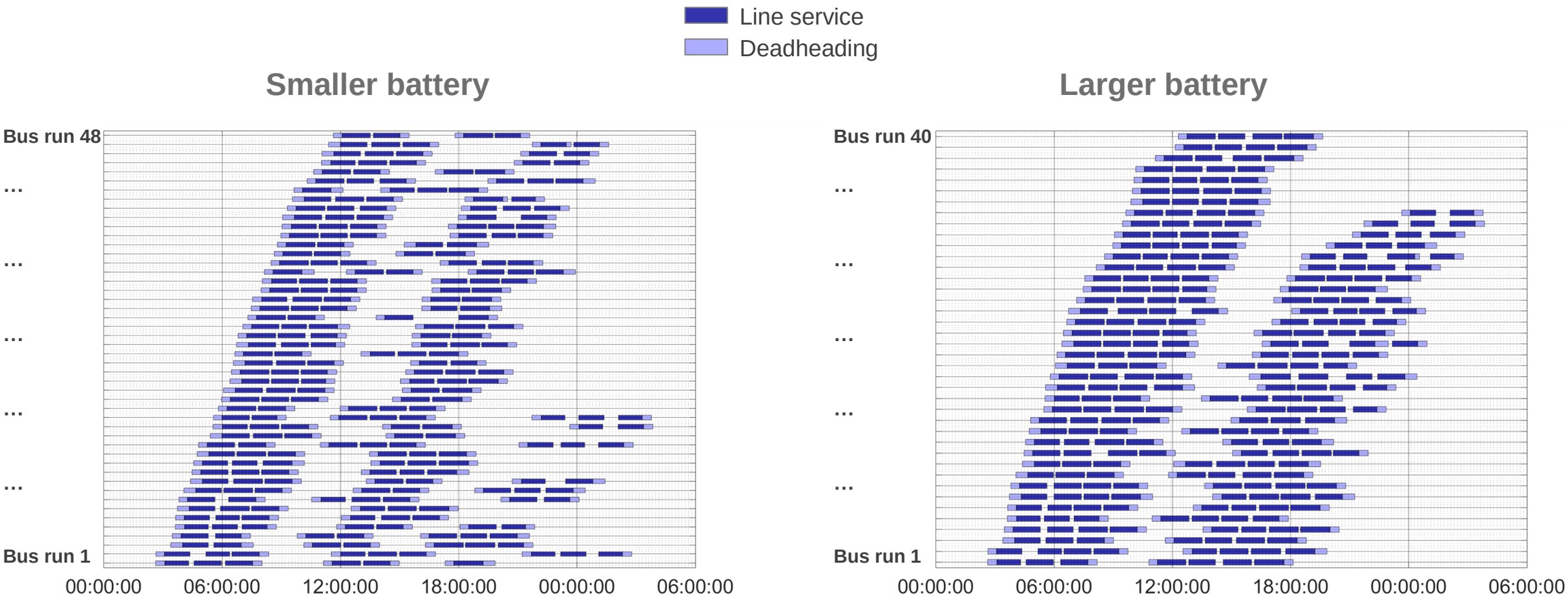

Larger battery → Longer bus runs → Fewer vehicles required

Effects of Technology Choice on Operations

Technology Choice → Operations

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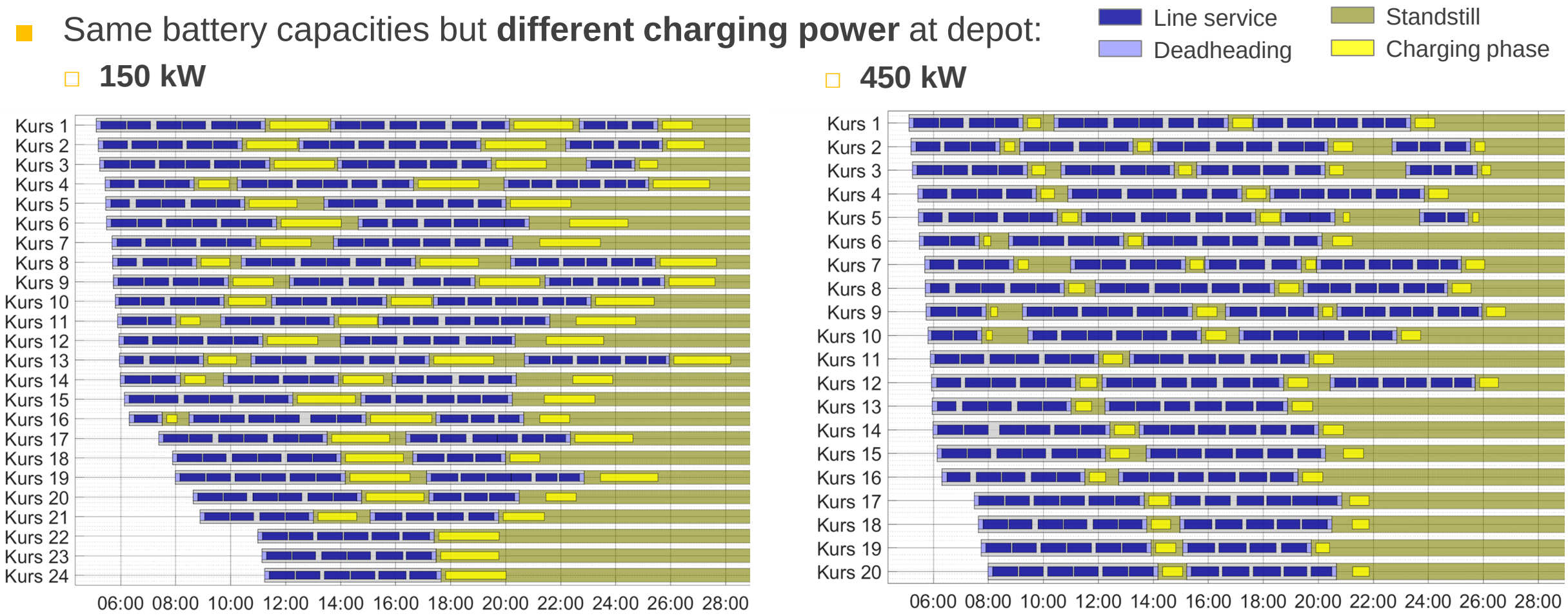
- Same battery capacities but **different charging power** at depot:
  - **150 kW**
  - **450 kW**



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

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Requirements of Operations → Technology

Expand electric operation with existing catenary system

Requirements of Operations → Technology

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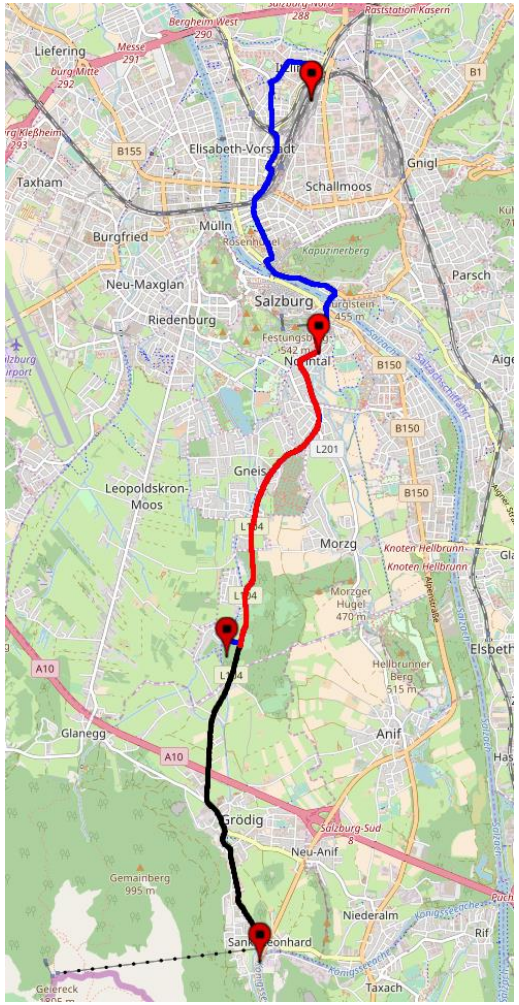
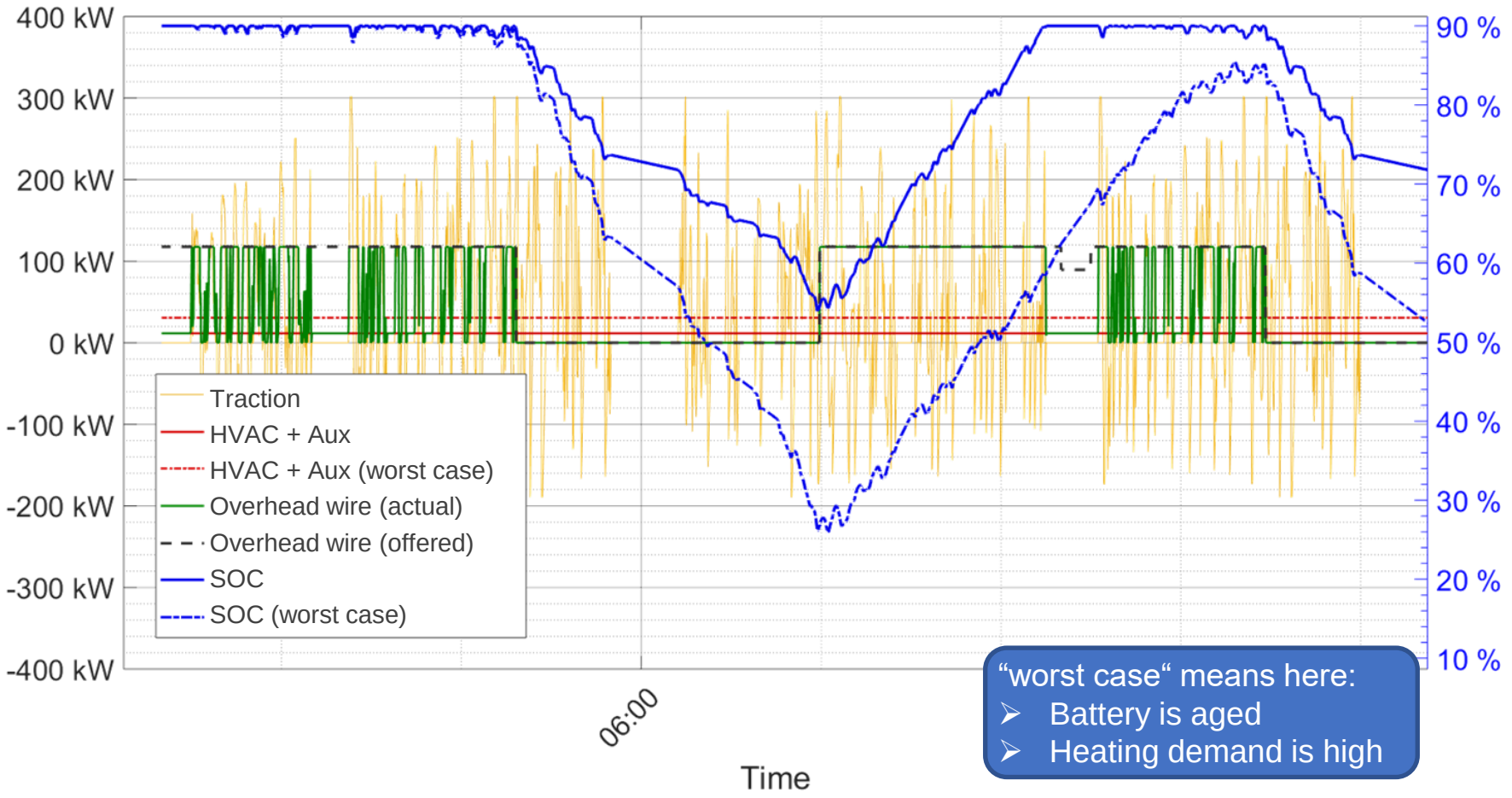
- Simulation of operations





"worst case" means here:
- Battery is aged
- Heating demand is high

Expand electric operation with existing catenary system

Requirements of Operations → Technology

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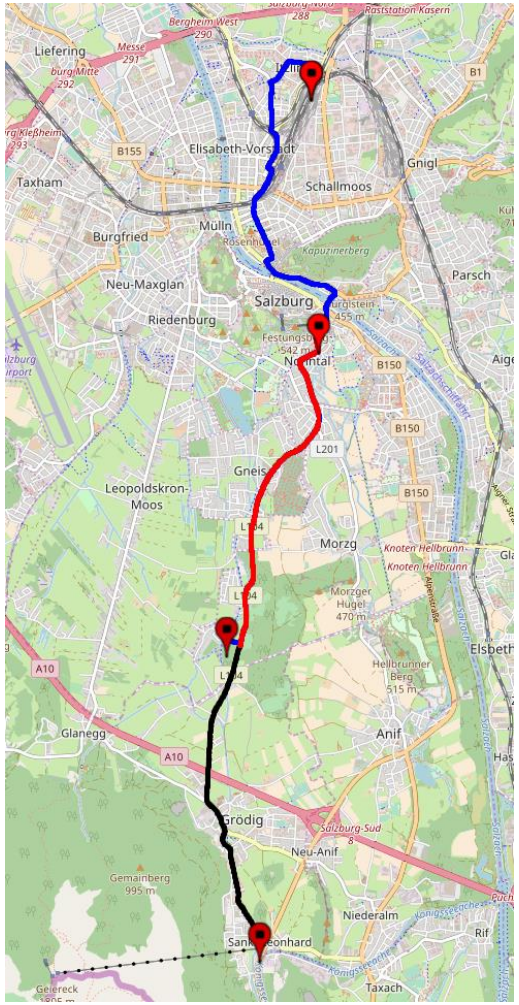

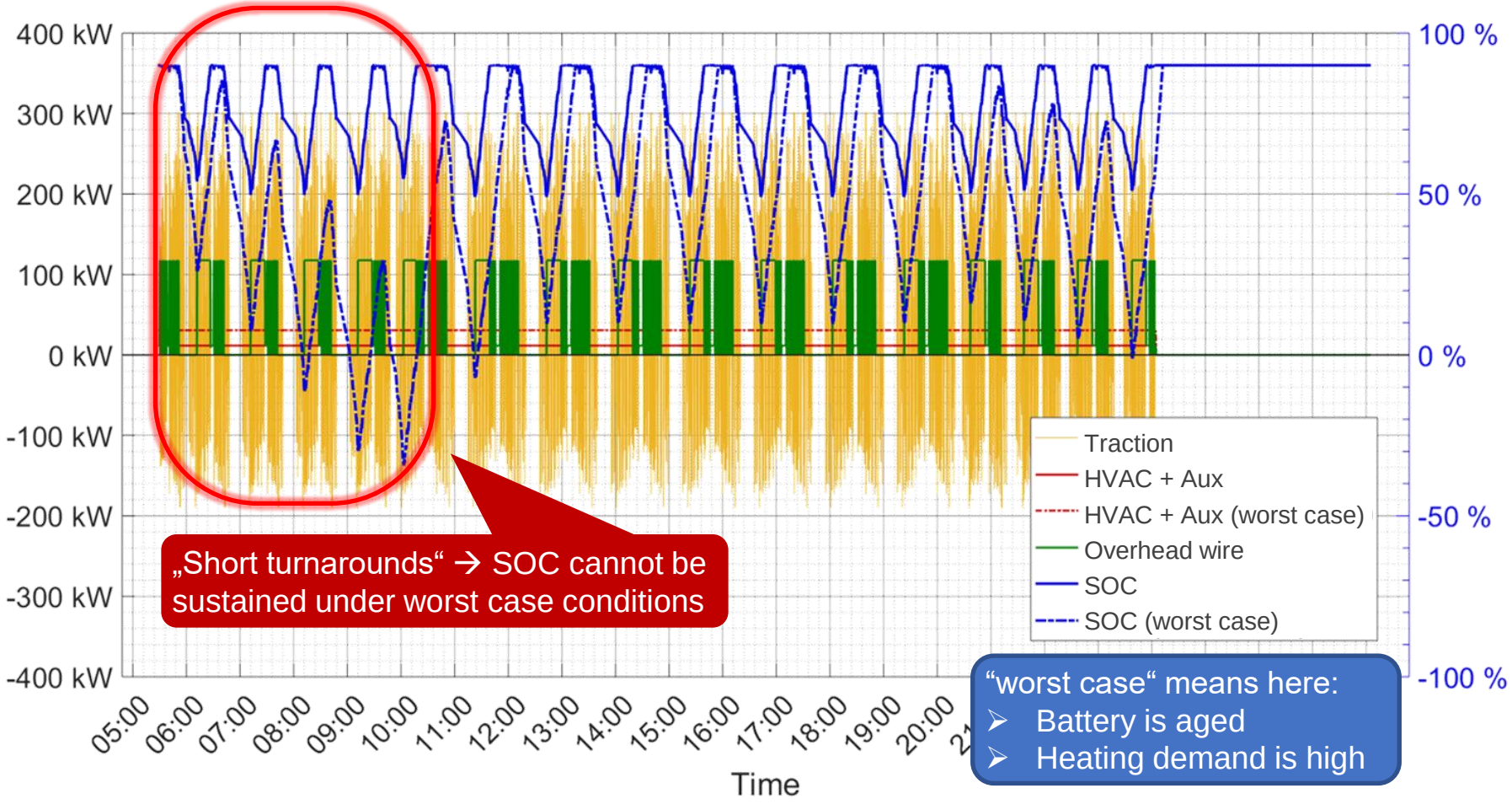

Expand electric operation with existing catenary system

Requirements of Operations → Technology

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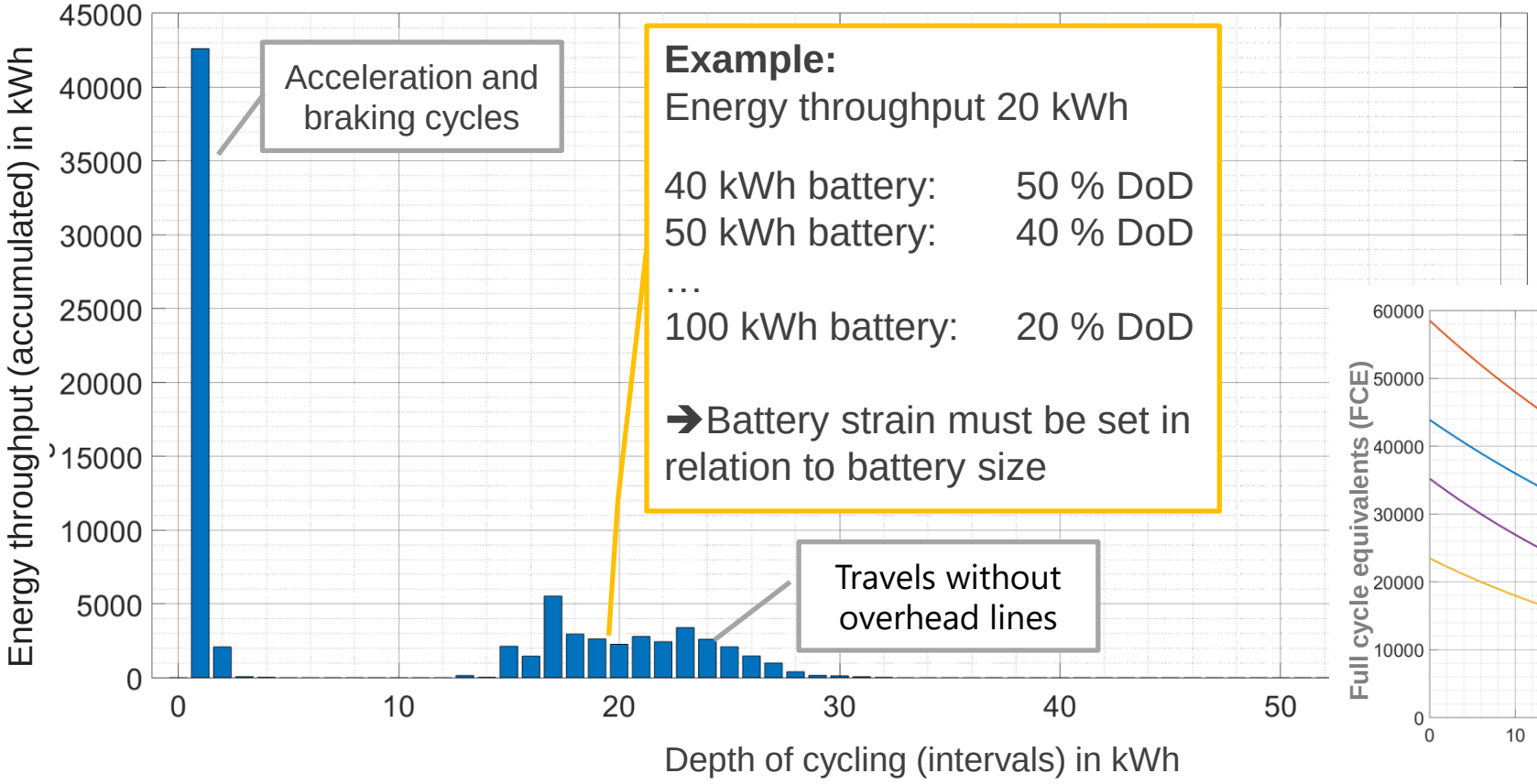
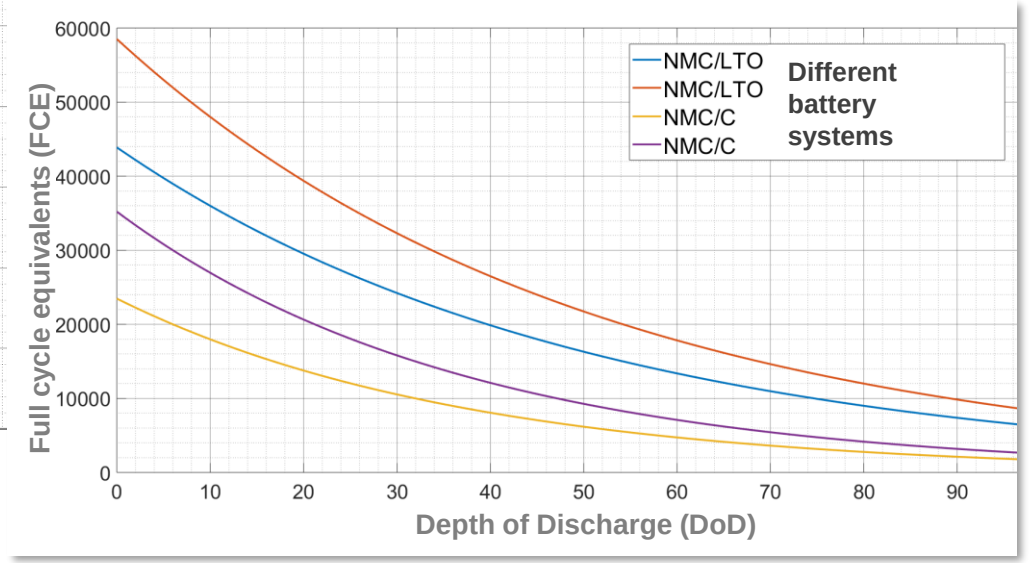
- Evaluation of Battery Strain and Lifetime Prediction
  - Breakdown of annual energy throughput by depth of cycling



Aging model
- Calendar life
- Cycle life



“Greenfield” planning
Identify Potential Catenary Tracks

Requirements of Operations → Technology

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Rheinbahn

- Evaluation of the frequency of each route section:

x trips per day
(on average and in both directions)

- 70 ≤ x < 200
- 200 ≤ x < 400
- 400 ≤ x < 650
- 650 ≤ x

“Greenfield” planning
Identify Potential Catenary Tracks

Requirements of Operations → Technology

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Rheinbahn

- Evaluation of the frequency of each route section:

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1. Neglect sections below … trips per day.

“Greenfield” planning
Identify Potential Catenary Tracks

Requirements of Operations → Technology

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Rheinbahn

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1. Neglect sections below … trips per day.
2. Reduction:
   1. Exclude bus lines with insufficient time / distance under catenary.
   2. Re-evaluate frequencies of each route section.

“Greenfield” planning
Identify Potential Catenary Tracks

Requirements of Operations → Technology

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Rheinbahn

- Evaluation of the frequency of each route section: (iterative procedure)

x trips per day
(on average and in both directions)

- 70 ≤ x < 200
- 200 ≤ x < 400
- 400 ≤ x < 650
- 650 ≤ x

1. Neglect sections below … trips per day.
2. Reduction:
   1. Exclude bus lines with insufficient time / distance under catenary.
   2. Re-evaluate frequencies of each route section.
3. Continue at 1. until no further reduction

➢ "Short List" contains "self-sustaining" sections and bus lines

Wrap Up and Conclusion

- A sustainable decision requires
  - An analysis of operations and local-specific preconditions
  - Quantification of impact of each technology on operations (PVR, deadheading, driver time, infrastructure)

- Software makes complexity manageable
  - Analyse operations and identify potential charging locations
  - Model operations, determine energy consumption, determine 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 → www.ebusplan.com
- Software → www.strategie-e.de

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EFRE.NRW Investitionen in Wachstum und Beschäftigung

EUROPÄISCHE UNION
Investition in unsere Zukunft
Europäischer Fonds für regionale Entwicklung

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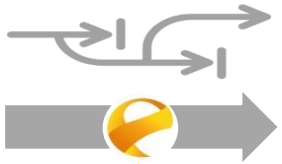
Our Consultancy Services



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Workshops and Seminars

Kick-start into the topic „Electric Buses“;
Public seminars;
Individual seminars on selected topics

Feasibility Studies

Compare all vehicle & charging concepts considering their implications for operations;
Derive concrete path for changeover of the entire fleet

Electrification Concepts

Reliable and cost-optimized electrification concepts including specs;
Bus garage charging infrastructure planning

Support Implementation

Funding opportunities;
Specs, procurement and offer evaluation;
Monitoring, evaluation and optimization of operation

Charger Optimization and Load Management (Smart Charging)

Requirements of Operations → Technology

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Scenario no.	Bus type	Charging power	No. of buses (PVR)	Service mileage	Deadheading	No. of chargers	No. of chargers *optimized*
…	… (18m, 320 kWh)	150 kW	79	15,849 km	3,379 km	33	13