CACTUS

Models and Methods for the Evaluation and the Optimal Application of Battery Charging and Switching Technologies for Electric Busses

Copenhagen

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Goals of the Project at a Glance

- Development of **models** for battery charging and changing technologies
  – public transport networks
  – timetables and bus schedules
  – energy consumption of busses
- Development of **methods** to answer questions like
  – How many battery charging or changing facilities are required?
  – Where do they have to be located?
  – When charging should be performed and for how long?
- Development of a **software tool** in order to compare the different available technologies to each other for concrete public transport networks and timetables

Contribution to the Key Dimension Objectives

- Key Dimension 3
  Strategic research on technical dimensions of the recharging, storage and contribution systems
  - Development of technical models of battery recharging solutions (3a)
  - Consideration of inductive charging technology (3c)
- Key Dimension 5
  Technology-based Innovation/Applied Research
  - Application of the methods at the public transport companies

Research Institutions and Associate Partners

ifak – Institut für Automation und Kommunikation e.V. Magdeburg, Germany

IML – Fraunhofer Institut for Materialflow and Logistics
Dortmund, Germany

SUFT – Silesian University of Technology, Faculty of Transport
Katowice, Poland

HVB – Harzer Verkehrsbetriebe GmbH
Germany

MVB – Magdeburger Verkehrsbetriebe GmbH, Germany

PKM – The Urban Transit Authority Ltd. Sosnowiec, Poland

PVGS – Personenverkehrsgesellschaft Salzwedel mbH, Germany

Work Packages

Requirements

- Aspects (transportation, technique, economic, environment)
- Objectives
- Input and output variables

Models

- Kinds of models (analytic, simulation)
- Objects to model (networks, batteries, buses, bus schedules, time tables)
- Economical model
- Ecological model

Methods

- Optimization
- Simulation

$A \cdot x = b$

$c \cdot x \to \min$

Tool

- Implementation of the models and methods
- Import for transportation networks, time tables and bus schedules
- User interface

Application

- Application of the tool for participating public transport companies
- Recommendations for building a charging infrastructure

Input Variables and Design Goals

Extended Bus Schedule

- Departure from Bus stop
- Arrival at bus stop
- Travel time
- Energy consumption

Design Goals

- Primary Goal
  - Optimize the location of the charging stations
- Secondary Goals
  - Minimize the environmental footprint
  - Minimize the costs for invest and operation

External Parameters Initial Values

- Global Parameters
  - Temperature
- Infrastructure boundaries
  - Forbidden locations for battery charging and changing
- Bus specific Parameters
  - Battery capacity
  - Initial Battery Charge

Models and Methods

Analytical Model

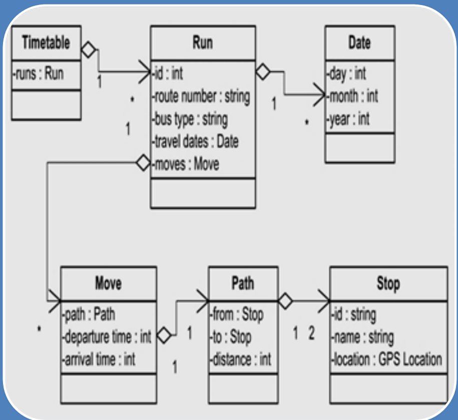
$$S_s = S \cdot I'^T$$

$$S_s = \begin{pmatrix}5&5&5&0&0\\0&3&0&3&3\\2&4&2&2&2\end{pmatrix}\cdot\begin{pmatrix}0&1&0&0\\0&0&1&0\\1&0&0&0\\0&1&0&0\\0&0&0&1\end{pmatrix}$$

$$S_s = \begin{pmatrix}5&5&5&0\\0&3&3&3\\2&4&4&2\end{pmatrix}$$

- Method: Linear approximation
- Advantages:
  - Mathematical optimization can be applied easily
  - Well known method in engineering
- Disadvantage: Models become large

Simulative Model



- Method: Time domain event based simulation
- Advantages:
  - Well known method in industrial applications
  - Easy to handle
- Disadvantage: Execution time becomes long

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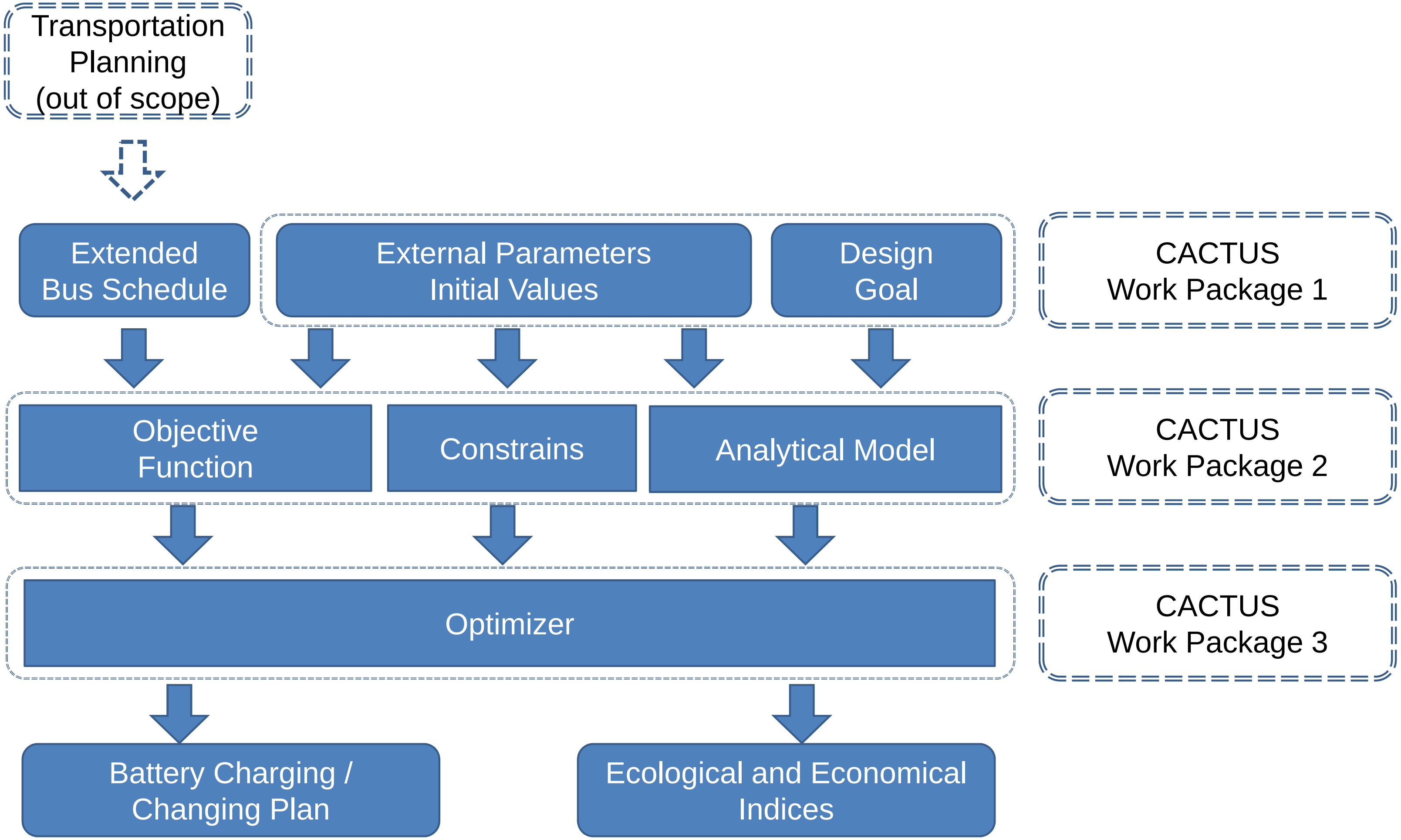
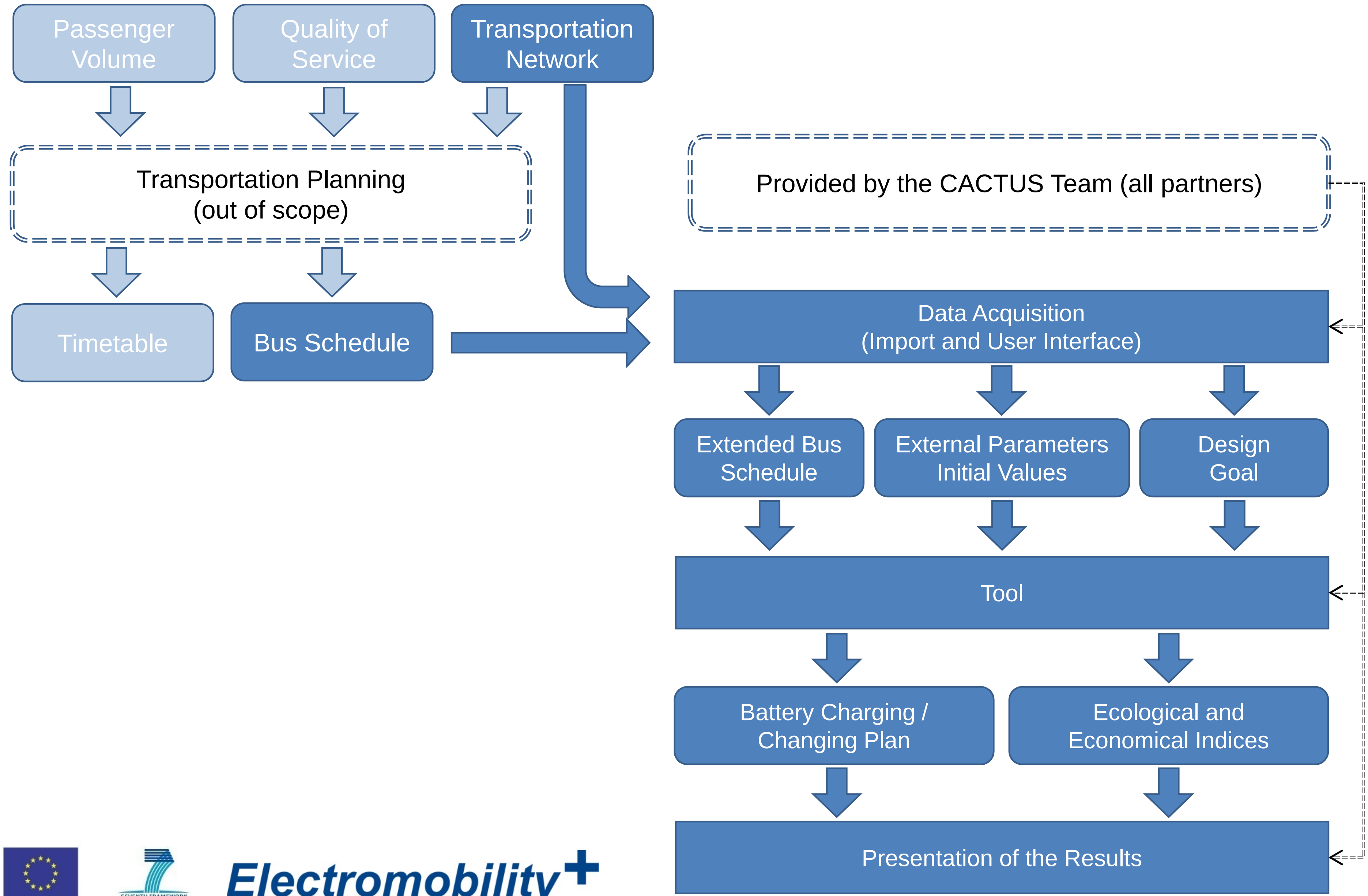
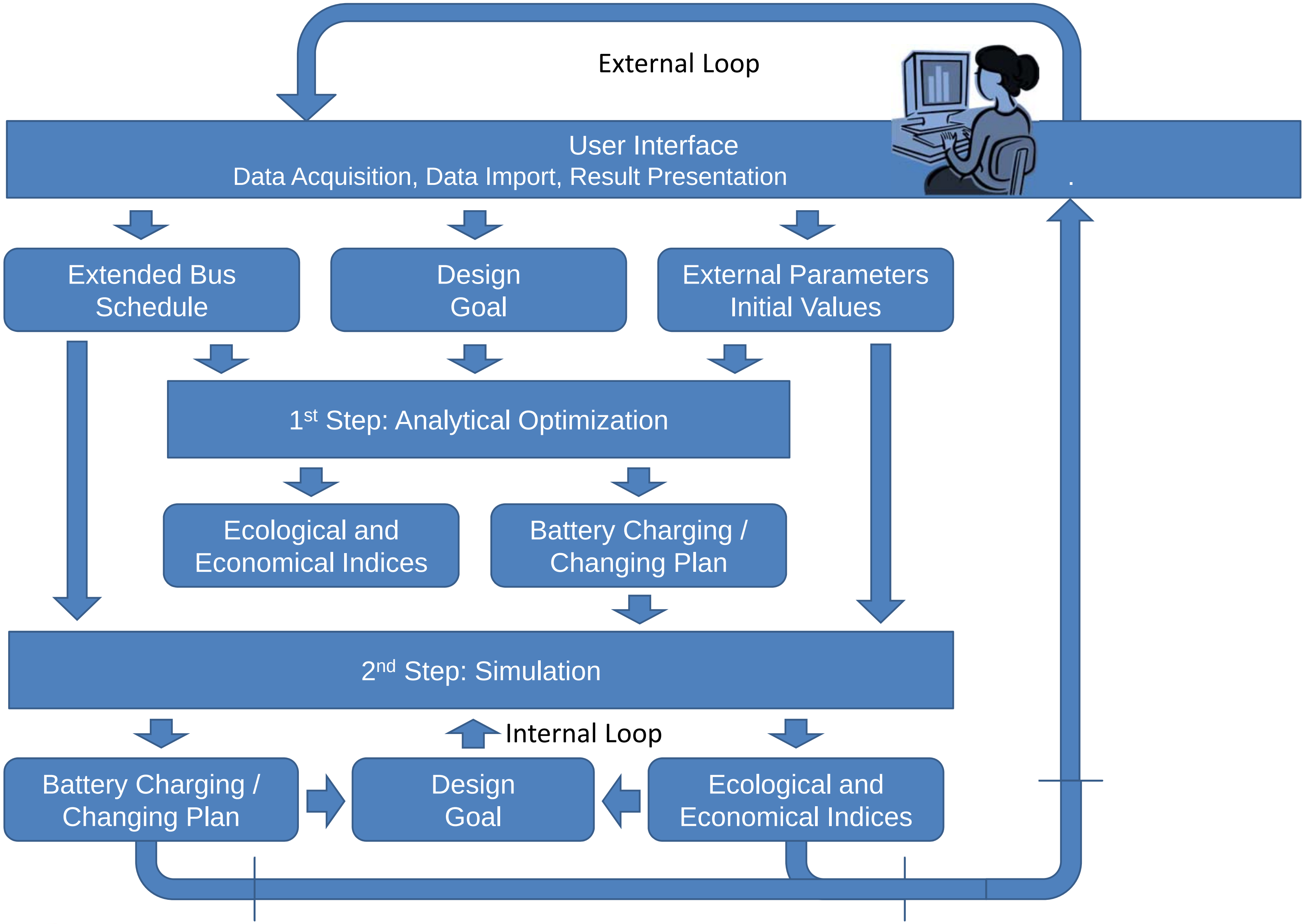
Optimization Based on Analytical Models



Data Flow


Passenger Volume
Quality of Service
Transportation Network
Transportation Planning (out of scope)
Timetable
Bus Schedule
Provided by the CACTUS Team (all partners)
Data Acquisition (Import and User Interface)
Extended Bus Schedule
External Parameters Initial Values
Design Goal
Tool
Battery Charging / Changing Plan
Ecological and Economical Indices
Presentation of the Results

Cascaded Iterative Optimization



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First Results and Next Steps

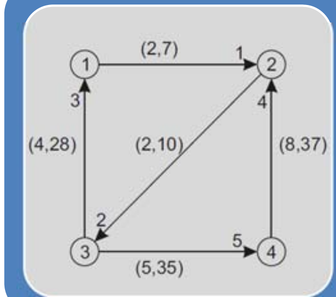
$$S_s = S \cdot I'^T$$

$$S_s = \begin{pmatrix} 5 & 5 & 5 & 0 & 0 \\ 0 & 3 & 0 & 3 & 3 \\ 2 & 4 & 2 & 2 & 2 \end{pmatrix} \cdot \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$S_s = \begin{pmatrix} 5 & 5 & 5 & 0 \\ 0 & 3 & 3 & 3 \\ 2 & 4 & 4 & 2 \end{pmatrix}$$

Theoretical results

- Input and output variables are defined
- Models are defined and can be used
- Methods have being developed (work in progress)



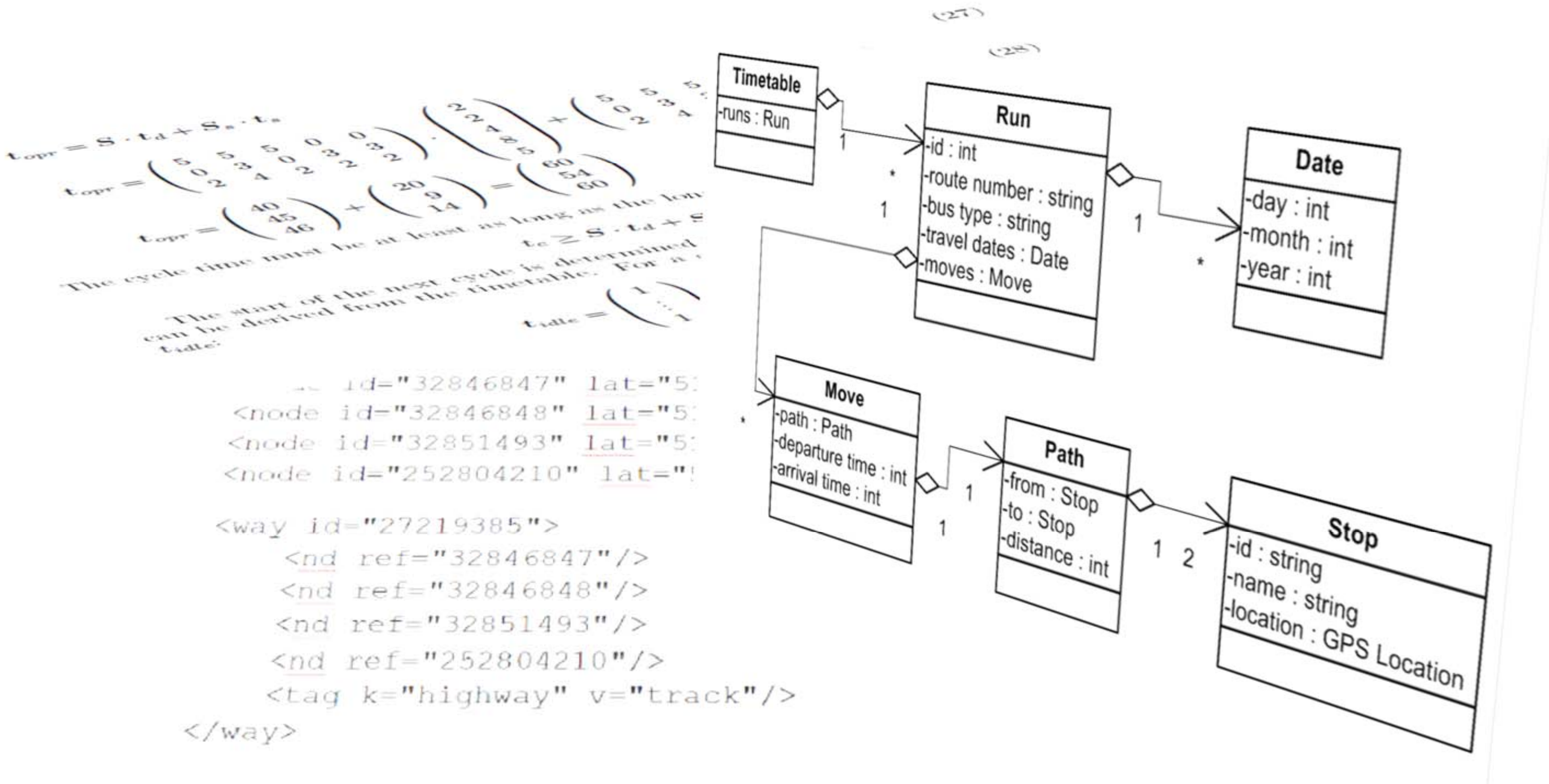
First practical results

- Successful optimization on small and on large artificial problems
  - Charging on the road (e.g. inductive or conductive)
  - Charging at bus stops
- Data import from real HAFAS sources has been done exemplary

Next steps

- Improving of the optimizer
- Allowing the optimizer for battery switching
- Starting development of the tool

Conclusion



Timetable
-runs : Run
Run
-id : int
-route number : string
-bus type : string
-travel dates : Date
-moves : Move
Date
-day : int
-month : int
-year : int
Move
-path : Path
-departure time : int
-arrival time : int
Path
-from : Stop
-to : Stop
-distance : int
Stop
-id : string
-name : string
-location : GPS Location
<node id="32846848" lat="5
<node id="32851493" lat="5
<node id="252804210" lat="
<way id="27219385">
<nd ref="32846847"/>
<nd ref="32846848"/>
<nd ref="32851493"/>
<nd ref="252804210"/>
<tag k="highway" v="track"/>
</way>