SUMO CONFERENCE 2024

Integrating Topographical Map Information in SUMO to Simulate Realistic Micromobility Trips in Hilly and Steep Terrains

—

Andreas Freymann
Damir Ravlija

Fraunhofer IAO

HOCHSCHULE ESSLINGEN

KEIM

HOCHSCHULE ESSLINGEN

Fraunhofer IAO

Introduction

Motivation and Problem Definition

Micromobility

Micromobility is an auspicious approach and an **alternative** way of **travelling** that can reduce the use of private vehicles

Number of automotive vehicles

The number of **automotive** vehicles **increases** more and more in urban areas, cities are faced with congestion, noise and pollution

Growing population

Two thirds of the world's **population** live in cities

Challenge: Elevations

Micromobility gets challenging if there are altitude differences that have to be overcome during a trip

- This causes **imbalance problems** (stations are more full or empty)
- This implies that users **cannot freely borrow** or **return** vehicles anymore
- Stations at higher altitudes are more likely to face a **shortage** of vehicles
- Altitudes have an additional effect on the **battery consumption** in steep terrain

Requirement:

These **challenges** need to be taken into account and should be further investigated using **Simulation**

© Fraunhofer IAO

Introduction

Parts of the work

- This paper investigates micromobility for electric vehicles in combination with hilly and steep terrain.
- There are three important parts this work is dealing with:

Part 1:
Defining Workflow

Workflow, which describes steps to prepare and define a simulation model for the tool SUMO in the context of cities with steep terrain

→

Part 2:
Creation of a Scenario

Creation of a **micromobility simulation scenario** using the presented workflow

→

Part 3:
Validation

Validation by analyzing the results of the simulation scenario

© Fraunhofer IAO

Micromobility Scenario with Topographical Map Information

Using Stuttgart as Example

- For the simulation of micromobility a map with different altitudes is necessary
- We choose an area of Stuttgart as Stuttgart has the following characteristics
  - Interesting topographic structures with **altitude differences** of more than **300 meters**
  - The **center** of Stuttgart lies in a sink at a height **of 245 meters**
  - There are **different valleys** with various lengths and different elevations

Figure 1 shows the different altitudes in and around Stuttgart. Especially, the southeast of Stuttgart has various and changing altitudes.

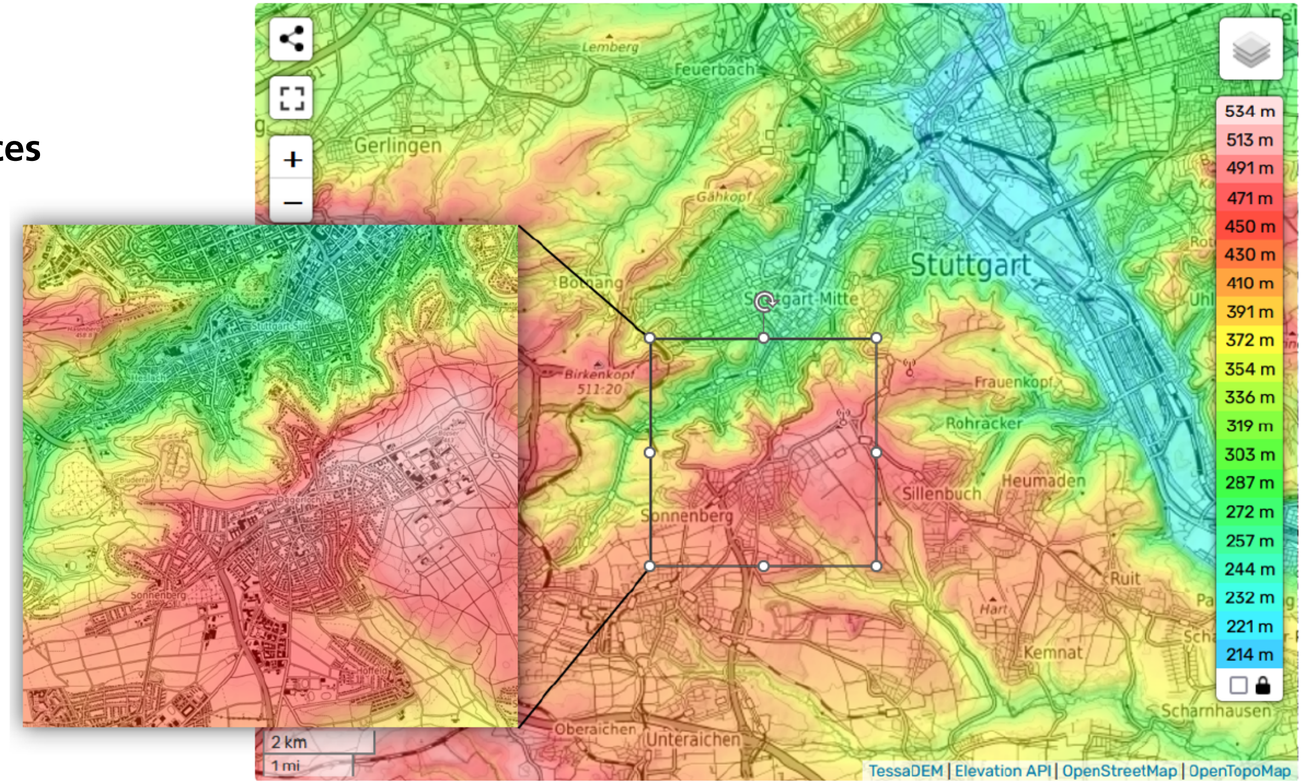


Figure 1. Topography of Stuttgart and its different altitudes

 © Fraunhofer IAO | © Hochschule Esslingen

Stuttgart

 © Fraunhofer IAO | © Hochschule Esslingen

Part 1
Defining Workflow

Part 1:
Defining Workflow

Workflow, which describes steps to prepare and define a simulation model for the tool SUMO in the context of cities with steep terrain

Part 2:
Creation of a Scenario

Creation of a micromobility simulation scenario using the presented workflow

Part 3:
Validation

Validation by analyzing the results of the simulation scenario

© Fraunhofer IAO

Part 1

Defining Workflow

Part 1:
Defining Workflow

Workflow, which describes steps to prepare and define a simulation model for the tool SUMO in the context of cities with steep terrain

Part 2:
Creation of a Scenario

Creation of a micromobility simulation scenario using the presented workflow

Part 3:
Validation

Validation by analyzing the results of the simulation scenario

© Fraunhofer IAO

Part 1
Defining Workflow

The workflow consists of **three steps**:

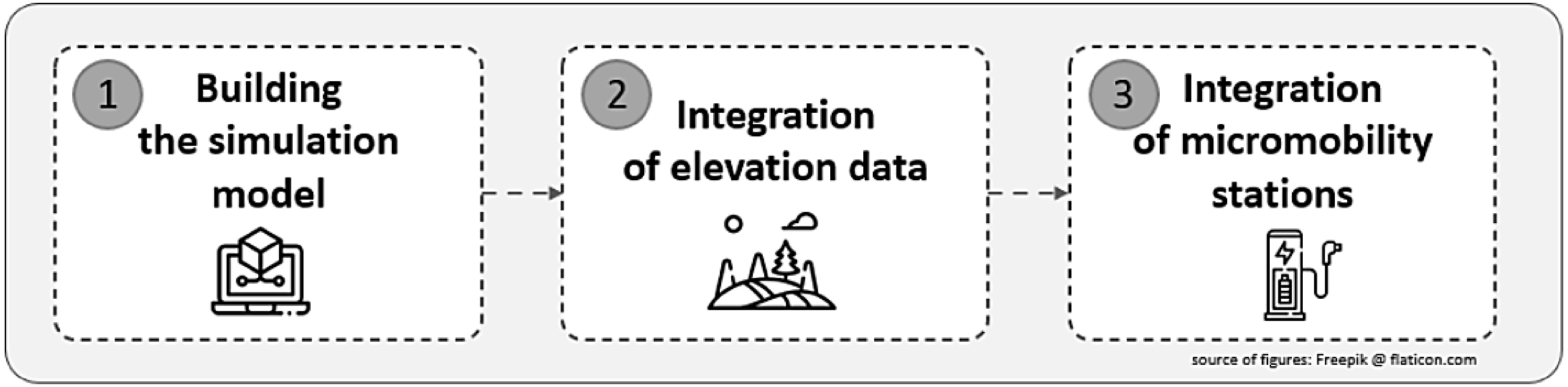
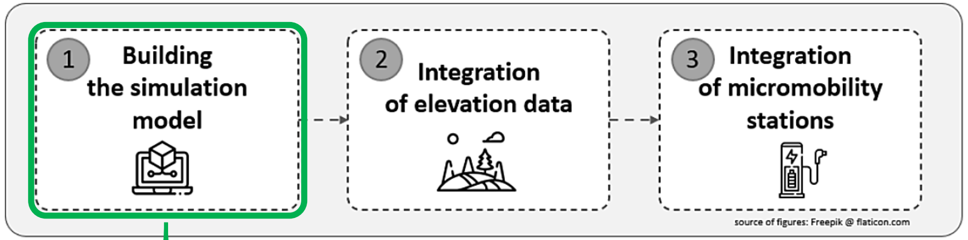


Figure 2. Steps and validation of the workflow

 © Fraunhofer IAO

Part 1 – Defining Workflow

Building the simulation model



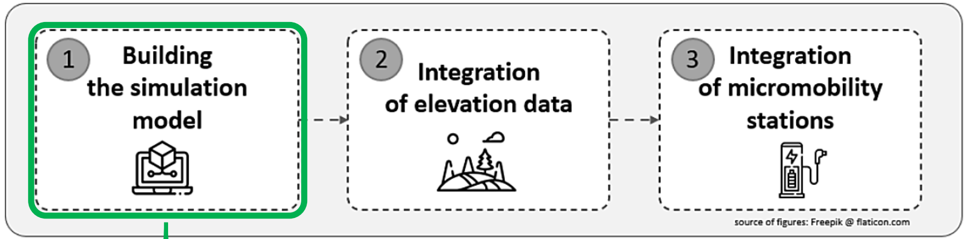
OSMWebWizard → **Initial Net File**

 © Fraunhofer IAO

Part 1 – Defining Workflow

Building the simulation model

Part 1:
Defining
Workflow



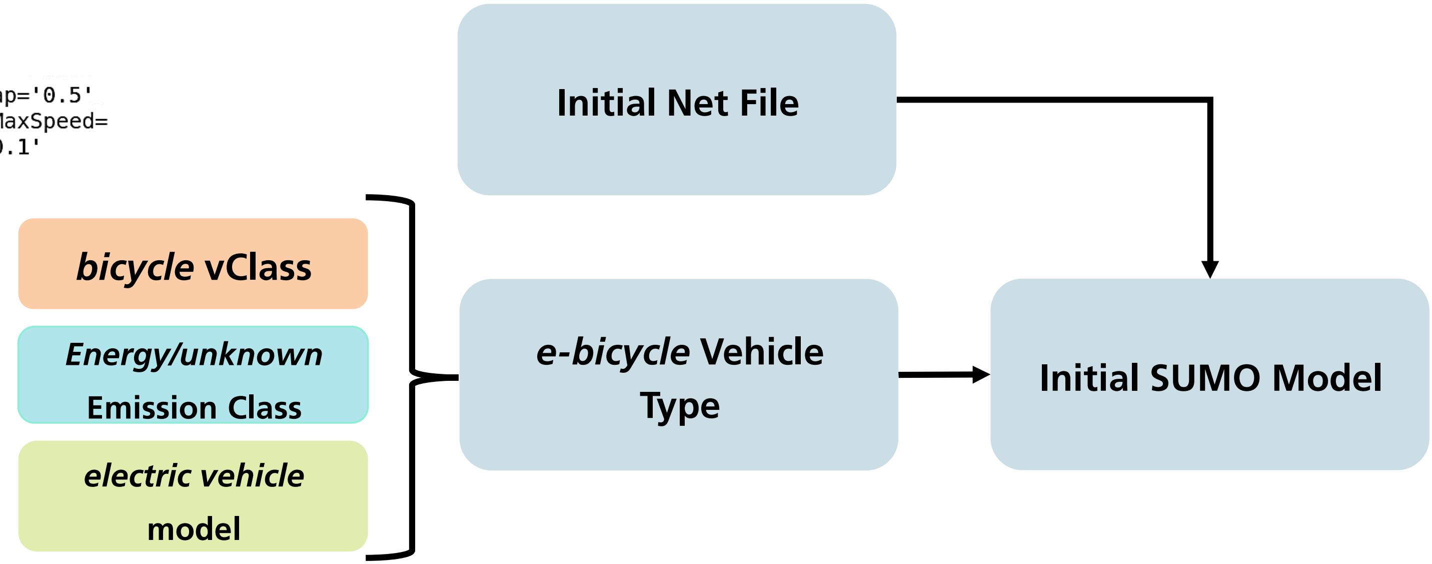

```
<?xml version="1.0" encoding="UTF-8"?>

<routes xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:
noNamespaceSchemaLocation="http://sumo.dlr.de/xsd/routes_file.xsd">

    <vType id="e_bicycle" length='1.6' width='0.65' height='1.7' minGap='0.5'
    accel='1.2' decel='3' emergencyDecel='7' maxSpeed='13.89' desiredMaxSpeed=
    '5.56' emissionClass='Energy/unknown' vClass='bicycle' speedDev='0.1'
    color='1.1.1'>
        <param key="has.battery.device" value="true"/>
        <param key="device.battery.capacity" value="400"/>
        <param key="maximumPower" value="250"/>
        <param key="vehicleMass" value="100"/>
        <param key="frontSurfaceArea" value="0.5"/>
        <param key="airDragCoefficient" value="1.1"/>
        <param key="internalMomentOfInertia" value="0.01"/>
        <param key="radialDragCoefficient" value="0.1"/>
        <param key="rollDragCoefficient" value="0.01"/>
        <param key="constantPowerIntake" value="100"/>
        <param key="propulsionEfficiency" value="0.98"/>
        <param key="recuperationEfficiency" value="0"/>
        <param key="stoppingThreshold" value="0.1"/>
    </vType>

    <trip id="test_ebike" type="e_bicycle" depart="0.00" departLane="best"
    from="4821895#1" to="-96266013#0"/>

</routes>
```

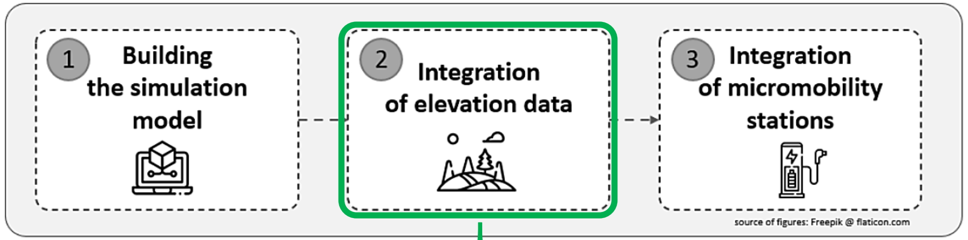


 © Fraunhofer IAO

Part 1 – Defining Workflow

Integration of the Elevation Data

Part 1:
Defining
Workflow



- SUMO **provides** a capability to process elevation data from the OSM data by using the **"ele"-tag**
- However, the **elevation** is used for **prominent topological areas** (mountain ranges and peaks)

- For a more **realistic** simulation model, we add the topography information to **all available geographical locations** within the SUMO model
- We used an Open Topo Data REST-service
- We divided it into three parts

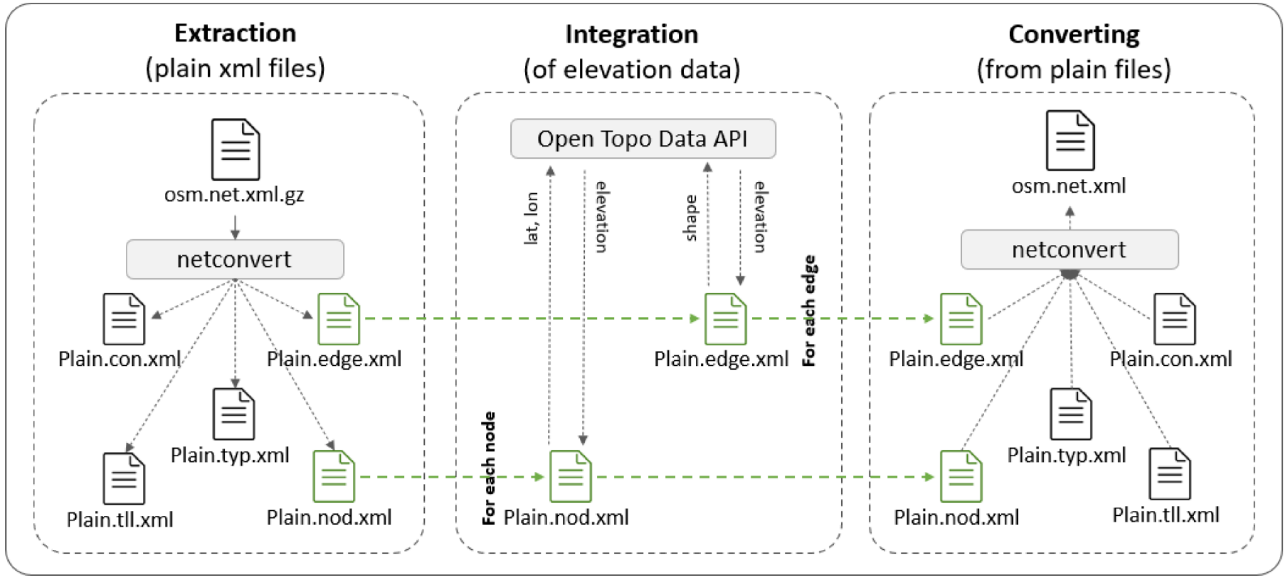


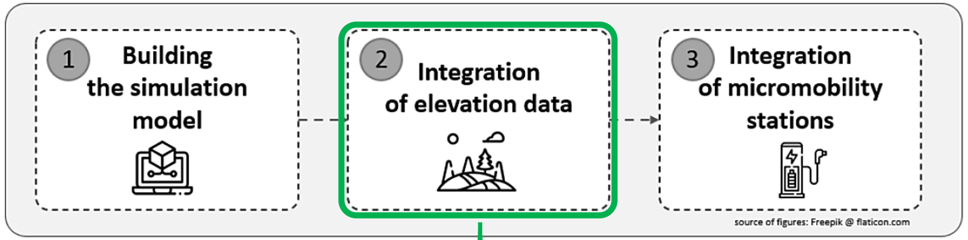
Figure 4. Overview over the steps to integrate elevation data

 © Fraunhofer IAO

Part 1 – Defining Workflow

Integration of the Elevation Data

Part 1:
Defining
Workflow



Extraction

- Extracts **five plain files** from the osm.net.xml.gz file using the **netconvert** -s command with the --plain-output-prefix attribute.
- The plain files contain concrete information about the network topology and geometry

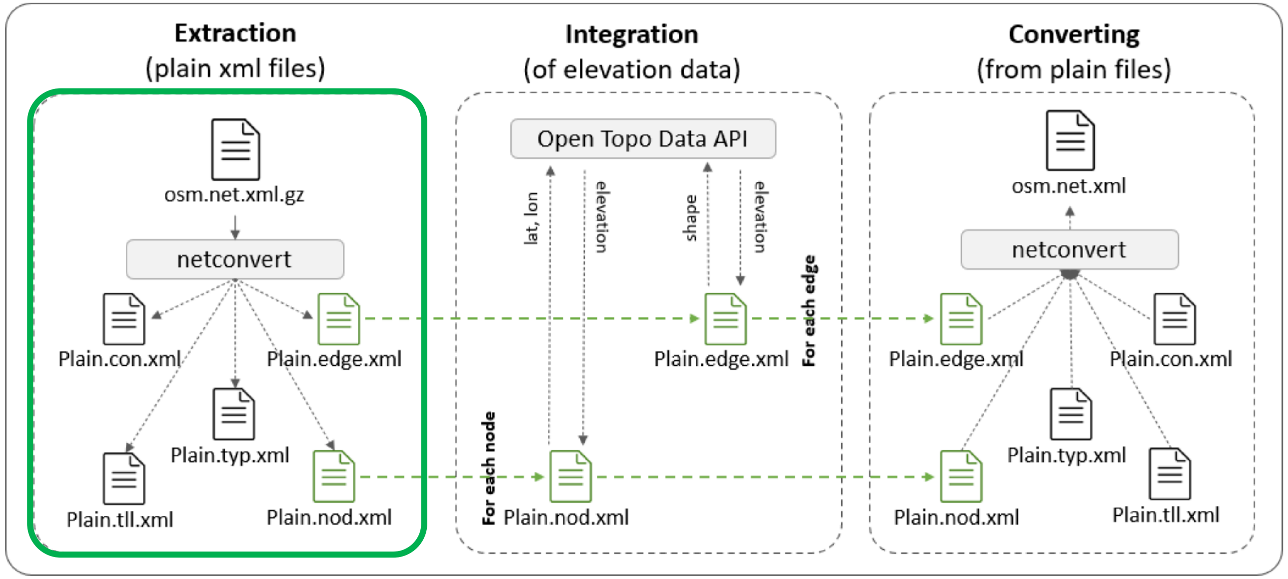


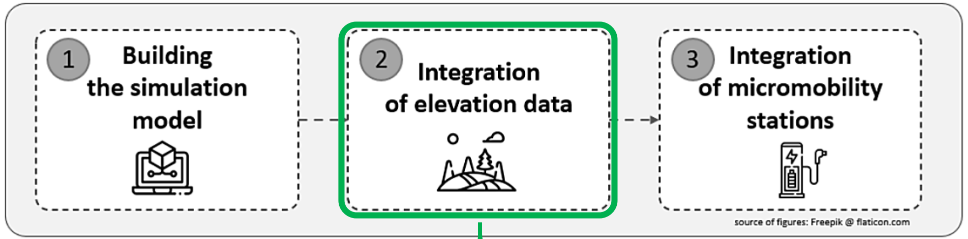
Figure 4. Overview over the steps to integrate elevation data

 © Fraunhofer IAO

Part 1 – Defining Workflow

Integration of the Elevation Data

Part 1:
Defining
Workflow



Integration

- The **node.xml** and **edge.xml** are the files of interest as they contain geographical information
- For the **node.xml** and **edge.xml** the elevation are fetched from the API
- **node.xml file:**
  - All nodes have geographical points **(x, y)**
  - The elevation is added by a **„z“:** (x, y, **z**)
- **edge.xml file:**
  - An edge has geographical points within a shape: **(x1,y1 x2,y2 x3,y3)**
  - The elevation is added by a **„z“:** (x1,y1, **z1** x2,y2, **z2**)

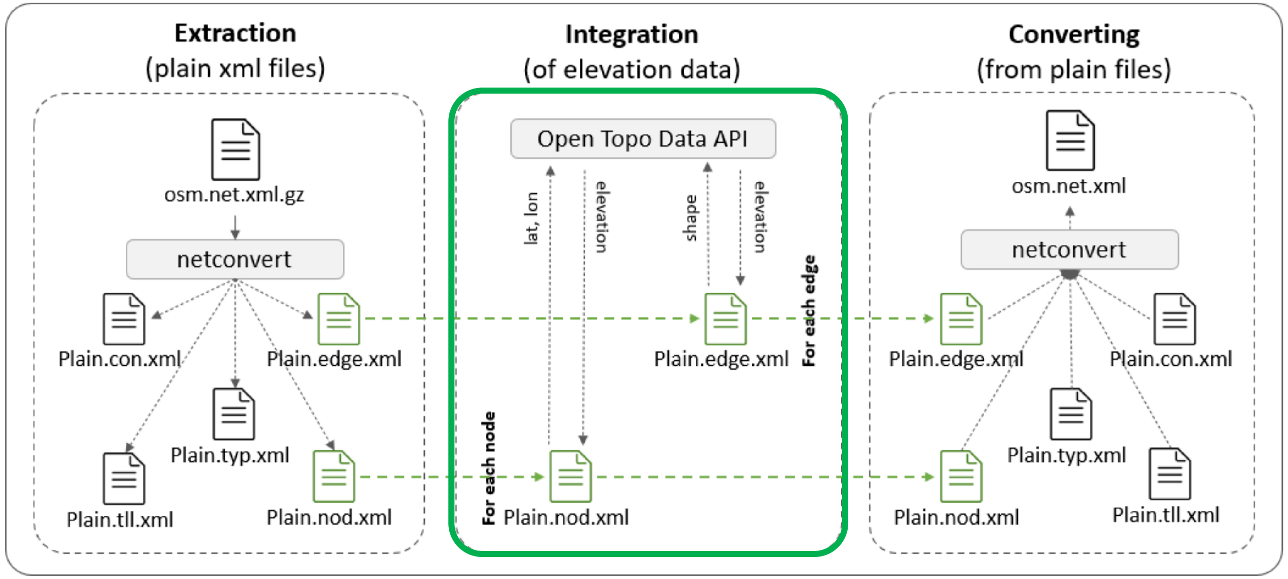


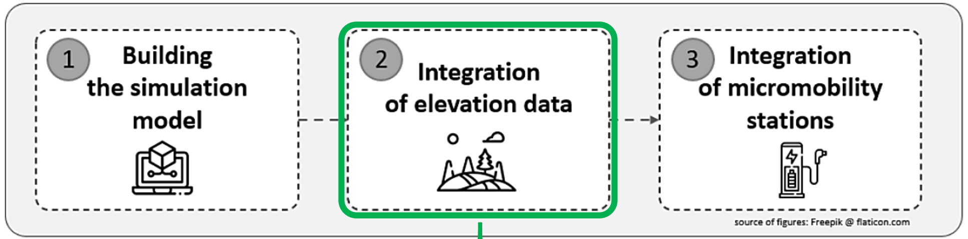
Figure 4. Overview over the steps to integrate elevation data

 © Fraunhofer IAO

Part 1 – Defining Workflow

Integration of the Elevation Data

Part 1:
Defining
Workflow



Converting

- Uses the **netconvert** command to convert the five plain files back to the **osm.net.xml** file
- by using certain command attributes for the existing plain files such as **--node-files** for the node file.
- **Result:**

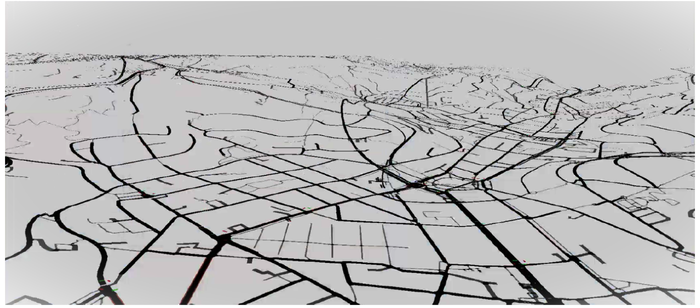


Figure 5. SUMO model enriched with elevation data displayed in sumo-gui with 3D view

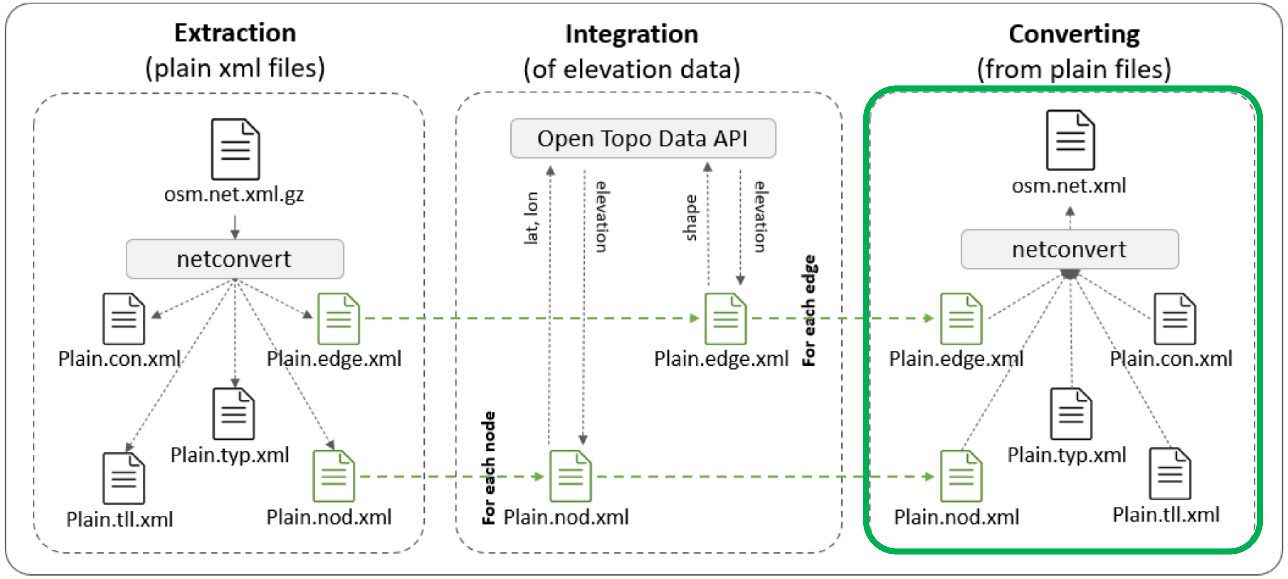
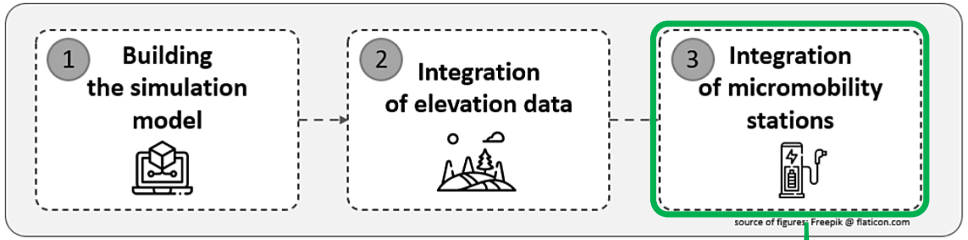


Figure 4. Overview over the steps to integrate elevation data

 © Fraunhofer IAO

Part 1 – Defining Workflow

Integration of Micromobility Stations



Integration

- Using OSM data or General Bikeshare Feed Specification Data (GBFS)
- GBFS Advantages:
  1. Up-to-date station data
  2. Possibly further data like number and type of available vehicles at the station
- *RegioRadStuttgart*
- Process:
  1. Reads **station_information.json** and the SUMO net file
  2. Maps station locations to SUMO edges
  3. Outputs an xml file with stations as *points of interest*

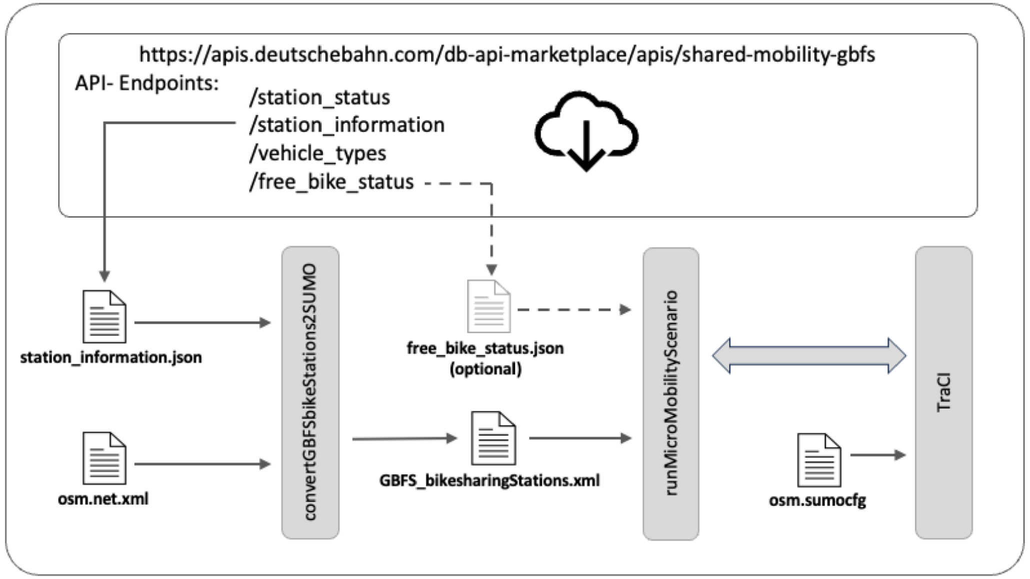


Figure 6. Workflow to utilize GBFS-Data for SUMO Micromobility Simulations

 © Fraunhofer IAO

Part 2

Creation of a Scenario

Part 1:
Defining Workflow

Workflow, which describes steps to prepare
and define a simulation model for the tool SUMO
in the context of cities with steep terrain

Part 2:
Creation of a Scenario

Creation of a micromobility simulation scenario using the presented workflow

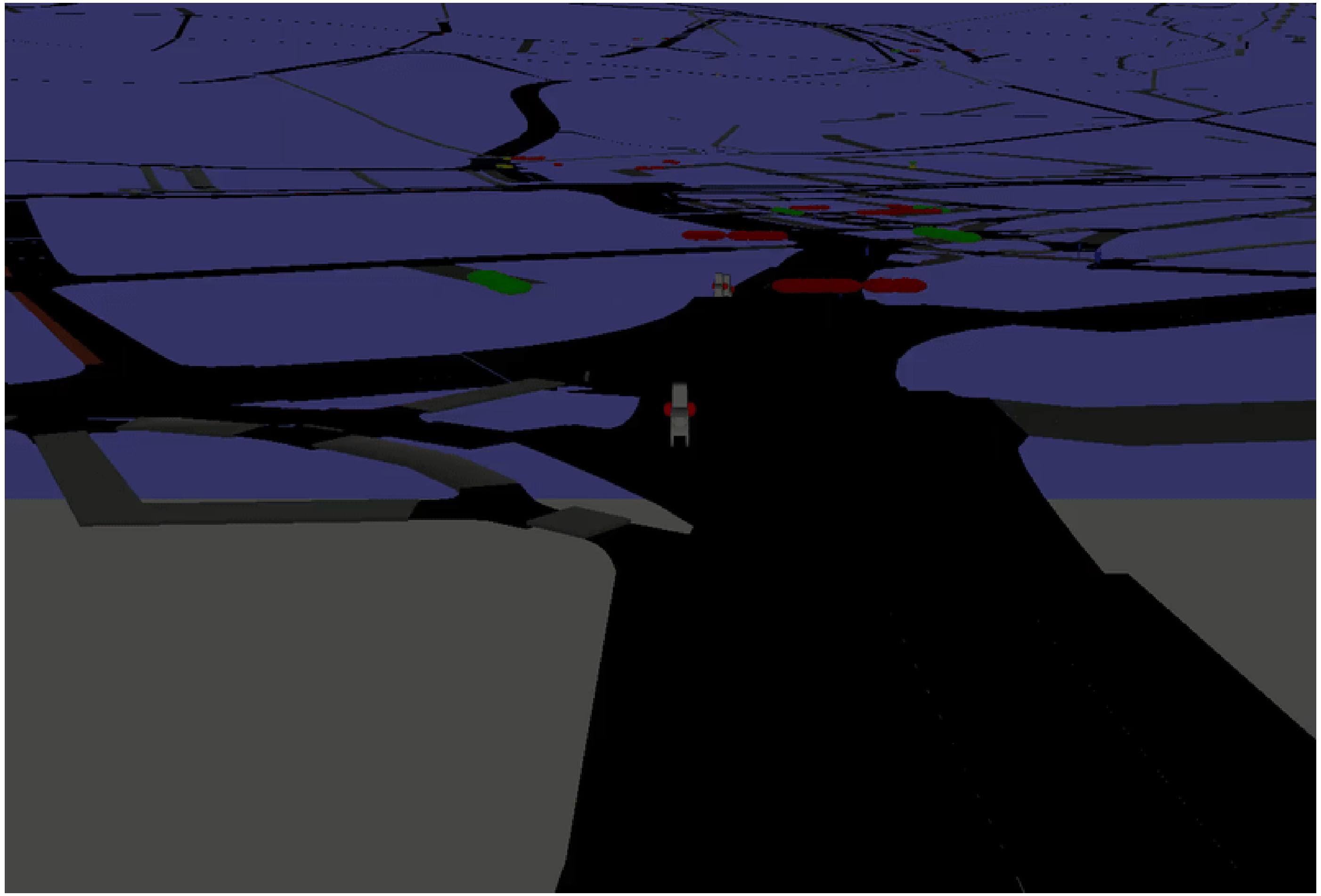
Part 3:
Validation

Validation by analyzing the results of the simulation scenario

 © Fraunhofer IAO

Part 2
Creation of a Scenario

Part 2:
Creation of a Scenario



 © Fraunhofer IAO

Part 3
Validation

Part 1:
Defining Workflow

Workflow, which describes steps to prepare and define a simulation model for the tool SUMO in the context of cities with steep terrain

Part 2:
Creation of a Scenario

Creation of a micromobility simulation scenario using the presented workflow

Part 3:
Validation

Validation by analyzing the results of the simulation scenario

 © Fraunhofer IAO

Validation

What and Where

- With micromobility trips between docking stations
- **Validation of the workflow**
  - o By checking:
    - Altitude differences
    - Availability of docking stations
    - Energy consumption of the e-bicycle
- Route between two elevated docking stations
  - o Route lowest point at 276m
  - o Route highest point at 472m

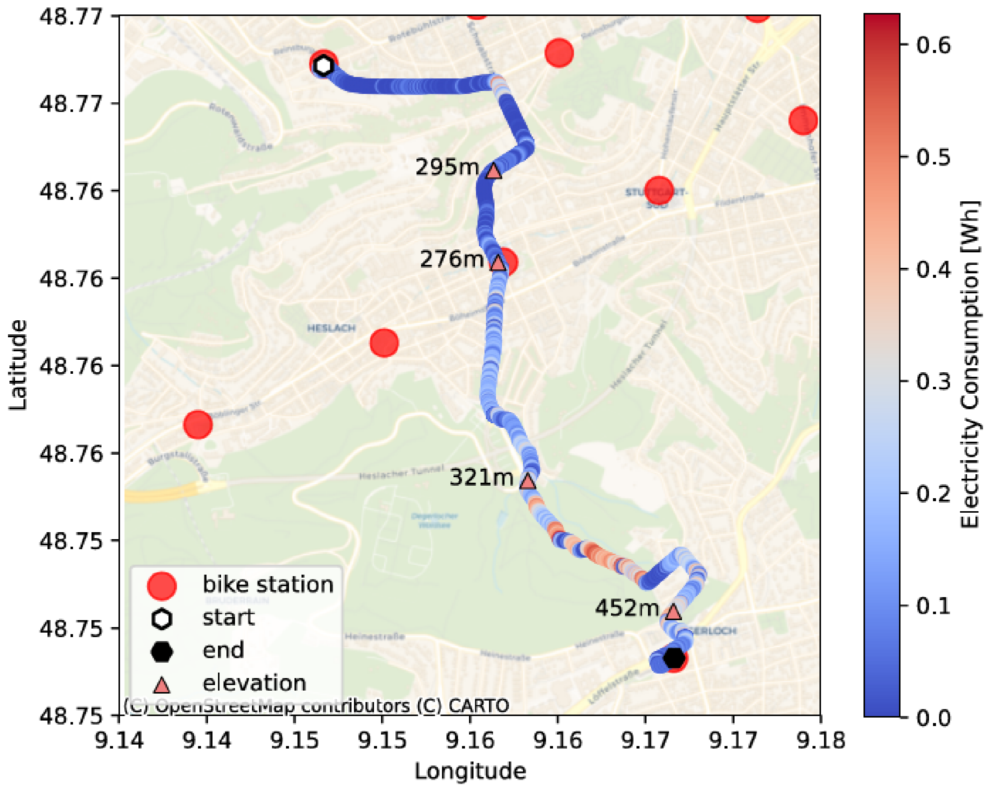


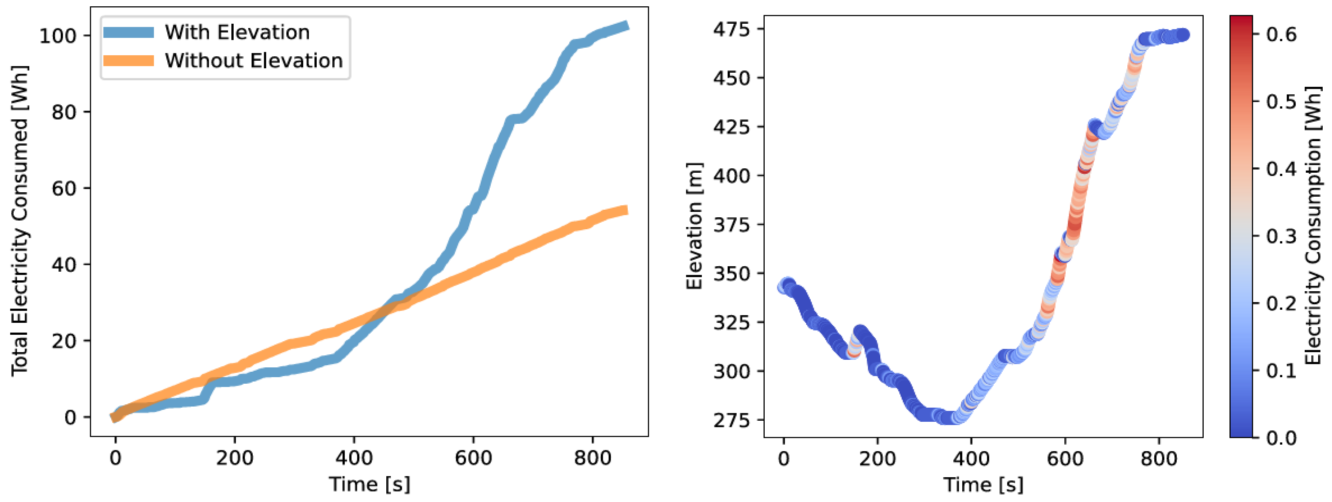
Figure 8. Route for validation of the implemented workflow

 © Fraunhofer IAO

Validation

Comparison

- Comparison
  - With elevation data
  - Without elevation data
- Electricity consumption without elevation data grows linearly with time – **unrealistic**
- No recuperation -> no negative electricity consumption
  - Still, **reduced** consumption
- Electricity consumption **dependent** on the **slope**



***(a)** Electricity consumption over time* ***(b)** Elevation change over time*

Figure 8. Consumption and elevation change over time

 © Fraunhofer IAO

Conclusion

- **Workflow for the inclusion into SUMO simulation models**
  - Elevation data
  - Docking station data
- **Elevation data from REST API**
  - No need for expensive topographical map data
- **Validation with a scenario using an e-bicycle vehicle type in a hilly area**
  - Comparison with and without elevation

 © Fraunhofer IAO

Future Work

Possible working contents for the future

More infrastructure

Considering of more infrastructure details such bridges or tunnels

Elevation feature

Integration of an elevation feature within the OSMWebWizard
(without request limitation)

Tool for micromobility fleet scenarios

Tool to generate shared micromobility fleet scenarios from origin-destination tables representing customer interests

Driving behaviour

Considering of the driving behaviour (speed and acceleration) of micromobility behaviour

© Fraunhofer IAO

Andreas Freymann
Tel. +49 1522 254 3925
andreas.freymann@iao.fraunhofer.de

Anwendungszentrum KEIM
Flandernstraße 101
73732 Esslingen am Neckar
https://www.keim.iao.fraunhofer.de/

Damir Ravlija
Tel. +49 711 397 4226
damir.ravlija@hs-esslingen.de

Anwendungszentrum KEIM
Flandernstraße 101
73732 Esslingen am Neckar
https://www.keim.iao.fraunhofer.de/

HOCHSCHULE ESSLINGEN

Fraunhofer IAO

Related Work (Damir)

Topic elevations and bicycles

In reference to elevations

- **Monaco SUMO Traffic (MoST) Scenario** [1]
  - First freely-available mobility scenario for SUMO with elevation
  - The scenario covers an area of approximately 70 km^2
  - It contains predefined routes for pedestrians, for different kinds of vehicles and for the local public transport system
- **SUMO Activity Generation (SAGA) framework** [2]
  - Is based on the MoST scenario
  - Provides a workflow and a tool chain to create complex multi-modal activity-based simulation scenarios
  - SAGA extracts streets infrastructure and environmental features (e.g., parking areas, buildings, and PoIs)
  - It supports multiple travel modes (i.e., walking, cycling, public transport, on-demand mobility and user-defined vehicles)

In reference to bicycle modeling

- **The State of Bicycle Modeling in SUMO** [3]
  - Stated that micromobility vehicle types are becoming more and more important within simulations
- **Framework for Simulating Cyclists in SUMO** [4]
  - Allows a more realistic modelling of cyclists by allowing a higher degree of freedom of movement
  - They considers cyclists and their behavior intermediate between motorized vehicles and pedestrians.

[1] L. Codeca and J. H¨ arri, "Monaco SUMO Traffic (MoST) Scenario: A 3D Mobility Scenario for Cooperative ITS," en, 2018, pp. 43–29. DOI: 10.29007/1zt5.
[2] L. Codeca, J. Erdmann, V. CAHILL, and J. Haerri, "Saga: An activity-based multi-modal mobility scenariogenerator for sumo," SUMO Conference Proceedings, vol. 1, pp. 39–58, 2022. DOI: 10.52825/scp.v1i.99.
[3] A. Roosta, H. Kaths, M. Barthauer, J. Erdmann, Y.-P. Fl¨ otter¨ od, and M. Behrisch, "State of bicycle modeling in sumo," SUMO Conference Proceedings, vol. 4, pp. 55–64, 2023. DOI: 10.52825/scp.v4i.215
[4] H. Kaths and A. Roosta, "Framework for simulating cyclists in sumo," SUMO Conference Proceedings, vol. 4, pp. 105–113, 2023. DOI: 10.52825/scp.v4i.219.

 © Fraunhofer IAO | © Hochschule Esslingen

Commands

Converting Plain Files

Extract plain files from OSM File

"netconvert -s PATH_TO_OSM_FILE+ " --plain-output-prefix " + PATH_TO_PLAINFILES_DIR + "/PLAIN"

Convert plain files to OSM File

netconvert

--node-files=PATH_TO_PLAIN-NODE-FILE

--edge-files=PATH_TO_PLAIN-EDGE-FILE

--connection-files= PATH_TO_PLAIN-CON-FILE

--type-files= PATH_TO_PLAIN-TYPE-FILE

--tllogic-files= PATH_TO_PLAIN-TLLOGIC-FILE

--output-file=PATH_TO_OSM_FILE + osm.net.xml

© Fraunhofer IAO | © Hochschule Esslingen