URBAN EUROPE

SmartHubs

Smart Mobility Hubs as Game Changers in Transport

WP5. Impacts assessment of SmartHubs Living Labs
   T5.2. **Accessibility Impacts of Mobility Hubs**

Deliverable D 5.2

SmartHubs Accessibility Tool

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Responsible partner: TUM
Authors: Aaron Nichols, David Duran & Benjamin Büttner

TUM

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1	24/11/2023	Draft	Aaron Nichols	Overview, instructions, and assumptions
2	30/11/2023	Draft	Aaron Nichols	Updated Analysis Results
3	28/12/2023	Final	Aaron Nichols	Restructured document, more in-depth descriptions and analysis.

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EXECUTIVE SUMMARY

This document introduces and outlines the SmartHubs Accessibility Tool, a user-friendly planning tool designed for planners and practitioners to assess and develop mobility hubs. The tool measures accessibility to amenities using various modes, such as walking, cycling, e-scooters, and public transport. It is accessible to users with or without GIS software experience.

The tool's development involved an iterative process, transitioning from a terminal application to a user-friendly visual interface based on feedback from academics and planning professionals. It relies on assumptions related to travel speeds, e-scooter costs, and amenities data from OpenStreetMap.

In the analysis of SmartHubs living labs, including Brussels, The Hague/Rotterdam, Munich, Vienna, and Istanbul, the tool assesses mobility hub scenarios. It demonstrates the impact of adding shared modes to existing public transport options, providing insights into potential increases in amenity accessibility.

The tool's technical details include its Python-based structure, hosted on Streamlit, with complex background code for isochrone calculations and handling GTFS datasets. The tool's flexibility allows adjustments for different geographic locations and varying data qualities.

The living lab analyses highlight the tool's effectiveness in assessing potential mobility hub locations, offering insights into increased accessibility and amenity reach. The Vienna analysis emphasizes the tool's role in assessing the general performance of existing bike-sharing stations.

The impact assessment involved diverse scenarios across cities like Brussels, the Netherlands, Munich, Vienna, and Istanbul. The SmartHubs Accessibility Tool demonstrated effectiveness in comparing scenarios and locations within a scenario, offering valuable insights for planners.

Despite its utility, the tool faces limitations, particularly its reliance on OpenStreetMap (OSM) data, which can vary in quality and pose time-consuming challenges in data retrieval. Future development needs to address these constraints. The tool's simplicity is an advantage but also a potential drawback, as it may draw conclusions from poor data. Striking a balance between user-friendliness and incorporating local datasets is crucial for future improvements.

In summary, the SmartHubs Accessibility Tool is a versatile and user-friendly planning tool that contributes to the development and assessment of mobility hubs, with applications worldwide. The living lab analyses demonstrate its effectiveness in evaluating potential scenarios and informing decision-making for planners and practitioners.

1. INTRODUCTION AND OVERVIEW

This document serves as an overview and demonstration of the SmartHubs Accessibility Tool, a user-friendly planning tool to help planners and practitioners develop mobility hub scenarios and test their accessibility. The document is structured into three main parts: a general overview and step-by-step guide to using the tool, an application of the tool featuring analyses in the SmartHubs living lab cities, and background assumptions and technical details about the tool.

1.1. Concept
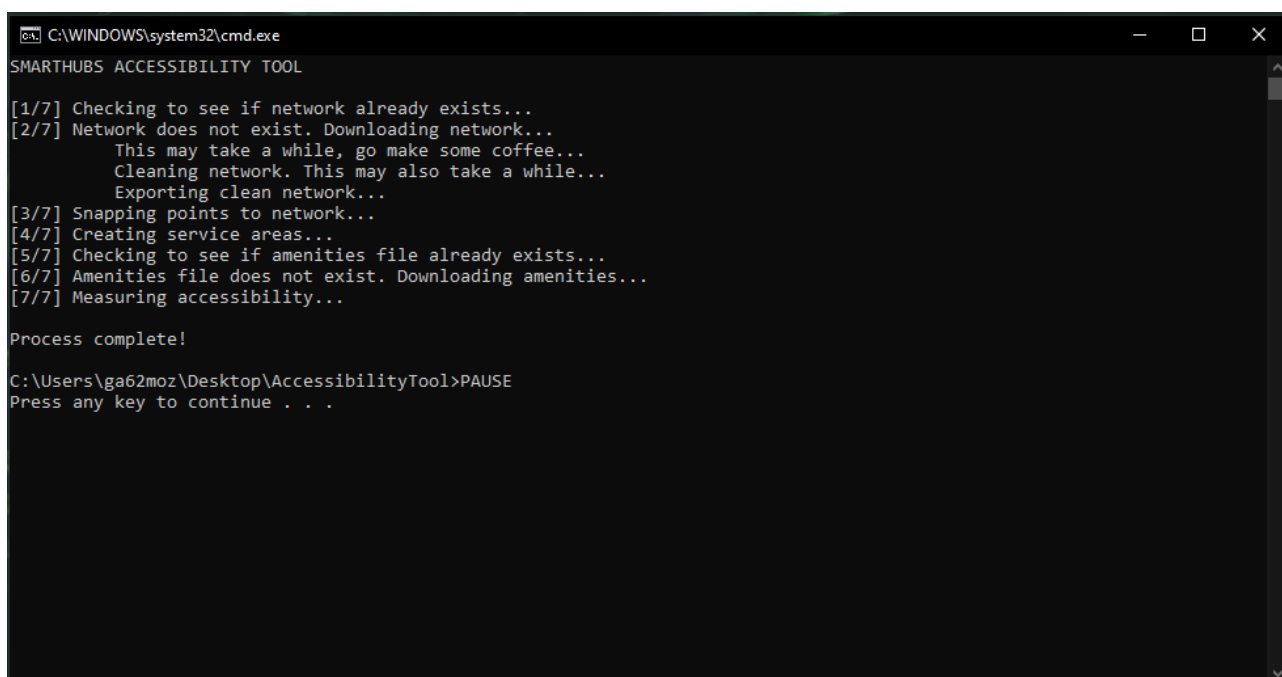
The aim of the SmartHubs Accessibility Tool is to be a user-friendly, easy-to-access tool that allows users to measure accessibility of amenities using multiple modes (walking, cycling, e-scooters, public transport) to and from mobility hubs. While the tool performs a relatively simple geospatial analysis that could be done by most people with experience using GIS software, it contributes to the tools available to planners and practitioners by being automated and simple. Users are not required to have experience with GIS software in order to use the tool. The simple user-interface and automated processes of the tool make it approachable and easy to use. However, the tool can still be useful to those with more skills since the outputs can be downloaded and used in external GIS software for additional analysis.

2. METHDOLOGY

2.1. Development Process

The SmartHubs Accessibility Tool was developed in an iterative process that involved creating an initial version of the tool, presenting it to various groups of academics and practitioners, collecting feedback, then making updates to the tool and staring the process over again.

The initial version of the tool, as seen in **Error! Reference source not found.**, was a terminal application that required relatively complex user input and had an intimidating user interface. Users were required to prepare files ahead of time with potential hub locations. While the analysis was more or less the same, the lack of visual interface failed to catch the attention of potential users.

Figure 1: Accessibility Tool Terminal Application

The creation of a visual interface allowed for users to give all input within the tool without needing to prepare files ahead of time. Potential users also began to express an interest in more features and functionalities. This led to changes in the tool that shifted it away form a basic accessibility analysis to a tool with a stronger focus on developing and assessing mobility hubs.

Workshops and demonstrations were held with academics and planning professionals in each of the living lab cities throughout the tool's development process. During these workshops and demonstrations, participants would be asked to use the tool in its current form to perform a basic task. Afterwards, participants would give feedback about their experiences and suggestions for the tool. These suggestions would be used to determine which upcoming features should be prioritized for future development. Additionally, some changes were made to the tool based on observing how users used the tool. This means that some changes may have been prioritized

based on what was observed instead of what was directly recommended by the participants. For example, in an earlier version of the tool, a hub location would be added to the map after every click on the map. It was observed that users would typically start clicking on the map immediately after opening the tool and would add hub locations without really intending to. Changes were made to the tool based on these observations. The process of adding locations to the map was changed to include more steps so that users would have to be more deliberate in the process of adding locations. Workshops that happened with later versions of the tool no longer had this issue and hub locations were only really added where they intended.

2.2. Background Assumptions

This section explains some of the assumptions that went into the SmartHubs Accessibility Tool.

Travel Speeds

Users can select different travel speeds when performing an analysis using active modes. Each active mode (walking and cycling) has three different speed options (slow, moderate, fast). The speeds for each option are hard-coded into the analysis, but the rough options still allow for detailed scenario creation with active modes. The speed assumptions are based on typical speed ranges for each mode. They are summarized in the table below. Travel speeds for e-scooters are hard-coded into tool and cannot be changed. However, this travel speed is based on an analysis of actual e-scooter trips in Munich. A summary of the assumed travel speeds can be found in Table 1.

Table 1: Built-In Travel Speed Assumptions

Mode	Speed Option	Speed (km/h)
Walk	Slow	3.50
	Moderate	4.25
	Fast	5.00
Bike	Slow	12.00
	Moderate	15.00
	Fast	18.00
E-Scooter	Default	14.00

E-Scooter Costs

The e-scooter analysis is unique since it considers two different types of travel costs: time and money. The monetary travel cost allows users to specify a monetary budget, then calculates an isochrone based on the distance that can be reached within the cost budget.

Amenities

The main way the SmartHubs Accessibility Tool measures accessibility is by counting amenities that can be reached within a specified time (or cost) budget. This requires data on available amenities in order to come up with these counts. These data are downloaded from OpenStreetMap. Amenities in OpenStreetMap data have thousands of potential tags, many of which are either similar to other tags or occur very infrequently. For example, "supermarket" and "grocery store" are essentially the same things, but they can be labeled differently. Additionally, some amenities might have tags that occur only a couple of times. This might be because of spelling errors. The data is messy and similar tags need to be grouped into categories in order be less confusing. The SmartHubs Accessibility Tool extracts a handful of useful tags and groups them into six different categories. However, these categories are flexible and may be adjusted in future versions of the tool. A summary of the OSM tags and their respective groups can be found in Table 2.

The quality of the basic analysis performed by the tool is largely dependent on the quality of the data in OpenStreetMap. However, it is still possible to perform a useful analysis even if the OpenStreetMap data is poor since the isochrones can be downloaded and analyzed further with more data.

One of the main goals of the SmartHubs Accessibility Tool is that it should be generally applicable anywhere in the world. However, the quality of available OpenStreetMap data varies significantly throughout the world. Even within the five living lab cities used in this project there is significant variation in the data and how things are labeled. For example, benches are the most frequently occurring amenity in Munich, but it is not entirely clear if there are actually that many benches, or if the benches in Munich are more consistently labeled. This means that the ability to download the isochrones and combine them with local datasets is very important and makes the tool useful, even in places where the OpenStreetMap data is not always very good or consistent.

Table 2: Amenities and OSM Categories

Tool Category	OSM Categories	Tool Category	OSM Categories
Restaurant/Cafe/Bar	cafe	Entertainment	cinema
	pub		theater
	pastry	Healthcare	pharmacy
	bar		chemist
	biergarten		healthcare
	coffee		doctors
	fast_food		dentist
	restaurant		hospital
	bakery		clinic
	fastfood	Service	bank
Education	kindergarten		copyshop
	school		toilets
	college		atm
	university		laundry
Supermarket	greengrocer		post_office
	supermarket		library

Technical Details

The SmartHubs Accessibility Tool is a python-based application that is hosted using Streamlit, a python package that facilitates web-tool development. The user interface is simple, but much of the background code is quite complex. In particular, the development of the accessibility tool required creating python functions to create accurate travel-time isochrones and python functions to handle GTFS datasets and generate lists of accessible stops within specified travel times.

Isochrone Calculation

There are existing python tools for downloading OSM networks and generating isochrones, in particular, the OSMNX python package. However, after using these tools, it was found that the isochrones were not accurate enough. The main issue is that the existing tools could easily identify the nodes in a network that were within a certain distance of an origin point, but could

not handle situations where the travel budget ran out between two nodes, meaning a new node would need to be added to a network. This is not an issue where networks have many intersections, but in rural areas there could be significant distances between nodes and only the closest street segments would appear to be accessible within the specified travel budget. This was addressed within the SmartHubs accessibility tool by developing a new function for creating isochrones using OpenStreetMap networks. The new function is similar to existing ones, but it adds new nodes to the network in order to take into account parts of the network that are within the travel budget, but between two nodes.

GTFS Data

An important part of the tool is its ability to handle GTFS data and extract useful information from it. This is quite complicated since GTFS data can come in many different forms and this can pose many issues. In particular, dealing with multiple GTFS datasets simultaneously and handling different formats of service schedules can be significant issues.

Some public transport agencies, such as the one in Brussels, have a single, clear GTFS dataset, but other cities, such as Munich might have a more complex system with multiple GTFS datasets. This might involve one set of GTFS data for the local public transport agency and a separate set of GTFS data for the regional public transport agency.

The SmartHubs Accessibility Tool identifies accessible public transport stops, then identifies the services that use these stops within the given time constraints (time of day, day of week). Services in GTFS data typically have specific date ranges of activity. However, in order to keep the user experience simple, the SmartHubs Accessibility Tool does not ask for specific date ranges. Instead, it just considers a single day of the week. It does this by extracting a sub-set of GTFS data from the data that is uploaded into the tool. The subset of GTFS data is the first whole week starting on a Monday. The exact week is dependent on the dataset that is uploaded. If the dataset starts in April, the first week will be in April. If different datasets with different date ranges are used, the tool will still consider the first whole week of each dataset, regardless of the different date ranges. The downside is that there could be inaccuracies, especially if services have been added or removed. The upside is that the user experience is simple.

Public Transport Transfers

Some GTFS datasets include information about which services can transfer at which stations, but this is not very typical. Therefore, the tool needs to use other methods for identifying which stations can be transfer points. This is done spatially be identifying which stations are within an acceptable distance of other stations. This is calculated by creating a matrix of all stations in the system and measuring the distances between them. Next, a dictionary containing a list of close stations is created for each station. An acceptable distance of 100 meters is hardcoded into the program. This cannot be changed in the user interface, but it can be changed in the code, if a user wants to download the code and run the program locally.

3. ANALYSIS OF SMARTHUBS LIVING LABS

This section uses the SmartHubs living labs to test the SmartHubs Accessibility Tool and demonstrate its potential to analyze existing and planned mobility hubs using different scenarios.

3.1. Brussels

The analysis of Brussels focuses on the comparison of two different public transport stops that have the potential to be upgraded to mobility hubs. This involves the comparison of a base scenario (walking and public transport) to a potential future scenario where shared modes are also available. The two public transport stops in question are the tram stop at Place du Conseil and the metro stop Clemenceau.

Table 3: Brussels - Before Scenario Assumptions

Time Budget	15 Minutes
Modes	Walk
Walk Speed	Moderate

Table 4: Brussels - After Scenario Assumptions

Time Budget	15 Minutes
Modes	Walk, Bike, E-Scooter, Public Transport
Walk Speed	Moderate
Bike Speed	Moderate
Public Transport Access Time	5 Minutes
Public Transport Access Walk Speed	Moderate
Public Transport Start Time	Monday, 12:00
Public Transport Transfers	No

Place du Conseil / Raadsplein

The base scenario at Place du Conseil, considers walking and public transport with a 15-minute travel budget since both of these modes are already available here. The results of the base scenario can be seen in Figure 2.

Analysis Results
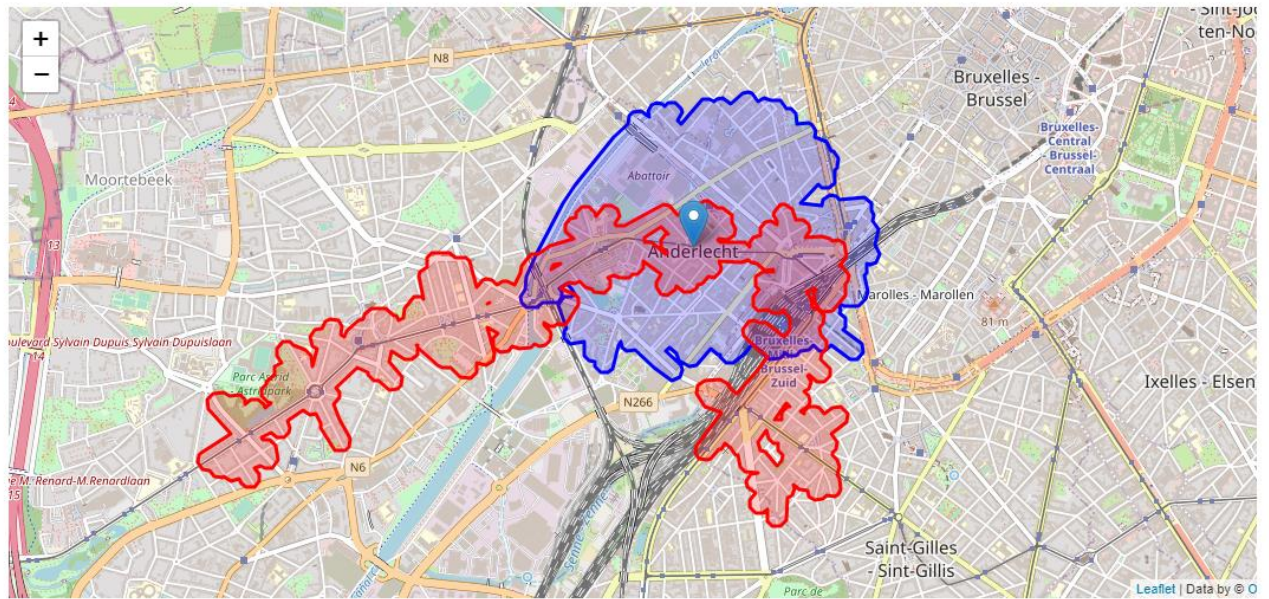
	id	mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
0	hub1	Walk	74	5	20	19	6	1
1	hub1	Public Transport	83	1	24	21	6	1

Walk Area

Public Transport Area
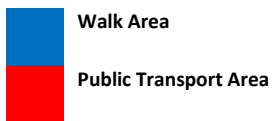
Figure 2: Base Scenario - Place du Conseil

The potential future scenario includes the addition of shared bikes and e-scooters, both with a 15-minute threshold. The resulting map of the potential future scenario can be seen in Figure 3.

Analysis Results
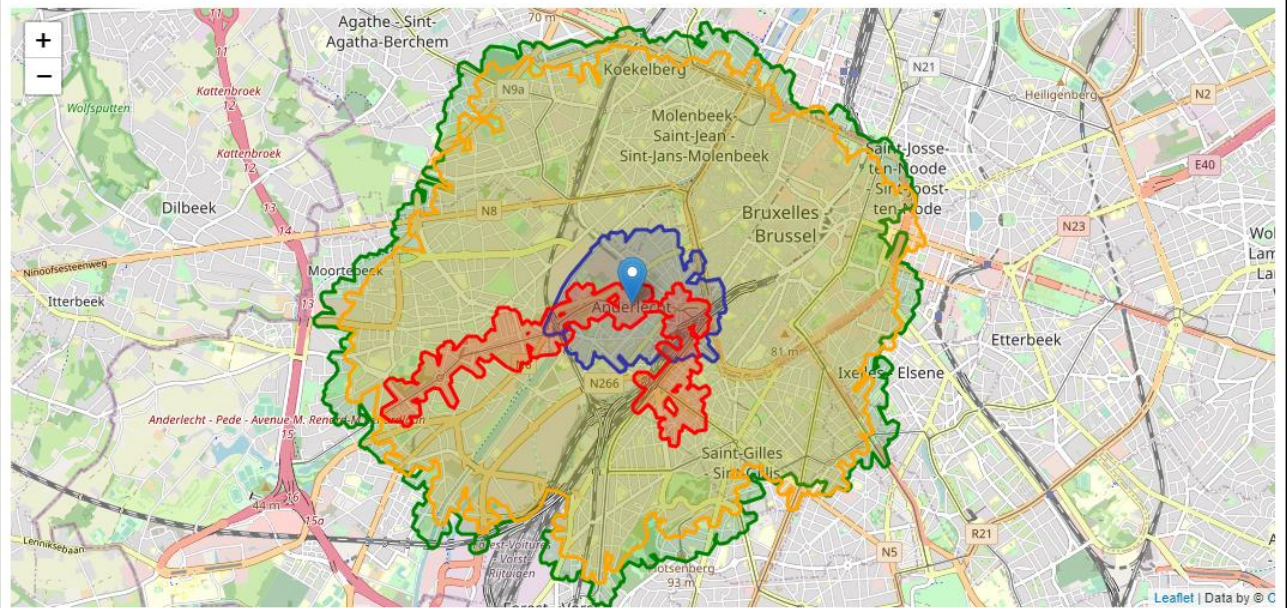
	id	mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
0	hub1	Walk	74	5	20	19	6	1
1	hub1	Bike	1731	64	213	228	71	10
2	hub1	E-Scooter	1638	58	202	201	65	9
3	hub1	Public Transport	83	1	24	21	6	1

Figure 3: Place du Conseil - After Scenario

🟦 **Walk Area**

🟩 **Bike Area**

🟨 **E-Scooter Area**

🟥 **Public Transport Area**
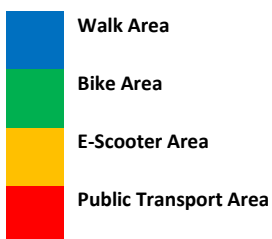
Table 5 summarizes the difference between the before and after scenario, as measured by the SmartHubs Accessibility Tool. While it is not surprising that better integration of multiple modes might lead to better access to more amenities, the SmartHubs Accessibility Tool can quantify the extent to which there might be an improvement in accessibility to amenities.

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Table 5: Place du Conseil - Results Summary

Scenario	Mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment	Total
Before	Walk	84	4	20	19	6	1	134
	Public Transport	103	3	28	25	7	1	167
	All Modes	132	6	33	33	9	1	214
After	Walk	84	5	20	19	6	1	135
	Bike	1716	62	213	230	69	10	2300
	E-Scooter	1624	60	200	202	61	9	2156
	Public Transport	103	3	28	25	7	1	167
	All Modes	1740	63	216	231	69	10	2329

Metro Clemenceau

The base scenario for Clemenceau is focused on the Clemenceau metro station. The base scenario includes walking and public transport since both of these modes are already available at this location. The map of the base scenario can be seen in Figure 4.

Analysis Results
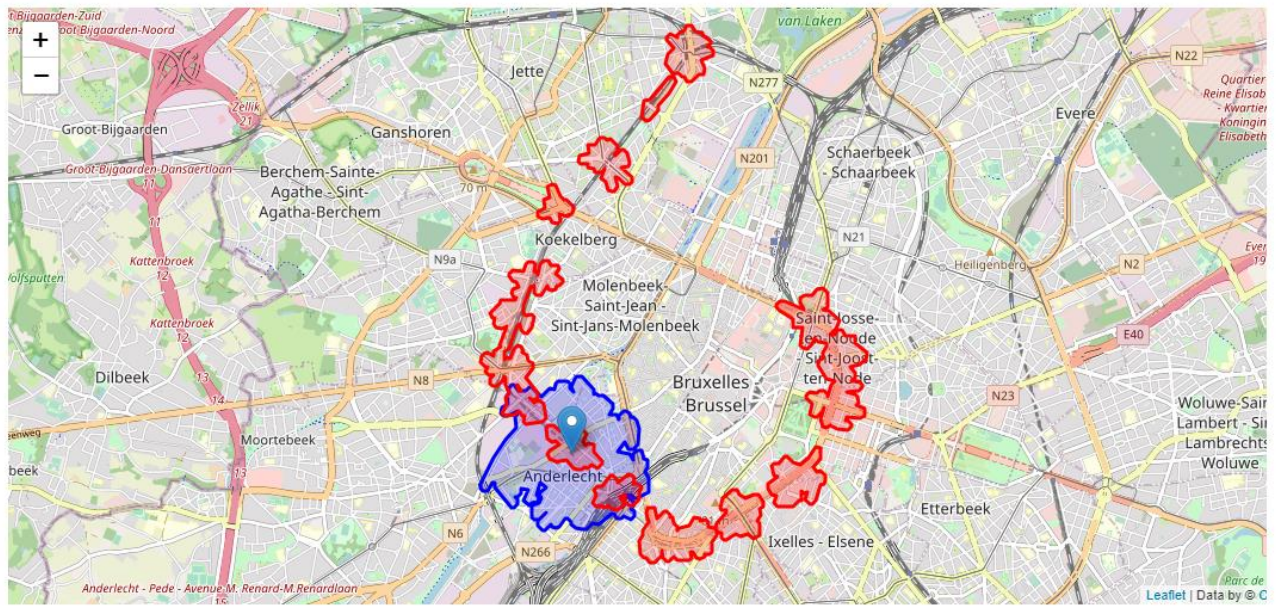
	id	mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
0	hub1	Walk	64	2	20	17	4	1
1	hub1	Public Transport	268	6	52	41	8	1

Figure 4: Metro Clemenceau - Before Scenario

Walk Area

Public Transport Area
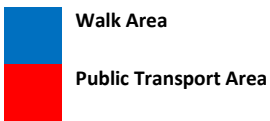
The after scenario at metro Clemenceau includes the addition of shared bicycles and e-scooters. The metro stop Clemenceau and Place du Conseil are very close to one another, but a notable difference between the two is that the public transport isochrone at Place du Conseil largely follows the tram line and the public transport isochrone at Clemenceau follows the metro line, thus accessing different parts of the city. A map of the after scenario can be seen in Figure 5.

Analysis Results
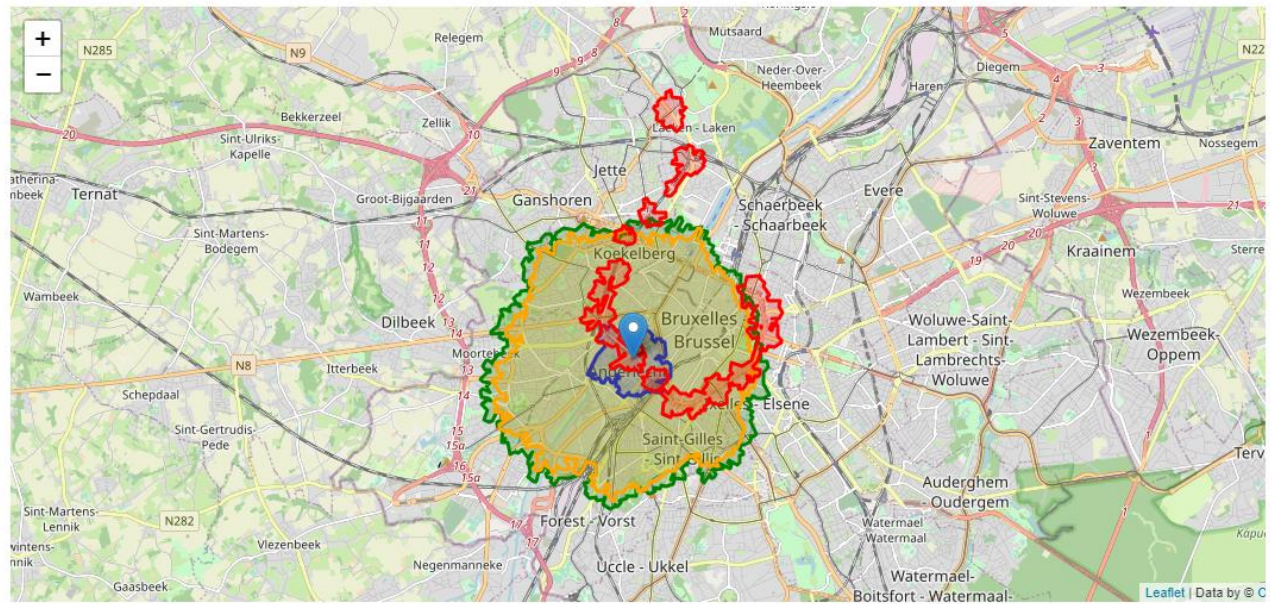
	id	mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
0	hub1	Walk	62	2	20	16	4	1
1	hub1	Bike	1742	70	212	224	72	10
2	hub1	E-Scooter	1532	51	193	194	66	9
3	hub1	Public Transport	330	4	67	57	16	2

Figure 5: Metro Clemenceau - After Scenario

■ **Walk Area**

■ **Bike Area**

■ **E-Scooter Area**

■ **Public Transport Area**

Table 6: Metro Clemenceau - Results Summary

Scenario	Mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment	Total
Before	Walk	62	1	20	18	4	1	106
	Public Transport	337	4	67	57	16	2	483
	All Modes	365	5	74	69	19	2	534
After	Walk	63	1	20	18	4	1	107
	Bike	1795	69	212	225	71	10	2382
	E-Scooter	1590	59	196	197	66	9	2117
	Public Transport	337	4	67	57	16	2	483
	All Modes	1942	69	240	255	77	10	2593

Table 7: Brussels - Percentage Change in Accessibility

	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment	Total
Metro Clemenceau	432%	1280%	224%	270%	305%	400%	386%
Place du Conseil	1218%	950%	555%	600%	667%	900%	988%

Valuable insights can be gained by looking at the relative increases in accessibility gained at each potential mobility hub by added new transportation modes. A summary of this can be seen in Table 7. This shows that a mobility hub at Place du Conseil would have a improvement in the relative accessibility to amenities compared to Metro Clemenceau. However, the relative percentages do not necessarily tell the whole story. While a mobility hub could potentially increase the accessibility to amenities as Place du Conseil by almost 10 times, the actual number of new amenities that could be reached by adding the mobility hub is about the same as it is at Metro Clemenceau. Both of these locations potentially gain access to roughly 2000 amenities by adding a mobility hub.

3.2. The Hague/Rotterdam

The living lab in the Netherlands is split between The Hague and Rotterdam. The analysis included in this report focuses on four potential hub locations in Rotterdam and four potential hub locations in The Hague. This analysis considers a before/after scenario for each living lab. In the before scenario, only walking is considered. In the after scenario, walking, cycling, shared e-scooters, and public transport are considered. The assumption is that the analysis shows the best case scenario for accessibility if a mobility hub can improve the integration of these different

services. Each scenario considers 15 minutes of travel time. An additional analysis was done for these locations that only considers shared electric scooters and mopeds, but with a financial constraint. It should be noted that the e-scooter mode in this analysis was modified to accommodate the types of scooters that are available in the Netherlands at this time. This means that the travel speed was adjusted.

Table 8: Netherlands - Before Scenario Assumptions

Time Budget	15 Minutes
Modes	Walk
Walk Speed	Moderate

Before/After Analysis
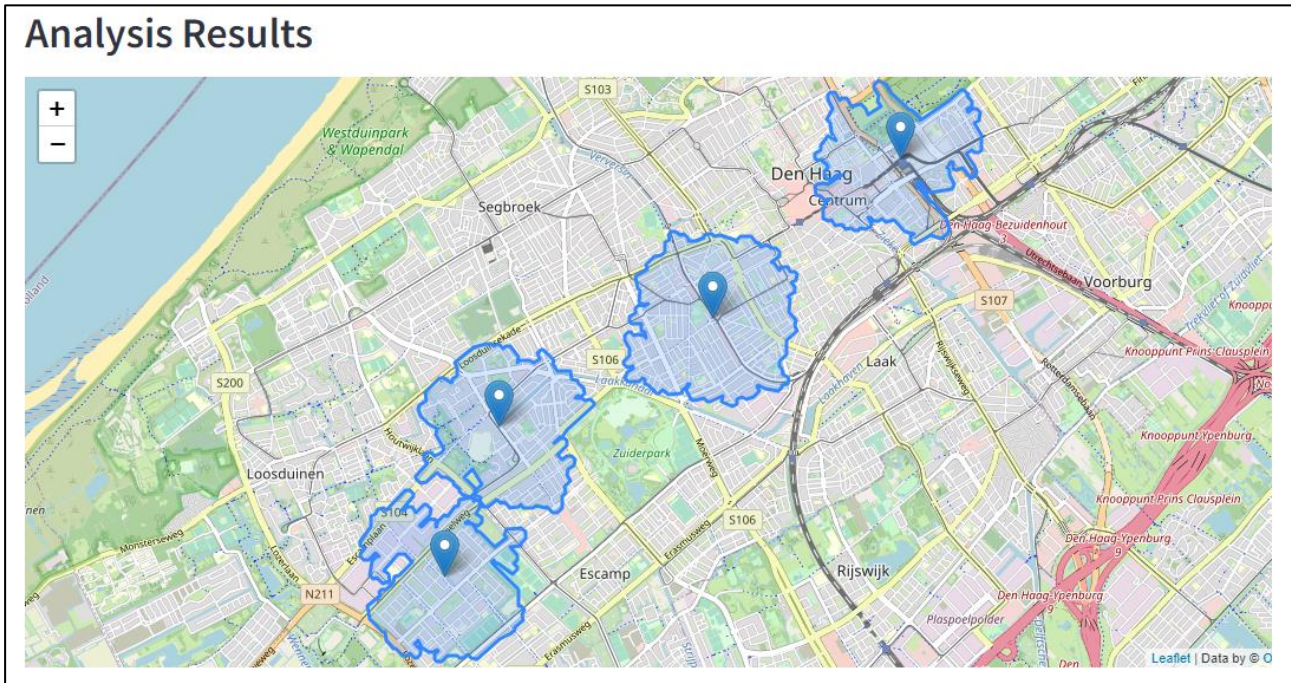
Figure 6: The Hague - Before Scenario

Walk Area

Analysis Results
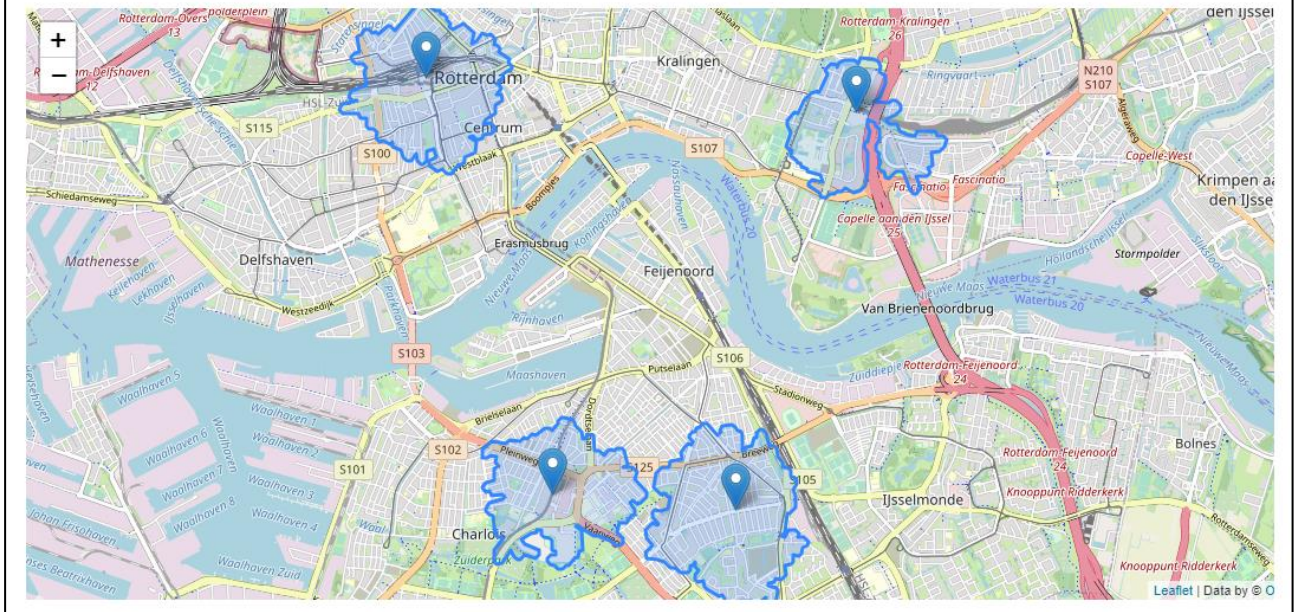
Figure 7: Rottterdam - Before Scenario

█ Walk Area

Table 9: Netherlands - After Scenario Assumptions

Time Budget	15 Minutes
Modes	Walk, Bike, E-Scooter, Public Transport
Walk Speed	Moderate
Bike Speed	Moderate
Public Transport Access Time	5 Minutes
Public Transport Access Walk Speed	Moderate
Public Transport Start Time	Monday, 12:00
Public Transport Transfers	No

Analysis Results

Figure 8: The Hague - After Scenario

- **Walk Area**
- **Bike Area**
- **E-Scooter Area**
- **Public Transport Area**
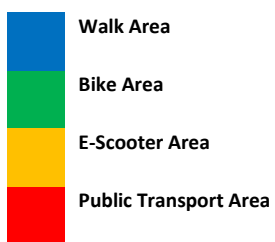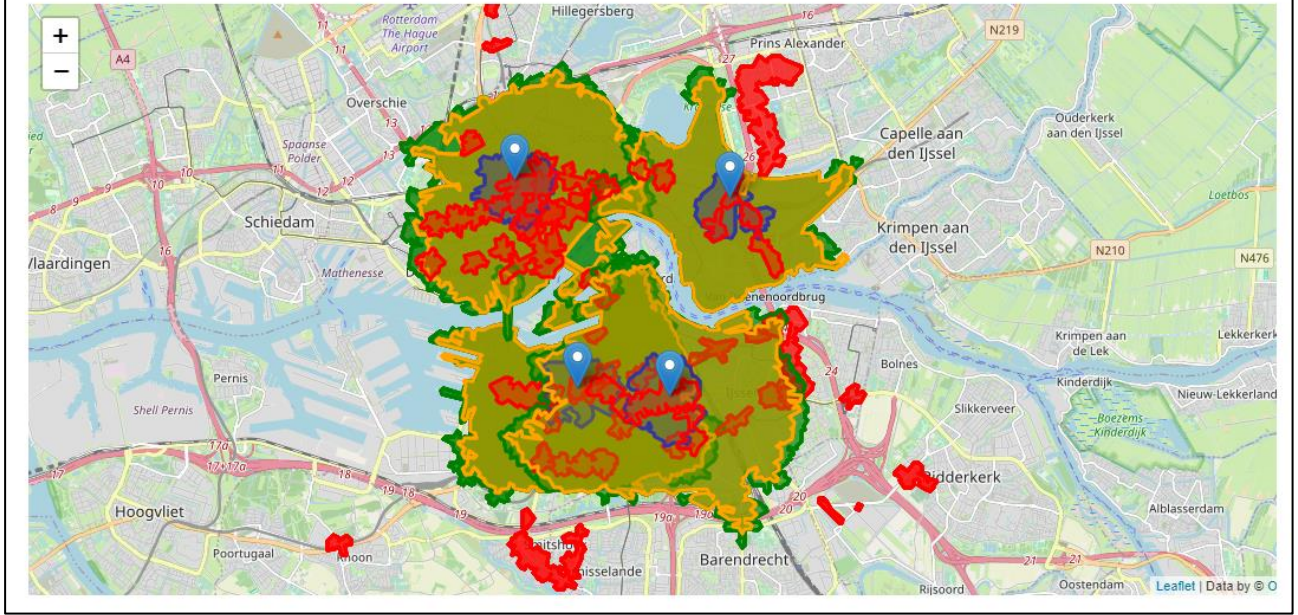
Figure 9: Rotterdam - After Scenario

■ **Walk Area**

■ **Bike Area**

■ **E-Scooter Area**

■ **Public Transport Area**
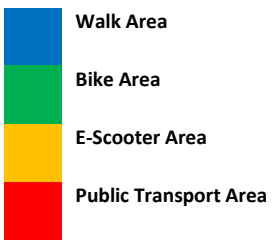
Table 10: Summary of all Results - Rotterdam

Name	Mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
Zuidplein	Walk	58	1	10	8	7	0
	Bike	273	37	38	51	45	2
	E-Scooter	265	33	32	49	45	1
	Public Transport	190	9	38	28	24	1
	All Modes	377	37	62	61	53	3
CS	Walk	213	12	29	10	15	2
	Bike	1009	62	97	73	75	4
	E-Scooter	954	57	92	70	72	4
	Public Transport	518	26	48	35	33	2
	All Modes	1049	63	104	80	76	4
Kralingse Zoom	Walk	12	2	5	2	1	0
	Bike	128	8	11	17	14	0
	E-Scooter	77	8	9	14	10	0
	Public Transport	259	7	31	21	22	1
	All Modes	335	13	39	32	29	1
Vreewijk	Walk	15	4	2	7	4	0
	Bike	222	32	34	47	43	1
	E-Scooter	208	30	32	43	42	1
	Public Transport	18	1	3	3	5	0
	All Modes	222	32	34	46	43	1

Table 11: Summary of all Results - The Hague

Name	Mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
Hobbemaplein	Walk	186	4	12	31	17	0
	Bike	1278	55	123	196	93	4
	E-Scooter	1224	50	118	182	89	4
	Public Transport	275	11	33	52	34	0
	All Modes	1282	56	122	199	93	4
CS	Walk	198	8	27	11	9	2
	Bike	1137	48	103	164	79	3
	E-Scooter	1072	39	97	148	68	3
	Public Transport	681	26	72	82	49	3
	All Modes	1179	54	110	177	83	3
Leyenburg	Walk	25	2	5	8	6	0
	Bike	470	33	65	125	72	0
	E-Scooter	423	32	59	111	69	0
	Public Transport	197	5	28	55	32	0
	All Modes	499	34	66	132	75	0
Centrum Bouwlust	Walk	12	2	2	6	9	0
	Bike	138	14	43	47	42	0
	E-Scooter	117	12	37	42	37	0
	Public Transport	9	0	3	6	5	0
	All Modes	142	14	44	47	42	0

While the raw counts of amenities near each mobility hub might have some value, it is more useful to look at the percentage change between the before scenario and the after scenario. The base scenario only considered walking and the after scenario considered walking, cycling, e-scooters, and public transport. It is not surprising that more amenities would be accessible when more modes are available, but the SmartHubs Accessibility Tool allows for direct comparison

between hubs. This might show which areas might enjoy the highest increases in amenity accessibility after a mobility hub is installed. The summary of these findings in Rotterdam and The Hauge can be found in Table 12 and Table 13, respectively.

Table 12: Percentage Change in Amenity Accessibility - Rotterdam

Rotterdam	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment	Total
Zuidplein	550%	3600%	520%	663%	657%	0%	**606%**
CS	390%	425%	259%	700%	407%	100%	**388%**
Kralingse Zoom	2692%	550%	680%	1500%	2800%	0%	**1941%**
Vreewijk	1380%	700%	1600%	557%	975%	0%	**1081%**

Table 13: Percentage Change in Amenity Accessibility – The Hague

The Hague	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment	Total
Hobbemaplein	593%	1300%	917%	522%	447%	0%	**602%**
CS	498%	500%	293%	1509%	822%	50%	**527%**
Leyenburg	1896%	1600%	1220%	1550%	1150%	0%	**1652%**
Centrum Bouwlust	1083%	600%	2100%	683%	367%	0%	**832%**

In the case of Rotterdam, it appears that the potential mobility hub at Kralingse Zoom could have the highest increase in amenity accessibility. When looking at the total number of amenities that could be reached, the number increases by more than 19 times when considering shared modes and public transport, compared to walking alone.

In the case of The Hague, adding at mobility hub at Leyenburg could have the highest potential increase in amenity accessibility. When looking at the total number of amenities that could be reached, the number increases by more than 16 times when considering shared modes and public transport, compared to walking alone.

Financial Cost Analysis

This part of the analysis focuses on the function that allows users to calculate accessibility with a financial cost instead of a time cost. The current version (December 2023) of the SmartHubs Accessibility Tool has built-in costs when it comes to shared e-scooters. It assumes an unlocking fee of €1.00, then an additional €0.20 per minute. These costs are not uncommon, but it is possible that there could be different costs. However, it is possible to adjust the costs in the code if the tool is being run locally. The costs and travel speeds have been adjusted for this analysis in order to make the results more representative of the services that are available in the Netherlands. Table 14 summarizes the variables values that were assumed in this scenario. This

type of analysis makes it possible to not only compare individual locations, but also assess the coverage of the system. The maps show that each hub location is within multiple service areas. This information can help decide where the placement of a hub might provide additional coverage to an area that is already covered, or provide coverage to areas that are currently not covered.

Table 14: Shared Electric Vehicle Costs - the Netherlands

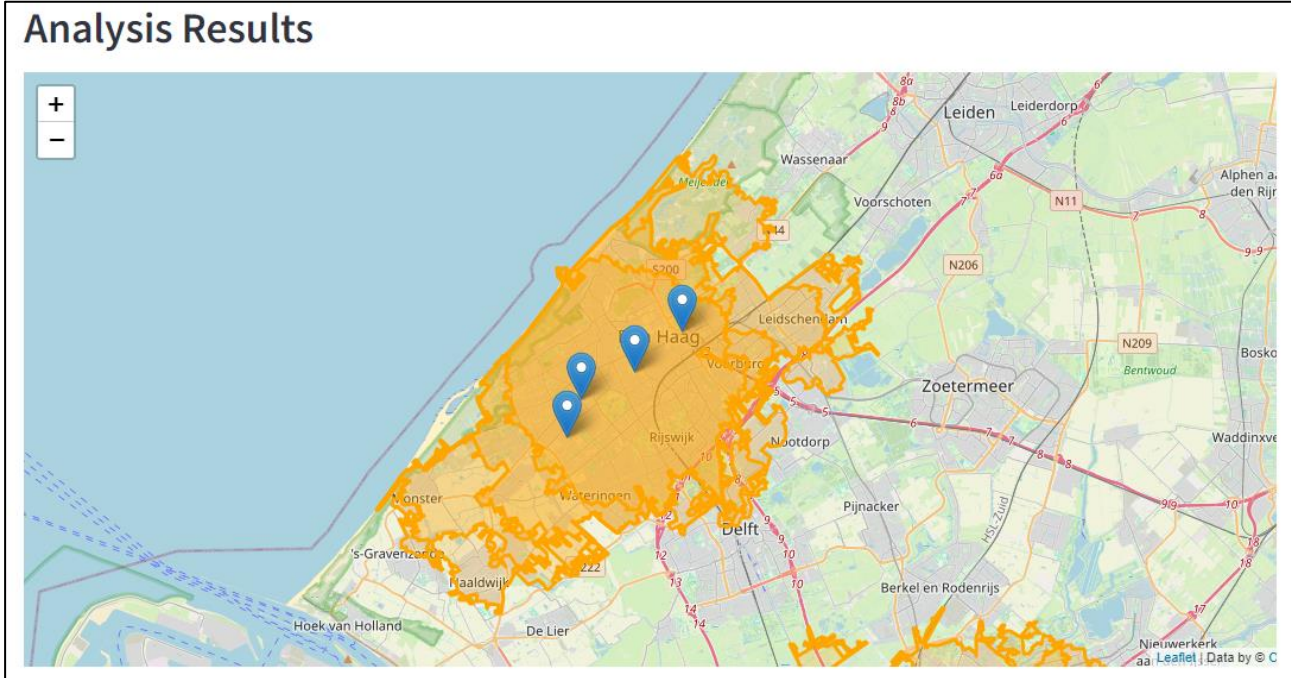| Variable	Netherlands Scenario
Speed	45 km/h
Unlock Fee	€1.00
Per-Minute Fee	€0.30

Figure 10: The Hague - Accessibility within €5.00

E-Scooter Area

Table 15: The Hague – Amenities accessible within €5.00

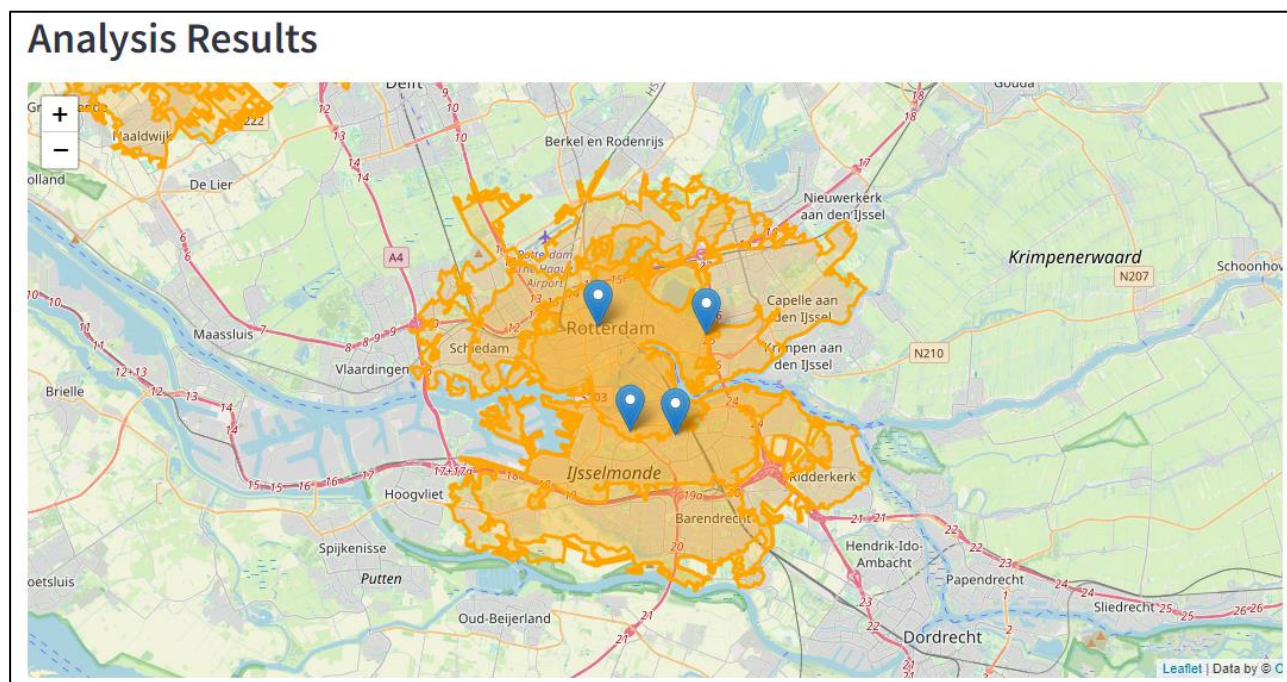| Name	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
Hobbemaplein	2013	133	237	402	206	6
CS	1992	136	238	406	203	6
Leyenburg	1910	118	232	365	199	5
Centrum Bouwlust	1826	122	219	342	192	4

Figure 11: Rotterdam - Accessibility within €5.00

E-Scooter Area

Table 16: Rotterdam - Amenities accessible within €5.00

Name	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
Zuidplein	1576	147	181	190	169	6
CS	1583	159	193	194	176	6
Kralingse Zoom	1400	128	165	157	142	5
Vreewijk	1453	142	173	183	160	5

3.3. Munich

The Munich living lab primarily focused on the transformation of a parklet near the Technical University of Munich into a mobility hub. This analysis shows the potential accessibility implications of making improvements to the parklet to convert it to a mobility hub. These improvements should improve the availability of shared modes and improve connectivity to public transport. The accessibility tool can be used to assess accessibility around the parklet before and after the improvements.

The before scenario (see Figure 12) looks at the amenities that can be accessed by walking from the parklet within 15 minutes. While it is possible to use other modes, it might be less likely that shared modes are used since there are no designated drop-off points and the nearby public transport connections are not obvious.

Table 17: Munich - Before Scenario Assumptions

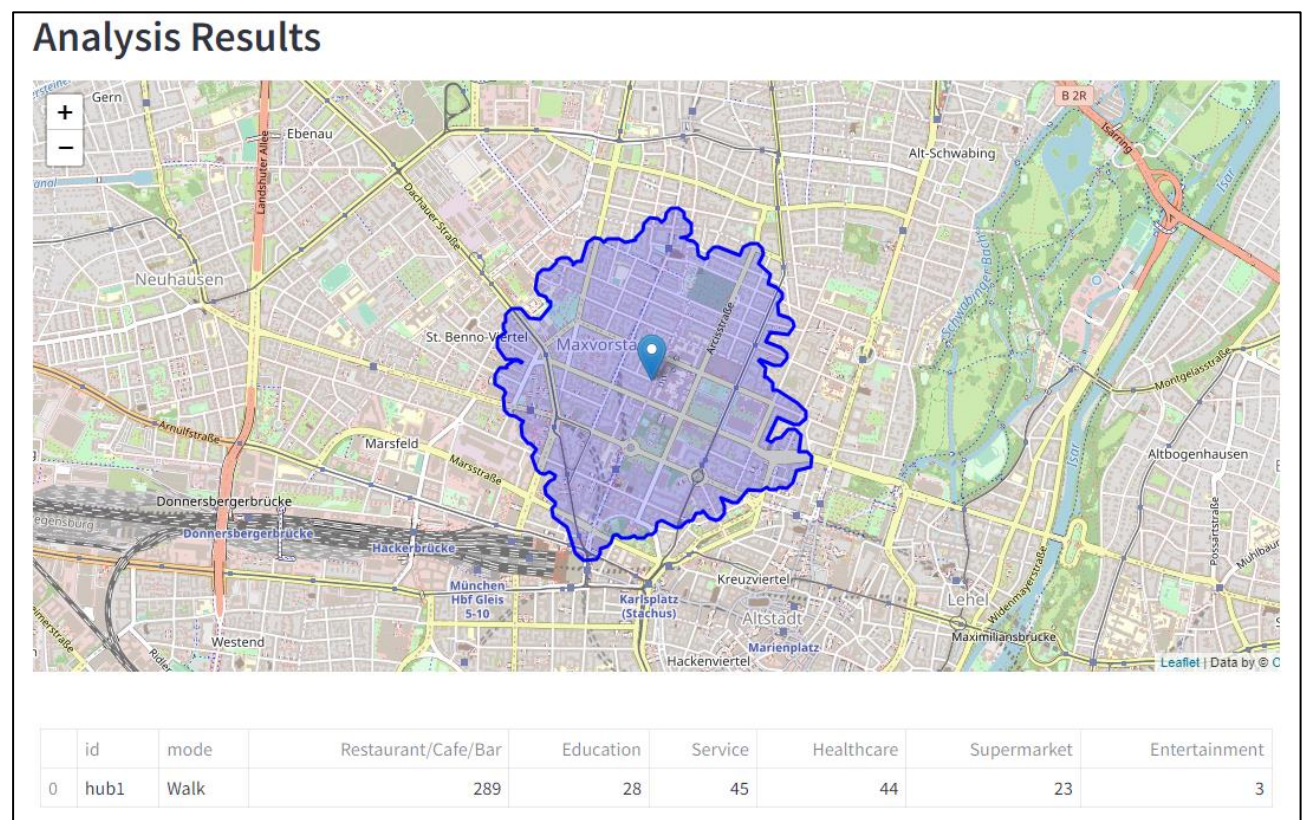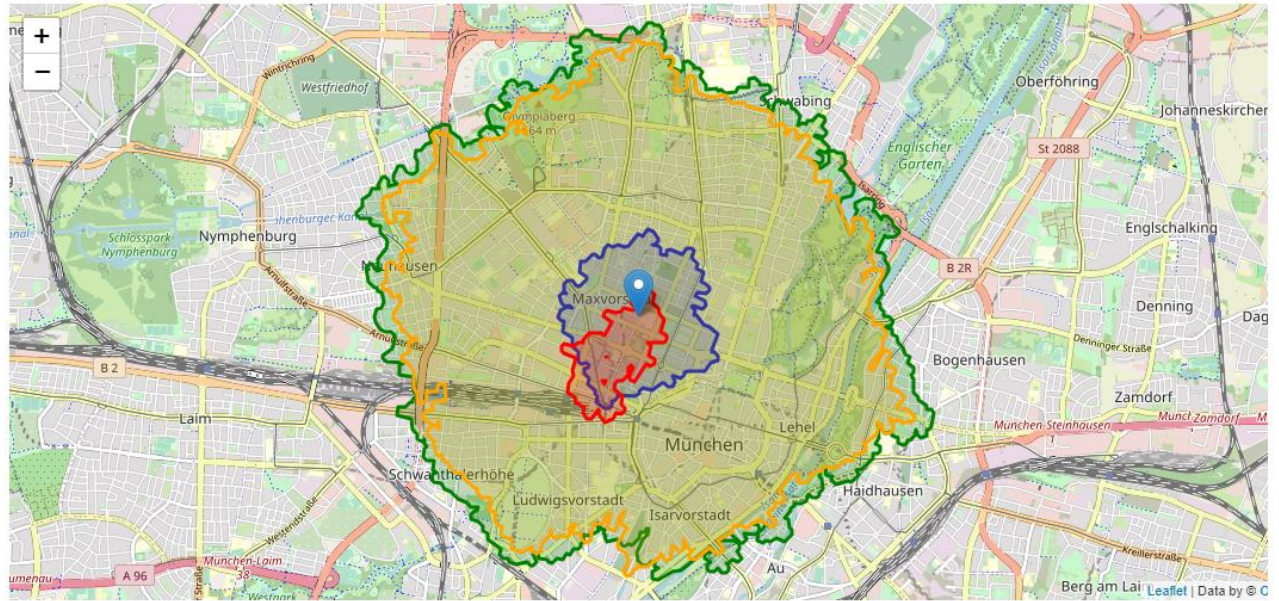| Time Budget	15 Minutes
Modes	Walk
Walk Speed	Moderate

Figure 12: Munich Results – Before

The after scenario (see Figure 13) also looks the number of amenities accessible near the parklet, but additional modes were added to capture a best-case scenario where the conversion of the parklet into a mobility hub increases a user's ability to use shared modes (cycling and e-scooters) and public transport. A 15-minute travel time was used for all modes.

Table 18: Munich - After Scenario Assumptions

Time Budget	15 Minutes
Modes	Walk, Bike, E-Scooter, Public Transport
Walk Speed	Moderate
Bike Speed	Moderate
Public Transport Access Time	5 Minutes
Public Transport Access Walk Speed	Moderate
Public Transport Start Time	Monday, 12:00
Public Transport Transfers	No

Analysis Results

	id	mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
0	hub1	Walk	289	28	46	45	23	3
1	hub1	Bike	2165	190	403	460	183	24
2	hub1	E-Scooter	2024	176	363	427	169	23
3	hub1	Public Transport	130	14	40	18	9	1

Figure 13: Munich Results – After

■ **Walk Area**

■ **Bike Area**

■ **E-Scooter Area**

■ **Public Transport Area**
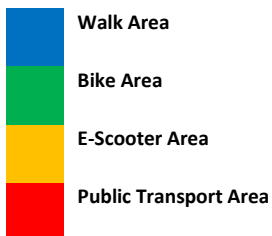
A comparison of the two analyses shows the potential accessibility implications of upgrading the parklet to a mobility hub. The exact numbers are summarized in Table 19. In the before scenario, roughly 300 amenities are accessible by foot from the parklet. In the after scenario, more than 2600 amenities are potentially accessible from the parklet when additional modes are available. This is about a 900% increase from the before scenario.

Table 19: Munich Results Comparison

Scenario	Mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment	Total
Before	Walk	195	21	35	29	17	3	300
After	Walk	194	21	35	29	17	3	299
	Bike	1708	146	306	363	142	21	2686
	E-Scooter	2026	176	362	428	171	23	3186
	Public Transport	99	14	32	14	8	1	168
	All Modes	1708	146	306	363	142	21	2686

3.4. Vienna

The analysis in Vienna focusses on four existing bike sharing stations in Aspern Seestadt. One of them – WienMobil Maria-Tusch Straße - also was looked at more in detail during the Design Game workshop on site (see SmartHubs Deliverable D 4.2). The objective here is to look at accessibility within 15 minutes using bicycles, walking, and public transport. Instead of a before/after scenario, this analysis is intended to assess general performance of the different bike sharing station locations.

Table 20: Vienna - Analysis Assumptions

Time Budget	15 Minutes
Modes	Walk, Bike, Public Transport
Walk Speed	Moderate
Bike Speed	Moderate
Public Transport Access Time	5 Minutes
Public Transport Access Walk Speed	Moderate
Public Transport Start Time	Monday, 12:00
Public Transport Transfers	No
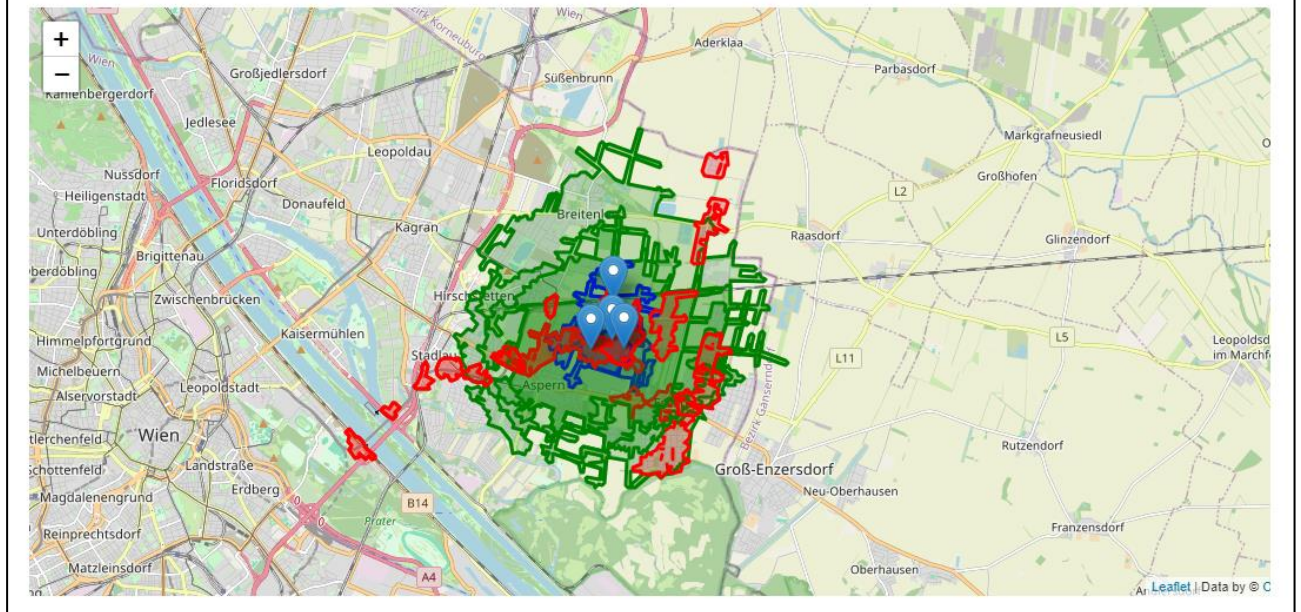
Figure 14: Vienna - Analysis Results

🟦	**Walk Area**
🟩	**Bike Area**
🟥	**Public Transport Area**

Table 21: Vienna - Analysis Results

Name	Mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment	Total
Seepark	Walk	14	9	9	19	2	0	53
	Bike	47	22	28	38	9	0	144
	Public Transport	19	9	13	20	4	0	65
	All Modes	47	22	28	38	9	0	**144**
Seestadt U	Walk	13	9	9	20	2	0	53
	Bike	42	21	26	38	6	0	133
	Public Transport	30	9	29	32	10	0	110
	All Modes	48	21	40	47	12	0	**168**
WienMobil Station Maria-Tusch-Straße	Walk	13	7	9	17	1	0	47
	Bike	51	22	39	46	11	0	169
	Public Transport	19	9	13	20	4	0	65
	All Modes	51	22	39	46	11	0	**169**
Aspern Nord S U	Walk	0	0	0	1	0	0	1
	Bike	43	17	30	34	8	0	132
	Public Transport	20	5	25	23	10	0	83
	All Modes	53	17	49	48	16	0	**183**

The final amenity counts (see Table 21) show very similar levels of accessibility for all four of the mobility hubs that were assessed in this living lab. The four living labs are within 15 minutes of 144-183 amenities. Local planners and practitioners may need combine these numbers with their local knowledge of the hubs and their performance. For example, if a planner knows that these four hubs are all performing adequately, then access to roughly 160 amenities within 15 minutes might be a goal that should be reached when planning locations for other hubs.

3.5. Istanbul

The Istanbul analysis is focused on three neighborhoods in the city's periphery: Esenyurt, İkitelli, and Bagcilar. The objective of this analysis is to measure accessibility to different rail stations in or near these neighborhoods by foot and using shared modes. This should assess the potential for adding mobility hubs to these stations.

Time Budget	15 Minutes
Modes	Walk, Bike, E-Scooter
Walk Speed	Moderate
Bike Speed	Moderate

The results show the Accessibility Tool's potential to visualize accessibility to different points. The most noteworthy part of the Istanbul results is Bahçeşehir Station, the point on the western side of the map. This is the nearest train station to the Esenyurt neighborhood, which is south of the station. No part of this neighborhood can access the train station within 15 minutes of walking, cycling, or using an e-scooter. This means that placing a mobility hub at this station may not provide the desired level of accessibility to the Esenyurt neighborhood.
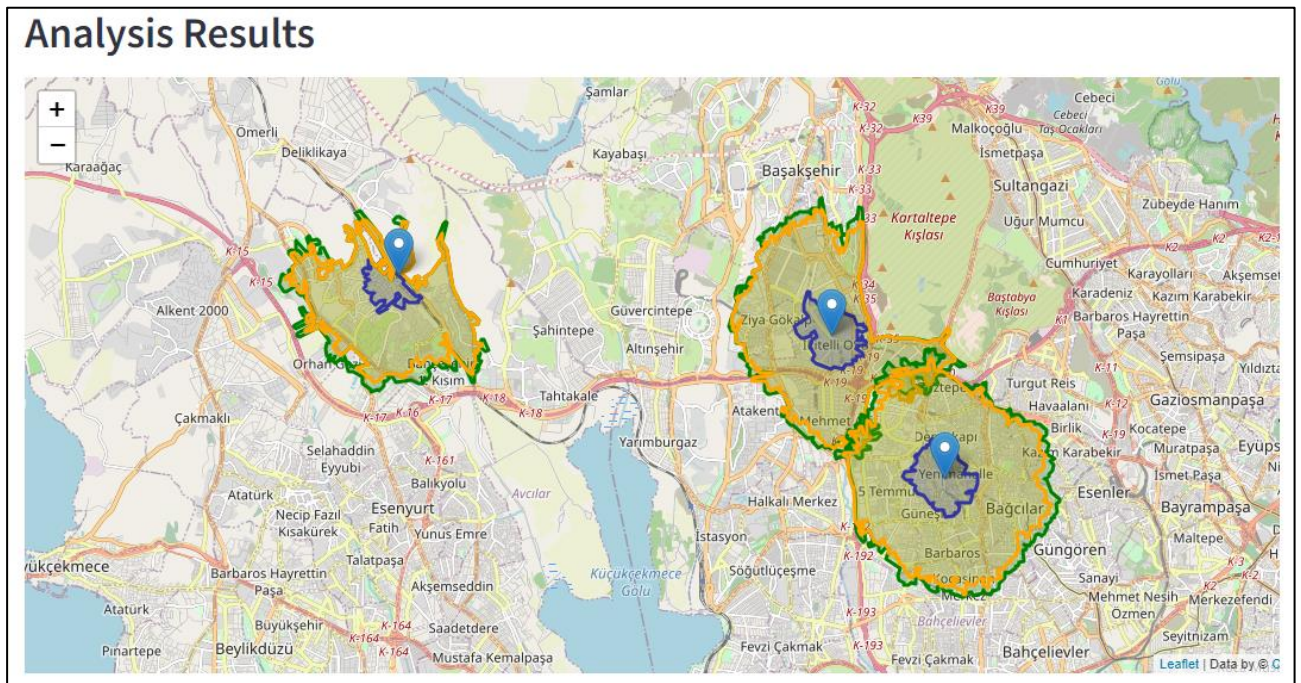

Figure 15: Istanbul - Station Accessibility

■ Walk Area

■ Bike Area

■ E-Scooter Area

Table 23: Istanbul - Summary of Results

Name	Mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
Bahçeşehir (Esenyurt)	Walk	0	0	0	0	0	0
	Bike	19	5	20	17	8	0
	E-Scooter	10	2	10	13	8	0
	All Modes	19	5	20	17	8	0
İkitellı Sanayı (İkitelli)	Walk	5	0	3	1	1	0
	Bike	40	2	24	29	10	1
	E-Scooter	38	2	23	24	7	0
	All Modes	40	2	24	29	10	1
Yenimahalle (Bagcilar)	Walk	62	4	23	17	40	0
	Bike	501	33	192	197	292	1
	E-Scooter	468	31	182	180	277	0
	All Modes	501	33	192	197	292	1

Table 24: Istanbul - Percentage Change in Accessibility

	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment	Total
Bahçeşehir (Esenyurt)	-	-	-	-	-	-	-
İkitellı Sanayı (İkitelli)	700%	-	700%	2800%	900%	-	960%
Yenimahalle (Bagcilar)	708%	725%	735%	1059%	630%	-	733%

In this analysis, the general accessibility of amenities near the stations is assessed with different modes, but this can also be seen as a before/after analysis if it is assumed that only walking is currently available (before scenario). The after scenario would be the addition of shared e-scooters and bikes. Table 24 shows the percentage increase in accessibility for each of the analyzed stations. Bahçeşehir Station is noteworthy since no amenities are accessible in the walking only scenario. It is unclear if this is true or if this is a result of poor data. The gains seen at the other two stations are comparable to what was seen in other living labs.

4. DISCUSSION AND CONCLUSION

This part of the SmartHubs project has two main parts. (1) Develop a tool that can be used to assess accessibility of amenities near mobility hubs and (2) use this tool to perform an impact assessment on the living lab locations. This section will provide a more detailed discussion on the overall impact assessment of the living labs and reflect on the Accessibility Tool's ability to perform these types of analyses.

4.1. Overall Living Lab Assessment

The impact assessment involved developing scenarios for each of the living labs, then using the SmartHubs Accessibility tool to analyze these scenarios. A summary of these scenarios can be seen in Table 25. With the exception of the e-scooter analysis done in the Netherlands, a travel budget of 15 minutes was used for every location and mode.

Table 25: Living Lab Scenarios

Living Lab	Scenario
Brussels	Before/after assessment of two potential mobility hub locations.
The Netherlands	Before/after assessment of eight potential hub locations (four in The Hauge, four in Rotterdam) and an accessibility analysis of each of these locations using shared electric scooters that are commonly found in the Netherlands with a cost budget of €5.
Munich	Before/after assessment of a parklet that was upgraded to a mobility hub.
Vienna	Comparison of four existing mobility hubs in Seestadt Aspern.
Istanbul	Before/after assessment of three train stations to assess to what extent they might benefit form being upgraded to a mobility hub.

The analyses performed in each living lab can be roughly grouped into two categories. The SmartHubs Accessibility Tool can be used for comparing scenarios, or the tool can be used for comparing different geographic locations. It is also possible to use the tool for an analysis that is a combination of these two possible analyses.

The analyses in Brussels, the Netherlands, Munich, and Istanbul all generally fall into the category of comparing scenarios. In Brussels, the analysis looks at two public transport stops that could be upgraded to mobility hubs if sharing services were consistently available. In the Netherlands, three different scenarios were examined in two different cities (The Hague and Rotterdam). A basic scenario (where only walking is assumed to be consistently available), a scenario with all mobility options available, and a scenario that only examines a financial budget for e-scooters were examined. In Munich, two scenarios (before and after) were studied in a single location. In Istanbul, a scenario that examined only walking accessibility to/from train stations in key neighborhoods was compared to a scenario that assumed the availability of shared mobility services at the train stations.

Making direct comparisons between these cities and the scenarios that were analyzed in each city is difficult because what may be an acceptable level of accessibility in one city is not acceptable in another city. Furthermore, differences in the quality of OSM data in each city also make it difficult to make direct comparisons. However, some basic comparisons can be made when looking at the relative improvements in accessibility. Metro Clemenceau in Brussels showed the smallest improvement (an increase of 386%) when upgraded to a mobility hub with more shared modes available while Kralingse Zoom in Rotterdam showed the highest increase in relative accessibility (1941% increase) compared to other locations that were examined. It is important to keep in mind that these numbers do not tell the whole story and accessibility can be complex and involve many different factors. The relative increase in accessibility to amenities might have been small at Metro Clemenceau, but this can be misleading. When comparing this result to the other potential mobility hub in Brussels, it becomes clear that the percentages are different, but they both experience an increase of roughly 2000 accessible amenities after the installation of a mobility hub. The only difference is that Metro Clemenceau started out with a higher level of accessibility, thus making the relative increase seem smaller. Furthermore, large or small increases in accessibility may have very little to do with the mobility hub or the modes made available. This is also dependent on the distribution and density of the amenities throughout the city. If a city has a relatively even distribution of amenities, any changes to a mobility hub will show significant increases in accessibility. However, if amenities are concentrated in key areas, then only improvements to mobility hubs that allow these key areas to be reached will show significant improvements. Planners and practitioners may need to combine their local knowledge and data with the output of the SmartHubs Accessibility Tool to make informed decisions.

The second category of analyses that the SmartHubs Accessibility Tool is useful for is comparing multiple locations within a scenario. This is seen in the living labs in Brussels, the Netherlands, Vienna, and Istanbul. The living lab in Brussels is the most straightforward. There are two potential locations in one neighborhood. It might not be possible to improve accessibility to amenities at both of these locations, but the direct comparison with the Accessibility Tool makes it possible to show which one might show the greatest improvements. In this case, Place du Conseil showed a greater relative improvement in accessibility to amenities. In the case of Vienna, four existing locations are compared to each other. The results showed that the level of accessibility was very similar for each hub. Local planners and practitioners might be able to use this information when combined with other performance metrics, such as number of bicycle rentals, to establish a benchmark for acceptable accessibility when planning new hubs in the future.

4.2. Limitations

The SmartHubs Accessibility Tool has a number of limitations that constrain its usefulness. The main constraint is the reliance on OSM data. The main benefit of the OSM data is that it is available to some extent anywhere in the world. This means that a wide range of users should have access to the tool. The downside of relying on OSM data is that OSM data can vary quite a lot in different regions and the quality is not always good. Additionally, the process of downloading OSM data is the most time-consuming part of the analysis. Calls to the OSM API can

be restricted and timeout if too many requests are being made. Future development of the tool will need to address this issue.

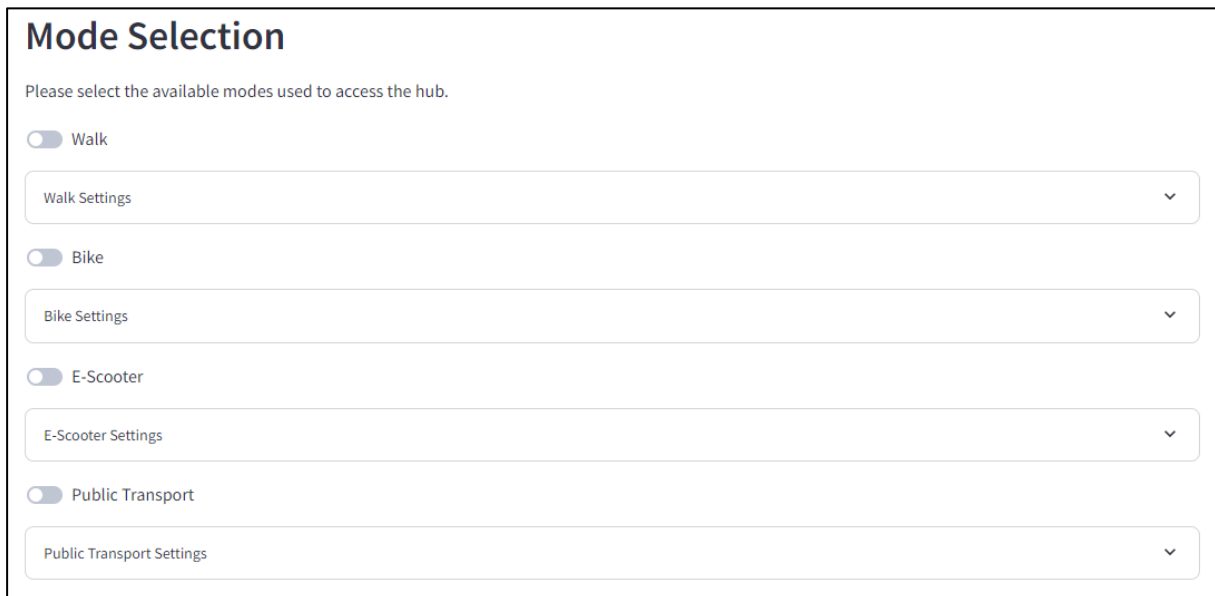## 4.3. Tool Performance and Future Development

It is important to assess not only the performance of the living labs, but also the performance and suitability of the SmartHubs Accessibility Tool for analyzing accessibility. There are pros and cons associated with this tool. The main benefit that the tool provides is that it is simple, easy to use, and draws on freely available data. The main downside is that is that the tool may make it possible to draw conclusions from poor data and important information may be missing. These pros and cons cannot be separated from one another. They are two sides of the same issue. The main benefits come from reliance on openly available data, but this is also the main downside. Improving the downsides by including more reliable data and flexibility would make the tool more complicated, harder to use, and not applicable everywhere. Understanding this relationship can help drive future development of the tool. Future version should still be easy to use, but could benefit from having more options to improve the results by adding local datasets.

APPENDIX I – STEP-BY-STEP GUIDE

The SmartHubs Accessibility Tool requires three main inputs from the user: transportation modes, amenities, and locations. A basic analysis can be completed by entering the inputs into the visual interface. More advanced analyses, such as those requiring public transport, require external data. However, the process of adding the data is easy and intuitive.

Mode Selection

The first step is to specify the transportation modes that are available at the hubs that will be analyzed. The SmartHubs Accessibility tool currently supports walking, cycling, e-scooters, and public transport. Modes are selected by clicking on a series of toggle switches, as seen in Figure 16. At least one mode must be selected, but multiple modes can also be selected.

Figure 16: Mode Selection

In addition to having the ability to select different transportation modes, users can also adjust custom settings and assumptions for each mode. For example, travel speeds, travel times, and travel costs. Users can adjust the travel time and speed for walking and cycling (see Figure 17).

Figure 17: Mode Settings - Walk

If the user wants to consider e-scooters, the travel cost can be customized. This could be a financial cost or a time cost.
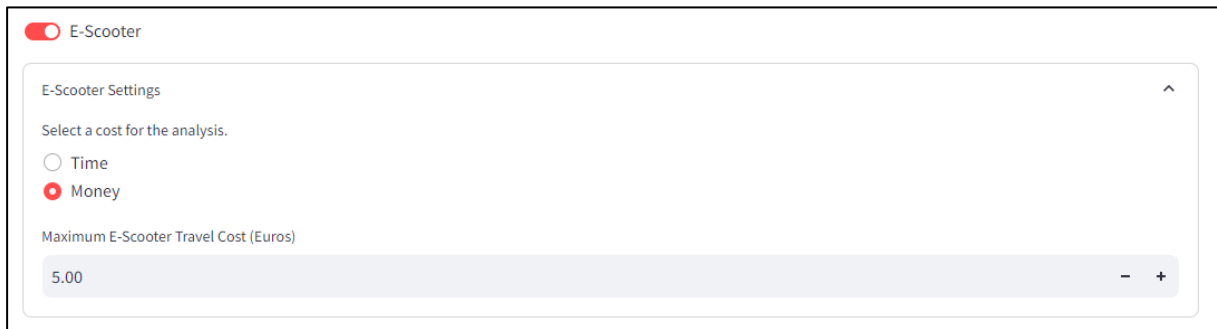

Figure 18: Mode Settings - E-Scooter

Public transport is the most complicated mode that is available and the settings allow the user to specify a specific departure day, departure time, maximum travel time, maximum walk time, walk access speed, and the ability to consider transfers. If transfers are not allowed, then only public transport services that depart from the nearest public transport station will be considered and additional services that could be reached by switching at other public transport stops will not be considered. If transfers are allowed, then all public transport services that can be reached will be considered. If the user turns on the public transport mode, a new section should appear that allows users to upload GTFS data. If public transport is selected, GTFS data must be uploaded in order for the analysis to work. Users also have the ability to upload multiple GTFS datasets to be used in a single analysis. This is useful in situations where public transport services in an area are not unified. For example, local and regional public transport services could be operated by different providers and have separate GTFS datasets.

Figure 19: Mode Settings - Public Transport

Amenity Selection

Next, users must select the amenities that will be counted near their mobility hubs. This is done by selecting amenity categories from a dropdown menu. Users must select at least one amenity category. It is also possible to select all six categories. Categories can be easily added or removed to the analysis. The full list of amenities that are included in these categories can be found in Table 2.

Figure 20: Amenity Selection

Location Selection

The final input that is required for an analysis is at least one location. There are two different ways users can add locations to their analysis. It is possible to either manually add individual hub locations on the map, or upload a CSV file containing the coordinates of the locations. It is also possible to use both methods simultaneously. This means uploading a CSV file with locations, then adding additional locations to the map.

Figure 21: Location Selection

If the user wishes to add hub locations individually, this can be done by clicking on the "draw a marker" button (see Table 26) at the top-left corner of the map, then clicking again on the map to place the marker. It is also possible to edit or remove potential locations by clicking on the corresponding buttons.

Table 26: Location Selection Buttons

Button	Purpose
	Draw a marker
	Edit a marker
	Delete a marker

If a user wishes to upload a CSV file with hub locations, this can be done using the box underneath the map. There are some important things to consider when using this function. The file that is uploaded must be a CSV file, the file must have a column called "id", a column called "lat", and a column called "lon". The column names must be written exactly like this. For example, "LAT" instead of "lat" will not be accepted. See Table 27 below for an example of how this table might look. Once points have been uploaded to the map, they should appear with red markers. Hub locations that are added manually will be shown as blue. Figure 22 shows a map with four locations that were added by uploading a CSV file (shown in red) and an additional two locations that were added by manually adding them to a map (shown in blue).

Table 27: Example of Table for Uploading Points

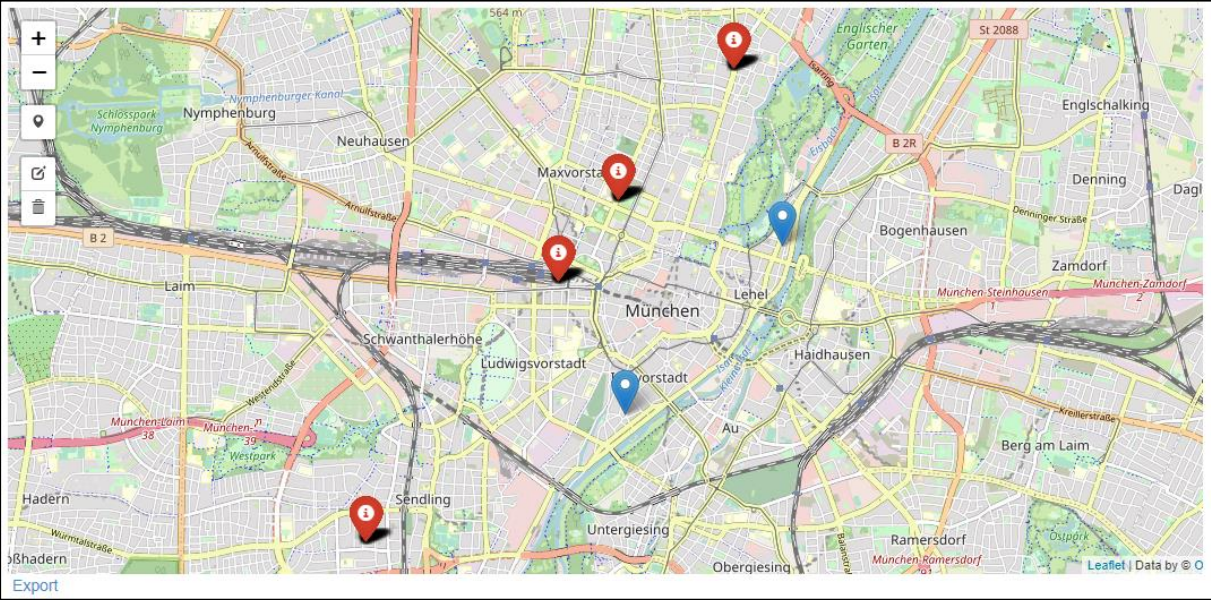| id	lat	lon
hub1	51.88702129	4.488384655
Hub2	51.92426425	4.470005233

Figure 22: Location Selection - Mixed Inputs

Running an Analysis

Once at least one transportation mode, one amenity group, and one location have been selected, a new button should appear at the bottom of the page. Simply click on the button to run the analysis.

Figure 23: Run Analysis Button

Once the "Run Analysis" button has been clicked, the page will change and the user will be presented with a summary of the analysis inputs and a progress bar. How long the analysis takes depends on the number of hubs, the number of modes, and the allowed travel time. Larger, more complex analysis, especially those involving public transport will take longer. An analysis involving a single walking isochrone might take seconds, but an analysis involving a single public transport isochrone could take several minutes.
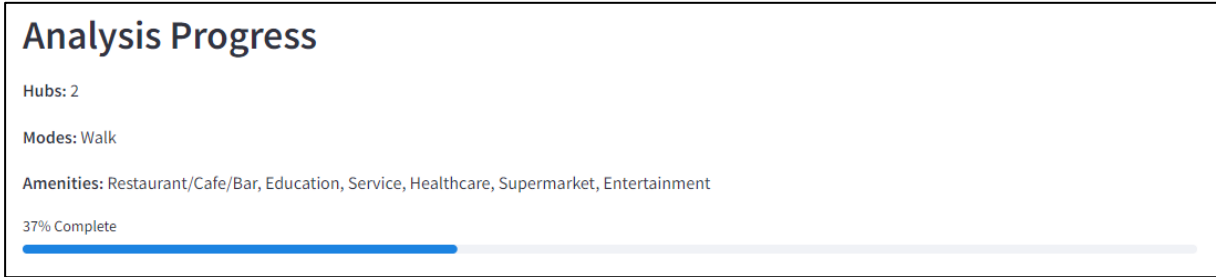

Figure 24: Analysis Progress

Interpreting Results

When the analysis is complete, the progress bar will disappear and the user will be presented with a map and a table showing a summary of the results. The map shows the accessible service areas around the designated hub locations and the table shows counts of the number of amenities accessible within each of these areas. The table also has fields that contain the unique id number and the mode that was considered. Other settings are currently not available after the analysis has been run. However, this may be changed in future versions.

The following example shows a direct comparison between two potential hub locations in the Maxvorstadt neighborhood in Munich, Germany. The user can see the different shapes and sizes of the service areas as well as the different amenity counts associated with each hub. It can be seen that the two locations are comparable, but "hub1" has better access to supermarkets and educational facilities while "hub2" has better access to other services.

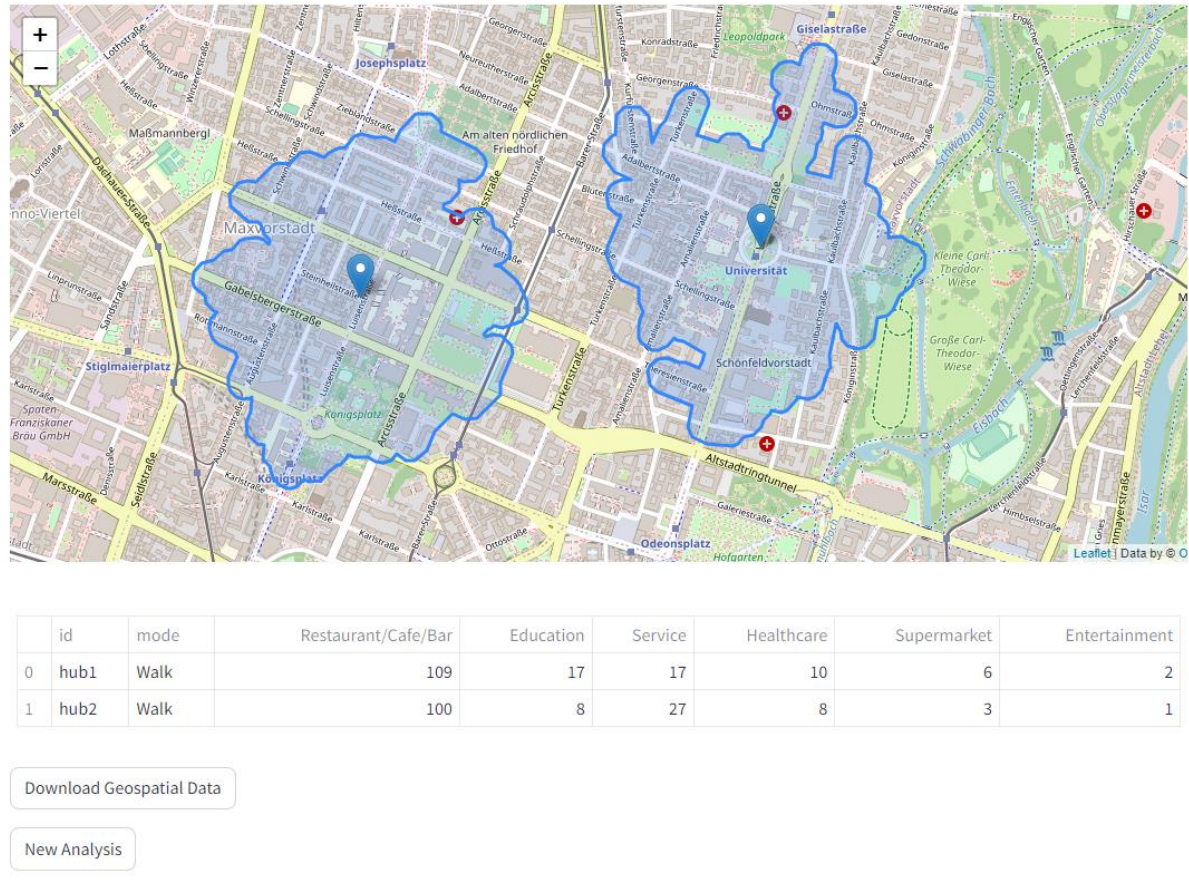|	id	mode	Restaurant/Cafe/Bar	Education	Service	Healthcare	Supermarket	Entertainment
0	hub1	Walk	109	17	17	10	6	2
1	hub2	Walk	100	8	27	8	3	1

Download Geospatial Data

New Analysis

Figure 25: Analysis Results

There are two additional buttons underneath the table. One allows the user to download the geospatial data that was created while running the analysis. The other allows the user to start over and create a new analysis. If the user clicks on the "Download Geospatial Data" button, a GEOJSON file will be downloaded containing the polygons of the service areas. The attribute table of the GEOJSON file contains the amenity counts that are shown in the table. A user may want to download the data in order to perform additional analyses within external GIS software.