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Measuring and Visualising 15-Minute-Areas for Fair CO_2 Budget Distribution

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Abstract

The "MyFairShare" project develops fair CO_2 mobility budgets for individuals. Here, "fairness" mainly depends on the people's location as everyone should be capable to access all the destinations needed to perform everyday tasks. As such, a basic understanding about the accessibility within an area is needed, regarding all activities that must be performed. To achieve this, a software system for benchmarking areas has been developed. It is based on open source applications and uses data that – besides public transport data in GTFS format – is freely available throughout Europe. This paper introduces this application and shows some first results. They show that even in major European cities and regions the locations of everyday actions cannot be accessed within 15 minutes for most of the population.

Keywords:

CO_2 budgets, 15-minutes accessibility

Introduction

National undertakings throughout Europe aim at reducing the amount of CO_2 emissions from traffic to fight the climate crisis. The main idea behind the European joint undertaking "MyFairShare" is to make national carbon reduction targets comprehensible and relatable in the everyday context of individuals by scaling them down to their opportunity space of action. As research indicates [1, 2] that people are rather willing to accept restrictions and disadvantages if these can be perceived as being fair, the project develops fair, individual CO_2 mobility budgets for initiating and accelerating behaviour change. The main assumption taken is that a fair CO_2 budget allows an individual to perform all needed activities, ideally at locations in their vicinity, and if no nearby locations exist by providing an according supply with preferably sustainable mobility options [3].

This view at the distributions of population and of places has a strong correlation to one of the most promising approaches for reducing the amount of CO_2 emissions in traffic: the so-called 15 minutes cities [4]. In the following, an approach for benchmarking areas regarding their applicability for being called areas of 15 minutes is presented. Here, the term "areas of 15 minutes" is chosen, as the benchmark disaggregates a city into a grid on the spatial level. The main reason for doing so is the wish to reveal which parts of a city or region need additional facilities or better connections regarding active modes or public transport. Other approaches to map 15 minutes cities are usually based on walkability and accessibility of facilities by foot [5, 6]. While the ideal city of 15 minutes allows access to all facilities by walking, current cities are far away from this goal. Hence, the approach looks at accessibility using the least CO_2 intensive mode for different facilities.

The approach relies completely on open data and open source applications and includes the computation of the benchmark as well as its web-based visualisation. Within the "MyFairShare" project itself, this approach has been applied to the areas of the project's Living Labs, namely the cities of Berlin (Germany), Jelgava (Latvia), London (UK), Sarpsborg (Norway), and Vienna (Austria), depicted in Figure 1. Fair individual mobility budgets will be determined and tested in these Living Labs in the following project steps.

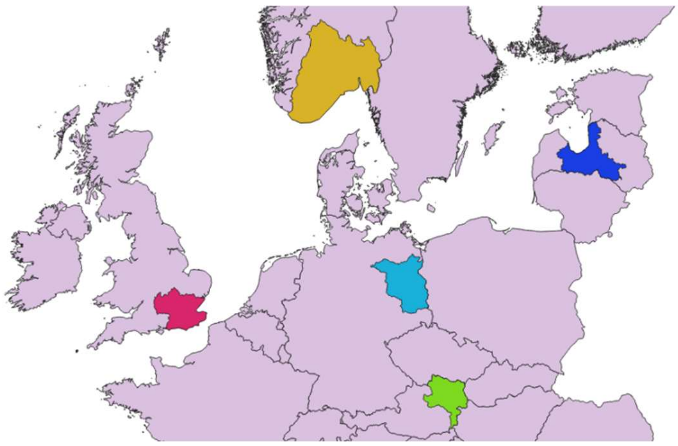


Figure 1 – Investigated areas around the Living Labs of the MyFairShare project.

The remainder is structured as following. First, an introduction into the concept of the areas of 15 minutes and the data needed to determine whether an area can be counted as such is given. Afterwards, the methodology developed for benchmarking areas as such is described, together with the used data sources. Then, the web-based visualisation of the computation results is introduced. A short discussion of the results given afterwards. The paper ends with a discussion and conclusions.

Areas of 15 Minutes and Data Needed for Benchmarking Them

The concept of cities of 15 minutes is that all places needed to be visited can be accessed using active modes of transport or using public transport within 15 minutes. When attempting to determine which areas comply with this concept, four kinds of data are needed. First, the distribution of the population within the regarded area. Second, the transport network within the area together with the public transport supply. Third, a classification of mandatory activities, i.e., activities (work, education, errand, leisure and shopping) and the frequencies these activities need to be performed by different subgroups of the population (e.g. working parents, single working parents, elderly, kids) during a week (i.e. a working parent without possibility of telework needs to go to work 5 times, shopping 2 times, fulfil 2 errands and bring kids to a place of education 2.5 times) and the kind of facilities they can be performed at. Finally, the distribution of the corresponding facilities or places within the area must be given.

Nowadays, the open digital atlas OpenStreetMap[1] (OSM) built up by volunteers, is a source of a large amount of information, though with different grades of reliability across Europe. Regarding the infrastructure for active modes of transport, as well as for the motorised individual transport, it can be assumed to be the best open data source available. Public transport (PT) connections are given in OSM as well, yet with a lower quality and usually lacking the information about schedules. For this reason, Google Transit Feed Specification (GTFS) files are used, which are available for many cities, regions and even countries in Europe.

Information about the area's population is retrieved from the GEOSTAT population data[2] (2018 version) derived from the 2011 census given in the INSPIRE grid of 1 km^2 for whole Europe. This data source is assumed to be updated in 2023.

To some part, the needed facilities can be retrieved from OSM as well. Filters are used on the OSM data to retrieve the locations of amenities of different type which are assigned to daily activities. These concrete amenities are represented as points of interest (PoIs) via the geocoordinates of their centroid. Yet, some information, especially the work places in an area, are not included in OSM. Here, only land use information can be used as a proxy for the according locations. Table 1 shows the facilities and land uses included in the benchmark.

Table 1 – Extracted activity proxies with the respective representation.

Facility Type	Proxy for	Included as
Buildings	Buildings	distinct PoIs
Schools, Colleges, Universities	Education	distinct PoIs
Banks, Post Offices, Embassies, Healthcare, Hairdresser, etc.	Errands	distinct PoIs
Kindergarten	Kindergarten	distinct PoIs
Bars, Fast Food, Restaurant, Cinema, Sports, Park, Beach, etc.	Leisure	distinct PoIs
Park+Ride	Park+Ride	distinct PoIs
Public Transport Stops	PT Halts	distinct PoIs
Rail Stations	Rail Stations	distinct PoIs
Schools	Schools	distinct PoIs
Shops, Marketplaces	Shopping	distinct PoIs
Commercial	Work Places	Area (Land Use)
Farmyard	Work Places	Area (Land Use)

1 https://www.openstreetmap.org/

2 https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/population-distribution-demography/geostat

Industrial	Work Places	Area (Land Use)
Residential	Living	Area (Land Use)
Retail	Work Places	Area (Land Use)

The number of obtained facilities of a certain type as well as the area covered by the respectively regarded land use types is afterwards collected for all cells of the 1 km^2 grid.

Methodology Applied for Benchmarking Areas

Given the named input data, the regions of interest are determined in the first step. To avoid boundary issues as well as for including sub-urban and rural areas into the investigation, wide areas beyond the borders of the MyFairShare Living Lab cities were chosen. Table 2 compares the Living Labs' original sizes and the respectively selected areas. The surrounding areas were chosen based on NUTS regions, including all NUTS 2 regions near to the respective Living Lab city.

Table 2 – The sizes of the Living Lab and the size of respectively chosen area.

Living Lab	City size	Size of the chosen area
Berlin	891.7 km^2	30546.34 km^2
Jelgava	60.56 km^2	21188.2 km^2
London	1572.03 km^2	24171.72 km^2
Sarpsborg	405.61 km^2	62373.20 km^2
Vienna	414.82 km^2	23576.23 km^2

For these areas, the population grid is extracted as well as the respective area from the OSM database. For retrieving the latter, it is usually convenient to extract a complete country and filter the area of interest from this data, e.g., using the tool osmconvert. The information about facilities and land use as well as the road network is extracted from the resulting OSM map using own scripts, available as open source. By doing this, database tables containing the road network, the facilities as points of interest, and the land use information given as (multi-)polygons are build. In addition, necessary GTFS data needed for computing travel times using the public transport within the area is collected. In some cases, no single source for GTFS data is available or does not cover the complete area. In such cases, different GTFS sources were joined.

In the next step the travel times between the centres of the population grid's cells were computed using the accessibility computation tool "UrMoAC" ("Urban Mobility Accessibility Computer")[7], which is available as open source[3]. UrMoAC computes different accessibility metrics between a set of sources and a set of destination along a given, mode-specific road network and supports public transport schedules given in the GTFS format. Even though UrMoAC has proved to be applicable to large scale areas with sources and destinations given on a disaggregated level of single buildings, it

[3] https://github.com/DLR-VF/UrMoAC

was decided to use the centres of the population grid for different reasons. First, the distribution of the respective population within a 1 km^2 grid cell is unknown and can be derived from OSM data only to some degree and only within some areas. Second, using single buildings for such areas would yield very big result sets. Even though being aggregated to a 1 km^2 grid, the current result data sets are several Gigabytes in size and as such already cumbersome to handle.

The result of the accessibility computation is a distance and travel time matrix for each of the regarded modes of transport between all cell centres of the respective grid of a Living Lab. Here, the following modes of transport are distinguished: walking, cycling, public transport and motorised individual traffic. The latter would usually need the real travel times of motorised individual traffic as OSM only contains the allowed velocities on the roads. In principle, UrMoAC is capable to load additional travel times, but this information is not available for all Living Labs. It is assumed that this lack of data can be neglected herein as motorised individual transport is the mode of transport that shall be avoided due to its highest CO_2 emission per passenger in comparison to the other regarded modes of transport and is thereby always the worst option. The used velocities per mode are given in Table 3.

Table 3 – Maximum speeds used per mode.

Mode	Max. Speed
Walking	3.6 km/h
Bicycling	12 km/h
Public Transport	schedule from GTFS
Passenger Car	min(200 km/h, allowed speed on respective road)

Not all connections between all cells are regarded when computing the accessibility measures per mode. Instead, only the connections starting at inhabited cells to all cells that are either inhabited or have at least one facility are computed.

To compute the accessibility of the mandatory activities, one needs to define how the number of facilities per grid cell is calculated. Furthermore, it needs to be defined how many of these facilities a person needs to be able to reach to guarantee a satisfactory selection of different functions these facilities can take. Table 4 defines how these numbers are computed.

Table 4 – Activities, calculation of activities per grid cell and chosen number of facilities for mandatory activities.

Mandatory activity	(Proxy for) Number of facilities per grid cell	Number of facilities that need to be reached in later calculations.
Work	Number of leisure, errand and education PoIs since each of them also defines work places. Additionally, the areas of commercial and industrial land use are taken as possible work	1000 (the number is relatively high to guarantee that different types of work places can be reached to guarantee that a large number of people is able to reach a suitable work PoI)

	places. Since there might be many jobs of the same kind at these facilities, the number of square meters is divided by 400 to get to a number of different possible work places per area.	
Education	Number of kindergarten, school and university PoIs per grid cell.	3 (Since in a 15 minute city setting, the schools and kindergartens might not be chosen by the parents anymore but are assigned due to the area, only a small number of places was taken here)
Shopping	Number of shops and marketplace PoI per grid cell.	2 (Just shopping facilities for basic goods are considered, so only a small number of shops was taken)
Leisure	Number of Leisure PoIs per grid cell defined as in Table 2	30 (To be able to reach different kind of leisure activities, the number was set to 30 to give people a choice of different activities)
Errands	Number of errands PoIs per grid cell defined as in Table 2	10 (To guarantee that different facilities for errands are included, the number was set to 10)

To calculate the travel time by the four main modes – walking, bicycling, public transport, and an own motorised vehicle – to the mandatory activities, the grid cells were ordered by travel time to that cell in the given mode. The travel time to the mandatory activity was defined as the travel time to the cell where the threshold of number of PoIs of that activity was first reached. In addition to the 4 main modes, accessibility by bike & ride (B&R) and park & ride (P&R) was included in the following way. From each cell, the nearest cell including a rail or subway station was located. The travel time was then calculated as the travel time by public transport from that cell to the assigned number of facilities per mandatory activity and the travel time to the cell containing the public transport station from the starting cell by bike or car was added to that travel time.

Visualisation and User Interaction

Besides developing and computing the benchmark, a web-based visualisation tool has been developed in the scope of the project that allows to investigate the benchmark results in an interactive manner. Figure 2 shows a screenshot of the tool.

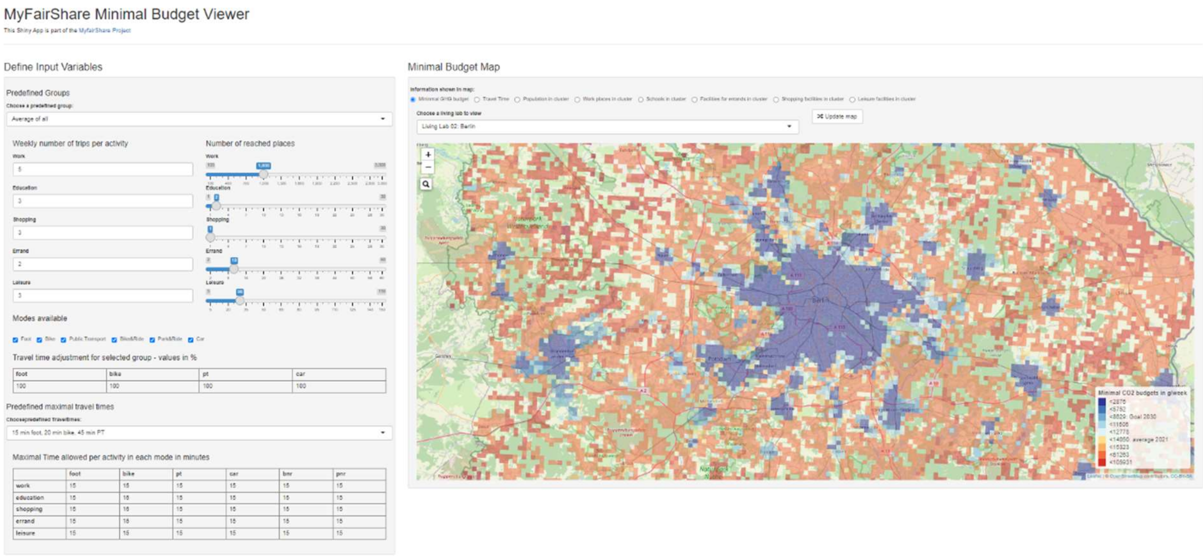


Figure 2 - The MyFairShare visualization tool.

The tool allows for computing different scenarios. One can choose the number of times an activity is performed per day. Also, predefined groups like kids, single parents or elderly can be chosen which predefines those numbers. In addition, the number of facilities that need to be accessible can be chosen, the possible modes and time per mode and activity can be defined in the panel on the left-hand side. On the right-hand side, a map is shown, giving one of: a) minimal CO_2 needed to perform all mandatory activities, b) the travel time needed to perform these activities with a minimal amount of CO_2, as well as c) the number of facilities per cell for the five activities per grid cell.

Selected Results

In the following, the first results of using the developed benchmark for evaluating the Living Labs using the Living Lab Vienna (Austria) as an example. Figure 3 shows the computed benchmark for the city of Vienna for the active modes of transport walking and bicycling. Grid cells with no population are grey. It gets obvious that even in a major city like Vienna one can hardly find areas where all necessary facilities can be accessed by walking within 15 minutes, see Figure 3 a). It gets possible when using a bicycle (Figure 3 b), but this holds as well only for the inner-city areas. At the boundary, the index drops fast to a value of 45-60 minutes needed to access all necessary facilities.

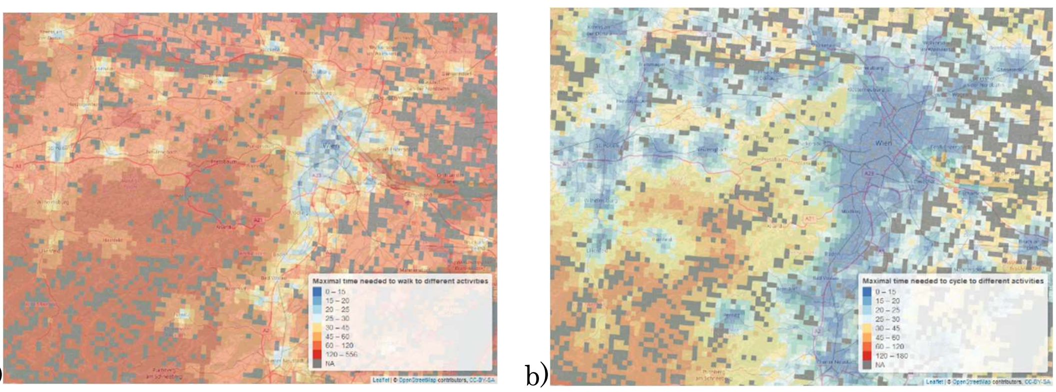
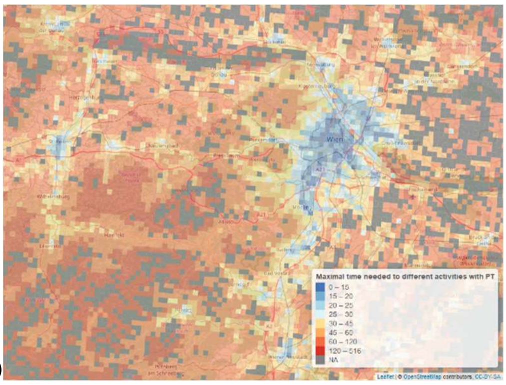
a)  b)

Figure 3 - Travel times needed to access all necessary facilities for a) walking and b) bicycling.

Even when using public transport (see Figure 4 a) or an intermodal combination of an own car with public transport (see Figure 4 b), only the inner-city areas fulfil the 15-minutes threshold.

a)


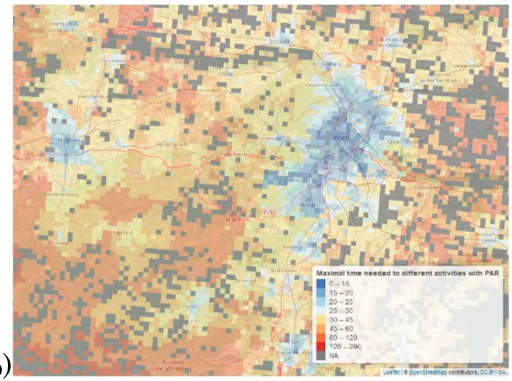
b)


Figure 4 - Travel times needed to access all necessary facilities for a) public transport and b) intermodal combination of public transport and a private vehicle.

Overall, as shown in Figure 5, only few regions within the city of Vienna up to now can be named "15 minutes area". The image shows, per grid cell, which mode of transport is needed to access all necessary facilities within 15 minutes of travel time. As already visible in the prior figures, only a few cells allow this when walking and only within the inner-city area all needed facilities can be accessed by bike in 15 minutes. Public transport, even in combination with a private car, extends this area only and only at some places. In the majority of the shown area a car is needed to access all facilities in 15 minutes. In some remote areas, even a car will not enable inhabitants to reach all facilities within 15 minutes (dark red).

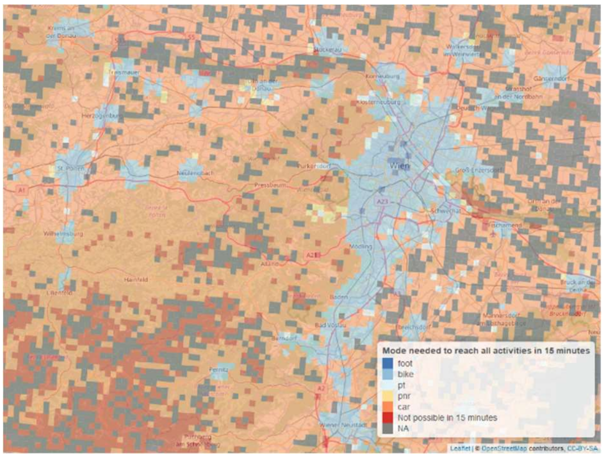
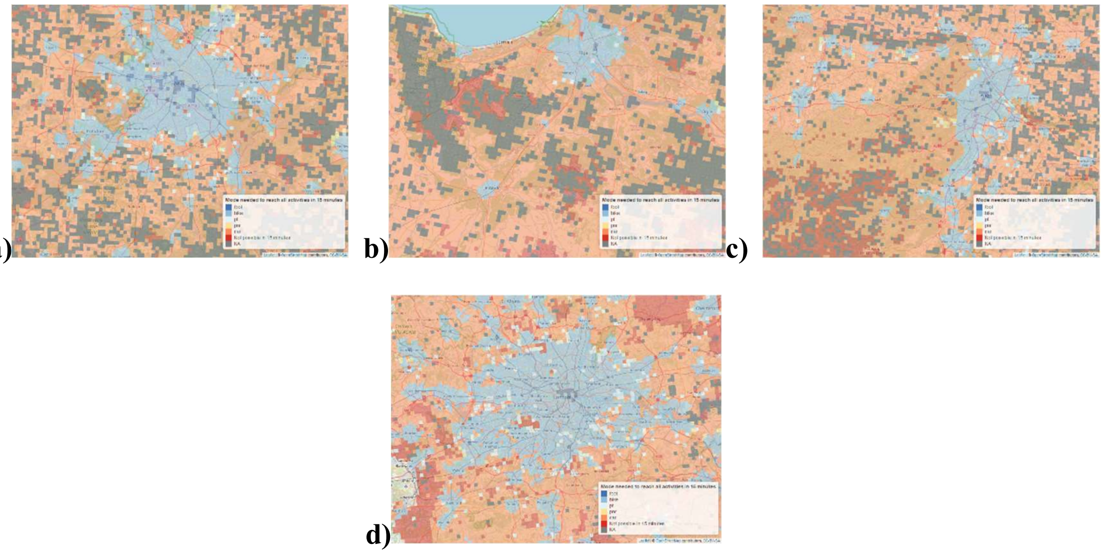


Figure 5 – The respectively most sustainable (in terms of CO_2 emissions) mode of transport applicable for accessing all necessary facilities in 15 minutes.

This holds with only minor differences for all of the project's Living Labs computed so far. Figure 6 shows which modes of transport are necessary to access all needed destinations in 15 minutes for the cities of Berlin, Jelgava (with Riga) and Vienna, in accordance with Figure 5. *The final paper will include the city of Sarpsborg additionally.*



a) b) c) d)

Figure 6 – The respectively most sustainable (in terms of CO_2 emissions) mode of transport applicable for accessing all necessary facilities in 15 minutes within a) Berlin, b) Jelgava/Riga, c) Vienna, d) London.

As the major scope of the project is the derivation of fair CO_2 budgets, we look at the respectively minimal CO_2 amounts needed to access all necessary activities from a single cell, shown in Figure 7.

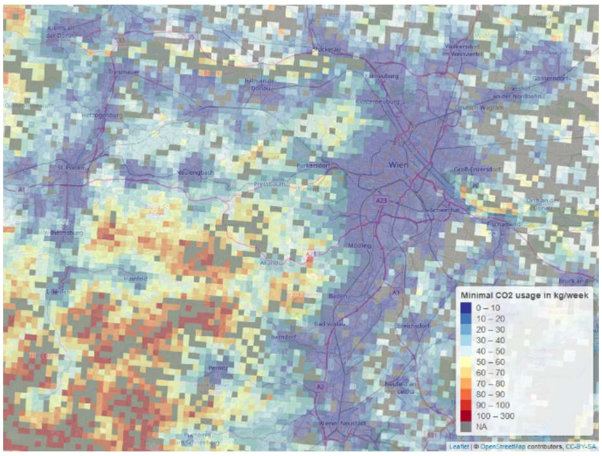


Figure 7 – CO_2 emissions in kg per week generated when accessing all necessary facilities using the respectively most sustainable mode of transport.

Conclusions

We presented an open source solution for benchmarking areas for being compliant with the concept of a city of 15 minutes. For this purpose, the locations within the respective areas were determined from the freely available OpenStreetMap database, first. This data has been then merged with the information about the population within this area into a grid with cells of 1 km^2 size, conforming with the INSPIRE standard. Finally, accessibility measures between the cells' centroids have been computed for determining which parts of the respective may be called "areas of 15 minutes" where all necessary activities can be accessed using active modes within 15 minutes.

The described approach relies completely on open source software and freely available data. It is, to a wide degree, applicable for the complete area of the European Union. Only the needed GTFS data is not available for all European regions. The information included in the OpenStreetMap database is sufficient for many activity types, yet a better source of information about the distribution of working places would improve the quality of the benchmark. Though, no such data set seems to exist for Europe in a sufficient resolution.

The next steps within the project will target at improving the evaluation and interpretation of the obtained results, especially at pointing out which improvements in the traffic options and the distributions of activity locations yield in biggest impact in terms of reducing the necessary CO_2 budget.

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