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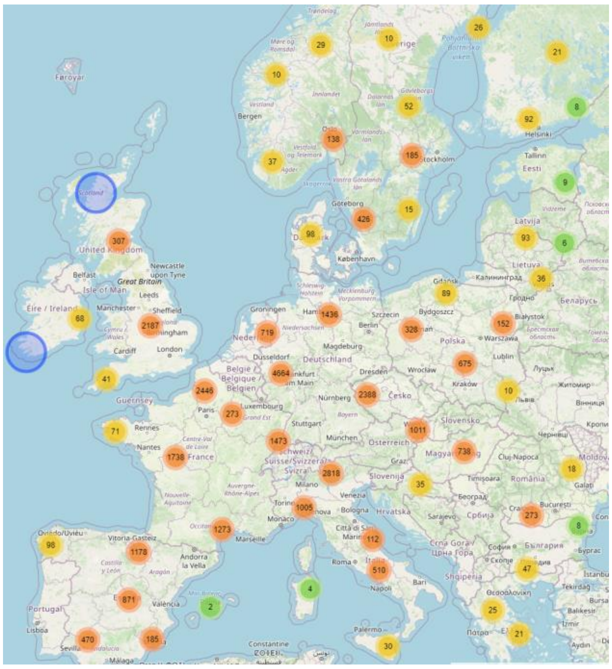

Truck Stop Locations in Europe

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Truck Stop Locations in Europe

Project coordination

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Summary

Introduction and Motivation

A significant fleet of electric trucks is expected to be on the roads in Europe within a few years to curtail CO_2 emissions from commercial vehicle operation. A large share of freight transport activity stems from heavy-duty vehicles in long-distance operation. However, the limited range of the battery electric trucks will make high power fast charging necessary during short breaks in long-distance or regional transport and medium power charging during longer stops.

A coordinated deployment of charging infrastructure is required to successfully roll out heavy-duty battery electric vehicles (HD-BEV). The locations of future charging infrastructure should ideally be chosen so that it does not interrupt current operation pattern, hence it should optimally match current locations of longer stops for many vehicles. To identify such locations, an analysis of stop locations of current commercial vehicles currently on road in Europe is required. The present study analyses such locations based on detailed information on logistics activity collected by seven OEM in Europe.

Data Sets and Aggregation

The truck stop location data contains stop locations from about 170,000 trucks in regional operation, i.e. 90% of truck locations are within a 200 km radius of the truck's home base, and about 230,000 trucks in non-regional, i.e. long-haul, operation.

The raw data on a total of about 750,000 truck stop locations was obtained individually from the seven OEM. For clustering, the DB scan algorithm was used. Stop locations with up to 200 m distance were aggregated. Only clusters with stop locations from at least three different OEMs and at least 100 stops per year were kept in the final data set. The final data on aggregated truck stop locations contains 31,145 aggregated truck stop locations in long-haul and 4,023 truck stop locations from trucks in regional operation (see Table 1 for summary statistics on the data sets).

Table 1: Summary statistics of truck stop location data.

Number of trucks in operation rounded to thousands.

	Long-haul operation	Regional operation
Number of trucks involved	230,000	170,000
Number of locations before aggregation	550,000	194,000
Number of locations after aggregation	31,145	4,023
Countries in Europe covered	35	23
Mean number of stops year	1678	1271
Standard deviation number of stops year	3615	3044
Median number of stops year	596	455

Source: Own compilation.

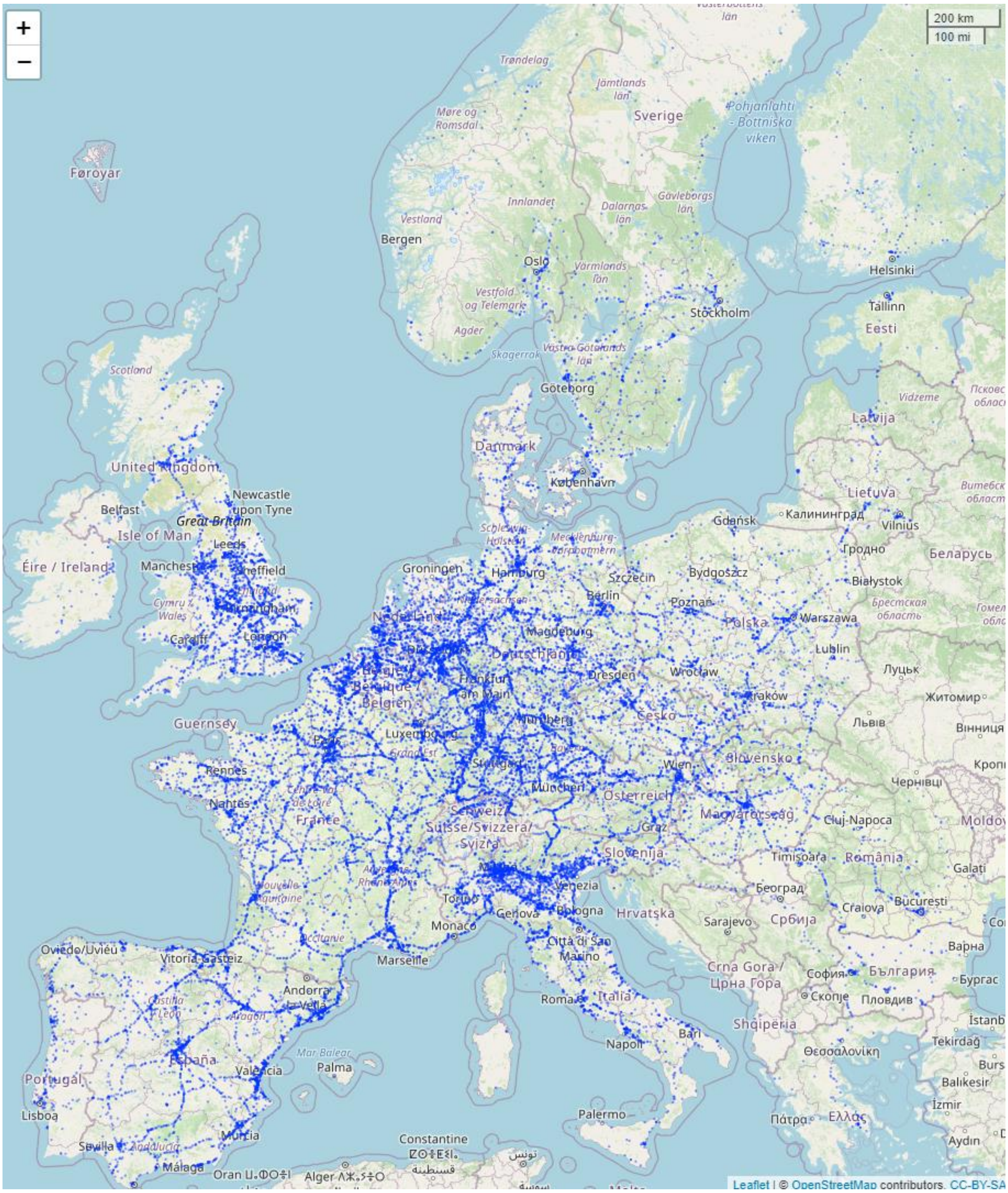
The number of trucks stops per location differ widely between the locations. Typical number of stops per year per location in the data set are around 400 – 600 truck stops per year (median 596 stops in long-haul locations and 455 stops in regional locations). However, the distribution of stops is heavily skewed: the top ten percent most frequented locations contain about half of the total number of stops, both for regional and long-haul trucks.

Map of Truck Stop Locations

The truck stop locations are distributed over all of Europe just as trucks are operated across the whole European continent. The long-haul stop locations cover 35 countries and the regional stop locations 23 countries.

Figure 1: Aggregated long-haul truck stop locations.

Shown are all 31,145 long-haul truck stop locations as small filled blue circles with country and regional boundaries. Filling is partly transparent such as darker blue is from an overlap of several circles.



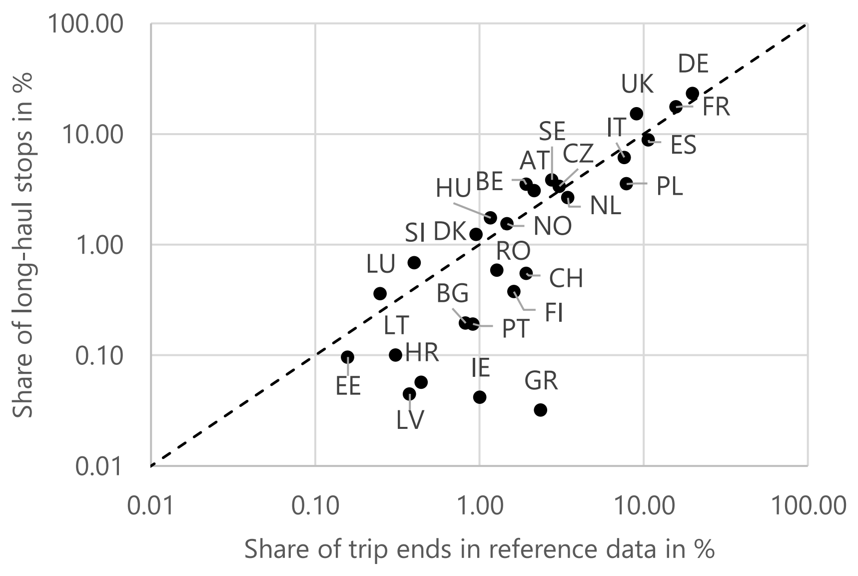
Source: Own illustration with map background from Open Street Map.

The truck stop locations are concentrated around highly populated areas in central Europe. The locations are denser around important industrial areas and major cities – e.g. in Northern Italy, Paris, Greater Manchester, Paris, Berlin, or Frankfurt – and follow main European roads. The locations of trucks in regional operation are mostly very close to locations of truck in long-haul operation (not shown in Figure 1). About 10 % of regional cluster locations are of aggregated regional truck location clusters are more than 600 m away from long-haul truck locations. Approximately 5% of the regional stop locations are more than 1 km away from existing cluster center away. Accordingly, charging points for regionally operating vehicles will also be useful for long-haul operation vehicles.

Representativeness

The stop locations cover all of Europe. However, to base infrastructure decisions on these locations, an assessment of its representativeness is required. Such an assessment is difficult as little is known about actual stop locations of the full heavy-duty truck stock in Europe. Several indicators can be used to compare the distribution of stop locations to other variables. First, seven major OEM are covered, indicating high vehicle stock coverage. Second, all countries in Europe are covered in the long-haul data and many in the regional data. Third, high correlation of number of stops per country and number of locations per country. Fourth, comparing the share of stops by country in the data to the share of trip ends by country as derived from the ETISplus data set (Szimba et al. 2013), we find good representativeness except for some smaller countries for long-haul (cf. Figure 2) and limited representativeness for regional truck stop locations.

Figure 2: Share of stops in long-haul and reference data by country.



Source: Own Compilation.

Some countries are underrepresented, especially from Eastern and Southern Europe such as Greece, Latvia, Bulgaria, Portugal, Hungary, or Lithuania. Again, coverage is good for central western and northern Europe.

Types of Truck Stop Locations

As trucks stop at many different types of locations, such as rest areas, industrial areas, ports, company sites, logistics hubs, and many others, a targeted deployment of charging infrastructure also requires an understanding of the distribution of location types.

As many truck stop locations follow major motorways, the distance to the nearest motorway can be used as a first simple criterion to characterize truck stop locations. Among the most frequently visited locations, 4% are within 200 m street distance from a motorway. They are likely to be rest areas directly located at or along the motorway. A quarter of the most frequented locations reach the motorway within one kilometer. About 40% of the locations have distances between 1 and 5 km to the nearest motorway, the remaining locations with a longer distance are most likely to be logistics centers off motorways or company locations.

A second approach uses classified objects in the vicinity of the truck stop locations. We used the land use categories of the stop locations from open street map (cf. https://www.openstreetmap.de/) and searched for all classified objects within a 200 m radius of the stop locations using the here API (Here, 2021). For a noteworthy share of locations, this approach does not yield any additional information or categorization. From the remaining pieces of information some locations can be clearly classified as rest areas, company locations, or ports but a strong uncertainty remains. However, some general tendencies can be observed: About one third to one half of the locations are rest areas close to motorways, about one quarter to more than one third are company sites or logistic hub locations, and finally, about 1 – 5% are ports and ferry terminals (cf. Table 2). However, for a noteworthy share of up to half of the locations, the specific type of location remains unclear from the present analysis.

Table 2: Types of truck stop locations in long-haul data.

Category	Approximate share
Rest area	30 – 50%
Companies & Logistics hubs	25 – 45%
Ports	1 – 5%
Unclear	< 50%

Source: Own compilation.

To put these numbers into context, there are about 75,000 highway km (counting both directions together) in Europe which implies several thousand rest areas if they are on average about 35 km apart. Additionally, there are about 330 main sea ports in Europe (as part of the TEN-T network). Note, however, that ports are often large commercial areas and more than a dozen locations can be easily be located at one port. For example, the port of Rotterdam is about 40 km long with even more road km.

Stop Durations

Stops are typically either rather short with less than three hours or longer than eight hours. More specifically, the mean share of long-haul stops per location with 30 min to one hour duration is 35% and 24% between one and three hours duration such that, on average almost 60% of stops are shorter than three hours. Only a few stops are between three and eight hours duration. The next large group of stops are between 8 and 23 hours duration and only 4% are, on average, longer than 23 hours. Thus, on average about 60% of stops are shorter than 3 hours and about one third is longer than eight hours. In general, these two groups (shorter than three and longer than eight hours) almost always cover the majority of stops. The mean share of stop durations are very similar for regional operation, but very short stops of less than one hour are more frequent (with 44%) and longer stops of 8 – 23 h duration less frequent (24%).

If durations are further grouped into short stops of up to three hours, intermediate stops of 3 – 8 h and long stops of more than 23 h, then hardly any stops are of intermediate stop duration. Figure 3 shows the two-dimensional distribution of short and long stops. For almost all individual locations, the shares of short and long stops sum up to almost 100% indicating that stops of intermediate durations play hardly any role, even on the level of individual locations. Comparing long-haul and regional truck operation, long stop durations are more common for long-haul trucks.

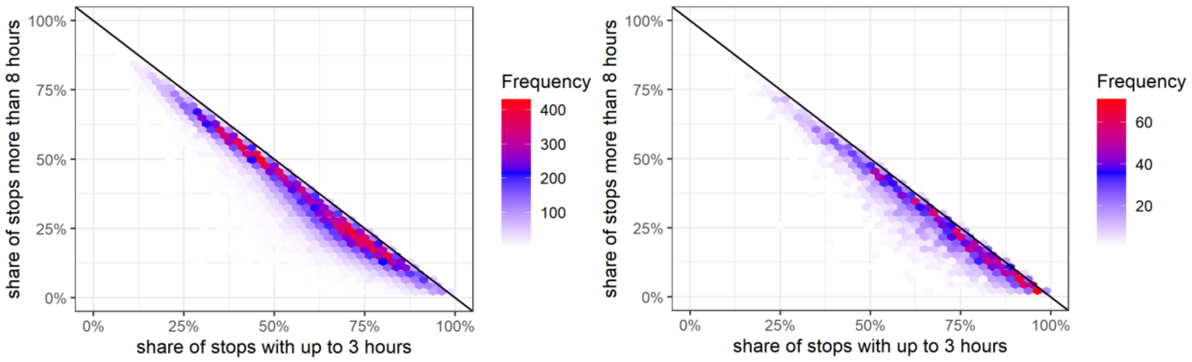
Table 3: Mean share of duration classes of truck stops.

Truck operation \ Duration	½ - 1 h	1 – 3 h	3 – 8 h	8 – 23 h	23 – 44 h	>44 h
Long-haul truck stops	35%	24%	6%	31%	2%	2%
Regional truck stops	44%	23%	6%	24%	1%	3%

Source: Own compilation.

Figure 3: Distribution of long and short stops.

Shown is a two-dimensional histogram of short stops (up to three hours) and long stops (more than eight hours). Truck stop locations in long-haul operation (left) and regional operation (right).



Source: Own calculation.

Distance to Potential Public Charging Locations

A first analysis of potential public charging locations was performed. Selecting the 10% most visited locations per country from the long-haul data set leads to a few hundred locations for large countries (Germany, UK, France) and a few dozen locations for most of Europe and less than ten locations for smaller countries or those with limited truck location data (Luxembourg, Ireland, Latvia, Romania, Croatia, Estonia, Bulgaria). The mean distance to all other truck stop locations from these potential first public charging stations is typically 2 – 5 km. The average distance to the nearest potential public charging station is similar when the number of potential public charging stations is further limited to those with at least one third of stops shorter than one hour duration.

Discussion and Conclusion

The present report summarizes a unique data set with truck stop locations based on driving of about 400,000 trucks in Europe and contains more than 30,000 aggregated truck stop locations. The long-haul data covers all of Europe and the regional truck data mainly Western Europe. In total, Western and Northern Europe are well represented in the data, but coverage is not optimal for Eastern Europe and parts of Southern Europe. Thus, the data set is rich and unique, and the data covers Europe fairly representatively, especially if the number of locations per country is predetermined. Furthermore, the rank of locations within a country by the number of stops at a given location is probably close to reality although the absolute number of stops in the data might be misleading for some countries.

Please note that the identified locations are suitable for establishment of charging infrastructure from a logistics point of view. Exactly which to use and how many charging points each should have is an aspects that requires additional analysis and an evaluation of additional criteria such as available electricity grid power, existing local initiatives, already present DC electric passenger car charging infrastructure, and many more. The present data alone is not sufficient to decide about high power fast chargers placement, but it is an important first step.

In summary, the present data set is a unique and useful source to plan charging infrastructure deployment for battery electric trucks, especially in long-haul operation.

1 Introduction

A significant fleet of electrical trucks is expected to be on the roads in Europe within a few years to curtail CO_2 emissions from commercial vehicle operation (ACEA and T&E, 2021). A coordinated deployment of charging infrastructure is required to successfully roll out these vehicles.

About 12% of CO_2 emissions from road transport are attributable to light-duty vehicles and medium-duty vehicles as well as 26% from heavy-duty vehicles and busses (EC, 2018). Although vehicle stock is dominated by cars, the high annual mileage and high fuel consumption of heavy-duty vehicles makes them important in road transport CO_2 emissions.

The locations of future charging infrastructure should ideally be chosen as to optimally match current locations of longer stops for many vehicles. To identify such locations, an analysis of stop locations of current commercial vehicles on road in Europe is required. The present report describes and analyses a data set containing exactly such locations based on detailed information on logistics activity collected by seven OEM in Europe. The aim of the present study is to analyse truck stop locations and to identify locations where shared charging infrastructure could be located. Accordingly, locations on public ground or locations used by single vehicle operators are out of scope for the present study although they will also be important charging of electric trucks.

The outline of this report is as follows. Chapter 2 describes the data collection and data aggregation method. Chapter 3 contains the results on coverage of countries in Europe (Section 3.1), representativeness of the data (section 3.2), an analysis of stop locations (section 3.3) and results on the distribution of stop durations (section 3.4). We close with a discussion and conclusions in chapter 4.

2 Data and Methods

2.1 Data Collection and Processing

Seven truck OEM provided GPS coordinates of truck stop locations. Locations from all trucks in VECTO vehicle classes 1-16 (GCW >= 7.5t) were included. Two groups of vehicles were distinguished: vehicles in "regional" operation are vehicles for which 90% of its geo-coordinates are within 200 km from the vehicle's home-base. "Home-base" is the most common last destination per day of a vehicle. Vehicles that are not in regional operation are considered as "long-haul" operation vehicles. Data was provided separately for regional and long-haul vehicles.

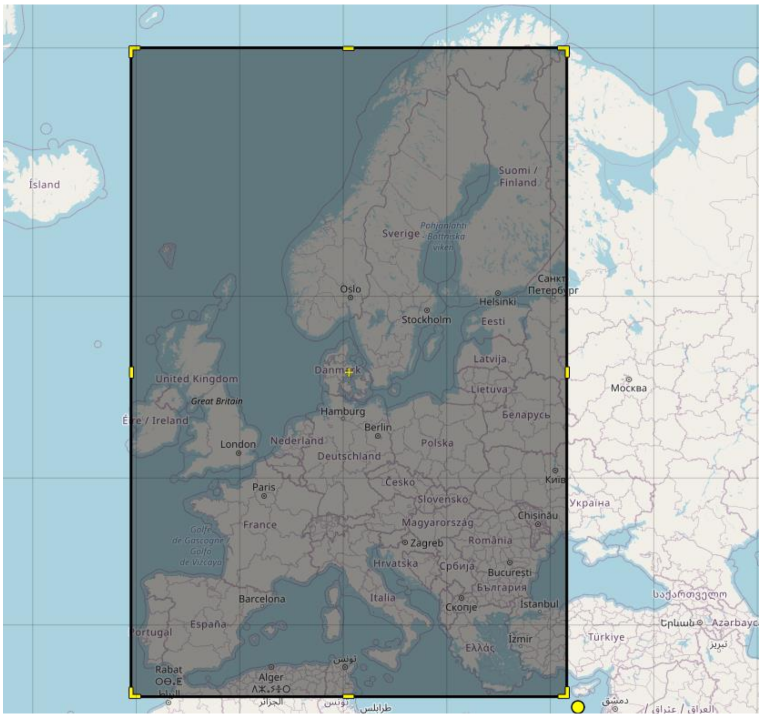
The data provided by each OEM was generated by extraction of on year of logged GPS positioning data retrieved by their respective fleet management system. Stop locations were identified by extracting positions with standing still of the vehicle for more than 30 minutes. Prior to delivery to the authors, the vehicle home-base was removed and data was appropriately aggregated to ensure compliance with the General Data Protection Regulation (GDPR) and competitive law.

Each OEM collected the stop duration in classes "½ – 1 hour", "1 – 3 hours", "3 – 8 hours", "8 – 23 hours", "23 – 44 hours", and "more than 44 hours". The OEMs aggregated locations within a radius of 10 – 100 m (varying between OEM). To limit the analysis to locations with many stops, OEMs provided only data with at least 10 stops per year per location.

As the focus in the present data is on Europe, only locations in the area covered between 10.5° Western longitude and 31.6° Eastern longitude as well as 34.5° to 70° Northern latitude were kept (see Figure 4).

Figure 4: Geographical coverage.

Only locations within the marked area were considered for further analysis.



Source: Own compilation and open street map background.

2.2 Aggregation

This data was sent to the authors as an independent third party for further aggregation and analysis. We checked consistency of the data sets and variables and aggregated the individual OEM data to larger clusters. For clustering, the DB scan algorithm as implemented in the `dbscan` package (Hahsler et al., 2019) of the R statistical software was used. The maximal distance to form clusters (`epsilon` parameter) was set to 200 m, the minimal number of points in a cluster (`minPts` parameter) was set to 3 and border points were included. The algorithm forms new clusters and only cluster meeting the following conditions were kept:

1. Stop locations from at least three different OEMs are in the cluster.
2. The cluster has at least 100 stops (sum over all time classes) per year.

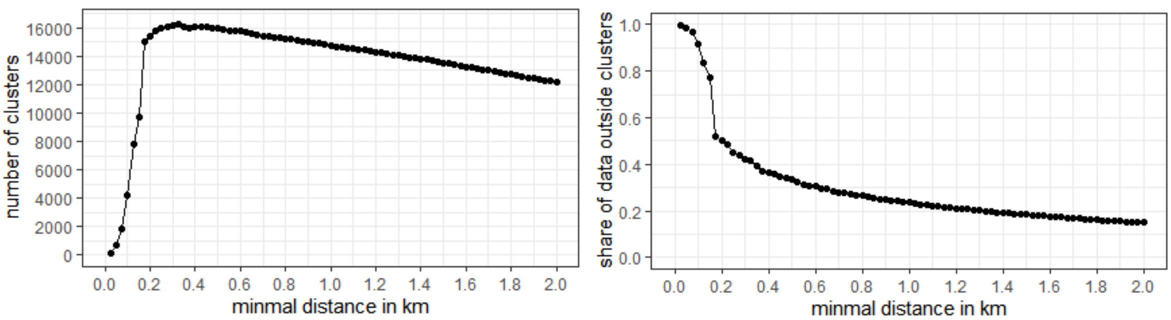
Only cluster meeting these criteria were kept and the mid point of each cluster was calculated as the average of the geo coordinates of the cluster members. For the long-haul data, the OEM individual data contains approx. 550,000 stop locations. During the aggregation procedure, about 150,000 locations (or 28%) are noise points, outside any cluster. About 80,000 locations (or 14%) are part of clusters but with less than three OEMs present. The remaining 320,000 locations (or 58%) belong to 34,000 clusters with at least three OEMs and about 31,000 of these cluster have at least 100 stops per year.

As the focus is on transport between European countries, data was kept for all EU member countries as well as the UK, Norway, Switzerland, Albania, Bosnia and Herzegovina, Liechtenstein, Macedonia, Monaca, and Moldova. Geo locations from Ukraine, Turkey, Belarus, and Russia have been deleted from the data.

The choice of 200 m clustering radius in defining the clusters has an effect on the final number of clusters and the share of locations that are inside clusters and thus potentially kept in the data set (a location even with a large number of stops is not kept, if trucks of only one or two OEMs are present). Figure 5 shows the number of clusters and the share of locations outside clusters as a function of clustering radius for a subset of the regional data irrespective of the minimal number of OEMs present or the minimal number of stops.

Figure 5: Effect of clustering radius.

Number of clusters and share of data outside clusters as a function of clustering radius for a subset of the regional data irrespective of minimal number of OEMs present or the minimal number of stops.



Source: Own compilation.

From the harmonized input data, six data sets of clustered stop locations were derived: all clusters from long-haul trucks, all clusters from regional trucks, all clusters from merged long-haul and regional trucks as well as only the location with highest traffic per country from these three cluster location data sets. For the merged long-haul and regional truck data, the individual truck stop locations from the OEM data were joined and the clustering algorithm applied to the full data set (instead of simply merging the locations from the clustered long-haul and regional trucks).

In a second step, only the best locations per country were kept. As the truck age and the availability of GPS devices in trucks varies across Europe, some countries contain more locations that other not because there are more trucks on the road but because there are more trucks with GPS devices on the roads. The number of locations per country was taken from (ACEA and T&E, 2021) which suggest a number of important truck stop locations for charging in the individual EU member states and the UK (Norway and Switzerland were added by the authors) based on truck sales, truck stock and GDP per capita. The number of extracted top locations per country is summarised in Table 4. The locations were chosen with the highest number of total truck stops according to the OEM truck data.

Table 4: Number of potential charging locations per country.

The number of potential locations from (ACEA and T&E, 2021), but Norway and Switzerland added.

Country	Locations	Country	Locations	Country	Locations	Country	Locations
Germany	3750	Switzerland	400	Slovakia	150	Croatia	20
UK	2450	Belgium	300	Ireland	100	Bulgaria	10
France	1500	Sweden	300	Luxembourg	100	Estonia	10
Italy	900	Czech Rep.	250	Portugal	100	Greece	10
Netherlands	900	Denmark	250	Slovenia	100	Cyprus	1
Spain	750	Lithuania	250	Finland	100	Malta	1
Poland	550	Norway	250	Latvia	50		
Austria	400	Hungary	150	Romania	50		

Source: (ACEA and T&E, 2021) and own calculations.

2.3 Final Data Sets

The following data sets were obtained as comma separated values (CSV) and as html maps:

1. All long-haul stop locations in Europe
2. Top long-haul stop locations in Europe by country
3. All regional stop locations in Europe
4. Top regional stop locations in Europe by country
5. All long-haul and regional stop locations merged in Europe
6. Top long-haul and regional stop locations merged in Europe by country

Each data set contains the following variables

- `Latitude`: mean GPS latitude of the cluster locations
- `Longitude`: mean GPS longitude of the cluster locations
- `Avg. number of stops per day (30-60 mins)`: Mean number of stops per days over a period of one year with stop duration between 30 and 60 minutes
- `Avg. number of stops per day (1-3 hrs)`: Mean number of stops per days over a period of one year with stop duration between one and three hours
- `Avg. number of stops per day (3-8 hrs)`: Mean number of stops per days over a period of one year with stop duration between three and eight hours
- `Avg. number of stops per day (8-23 hrs)`: Mean number of stops per days over a period of one year with stop duration between 8 and 23 hours
- `Avg. number of stops per day (23-44 hrs)`: Mean number of stops per days over a period of one year with stop duration between 23 and 44 hours

- `Avg. number of stops per day (>44 hrs)`: Mean number of stops per days over a period of one year with stop duration with more than 44 hours
- `Avg. number of stops per day`: mean total number of stops per day as the sum of the individual time classes.

Three of the six data sets, those with the stop locations by country, also contain the `country` of the stop location as additional variable.

Summary Statistics

The truck stop location data contains stop locations from about 170,000 trucks in regional operation, i.e. 90% of truck locations are within a 200 km radius of the truck's home base, and about 230,000 trucks in non-regional, i.e. long-haul, operation. The final data on aggregated truck stop locations contains 31,145 aggregated truck stop locations in long-haul and 4,023 truck stop locations from trucks in regional operation (see Table 1 for summary statistics on the data sets).

Table 5: Summary statistics of truck stop location data.

	Long-haul stop locations	Regional stop locations
Number of trucks involved	230,000	170,000
Number of locations before aggregation	550,000	194,000
Number of locations after aggregation	31,145	4,023
Countries in Europe covered	35	23
Mean number of stops year	1678	1271
Standard deviation number of stops year	3615	3044
Median number of stops year	596	455
Share of locations with > 1000 stops/year	30%	20%
Share of locations with > 10 stops/day	10%	6%

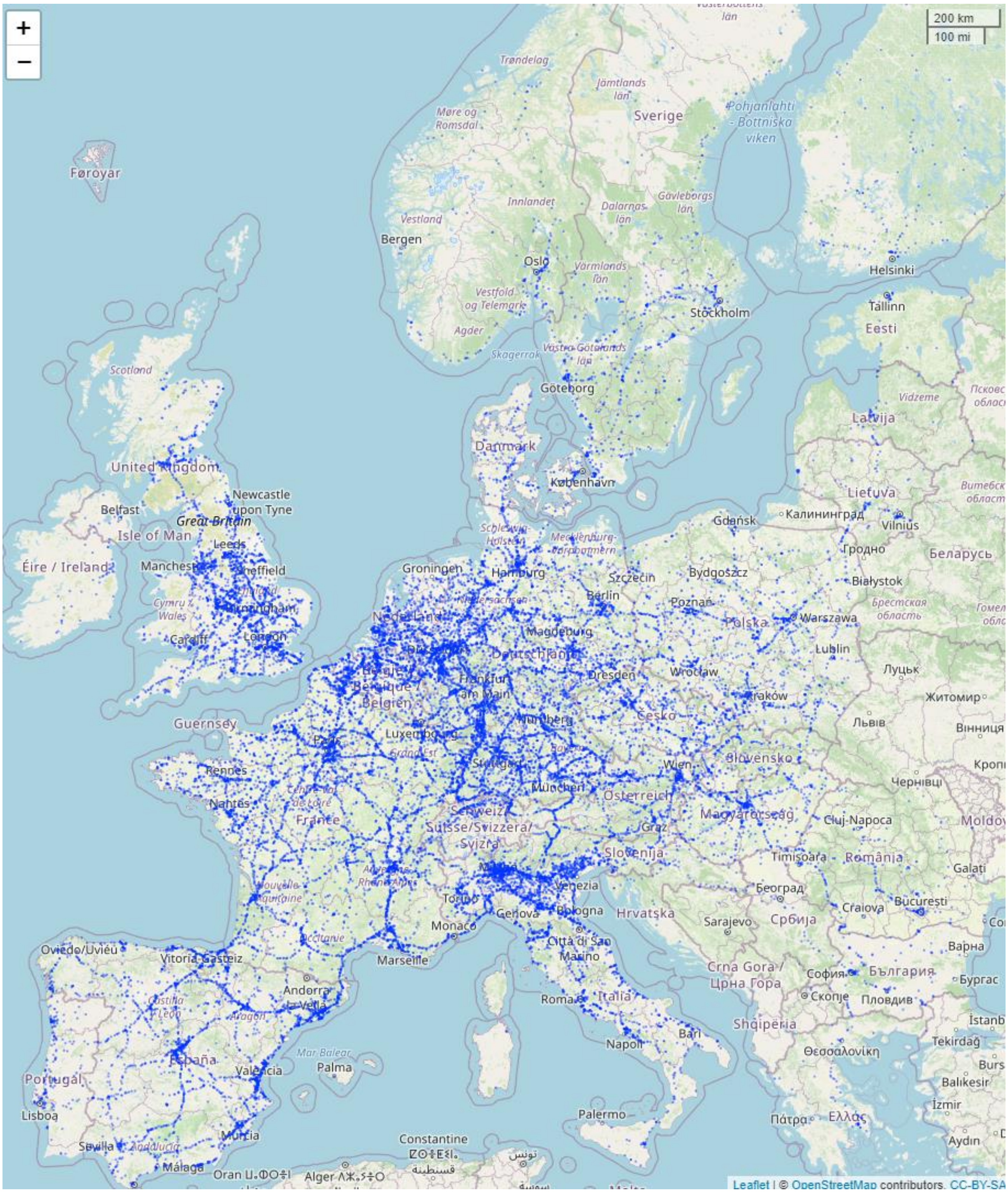
Source: Own calculations.

The number of trucks stops per location differ widely between the locations. Typical number of stops per year per location of the locations in the data set are around 400 – 600 truck stops per year (median 596 stops in long-haul locations and 455 stops in regional locations). However, the distribution of stops is heavily skewed: the ten percent most frequented locations contain about half of the total number of stops, both for regional and long trucks.

The truck stop locations are distributed over all of Europe just as trucks are operated across the whole European continent. The long-haul data stops cover 35 countries and the regional locations 23 countries.

Figure 6: Aggregated long-haul truck stop locations.

Shown are all 31,145 long-haul truck stop locations as small filled blue circles with country and regional boundaries. Filling is partly transparent such as darker blue is from an overlap of several circles.

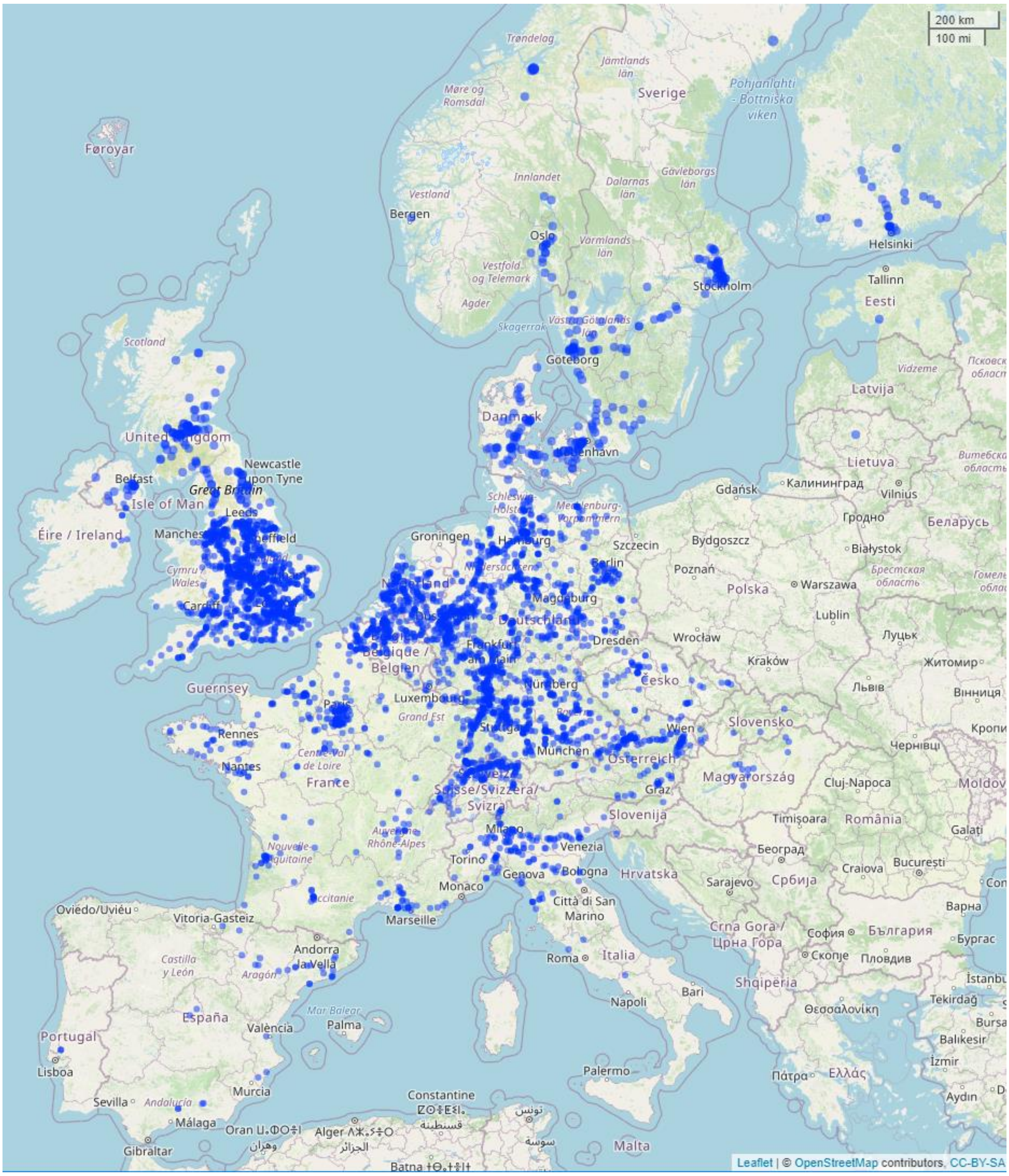


Source: Own illustration with map background from Open Street Map.

The truck stop locations are concentrated on the densely populated areas in central Europe. The locations are denser around important industrial areas – e.g. in Northern Italy, Paris, Greater Manchester, or Frankfurt – and follow main European roads. The locations of trucks in regional operation are almost all very close to locations of truck in long-haul operation.

Figure 7: Aggregated regional truck stop locations.

Shown are all 4,023 regional truck stop locations as filled blue circles with country and regional boundaries. Filling is partly transparent such as darker blue is from an overlap of several circles.



Source: Own illustration with map background from Open Street Map.

In the regional truck stop locations, Eastern and Southern Europe is clearly missing. However, the UK, Germany, France and the Benelux countries are well covered.

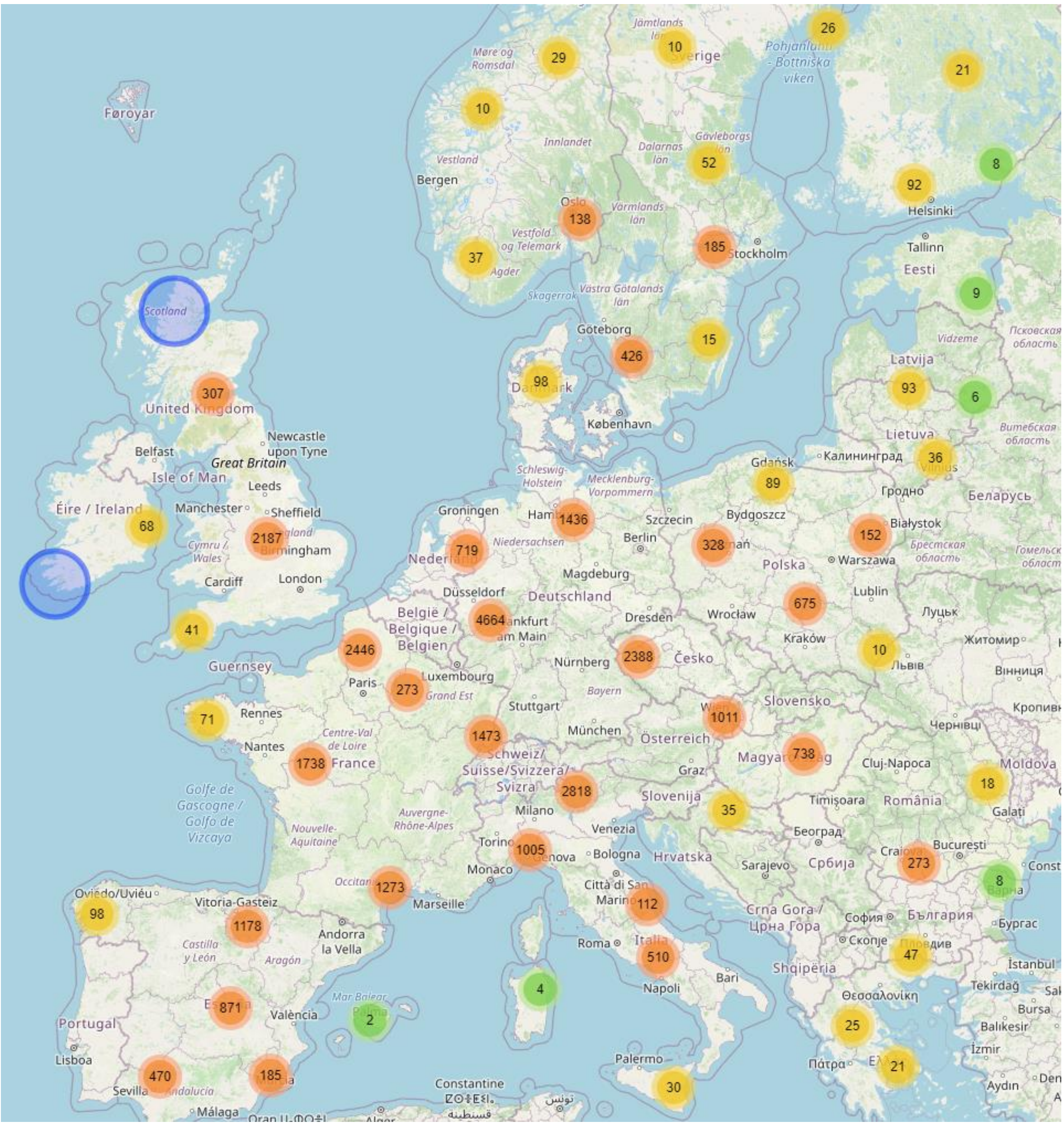
About 10 % of regional cluster locations are more than 600 m away from long-haul truck locations. Approximately 5% of the regional stop locations are more than 1 km away from existing cluster center away.

2.4 Html Visualisation

We generated html based maps for a better understanding of the locations for all six data sets. The maps were generated with the `leaflet` package (cf. https://cran.r-project.org/web/packages/leaflet/index.html) of the R statistical software and use an open street map background and exported to html with the `htmlwidgets` package (cf. https://cran.r-project.org/web/packages/htmlwidgets/index.html).

Figure 8: Exemplary html visualisation.

Exported long-haul data with local groups and isolated points as circles of 30 pixels size. Note that the shown groups are simple local aggregations irrespective of political country borders.



Source: Own illustration based on open street map.

Individual truck stop locations are marked by circles of fixed screen size of 30 pixel, i.e. the size appears fixed when zooming. The idea is that the location is the average locations of stop locations within the cluster and should indicate the location in general, such as at the port or at the motor stop, but not the specific location down to a few meters accuracy, such as this corner of the motor stop, as this needs to be decided on the local level. As the location is a mean of actual truck stop locations in can happen in few cases that a location appears to be in a building or in the water. Furthermore, the locations have been grouped locally in the html maps to avoid over-plotting. Please note that the grouping is not a country or county level but simple with respect to geographical neighbourhood irrespective of political borders.

2.5 Location Classification

We undertook initial steps to classify the identified locations to gain a deeper insight into their character. The approach was threefold: First, we calculated the distance to the nearest motorway. Second, we characterized the type of area the locations are placed using Open Street Map data. Third, geo-tagged objects nearby the locations were identified.

Determination of Motorway Distance

In order to identify parking areas directly connected to the motorway, we calculated the distance for the top 10% long-haul truck locations to the nearest motorway. First, we determined the closest point on the motorway network (direct distance). The motorway network was defined as all roads marked as "highway" in Open Street map (OSM). Subsequently, the points were moved 800 m in both directions on the motorway to ensure that the parking lot entrances and exits were in front of the points. Using "Google maps API", we calculated the distances from the truck locations to each of the two associated points. We kept the shorter distance in each case. Please note, that our results thus represent real distances on the road, not air line distances. For technical implementation, we used Python and QGIS, an open source geographic information system.

Identification of Industrial Areas

Using Open Street Map (OSM) area tags, a deeper understanding of the identified locations can be obtainer. Commercial areas as well as logistics centers are usually marked as "industrial". We checked, whether the identified locations are in industrial use. Therefore, we sent a request for each location to the "overpass API", an interface to OSM. The query checked whether the tag "industrial" is set for "landuse" at the identified location. As additional information, the "name" of the "landuse" area was requested, too. If the "name" contained the information "port", the location was identified as a port. The approach thus allowed us, with some uncertainty, to identify ports and locations in industrial areas. Since the requests take a comparatively long computation or server time, we only performed this investigation for the top 10% of the long-haul truck locations.

Identification of Nearby Objects

Surrounding buildings and facilities provide additional information of parking location use. At least for a part of the locations, the use or type of the location can thus be clearly identified. For each identified location, we sent a request to the "Here API" (Here.com 2021) via a Python script. Here.com is one of the largest location platform providers worldwide, along with Google Maps and TomTom. The corresponding services are used in various navigation devices. We used the "Here API" to discover every recorded facility within a 200 m radius of the identified locations. If possible, the query identifies several items for one location. In addition to the name, the category of the respective facilities or institutions was also queried. Subsequently, we used the categories to classify the locations. All locations having a "ferry-terminal" in their neighborhood were considered as ports. Additionally, we classified "toilet-rest-area", "EV-charging-station", "petrol-station" and "parking-facility" as rest areas. We performed this analysis with the top 10% of the long-haul truck locations as well as with the merged long-haul and regional data. This allows us to make initial statements about differences in the composition of the locations in the datas.

3 Results

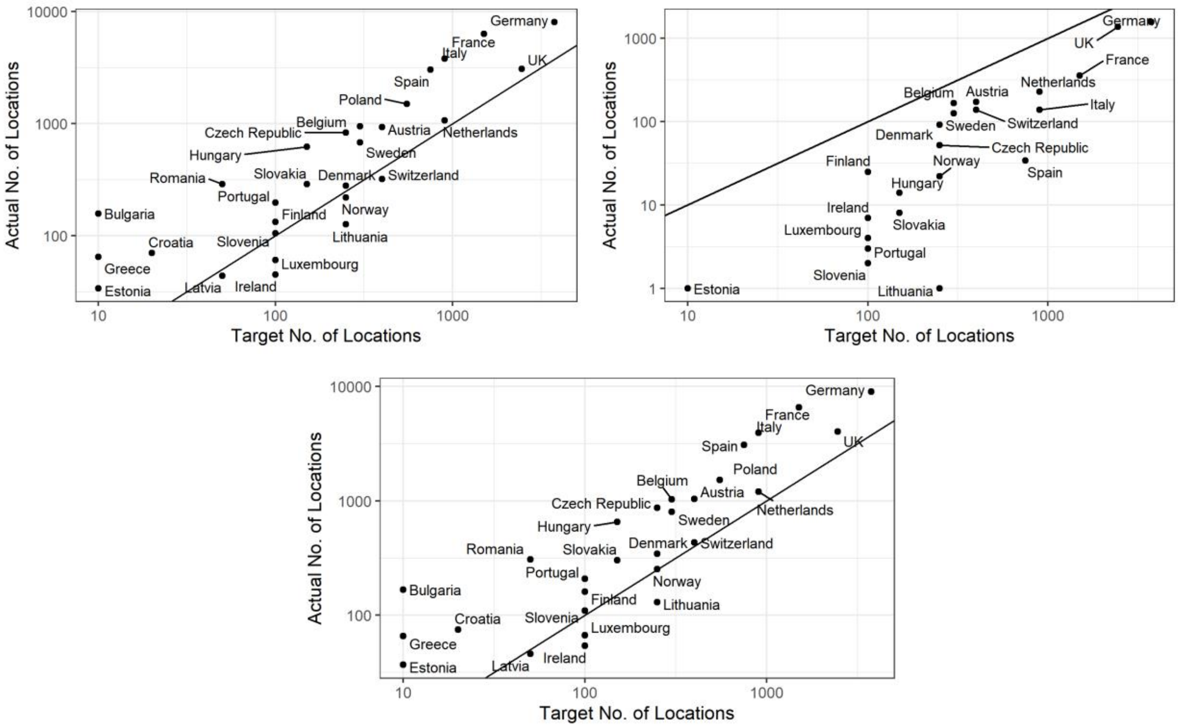
3.1 Coverage of Countries and Regions in Europe

Country Coverage

The visual inspection of the stop location maps already indicates a varying coverage of European countries. In a first step we compare the number of locations per country with the number of required chargers per country acc. to ACEA and T&E (2021). Figure 9 shows the number of actual locations and target locations per country in long-haul, regional, and the merged data set on a double logarithmic scale.

Figure 9: Comparison of actual and target no. of locations.

Long-haul (left) and regional (right) and merged long-haul and regional (bottom). The solid line is the unit slope and zero intercept line indicating x = y.



Source: Own calculations.

The long-haul and the merged data sets show a sufficient number of locations for most countries (except for Latvia, Ireland, Luxembourg, Lithuania, Norway, and Switzerland). However, the number of locations in the regional data set is smaller than the number of potential chargers per country. Note however, that many charging stations will have more than one charging point such that the number of locations can be smaller than the number of target chargers per country. Yet, for the regional data, the number of potential charging locations per country is still too small.

Coverage of Urban Nodes

A large share of freight transport is connected to urban nodes as urban areas are often important commercial areas, require many freight deliveries, and ports are often parts of urban areas. Accordingly, the questions arises how many of the European urban nodes are covered by the truck stop location data.

We identified urban nodes with NUTS-3 regions (cf. Table 6) to check coverage of urban nodes by the truck stop location data.

Table 6: Urban Nodes in Europe.

Node	NUTS code	Node	NUTS code	Node	NUTS code
Aarhus	DK042	Hanover	DE929	Porto	PT114
Amsterdam	NL326	Helsinki	FI181	Portsmouth	UKJ31
Antwerp	BE211	Heraklion	GR431	Poznan	PL415
Athens	GR300	Katowice	PL22A	Prague	CZ010
Barcelona	ES511	Krakow	PL213	Riga	LV006
Berlin	DE300	Las Palmas	ES705	Roma	ITE43
Bielefeld	DEA41	Leeds	UKE42	Rotterdam	NL335
Bilbao	ES213	Leipzig	DED31	Seville	ES618
Birmingham	UKG31	Lille	FR301	Sheffield	UKE32
Bologna	ITD55	Lisbon	PT171	Sofia	BG411
Bordeaux	FR612	Ljubljana	SI021	Stockholm	SE110
Bratislava	SK010	Lodz	Pl113	Strasbourg	FR421
Bremen	DE501	London	UKI11, UKI12	Stuttgart	DE111
Bristol	UKK11	Luxembourg	LU000	Szczecin	PL425
Brussels	BE100, BE241	Lyon	FR824	Tallinn	EE001
Budapest	HU101	Madrid	ES300	Thessaloniki	GR122
Bucharest	RO321	Malmö	SE224	Timisoara	RO424
Cagliari	ITG27	Manchester	ULD31, UKD32	Torino	ITC11
Cologne	DEA23	Mannheim	DE126	Toulouse	FR623
Copenhagen	DK011, DK012	Marseille	FR824	Turku	FI183
Cork	IE025	Milano	ITC45	Valencia	ES523
Dublin	IE021	Munich	DE212	Valetta	MT001
Düsseldorf	DEA11	Naples	ITF33	Venice	ITD35
Edinburgh	UKM25	Nice	FR823	Vienna	AT130
Frankfurt a.M.	DE72	Nicosia	CY000	Vilnius	LT00A
Gdansk	PL634	Nuremberg	DE254	Warsaw	PL127
Genova	ITC33	Ostrava	CZ080	Wroclaw	PL514
Glasgow	UKM34	Palermo	ITG12	Zagreb	HR011
Gothenburg	SE232	Palma de Mallorca	ES532		
Hamburg	DE600	Paris	FR101, FR105-107		

Source: Own compilation.

For the long-haul data, 17% of long-haul stops are in these Urban Nodes and 83 of 88 Urban Nodes are covered by the long-haul truck stop locations. Missing urban nodes are Heraklion (Crete), Nicosia (Cypres), las Palmas (Gran Canaria), Valetta (Malta), and Cagliari (Sardinia). For the Regional data, 19% of regional traffic in urban nodes and 57 of 88 urban nodes are covered. Mainly missing are several islands, parts of Eastern Europe, and some central European cities

In summary, the long-haul and thus also the merged long-haul and regional data shows a good coverage of urban regions in Europe.

3.2 Representativeness

The stop locations in the data cover all of Europe. However, to base infrastructure decisions on these locations, an assessment of its representativeness is required. Such an assessment is difficult as little is known about actual stop locations of the full heavy-duty truck stock in Europe. Here, we use several indicators can be used to compare the distribution of stop locations to other variables. First, we compare the number of stops per country and number of locations per country. Second, we compare the number truck stop locations per country the share of trip ends by country as derived from a reference data set on road freight transport among NUTS-3 regions in Europe, the ETISplus data set (Szimba et al. 2013).

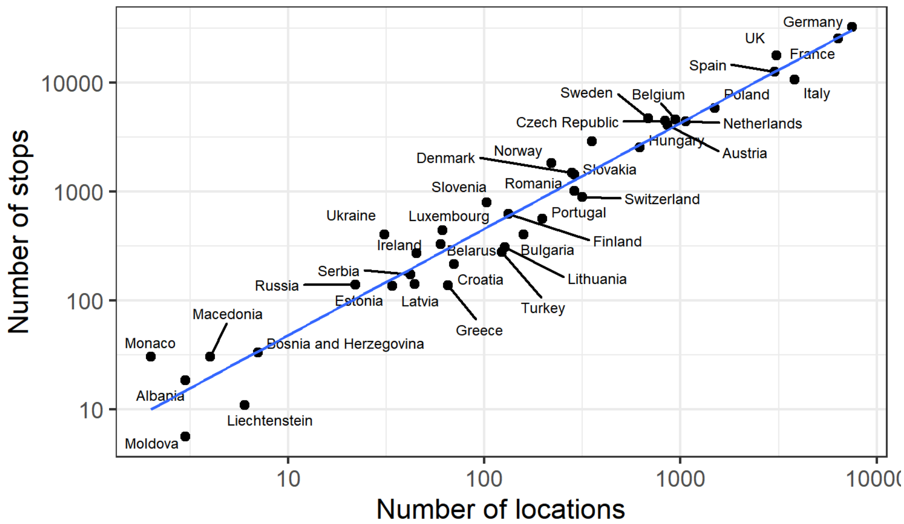
Match between Number of Locations and Stops

Countries that are larger or have more truck traffic should show a higher number of locations where trucks stop and also a higher number of total stops by trucks. We compare the total number of locations and total number of stops by country in the present section.

Figure 10 shows the number of stops as a function of the number of locations per country on double logarithmic axes for the long-haul data. The blue line is a simple linear regression to indicate which countries are above or below the general relationship between the number of locations and number of stops.

Figure 10: Number of stops versus number of locations per country for long-haul data.

Shown with double logarithmic axes. The solid line is a simple linear regression.



Source: Own calculations.

We find a close correlation and little deviation from the general relationship between number of locations and stops for most countries. A few countries have more stops than one would expect (Ukraine, Norway, Sweden, UK) and some have fewer, particularly in Eastern and Southern Europe (Greece, Turkey, Bulgaria, Italy). This indicate a certain bias in the number of stops for some of the countries.

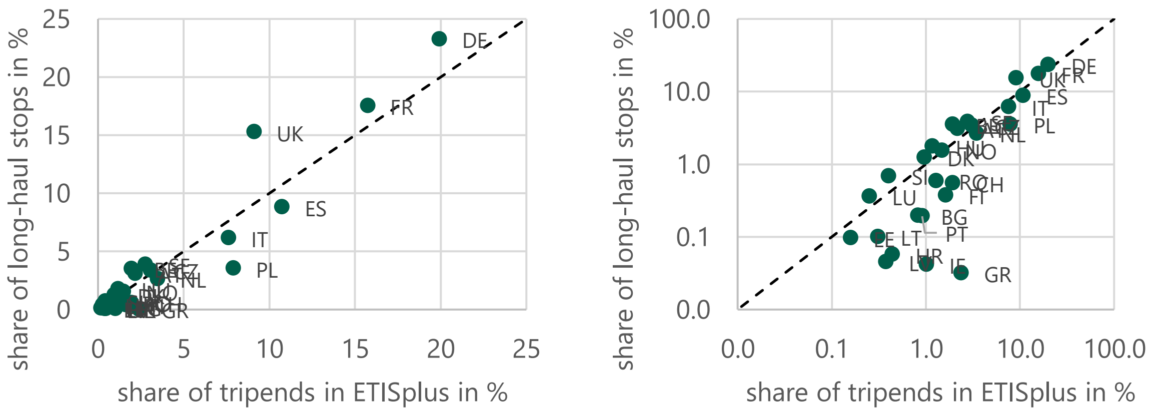
Match with other Data

As one indicator of the representability of the identified locations, we examine their fit with traffic volumes in Europe. The higher the traffic volume in a country, the more locations should be in the country. To represent European freight traffic, we used the ETISplus data (Szimba et al. 2013). Using an origin-destination matrix, the public data describes tons transported between counties (NUTS-3) in Europe. The 2010 data were scaled to 2019 at country level, using current Eurostat data (EC 2019). Afterwards, we assumed an average payload of 13.6 t (EC 2011) and converted the freight tonnages into vehicles. Using the Dijkstra algorithm, the origin-destination trips were mapped to the European road network. However, the data does not contain information about truck stop locations. Note that intra-regional transport is missing in this approach which is particularly relevant for large regions, e.g. in Scandinavian countries which have large NUTS-3 regions.

Only a weak correlation was found between the locations identified here and the volume of traffic on the corresponding road section. Therefore, the identified locations were matched to the destinations (trip ends) in the ETISplus data by country. Figure 11 shows for each country the share of trip ends in the ETISplus data set (x-axis) and the share of stops in the long-haul data (y-axis). To identify the results of smaller countries, the figure was additionally provided with a logarithmic scale. Perfectly represented countries are exactly on the unit slope line. Although the overall fit is quite good (R^2 = 0.91), we can still identify deviations. Among countries with high traffic, Germany and the United Kingdom tend to be overrepresented in the long-haul data, while Spain, Italy and Poland are underrepresented. Deviation also occur in countries with a low share of traffic such as Greece, Poland and Ireland.

Figure 11: Comparison of long-haul locations and ETISplus data

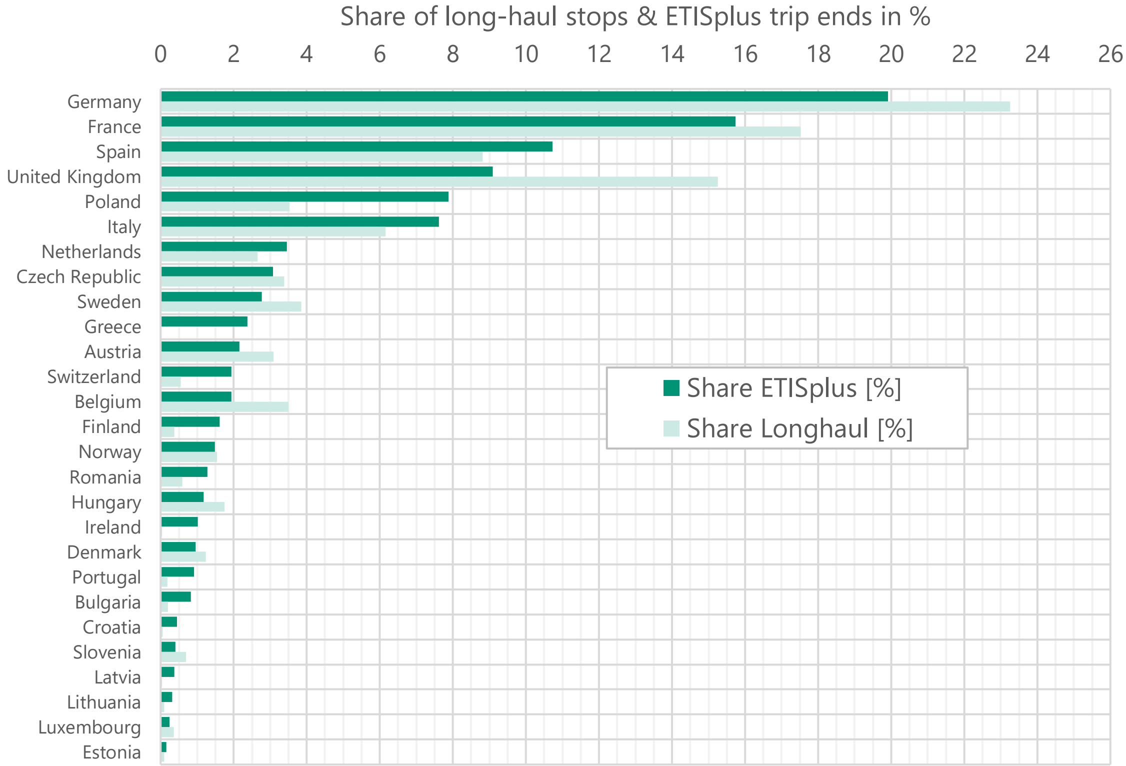
Linear scale (left) and logarithmic scales (right).



Source: Own calculations.

Figure 12 shows the comparison of the long-haul data and the ETISplus data broken down by countries and allows further insights into individual countries. Again, we observe that some countries have more stops in the truck stop data than one would expect from general road freight transport between the countries and regions in Europe.

Figure 12: Share of stops in long-haul data and ETISplus data



Source: Own calculations.

Discussion and Conclusion

In summary, the coverage of Europe is good especially in the long-haul data. Coverage is a complex and a clear statement about coverage and representatives is difficult as no fully comparable data set is available. However, the several indicators used here (relation between stops and locations, coverage of countries, and comparison to other data) show a sufficient representativeness for the long-haul data. The regional data covers a smaller set of countries. Most EU countries are covered in long-haul data and almost all urban nodes are covered in long-haul data.

3.3 Characterisation of Stop Locations

As trucks stop at many different types of locations, such as rest areas, industrial areas, ports, company sites, logistics hubs, and many others, a targeted deployment of charging infrastructure also requires an understanding of the distribution of location types. In the present section, we aim to characterise truck stop locations to support future construction of truck charging points. The following analysis is two fold: We study the top 10% most visited locations in the long-haul data as these are probably the most interesting locations for the first public charging stations. However, in the long run with higher market shares of battery electric trucks more locations will be a needed and a dense network will be required. Thus, in a second step, we extend the characterisation of stop locations to all stops in the long-haul data set, as a dense and efficient public charging network will require all types of locations. Please note that (1) we limit ourselves to the long-haul truck data in the present section, as 90% of the regional stop locations are identical to long-haul locations and (2) that we cannot make any statements about accessibility, property ownership, or grid access to any of the locations here as this is beyond the scope of the present study.

Determination of Motorway Distance

Table 7 summarizes the distance from the top 10% long-haul locations to the motorway on the road network. About 4% of the locations reach the motorway within 200 m. They are certainly rest areas directly located on the motorway. A quarter of the locations reach the motorway with one kilometer road distance. If the methodological approach is taken into account, direct motorway access can be assumed with a high degree of probability here as well. For distances between 1 and 5 km, which applies to about 40% of the locations, logistics centers, industrial sites, company locations, as well as rest areas without direct motorway access can be involved. Locations with a longer distance are most likely to be logistics centers off the motorway or company locations.

Table 7: Distance of the top 10% long-haul locations to motorway

Distance to motorway	Cumulative share
20 m	0%
50 m	1%
100 m	2%
200 m	4%
500 m	12%
1 km	24%
2 km	40%
5 km	65%
10 km	78%
20 km	88%
50 km	95%
100 km	98%

Source: Own calculations.

Identification of Industrial Areas

Using Open Street Map (OSM) data, we identified 1,613 locations of the approx. 3,100 top 10% long-haul stop locations as being in an industrial area. Of these locations, 25 were identified as ports. In relative numbers, 1% of the top 10% long-haul stops were identified as ports and 45% were identified as industrial areas. However, these figures are subject to a high degree of uncertainty. For example, it cannot be avoided that the location standing for a cluster contains both rest areas and industrial areas. The assignment is then dependent on the centre point and thus somewhat uncertain. If one adds further land use tags in addition to "industrial" and extends the determination to subcategories, a more detailed classification is possible. Therefore, we estimate the share of stops at companies or logistics hubs to be 30% to 50%. Ports represent at least 1% of the locations.

Identification of Nearby Objects

With regard to the top 10% long-haul data, the "Here API" identified objects in the surrounding area for 80% of the locations. On a mean basis, 4.4 objects per location were identified. Based on the method described, half of the locations could be assigned as either "port" or "rest area".

Within the top 10% long-haul data, 47% of the locations are identified as rest areas. This means, that there is a toilet-rest-area, a charging station, a petrol station or a parking facility within 200 meters radius. However, some of these may also be parking areas at logistics centers, which cannot be clearly distinguished using the approach described here. As a minimum requirement, the EU defines that in the Trans-European Transport Network (TEN-T), rest areas for trucks must be available at intervals of 100 km in order to safely comply with break times (EU 2013). In fact, in the core network with a total length of almost 25,000 km, the ratio is 4 rest areas per 100 km (CEDR 2020). Looking at the total TEN-T network of slightly less than 75,000 km, the ratio drops to 2.5 rest areas per 100 km (CEDR 2020). This results in 1,000 (core network) to 1,875 (total network) rest areas in the TEN-T network. Therefore, we assume that approximately 25% to 55% of the top 10% long-haul locations are at rest areas. Please note that 200 m clustering radius ensures tat separated rest areas on opposite sides of the motorway usually clustered into one location and thus counted as one location.

Companies and logistics hubs cannot be identified directly, since the Here API does not provide a unique tag for them. For the top 10% long-haul locations, we therefore use the estimate from the identification of the industrial areas. We assume 30% to 50% to be companies or logistics hubs. In future, the use of further map services, like Google or TomTom, would allow us to specify this even more precisely.

50 locations are ports. TEN-T includes 328 maritime sea ports all over Europe. About one third of them belong to the core network (EU 2013). Additionally, there are about 220 inland waterway ports, a solid third of them are also part of the core network (EU 2013). Assuming that the core network maritime sea ports are included in the top 10% long-haul stops, their share would be at least 3%. If the core network inland waterway ports are part of the top 10% long-haul stops too, the share could be approximately 5%.

Table 8 sums up the clearly specified locations. The results of the top 10% long-haul locations are shown in the left column and for the merged long-haul and regional data in the right column of the table. On average, we identified 3.5 objects per location using the Here API. In total, 75% of the locations could be assigned to at least one object. However, only 34% of the locations could be identified. The lower share compared to the top 10% long-haul data is probably due to the fact that more rural locations are considered.

Table 8: Exact classification of locations

Category	top 10% long-haul stops (n = 3,506)	merged long-haul + regional (n = 34,227)
Rest area	47%	34%
Ports	1%	<1%
Not fully clear	52%	66%

Source: Own calculations.

Compared to the top 10% long-haul data, the share of rest areas decreased to 34%. There are two possible explanations: First, regionally used vehicles stop more often at logistics centers, less frequently at rest areas. Second, rest areas are among the most visited locations and are therefore already included in the top 10% long-haul data. If only the number of rest areas in the TEN-T network (approx. 1875) is considered, rest areas are even overrepresented. This shows that there must also be locations outside the TEN-T network with a public toilet, petrol station, electric car charging station, or rest area nearby. Possibly, some companies or logistics hubs provide similar conditions. This can lead to overlaps and should be investigated in more detail. In the full merged data, the share of ports drops to well below 1%. Even if all maritime sea ports and inland waterway ports of the TEN-T network (~550) were included, the share would be only 1.5%. However, a large part of them are comparatively insignificant for freight traffic. Using the Here API, a total of 66 locations were identified as ports. It is unclear whether a large proportion of ports are not identified or whether smaller ports are correspondingly insignificant for cargo traffic. As stated before, the approach described here does not uniquely identify companies or logistics hubs. However, their share is expected to increase in the merged long-haul and regional data.

Combing the individual approaches, some general tendencies can be observed (cf. Table 9).

Table 9: Approximate general classification of locations

Category	Approx. share
Rest area	30 – 50%
Companies & Logistics hubs	25 – 45%
Ports	1 – 5%
Unclear	< 50%

Source: Own calculations.

About one third to one half of the locations are rest areas close to motorways, about one quarter to more than one third are company sites or logistic hub locations, and finally, about 1 – 5% are ports and ferry terminals (cf. Table 2). However, for a noteworthy share of up to half of the locations, the specific type of location remains unclear from the present analysis.

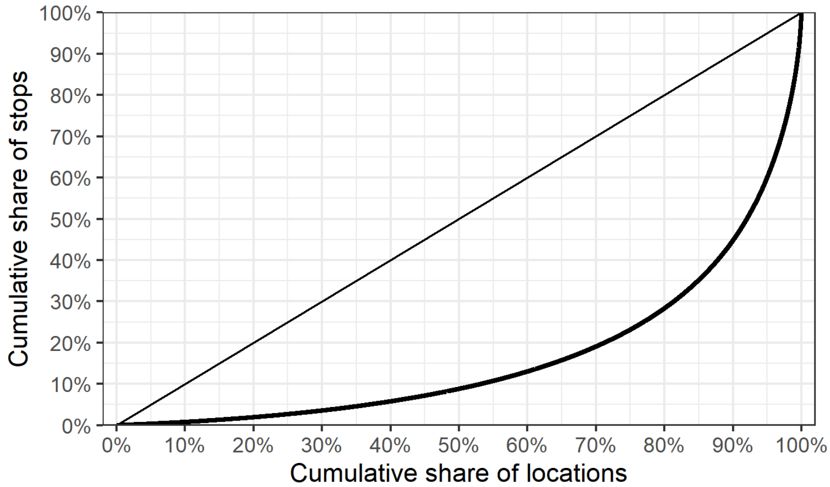
The results presented here for the classification of locations can be an initial indication and are primarily to be understood as a first estimation. In the future, the three approaches need to be combined and further specified to obtain detailed robust estimates.

3.4 Analysis of Stops and Durations

The duration of stops are important for future electric truck charging infrastructure to decide about low, medium or high power for charging. Likewise, not all stops are equally visited by trucks and charging infrastructure should first be constructed where most trucks benefit from it.

Figure 13 shows the cumulative share of stops as a function of the cumulative share of locations, with the locations sorted by the total number of stops. The figure indicates that the top 10% of locations make up about 50% of stops and that the top 5% of locations make up about 40% of stops. The figure demonstrates that a few stops are heavily frequented whereas a few locations are visited by only a few trucks. Please note, that we excluded locations with less then three OEMs present and with less than 100 stops per year.

Figure 13: Lorenz plot of long-haul locations.



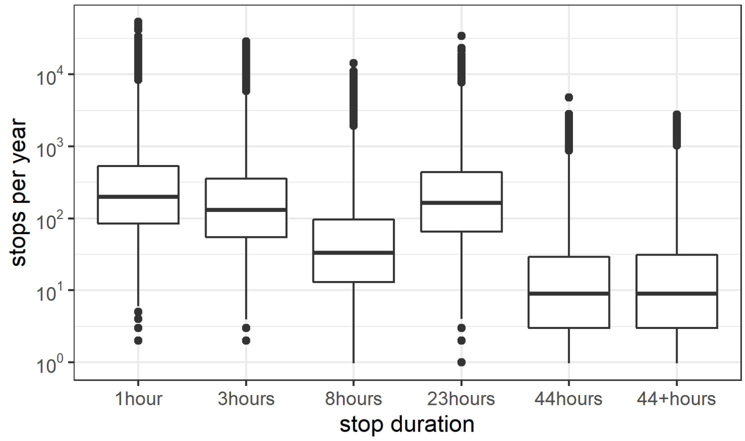
Source: Own calculations.

The typical number of stops per year by duration of the stop is shown in Figure 14. It shows a boxplot of the number of stops per year by duration on a logarithmic scale. Please note that there can be fewer than 100 stops per year for a given duration as the threshold of at least 100 stops per year concerns the sum over all duration classes.

The figure shows that most common stops are short stops with up to three hours, followed by stops with 8 – 23 hours. Both are typically a few hundred stops per year at a give location and can go up to several thousand or even several ten thousand stops per year or a few dozen trucks per day. One type of location for such high number of trucks are, e.g., ports or ferry terminals such as the ferry terminals in Calais and Dover for freight transport over the Channel.

Figure 14: Boxplot of stops per year by duration.

In the x-axis, "1hour" refers to ½ - 1 hour, "3hours" to 1 – 3 hours, "8hours" to 3 – 8 hours, "23hours" to 8 – 23 hours, "44hours" to 23 – 44 hours, and "44+hours" to more than 44 hours.

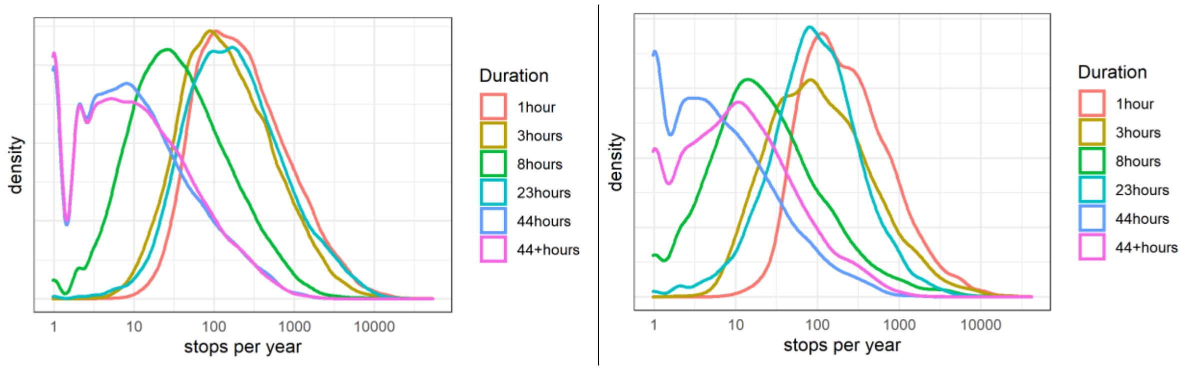


Source: Own calculations.

The distribution of stops per year by duration is shown on a logarithmic scale in Figure 15. It confirms the heavily skewed distribution of stops per year for a given locations as a bell shaped curve on a logarithmic scale belongs to a right skewed distribution on a linear scale, such as, e.g., the log-normal distribution. Both in long-haul and regional operation, most stops are short with up to three hours of duration.

Figure 15: Distribution of stops per year by duration.

Shown is long-haul operation (left) and regional operation (right). In the legend, "1hour" refers to ½ - 1 hour, "3hours" to 1 – 3 hours, "8hours" to 3 – 8 hours, "23hours" to 8 – 23 hours, "44hours" to 23 – 44 hours, and "44+hours" to more than 44 hours.



Source: Own calculations.

The summary statistics of the share of stops by duration at the locations is given in Table 10. On average, about one third of stop in long-haul operation is shorter than one hour and about one quarter is between one and three hours. The longer stops are typically 8 – 23 hours long and make up between one quarter and one third. Stops longer than 23 hours are quite exceptional and are typically less than 5%.

The typical shares of stop durations in regional operation are similar: Short stops are most common and very long stops quite exceptional. However, very short stops of below one hour play and even higher role in regional truck operation and are about 44% on average.

If durations are further grouped into short stops of up to three hours, intermediate stops of 3 – 8 h and long stops of more than 23 h, then hardly any stops are of intermediate stop duration. Figure 16 shows the relative frequency of different shares of stops with less then three hours for the long-haul and regional data. Most stops are short stops with less than three hours duration, even more so for the regional data.

Table 10: Summary statistics of stop duration distributions

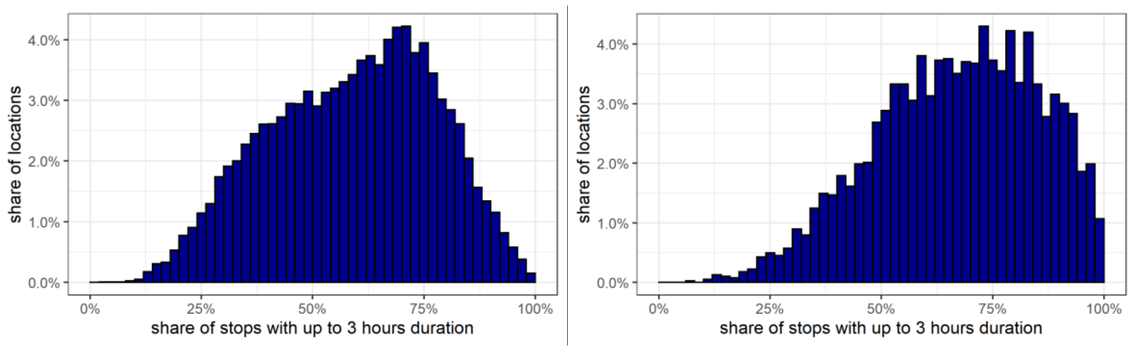
Shown are the mean, median and standard deviation (SD) of the share of given stop durations in long-haul and regional operation by duration. Differences from 100% sums are due to rounding.

Duration	½ - 1 h	1 – 3 h	3 – 8 h	8 – 23 h	23 – 44 h	>44 h
Long-haul operation						
Mean	35%	24%	6%	31%	2%	2%
Median	34%	25%	5%	27%	1%	1%
SD	12%	13%	5%	18%	2%	3%
Regional operation						
Mean	44%	23%	6%	24%	1%	3%
Median	44%	22%	4%	24%	1%	1%
SD	15%	12%	5%	17%	2%	43%

Source: Own calculations.

Figure 16: Distribution of share of short stops.

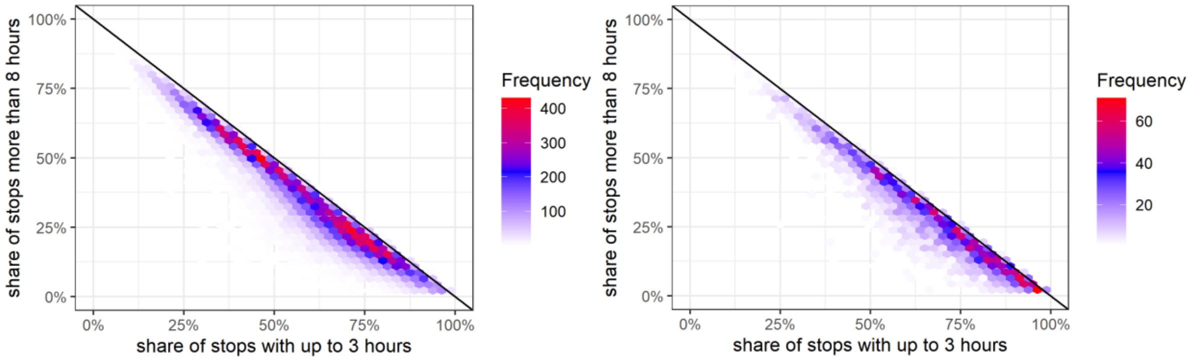
Long-haul (left) and regional (right)



Source: Own calculations.

Figure 17: Distribution of long and short stops.

Shown is a two-dimensional histogram of short stops (up to three hours) and long stops (more than eight hours). Truck stop locations in long-haul operation (left) and regional operation (right).



Source: Own calculations.

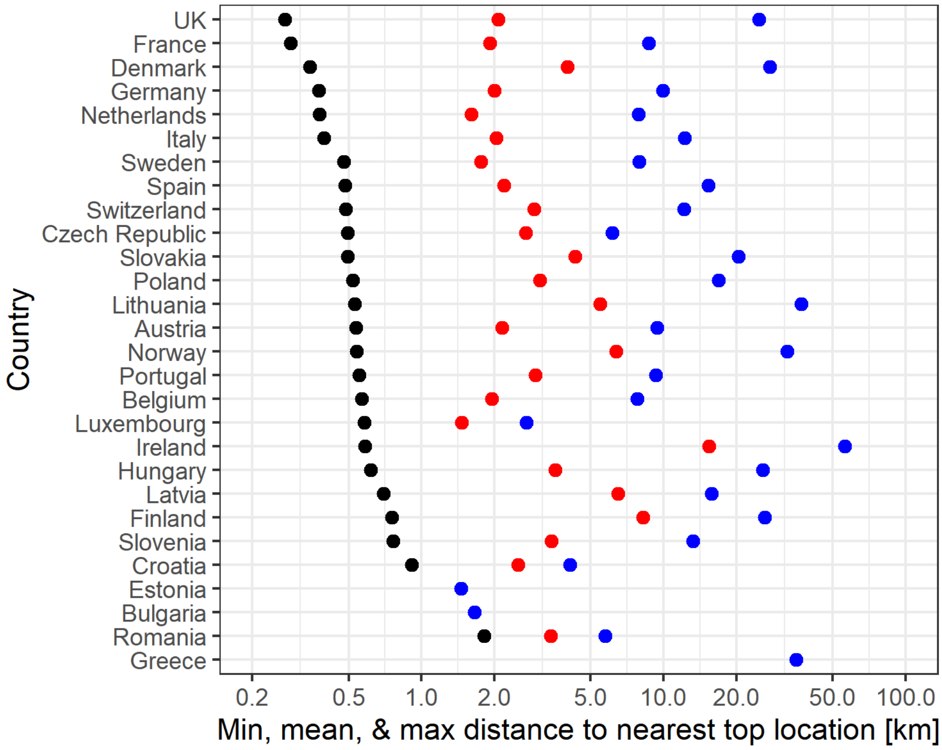
Figure 17 shows the two-dimensional distribution of short and long stops. For almost all individual locations, the shares of short and long stops sum up to almost 100% indicating that stops of intermediate durations of 3 – 8 hours play hardly any role, even on the level of individual locations. Comparing long-haul and regional truck operation, long stop durations are more common for long-haul trucks.

3.5 Distance to Potential Public Charging Locations

A first analysis of potential public charging locations was performed. We selected the 10% most visited locations per country from the long-haul data set with the number of total locations per country limited to the target number of charging points according to (ACEA and T&E, 2021). His leads to a few hundred locations for large countries (Germany, UK, France) and a few dozen locations for most of Europe and less than ten locations for smaller Countries or those with limited truck location data (Luxembourg, Ireland, Latvia, Romania, Croatia, Estonia, Bulgaria), cf. Table 11. We then analysed the distance to the nearest potential public charging location from all other locations in the country. The minimal, mean, and maximal distance per country are shown in Table 11 and Figure 18.

Figure 18: Minimal, mean, and maximal distances to top 10% locations

Shown are the minimal (black), mean (red), and maximal (blue) distance of all locations in the top 10% long-haul locations per country to the nearest potential charging point. For countries with only one location (Estonia, Bulgaria, and Greece), min, mean, and max coincide.



Source: Own calculations.

The mean distance to all other truck stop locations from these potential first public charging stations is typically 2 – 5 km. The mean distance is larger than 5 km only in a few countries with a very small number of locations in total, such as Ireland, Latvia, Lithuania, Norway, and Finland.

Table 11: Number and distance in km to potential charging locations.

Also included is the number of required charging points acc. to (ACEA and T&E, 2021).

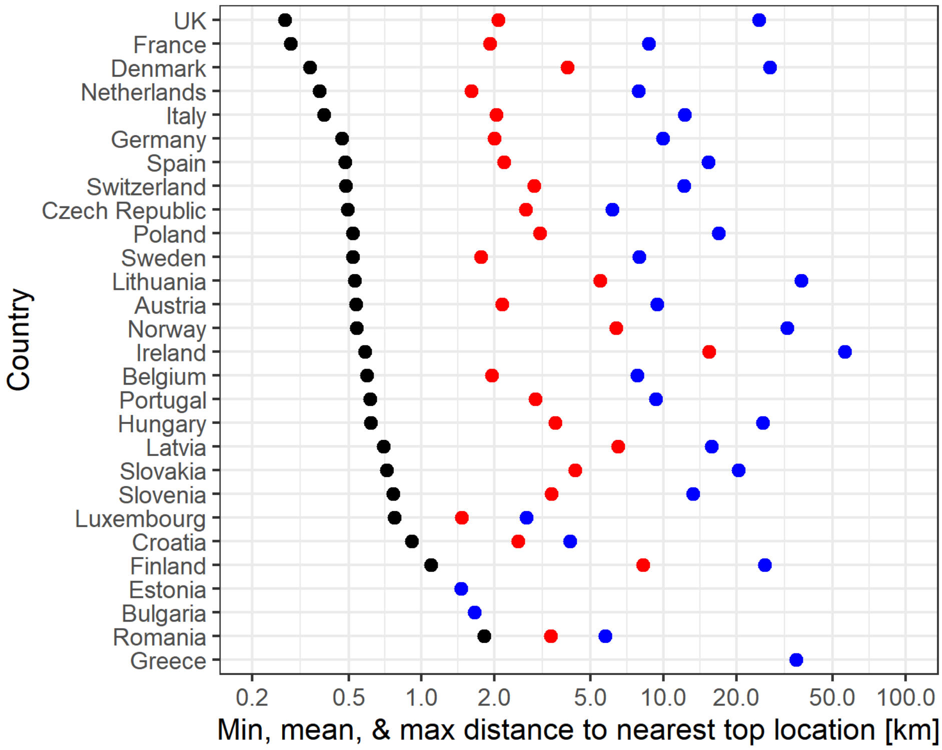
Country	Required charging points	Top 10% locations				Top 10% locations with >1/3 under 1 h			
		No. of locations	Min	Mean	Max	No. of locations	Min	Mean	Max
Germany	3750	375	0.4	2.0	10.0	168	0.5	2.0	10.0
UK	2450	245	0.3	2.1	24.8	154	0.3	2.3	24.8
France	1500	150	0.3	1.9	8.7	68	0.3	1.7	5.3
Netherlands	900	90	0.4	1.6	7.9	39	0.4	1.5	6.7
Italy	900	90	0.4	2.0	12.2	46	0.4	2.2	10.7
Spain	750	75	0.5	2.2	15.4	50	0.5	2.3	6.2
Poland	550	55	0.5	3.1	16.9	43	0.5	3.3	16.9
Austria	400	40	0.5	2.2	9.4	22	0.5	2.5	9.4
Switzerland	400	31	0.5	2.9	12.1	21	0.5	2.7	12.1
Sweden	300	30	0.5	1.8	7.9	20	0.5	1.9	7.9
Belgium	300	30	0.6	2.0	7.8	13	0.6	1.2	2.3
Denmark	250	25	0.3	4.0	27.5	23	0.3	3.0	21.0
Czech Republic	250	25	0.5	2.7	6.1	23	0.5	2.9	6.1
Norway	250	22	0.5	6.4	32.3	15	0.5	6.0	32.1
Slovakia	150	15	0.5	4.3	20.4	10	0.7	5.8	20.4
Hungary	150	15	0.6	3.6	25.7	12	0.6	4.2	25.7
Lithuania	250	12	0.5	5.5	37.0	6	0.5	7.6	37.0
Portugal	100	10	0.6	3.0	9.3	3	0.6	3.6	9.3
Finland	100	10	0.8	8.2	26.3	7	1.1	7.6	23.7
Slovenia	100	10	0.8	3.4	13.2	8	0.8	4.0	13.2
Luxembourg	100	6	0.6	1.5	2.7	4	0.8	1.4	2.3
Ireland	100	5	0.6	15.4	56.0	5	0.6	15.4	56.0
Latvia	50	5	0.7	6.5	15.8	5	0.7	6.5	15.8
Romania	50	5	1.8	3.4	5.7	5	1.8	3.4	5.7
Croatia	20	2	0.9	2.5	4.1	2	0.9	2.5	4.1
Estonia	10	1	1.5	1.5	1.5	1	1.5	1.5	1.5
Bulgaria	10	1	1.7	1.7	1.7	1	1.7	1.7	1.7
Greece	10	1	35.3	35.3	35.3	1	35.3	35.3	35.3
Mean		**49**	**2**	**5**	**16**	**28**	**2**	**5**	**15**

Source: Own calculations.

Figure 19 shows the minimal, mean, and maximal distance to the nearest potential charging point if the number of potential charging points is even further reduced. In this case, only the those locations out of the top 10% locations per country are taken with at least 1/3 of stops below one hour duration (except of countries with less than six locations as this would reduce the number of locations to zero or close to zero).

Figure 19: Minimal, mean, and maximal distances to top 10% locations with many short stops

Shown are the minimal (black), mean (red), and maximal (blue) distance of all locations in the top long-haul locations per country with at least 1/3 of stops shorter than one hour to the nearest potential charging point. For countries with only one location (Estonia, Bulgaria, and Greece), min, mean, and max coincide.



Source: Own calculations.

In summary, the typical distance from any truck stop locations to the nearest potential charging locations is around 2 – 5 km. The mean distance is larger than 5 km only in a few countries with a very small number of locations in total.

4 Discussion and Conclusions

The present report summarizes a unique data set of truck stop locations based on driving of about 400,000 trucks in Europe and contains more than 30,000 aggregated truck stop locations. The long-haul data covers all of Europe and the regional truck data mainly Western Europe. In total, Western and Northern Europe are well represented in the data, coverage is not optimal for Eastern Europe and parts of Southern Europe. Thus, the data set is rich and unique, and the data covers Europe fairly representatively, especially if the number of locations per country is predetermined (ACEA and T&E, 2021). Furthermore, the rank of locations within a country by the number of stops at a given location is probably close to reality although the absolute number of stops in the data might be misleading for some countries.

Please note that the identified locations are suitable for establishment of charging infrastructure from a logistics point of view. Exactly which to use and how many charging points each should have is an aspects that requires additional analysis and an evaluation of additional criteria such as available electricity grid power, existing local initiatives, already present DC electric passenger car charging infrastructure, and many more. The present data alone is not sufficient to decide about high power fast chargers placement, but it is an important first step.

In summary, the present data set is a unique and useful source to plan charging infrastructure deployment for battery electric trucks, especially in long-haul operation.

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