NAL Nationale Agenda Laadinfrastructuur

Attractiveness of truck charging locations in the Netherlands

Final documentation

Sluit aan

Fraunhofer ISI

Fraunhofer-Institut für System- und Innovationsforschung ISI

Final documentation

-

Attractiveness of truck charging locations in the Netherlands

Steffen Link, Patrick Plötz

Source: Own illustration

Agenda

1. **Organization**
2. **Overview ZIP-file**
3. **Methodology & Data**
4. **Results**
5. **Further Notes and Documentation**

Agenda

1. Organization
2. Overview ZIP-File
3. Methodology & Data
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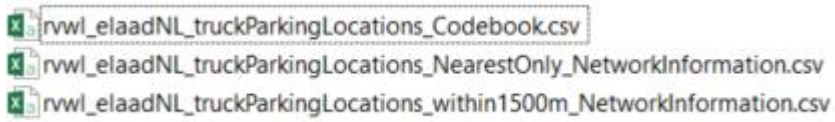
Agenda

Final data file: **rvwl_elaadNL_data_sendout.zip**



1. **Codebook: Explanatory file**
2. **Result A: Results if only information from the nearest ACEA location is being used**
3. **Result B: Results if information from all ACEA location within 1500m around is being used.**

Agenda

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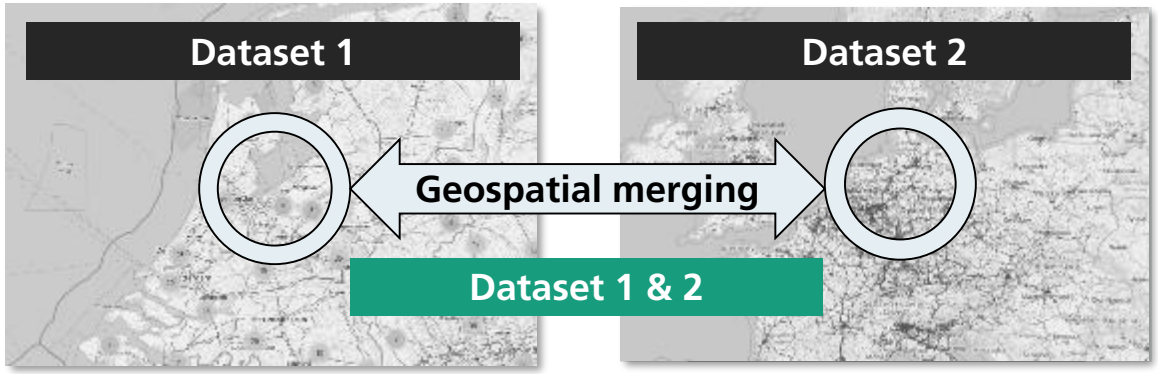
Methodology

Analysis of attractiveness using GIS-based analysis

Phase I



Identification of potential chargings locations and available information.

Based on a dataset containing public truck parking locations in Europe.

Attractivess of potential charging locations.

Based on the truck stop location study, commissioned by the ACEA.

Phase II

Evaluation of location attractiveness.

Recommendations for action and implications
Recommendations for the development of truck charging infrastructure at locations.

Image sources: Own illustrations

Phase I

Dataset 1

Geospatial truck parking locations data for Europe

Dataset 1: Public European Truck Parking Locations - Overview

Final:

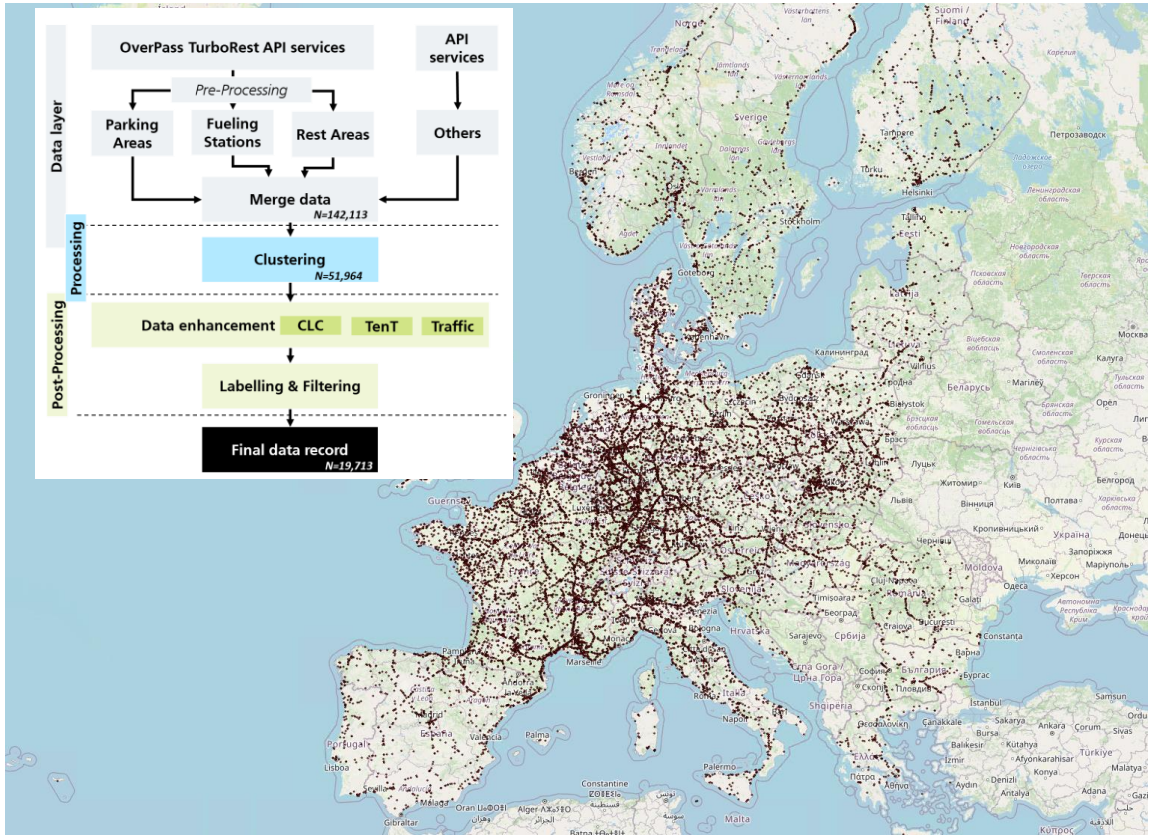
- **N = 19,713 locations in Europe.**
- **N = 345 locations in the Netherlands (Medium/High)**
- **N = 1,092 locations in the Netherlands (Low/Medium/High truck parking confidence)**

Utilized data sources and API services:

- **TomTom Truck routing**
- **HERE truck routing**
- **PTV truck routing**
- **OpenStreetMaps**

Documentation: Link, S., Plötz, P. Geospatial truck parking locations data for Europe. Data in Brief. Volume 54, June 2024, 110277

Overview



Source: https://doi.org/10.1016/j.dib.2024.110277

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Geospatial truck parking locations data for Europe

Dataset 1: Public European Truck Parking Locations – Codebook (1/2)

Phase I

Dataset 1

Variable	Type	Brief describtion
Category	Categorical	Location category. Four archetypal categories (truck stop, rest area, parking only, fuel station) are available. Multiple categories per location are possible.
Latitude	Float	Latitude information. WGS-84 format.
Longitude	Float	Longitude information. WGS-84 format
Parking area	Integer	Estimated total area in square meters, if available. The area data, denoted in square meters, was calculated by geometric information from OSM objects. The specified area represents the cumulative sum of the areas attributed to the respective cluster. When this geometric information is not accessible for the given location, the field remains empty. The area calculation using the enclosed area defined by OSM polygons exhibits limitations, occasionally encompassing roads, grasslands, and other service areas within its boundary. Moreover, only certain areas might be designated as truck parking zones. Hence, not all of the estimated area guarantees truck accessibility or parking.
truckParkingConfidence	Categorical	Truck parking confidence label (high, medium, or low). • Locations were labeled with "High" if multiple information sources, various tags, or the inherent category (such as truck stop) collectively imply a substantial probability of public accessibility and suitability for trucks, while there is no information conflict between different sources. • Locations were labeled with "Medium" if single information source or individual tags indicated a certain probability of public accessibility and suitability for trucks. • Locations were labeled with "Low" if discernible and reliable information was absent, incomplete, or where conflicting information prevailed.

Note that final latitude and longitude information may represent the centroid of the respective location cluster that originated from mean-shift clustering and filtering. Thus, the final coordinate may not perfectly align with exact geographical coordinates of single locations. We propose considering and utilizing these locations as candidates for conducting in-depth local analyses concerning ambient conditions and truck parking suitability.

Geospatial truck parking locations data for Europe

Dataset 1: Public European Truck Parking Locations – Codebook (2/2)

Phase I

Dataset 1

Variable	Type	Brief describtion
Country	Categorical	Assigned country (Dutch only)
TEN-T Core	Float	Calculated minimal distance to the TEN-T Core road network. In km. Source: See next slide.
TEN-T Comp	Float	Calculated minimal distance to the TEN-T Comprehensive road network. In km. Source: See next slide.
Truck flow data (nearest)	Float	Number of trucks in the immediate vicinity, measured in millions per year. Source: See next slide.
Truck flow data (max)	Float	Maximum number of trucks in the vicinity, measured in millions per year. Source: See next slide.

Phase I

Dataset 1

Geospatial truck parking locations data for Europe

Dataset 1: Public European Truck Parking Locations – Additional Data

TEN-T Information

TEN-T road network

Available information

Info: Distance and location of parking locations to main European highways (TEN-T).

Source: EC TenTec Information System

Truck Traffic Flow Data

Truck traffic flow data

Available information

Info: Traffic flow information (#trucks per time unit) in the vicinity of parking locations.

Source: https://doi.org/10.1016/j.dib.2021.107786

Truck Stop Locations

Dataset 2: ACEA Truck Stop Locations

N = 34,277 locations in Europe (Merged = Long-Haul & Regional)

N = 10,518 locations in NL, LU, BE, DE

N = 1,155 locations in the Netherlands

Added information to Dataset 1 (depending on the geospatial merging):

Share of short stops	Share (in %) of stops below 1h, if available. Bins only.
Share of long stops	Share (in %) of stops above 8h, if available. Bins only.
Attractiveness	Estimated number of truck stops (per year/ per day) – Percentiles only.

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Phase I

Dataset 2

Truck Stop Locations

Dataset 2: Data collection involved aggregating truck stop locations from seven OEMs

Data Collection: 2019/2020

Seven truck OEM provided GPS coordinates of truck stop locations from trucks GCW >= 7.5t

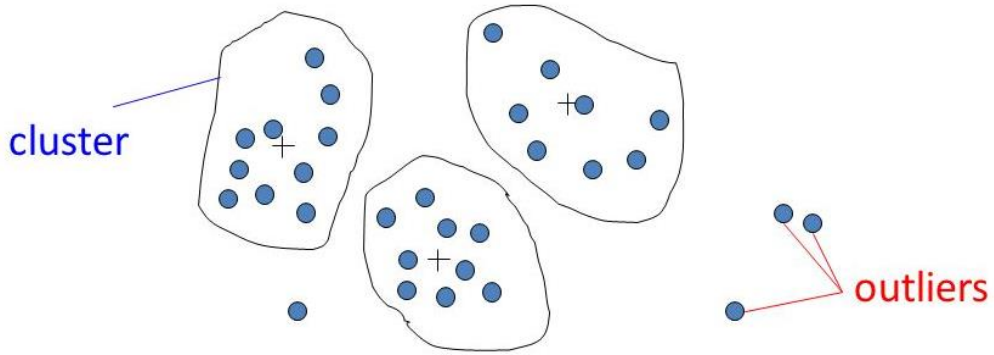
"regional": 90 % of coordinates within 200 km from the vehicle's home-base.
"long haul" = not regional

"stops" = at least 30 minutes less than 5 km/h

Harmonisation and data checks

Aggregation

- Clustering of individual locations into larger groups (DB scan algorithm with 200 m radius)



- We kept stop location cluster with
  - at least 100 stops per year
  - at least 3 OEMs present

picture source https://slideplayer.com/slide/2735334/

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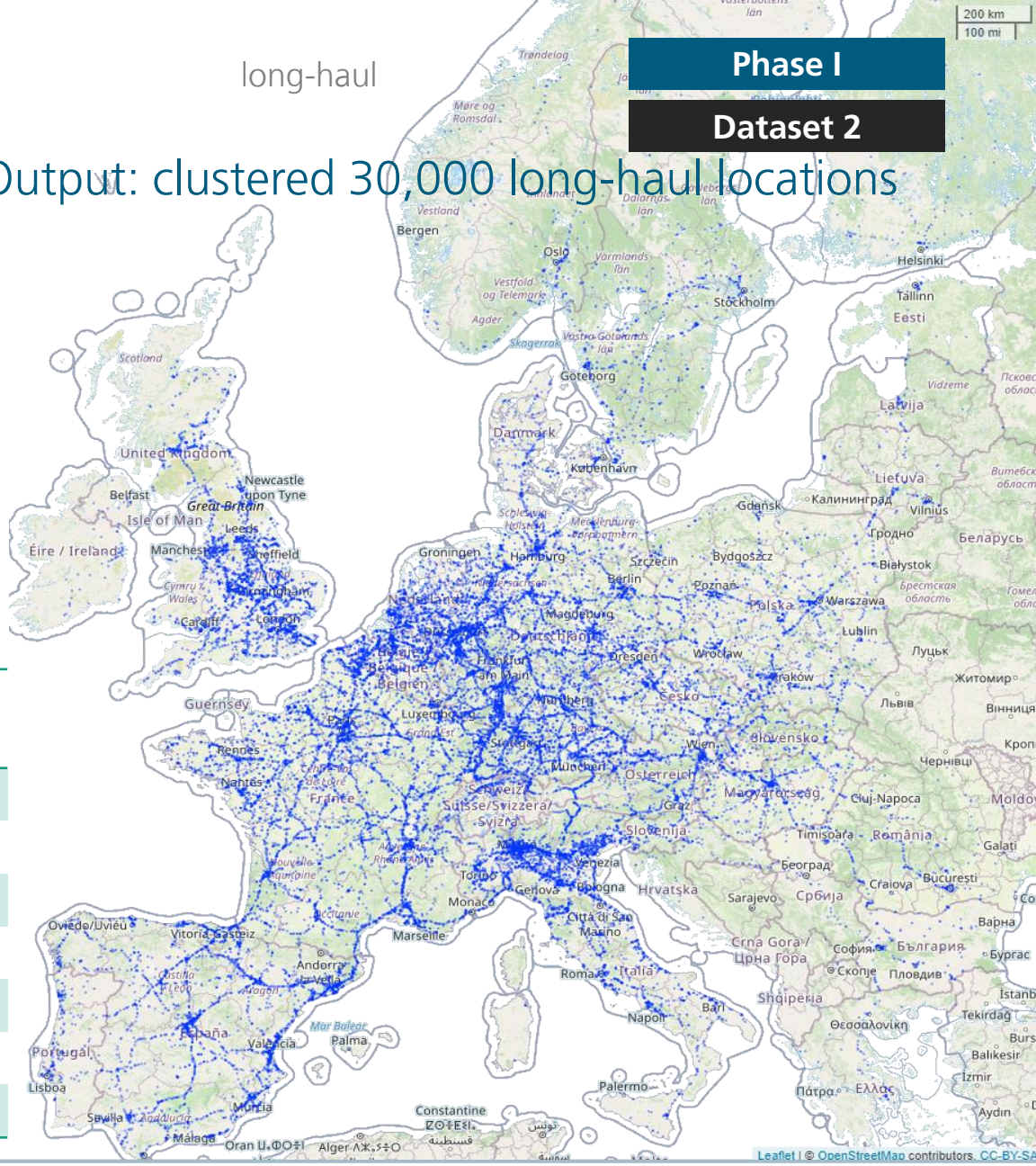
Truck Stop Locations

Dataset 2: 750,000 locations of 400,000 trucks (input) - Output: clustered 30,000 long-haul locations

Long-haul: 58% of stop 550,000 locations met the conditions and are aggregated into 31,145 cluster

Regional locations mostly covered in long-haul:
10 % of regional cluster more than 600 m away from long-haul truck locations (and 5% more than 1 km)

	Long-haul operation	Regional operation
Number of trucks involved	230,000	170,000
Locations before aggregation	550,000	194,000
Locations after aggregation	**31,145**	**4,023**
Countries in Europe covered	35	23
Mean no. of stops/year	1678	1271
Std. Deviation no. of stops/year	3615	3044
Median number of stops/year	596	455



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Phase I

Dataset 2

Truck Stop Locations

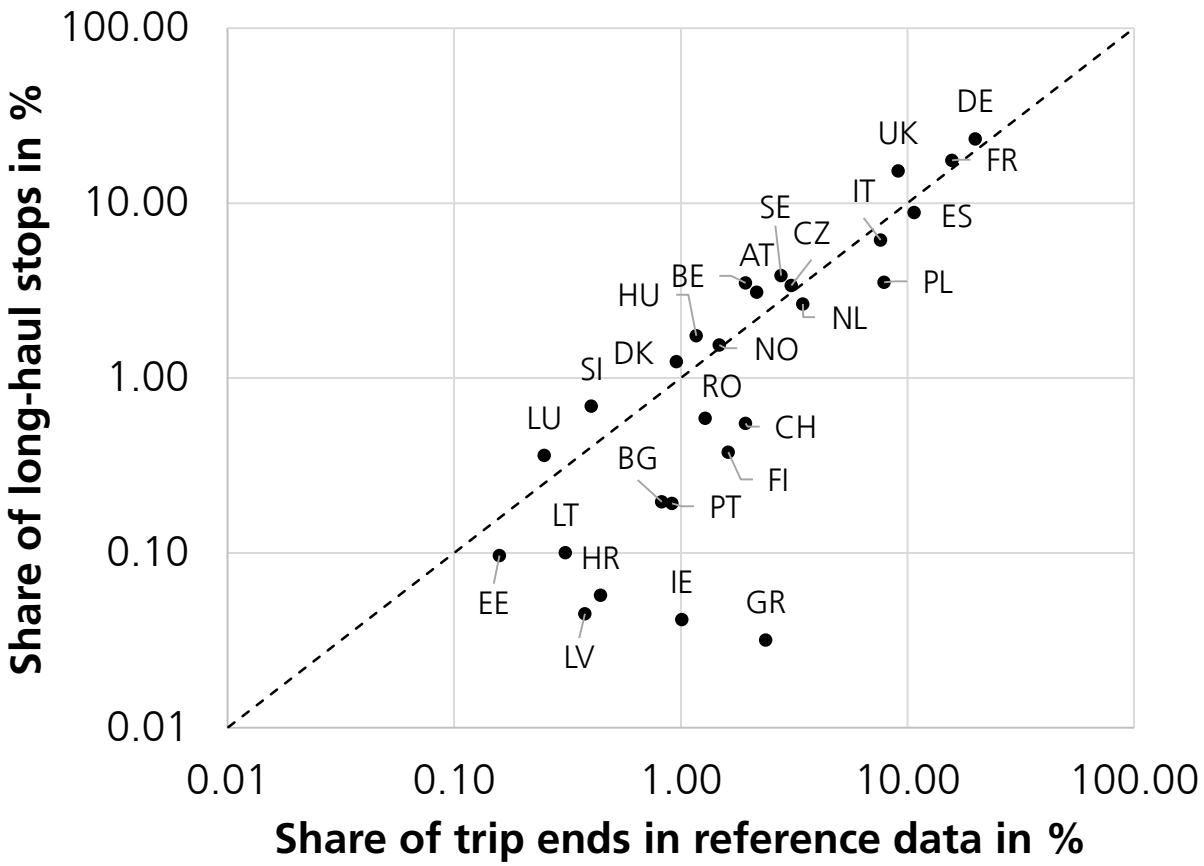
Dataset 2: Representativeness has been tested - Good coverage of Western Europe in long-haul data

Lack of reference data: assessment difficult

Several indicators have been used:

- Seven major OEM indicate high vehicle stock coverage
- All countries in Europe are covered in long-haul and many in regiona data
- High correlation between number of stops per country and number of locations per country
- Share of stops by country correlates to share of trip ends by country as derived from the ETISplus data on freight transport

Representativeness good for long-haul (except for some smaller countries) and limited for regional truck stop locations



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Phase I

Dataset 2

Truck Stop Locations

Dataset 2: Locations mainly at rest areas & logistics hubs. Many stops at few locations

Type of location difficult; combination with other geo-information data needed. Note that stops at private depot locations are included as well.

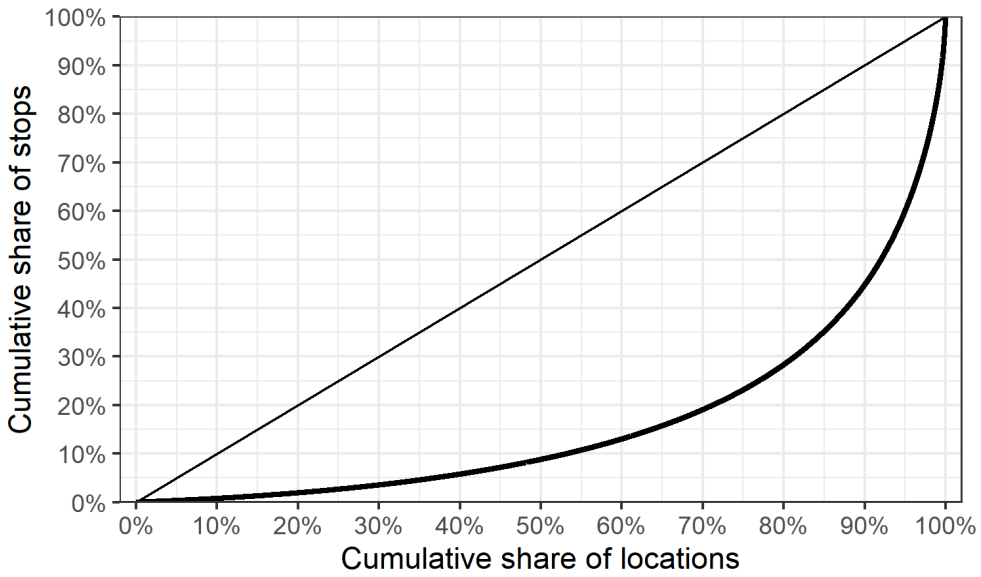
We extract tagged geo objects within 200 m radius of the long-haul locations

- Some locations can be clearly identified but many are uncertain
- Rest areas along the motorway, company sites, and logistics hubs including ports are most important

Important to note that most stops are at a few locations: 10% most visited locations contain about 50% of all stops

Long-haul coverage on total truck fleet: Around 1/3

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



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Truck Stop Locations

Dataset 2: Notes from the report and email conversation

Phase I

Dataset 2

From the report:

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 1 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.¶

From further discussions (see email)

Long-haul only: ¶

- Number of trucks = 230k¶
- Number of stops per year per truck: than (100 000 km per year / 80 km per hour) / 4.5 h driving between stops = at least 277 stops per year¶
- Total number of stops at perfect scheduling efficiency and very high mean speed = 277 * 230k = 64m, so let's assume 90m stops per year¶
- Assumed share of stops at the depot = 25%, Annual number of stops not at depot = 75% * 80m = 67m¶
- Annual stops at the 31k locations in the dataset = 31,145 * 1678 = 52m¶
- Conclusion: Around 75% of stops by trucks in long haul operation take place at these locations, and around 40% of all non-depot stops take place at the top 3k locations.¶

¶

Summary ¶

Around three quarters of non-home-depot stops by trucks in long-haul operation take place at the locations in the data set, and around 40% of all non-home-depot stops take place at the top 10% locations within the locations data. The long-haul stop locations do not cover all non-home locations but many and the most important locations ¶

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Truck Stop Locations

Dataset 2: Limitations

Phase I

Dataset 2

Country of origin of the vehicles that stop at the location (domestic or international):	**Not available**
Vehicle weight of the vehicles at the stop locations:	**Not available**
Seasonal differences at the stop locations:	**Not available**
Type of vehicle (rigid truck or tractor-trailer):	**Not available**
Average age of vehicles at the location:	**Not available**
Split between average duration at stops:	**Available (<1h, >8h)**

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Geospatial merging (1/5)

Overview

Legend:

- **Dataset 1:** Dutch parking locations - Low, Medium, High (N=1,092)
- **Dataset 2:** ACEA Locations TOP 10 (70-130 trucks/day)
  ACEA Locations TOP 11-100
  ACEA Locations Residuals (N=1,055)

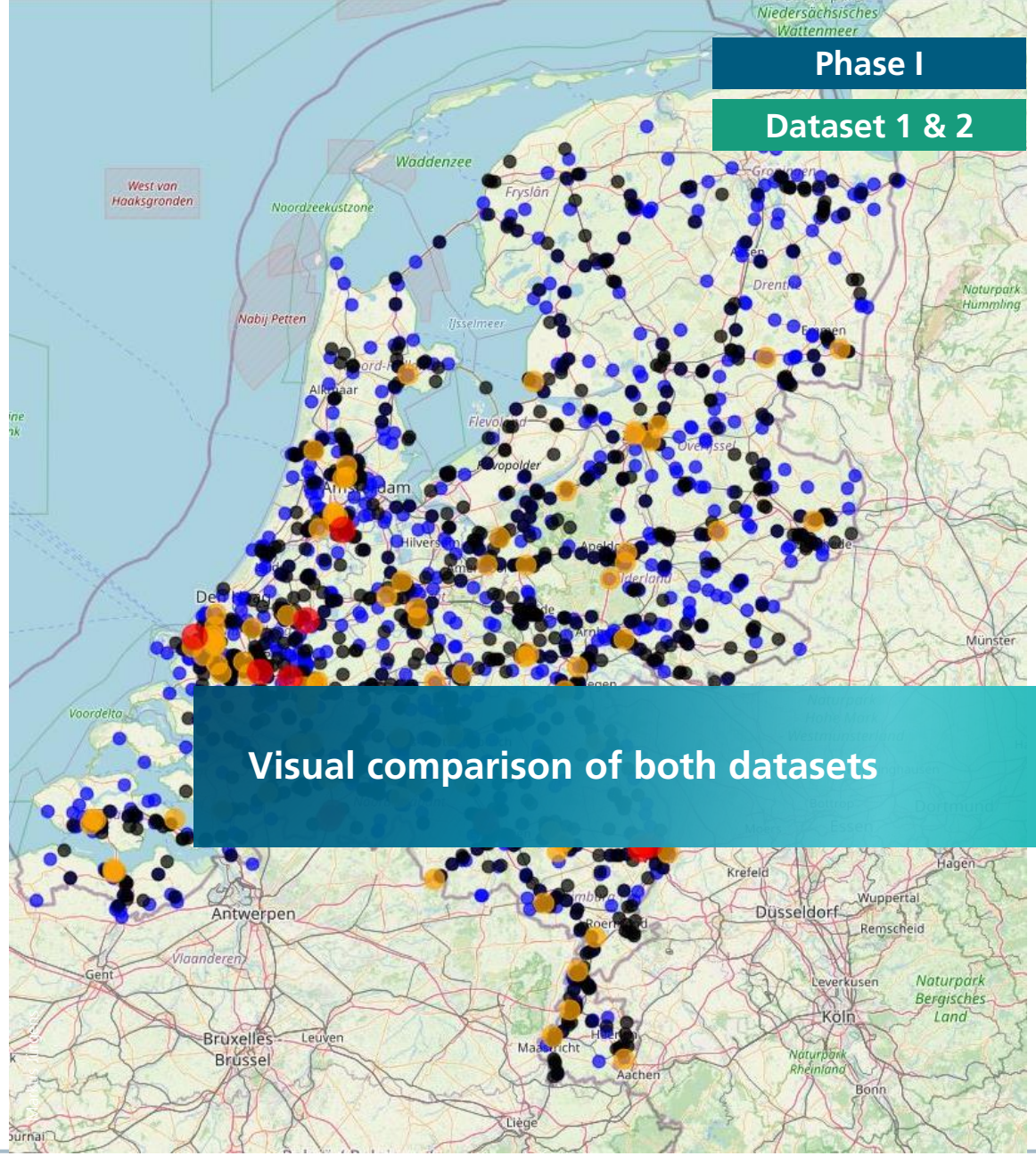

Image source: Own illustrations. Python Folium + OpenStreetMap background

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Geospatial merging (2/5)

Details

Phase I

Dataset 1 & 2

Approach

Data Aggregation necessary to condense the data and merge nearby locations.

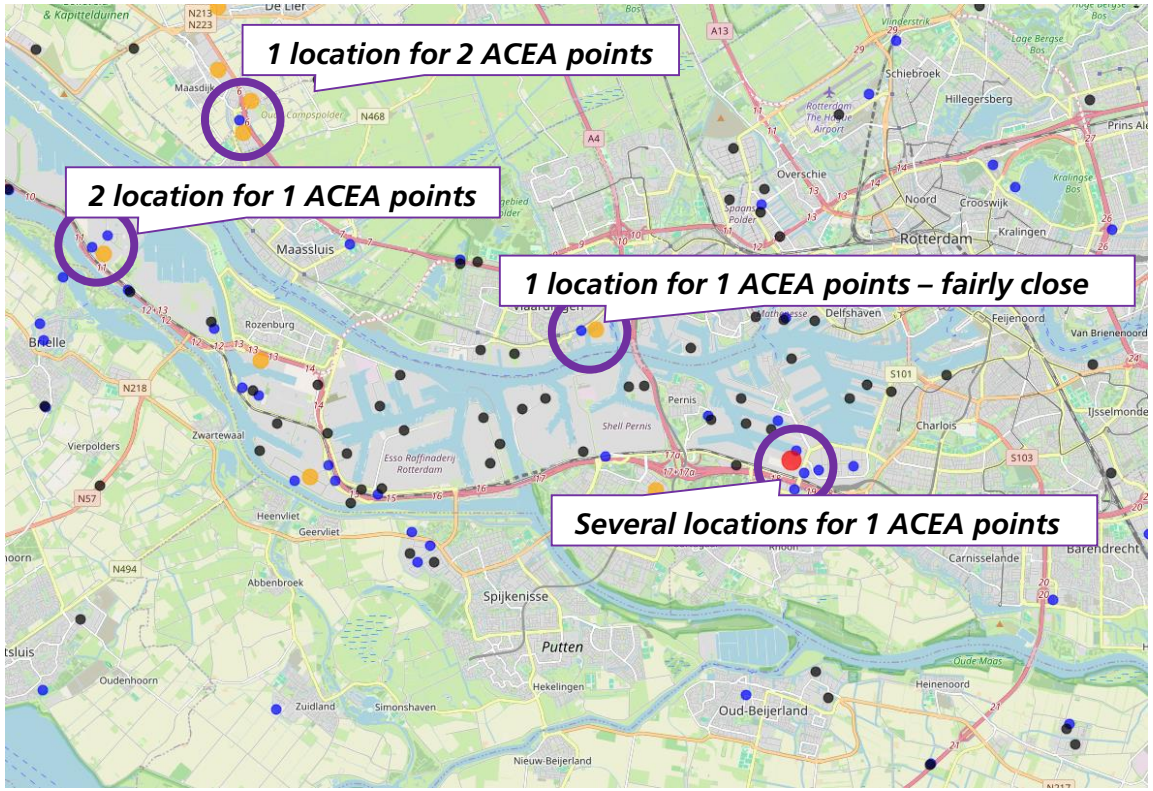
- **Transfer of ACEA properties (Dataset 2: number of trucks, time information…) to the Dutch parking locations (Dataset 1).**
- **Note: Geospatial inaccuracies due to clustering present in both datasets.**

Issue: Which proximity / distance threshold is appropriate?

-> Result A: Only nearest ACEA location (within 500m)

-> Result B: All ACEA locations within 1500m

Map (Excerpt)



~750m radius

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Geospatial merging (3/5)

Details -> Result A (Nearest Only)

Phase I

Dataset 1 & 2

- **Final filtering and clustering necessary:**
  - Avoid double counting (locations with same ACEA data)
  - Remove locations with insufficient information and “low” truck-Parking-Confidence (potentially private).
    - *Note: Insufficient information emerges from a combination of large distances to the next ACEA point, low number of truck stops and the "Low" truck parking confidence label. For the latter, we double checked the labelling with all original information from the different APIs.*
  - **Final number of potential locations: N=281**

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Phase I

Dataset 1 & 2

Geospatial merging (4/5)

Details -> Result B (Within 1500m)

Approach for Result B

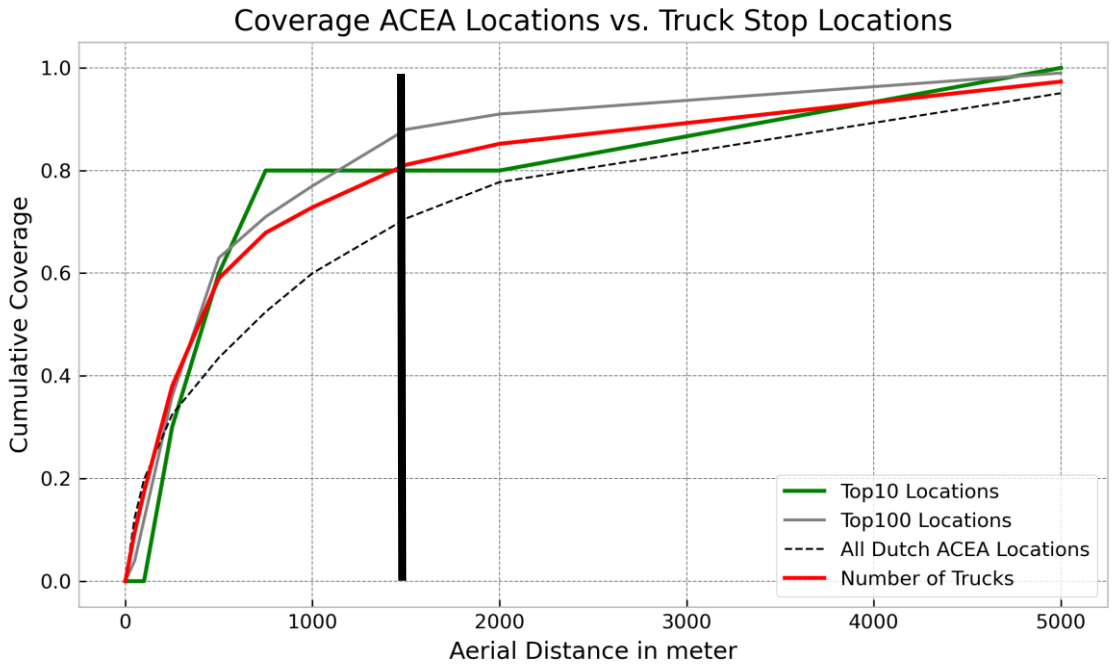
Data Aggregation necessary to condense the data and merge nearby locations.

- **Transfer of ACEA properties (Dataset 1: number of trucks, ...) to the Dutch parking locations (Dataset 2).**
- **Note: Geospatial inaccuracies due to clustering present in both datasets.**

Chosen distance threshold: 1500 meter
-> 702 matched locations

- Coverage Top 10 ACEA locations: 80%
- Coverage Top 11-100 ACEA locations: 88%
- Coverage All Dutch ACEA locations: 71%
- Coverage of Dutch ACEA trucks stops: 81%

Which proximity threshold is appropriate for Result B?



- *Note: We additionally provide the distance to the nearest ACEA locations („trust or reliability level") so that RVWL / ElaadNL can filter independently.*

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Phase I

Dataset 1 & 2

Geospatial merging (5/5)

Details -> Result B (Within 1500m)

- **Interim dataset -> N=702 locations**
- **Final filtering and clustering necessary:**
  - Avoid double counting (locations with same ACEA data)
  - Re-cluster nearby locations (MeanShift Algorithm with d=450m)
  - Remove locations with insufficient information and "low" truck-Parking-Confidence (potentially private)

Final coverage of Dutch ACEA truck stops: 47%

Final number of potential locations: N=287

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Agenda

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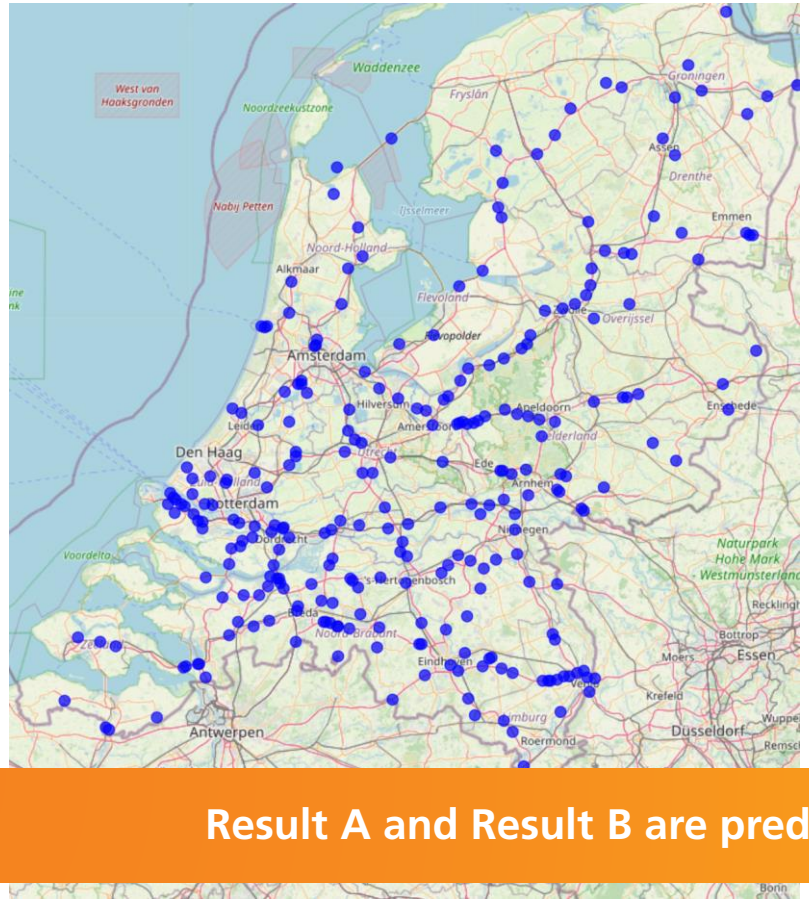
Phase I

Dataset 1 & 2

Data Results

Comparison Result A and Result B

Result A: Nearest ACEA only



Result B: Within 1500m

Result A and Result B are predominantly the same - especially at large locations.

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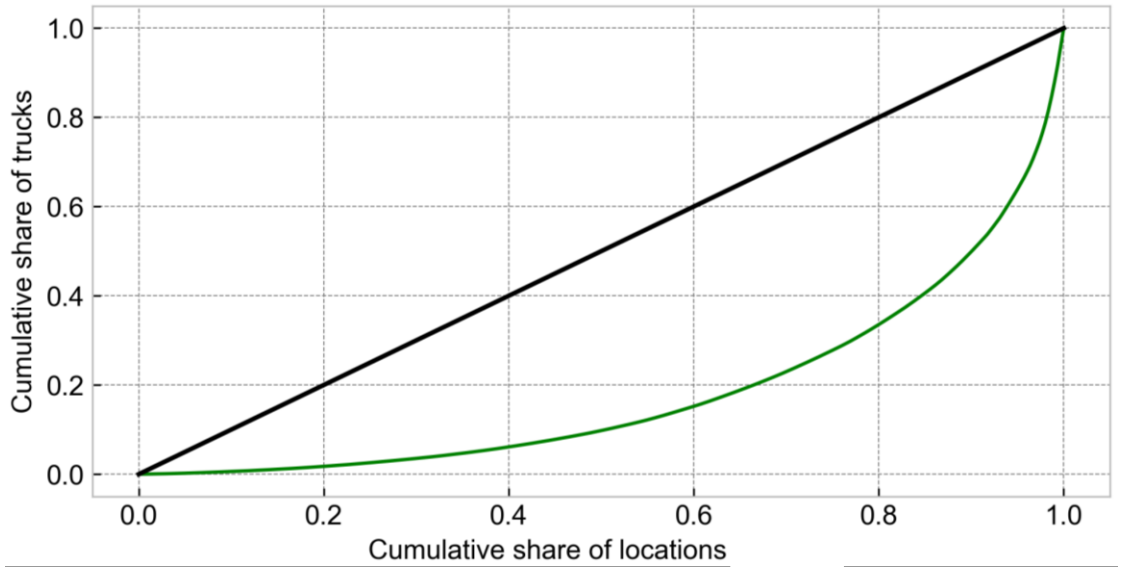
Phase I

Dataset 1 & 2

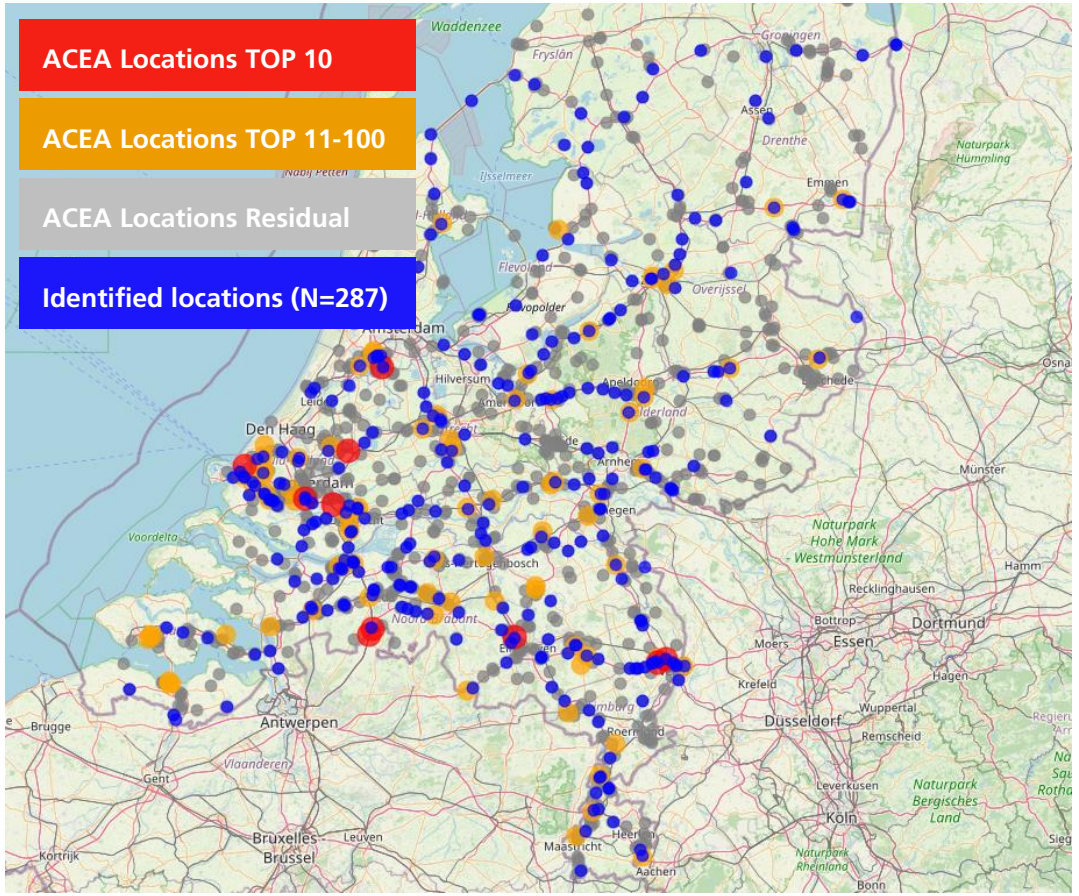
Data Results

Result B (Within 1500m) (1/2)

Lorenz Plot for the identified locations (N=287)



Map



One central characteristic of the ACEA data is retained

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Data Results

Result B (Within 1500m) (2/2)

Phase I

Dataset 1 & 2

Assessment

Short stops (below 1h – MCS relevant):

- **Around 1/3 (of all truck stops at this location) seems reasonable for all location types.**

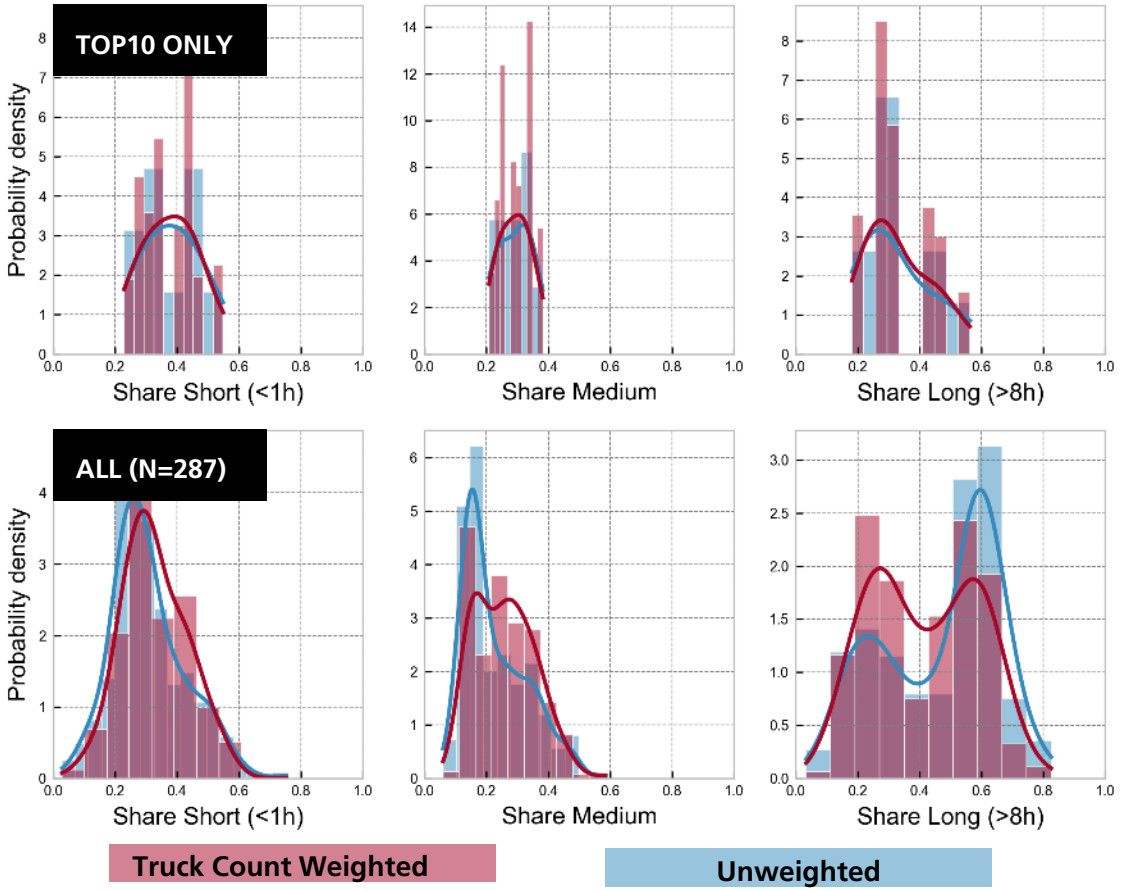
Medium and long stops:

- **Multimodal distributions. Combined share of around 2/3 (of all truck stops at this location) seems reasonable for all location types.**

Note: Influence of the surrounding area for every location (i.e., industrial zones with large truck operating truck fleets)

1/3 of stops for MCS but only 10% of chargers due to short charging break (~45min)

Evaluation of stop durations



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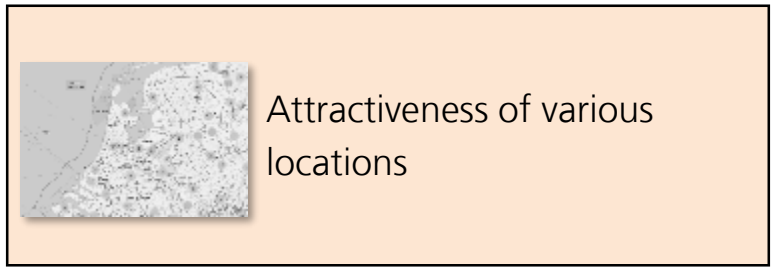
Further processing

Overview

Step 3: Evaluation of location attractiveness



Step 4: Recommendations for action and implications

- **Highlighting differences and similarities with regard to the attractiveness of different locations**
- **Identify most suitable locations along TEN-T segments**
- **Discussion of different concepts**
  - Hot-spot concept: focus on highly attractive areas
  - Gap concept: focus on less attractive locations for better coverage of the road network

Further processing required to condense the recommendation (i.e. number of locations)

Image sources: Own illustrations

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Further processing

Approach

Greedy strategy to ensure that each choice is locally optimal, aiming to incrementally build towards a solution that covers as much of the network (= Dutch TEN-T network) as possible using the most attractive points (from N=287).

Pros: **Simplicity and efficiency.**

Cons: **Local optimization (that gradually builds towards global ones) and no backtracking.**

Pseudo Code:

1. ***Buffer zone:*** *Define the captured area (buffer with radius) for each location.*
2. ***Location selection:*** *Select the location with the highest attractiveness that provides the most coverage for the uncovered network.*
3. ***Update Coverage:*** *After selecting a location, update the network to mark the parts covered by this location.*
4. ***Repeat:*** *Continue selecting locations until no more locations can improve the coverage (i.e., no more uncovered parts of the network or remaining locations).*
5. ***Addition:*** *Add completely isolated locations away from the TENT network*

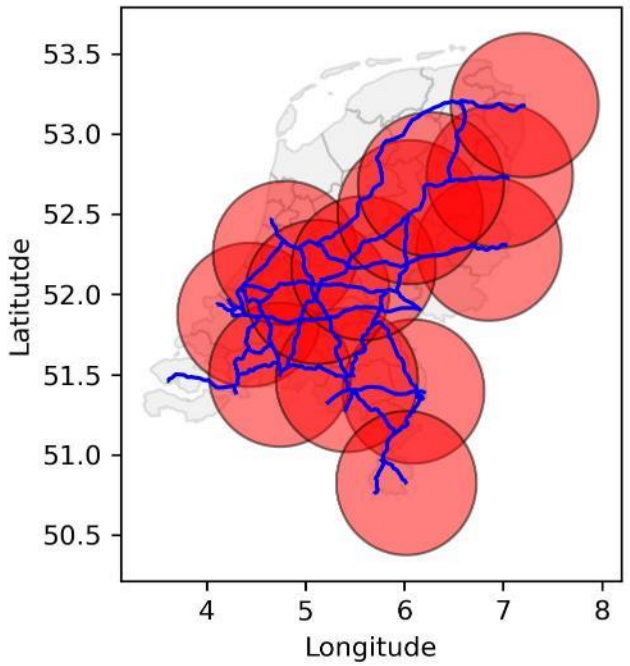
Phase II

Result B

Further processing

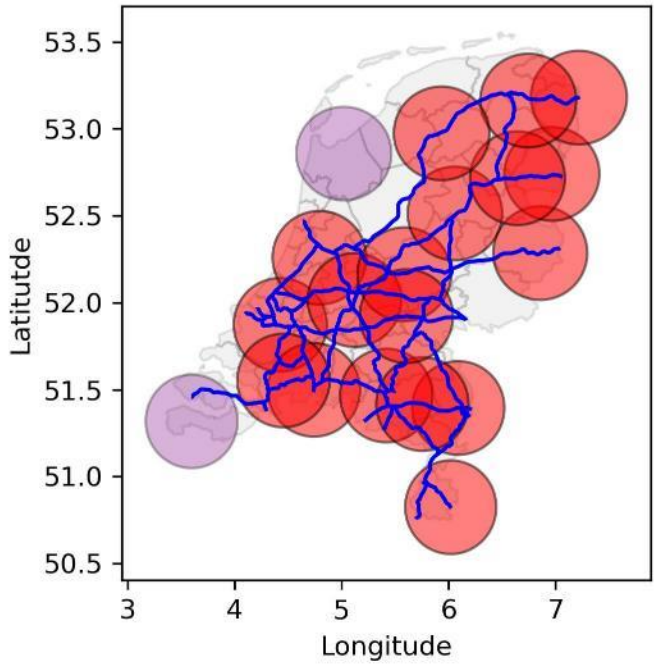
Results (1/2)

Radius = 50 km (wide-meshed)



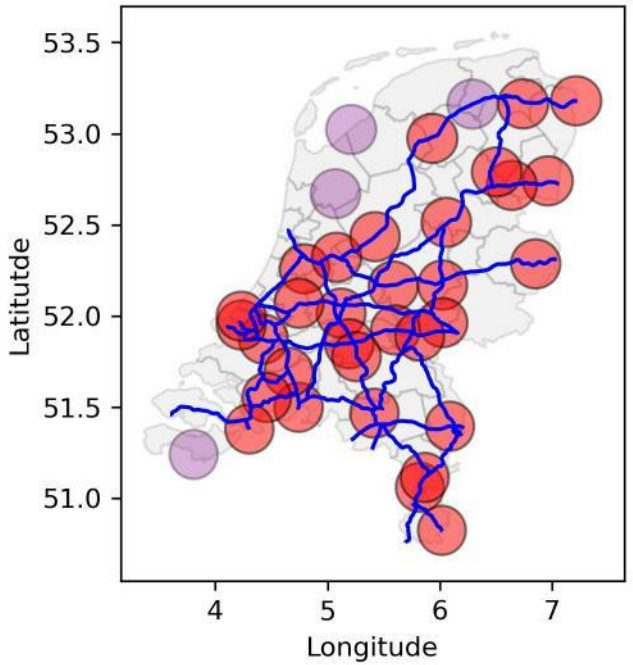
N=13 (13+0)

Radius = 30 km (dense)



N=20 (18+2)

Radius = 15 km (more dense)



N=36 (32+4)

Greedy locations

Added location (non TENT)

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Phase II

Result B

Further processing

Results (2/2)

Assessment

- **13 to 36 locations could be sufficient to cover most attractive truck parking hotspots along mainly the TENT network**
  - Note: Feasibility (area, grid connection, …) not ensured, so adjustments may be required
- **Few locations (left: marked in green) seem favourable in each deployment scenario**
  - Implies certain robustness
  - Focus on our identified Top10
- **The respective location should be considered a reference point, not an exact position (detailed search in this vicinity)**

Location IDs

Radius = 50 km	Radius = 30 km	Radius = 15 km
ID 1	ID 1	ID 1
ID 2	ID 2	ID 2
ID 4	ID 4	ID 4
ID 5	ID 5	ID 5
ID 7	ID 7	ID 6
ID 8	ID 8	ID 7
ID 10	ID 10	ID 8
ID 17	ID 15	ID 9
ID 21	ID 17	ID 10
ID 22	ID 19	ID 13
ID 27	ID 21	ID 17
ID 60	ID 22	ID 19
ID 94	ID 27	ID 21
	ID 28	ID 22
	ID 40	ID 25
	ID 94	ID 27
	ID 120	ID 28
	ID 129	ID 30
	ID 183	ID 33
	ID 251	ID 34
		ID 40
		ID 43
		ID 44
		ID 48
		ID 58
		ID 71
		ID 72
		ID 79
		ID 90
		ID 94
		ID 120
		ID 129
		ID 149
		ID 220
		ID 235
		ID 271

Phase II

Result B

Final data

Formatting example (excerpt ID1)

ID	**ID-1**
category	**Truck Stop, Rest Area, Fueling Station, Truck Parking**
lat	**51.39445, 6.09115**
totalArea_m2	**78,882**
CLC	**121 (industrial-commercial area)**
truckParkingConfidence	**High**
distance_NextACEA_km	**0.1713259**
share_shortStopps <1h	**20-30%**
share_mediumStopps	**20-30%**
share_longStopps >8h	**40-50%**
score_NumTrucks	**4.2% (~120 Trucks / day)**
tentCore_Distance_km	**0.00713957 (E034, A67)**
tentComp_Distance_km	**2.45491891 (E999, A74)**
Part of the 50km-meshed network	**yes**
Part of the 30km-meshed network	**yes**
Part of the 15km-meshed network	**yes**

Truckstop(s) Venlo

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Agenda

1. Organization
2. Overview ZIP-file
3. Methodology & Data
4. Results
5. Further Notes and Documentation

Further Notes and Documentation

Email conversation (1/4)

- **Q: What are the main differences between nearest and 1500 meters? Is it 1500 meters btw or is it a typo and should it be 500 meters?**

A: If we consider only the nearest location, we only match the nearest ACEA location (Dataset 2) to the public truck parking locations (Dataset 1). The chosen maximum distance was set to 500m. This affects the number of truck stops and the accompanying stop time information. If we use the second approach (i.e. consider all ACEA locations within a 1500m radius around any public truck parking locations, we summarize and combine the information (truck stop and stop times) per location.

- **Q: Are there many places where the nearest ACEA location is more than (1)500 meters away?**

A: Yes. The ACEA dataset contains all types of truck stops, public and at private depots. Therefore, it is evident that there are cases where the distance between an ACEA location (presumably private) and the next public truck stop is large. Note that the attractiveness of a public truck stop locations very likely also depending on the surrounding area where especially large (private) depots and fleets matter.

Further Notes and Documentation

Email conversation (2/4)

- **Q: Does the % of the ACEA locations represent real values in your dataset? I ask this question to check what happens when you aggregate (e.g. multiple ACEA locations for 1 truckparking, what value does the truckparking get in terms of truckstops)?**

A: Yes, these are orginal percentiles / classes not aggregated. If we aggregated several locations with different classes, we took the highest. Thus truck stops (around maximum 130 truck per day as given by the original dataset) can be scaled.

- **Q: Where are the 2 outliers of the top 10 ACEA locations?**

A: One around Waddinxveen (A12 - N219) and the other is at the Hoek van Holland Haven. In both cases, according to our truck parking location data, there is no completely free / public access to parking lots possible while there are lots with restricted (customer) access.

Further Notes and Documentation

Email conversation (3/4)

- **Q: Why was 450meters chosen here for the re-cluster? To what extent would this again require to have the truckparking dataset (dataset 1) to identify locations in practice in case a merge happened? (mostly from the perspective of a developer of local government)**

A: This 450m-distance was chosen as it has proven to be beneficial in the paper. The re-clustering applies in particular to the "within 1500m" approach (Result B) and it is irrelevant for the "nearest" dataset (Result A). Thus, inaccuracy can be correspondingly higher for the former. In particular, merging can also combine locations on opposite sides of the street.

- **Q: Greedy strategy -> Is there actually a way to take into account that trucks should not have to change highways to charge? Would this lead to significantly different results? Thinking a bit from a more practical perspective.**

A: Reachability in terms of start, middle and end section of the respective TEN-T section from this location is ensured. But especially in dense areas or if there are highway intersections, we cannot exclude a highway change.

Further Notes and Documentation

Email conversation (4/4)

- **Q: Greedy strategy -> is this an example of the hot spot or the gap concept?**

A: Using the most attractive locations to cover the network is more the hot spot concept (red circles). However, industry players will probably also start with the most attractive locations from above. You could then add the less attractive ones starting from the bottom of this list. The additional locations (purple locations) are then more like further gaps.

- **Q: Greedy strategy (slide 17) -> for the 15km radius I do still see some gaps between parts of road networks (e.g. in the bottom-right corner), does that mean that the coverage is not directly related that it's should be within reach of the corridor, but the ACEA locations?**

A: The coverage term is defined that the majority of this TEN-T section (geo-coordinate line string with LAT-LON information) is covered. Thus, certain interim sections might not be covered. We check the implementation and come back on that during our final meeting.

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Thank you!

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