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Comprehensive Methodology for Assessment of Road Transport Emissions in Seaports: Port of Barcelona Case Study

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MOTIVATION

The **transport sector is responsible for 25% of Europe's total GHG emissions**, with road transport contributing 71% of this share. National and international regulations, such as Fit for 55, aim to mitigate these emissions.

Ports play a crucial role in transport sector and significantly impact the transition towards environmental sustainability, given that they are key nodes in the supply chains.

However, quantifying emissions in ports is complex due to the variety of activities and vehicles involved. **Existing methodologies for calculating port-related GHG emissions often lack detailed estimation of vehicle travel distances within port boundaries**.

CHALLENGE AND APPROACH

CHALLENGE:
The main challenge in the literature is the lack of specific methodologies for collecting data on distance traveled or fuel consumption in port contexts.

PROPOSED SOLUTION:
This research proposes a **bottom-up approach** for estimating GHG emissions from road transport within port boundaries, using **ALPR cameras** located at the port gates to generate an **origin-destination matrix** of each type vehicles visiting the port.

→ This methodology estimates road vehicle travel distances within ports to calculate GHG emissions. This approach provides a comprehensive view of road transport operations in the port area, categorized by freight type (e.g., containers, bulk, automotive) and vehicle fleet characteristics.

ALPR DATA

To calculate emissions, the following key metrics are required:

- The composition of the vehicle fleet visiting the port (e.g., car, bus, truck).
- The distance traveled by each type of vehicle.
- The emission factors associated with each vehicle type.

This approach uses data collected from cameras positioned at the access and exit points of the commercial area of the port. This methodology requires a closed network with **ALPR (Automatic License Plate Recognition)** technology installed at the external gates and at port terminals. This technology is crucial for defining the **origin-destination matrix**, which is necessary for calculating the **total distance traveled within the port** and for the definition of the types of vehicles visiting the port.

LICENSE PLATE	DATE AND TIME	LANE	ACCESS NUMBER
1234AAA	01/01/2022 00:01	ENTRY	Puerta 29

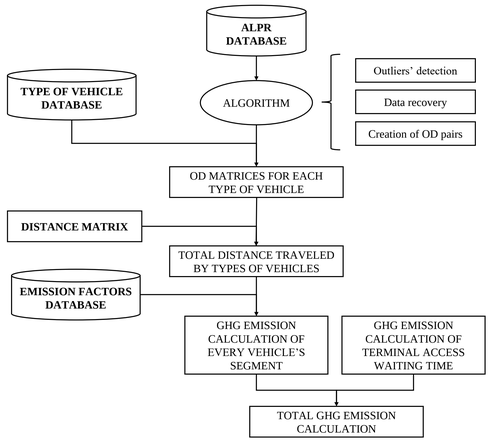
The ALPR information should be integrated with a dataset that associates every license plate to a type of vehicle, associating the type of fuel, environmental standard and mass.

It is important to specify the scope of the calculation in terms of both space and time.

METHODOLOGY FRAMEWORK

ALPR INFORMATION:

- Time information (date and hour)
- License plate number
- Direction of travel (entry or exit)
- Camera's location

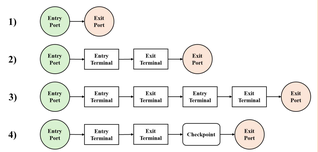


DISTANCE MATRIX

The distances between the cameras located in the area are stored in a matrix. Google Maps has been employed to measure the shortest path between two nodes of the network, represented by the cameras.
In the diagonal of this matrix, the value represents the distance for vehicles that enter and exit at the same point.

OD MATRIX DEFINITION:

The port is a closed network so there is no concern regarding route choice behavior by users, a non-assignment methodology can be employed to generate the origin-destination (OD) matrix.



EMISSION CALCULATION:

$$E_{tot} = \sum_i E_{cruise,i} + \sum_j E_{idle,j}$$

Cruise mode emissions:

$$E_{cruise,i} = \sum_i (OD_i \times D \times \overline{VF_i} \times \overline{EF_i})$$

The cruise mode emissions are calculated for each vehicle category *(i)*, depending on the vehicle fleet composition in terms of powertrain, EURO standard and vehicle size

Idle mode emissions:

$$E_{idle,j} = \sum_j (\Delta T_{median,j} \times N_j) \times FC \times EF$$

The idle mode emissions depends on the queues at terminal accesses. These emissions depend on the waiting time calculated as difference between the actual travel time and the minimum travel time. The median time for each terminal *(j)* has been used to avoid outliers.

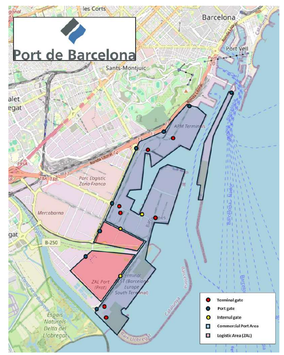
DATA RECOVERY:

The possible lacks in the database are the following:
- Unpaired action (see the table below)
- Illogical pairing

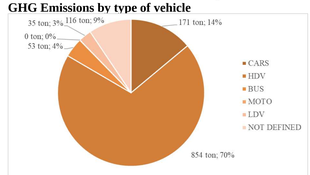
Unpaired Record's Action	Dummy Record added	Hypothesis
Entrance to the Port (EP)	Exit from the Port (SP)	An SP is added one second later than the EP, through the same gate.
Exit from the Port (SP)	Entrance to the Port (EP)	An EP is added one second before the SP, through the same gate.
Entry to the Terminal (ET)	Exit from the Terminal (ST) and Exit for the Port (SP)	An ST is added one second later than the ET. In addition, an SP is added through the most used gate.
Exit from the Terminal (ST)	Exit from the Port (SP)	An SP is added one second later than the ST, through the most used gate.
Entrance to the Checkpoint (EC)	Exit from the Port (SP)	An SP is added one second later than the EC, through the most used gate.
Exit from the Checkpoint (SC)	Exit from the Port (SP)	An SP is added one second later than the SC, through the most used gate.

RESULTS: PORT OF BARCELONA CASE STUDY

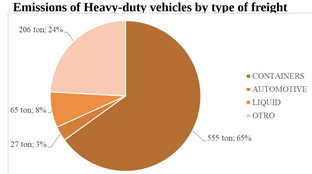
The Port Authority of Barcelona has set important GHG reduction targets, and it is elaborating an Energy Transition Plan (ETP) to achieve it. Annual calculation of the carbon footprint of the port activities, performed using clear methodologies and verified by a certification scheme (ISO 14064-1) is mandatory to monitor the effectiveness of the emissions reduction ETP actions.
It is possible to segregate the results on necessity base, for types of vehicles or type of goods.



GHG Emissions by type of vehicle



Emissions of Heavy-duty vehicles by type of freight



DISCUSSION AND CONCLUSION

- Other methodologies in literature suggests to compute emissions starting from:
  - **Traffic statistics**: limited just to freight transport and not detailed travelled distance;
  - **Surveys and GPS**: the automation is not possible;
- With the application of this framework, it is possible to compute the emissions of all the vehicles accessing to the port area, computing the distance travelled inside the network. Moreover, the matrices obtained can also be used for **transport management and planning** within the network.
- There is room for **improving the accuracy** increasing the number of cameras for detecting congestion phenomena in the network and reducing non identified vehicles and better emission factors by vehicle categories would be interesting and be also able to calculate other pollutants.
- **Future development** is the automation of the calculation within a digital twin that allows real-time emission calculations and enables predictions and simulations of scenarios involving the implementation of mitigation measures.

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