Reduction of CO_2-Emissions ejected by Heavy-Duty-Vehicles

in the Port of Hamburg

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Project Partner: Port of Hamburg

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EXECUTIVE SUMMARY

As one of largest ports in Europe, the Port of Hamburg is an important hub for international transport and supply chains. On average 33,000 vehicles use the main port roads every day – a third are heavy-duty vehicles (HDV) which account for a large proportion of the port's annual produced CO_2 emissions. Based on the provided data it can be estimated that around 17,500 tons of CO_2 were produced by HDV in the Port of Hamburg during the first half of 2018. To identify potential measures to reduce emissions, four different types where examined: Measures which…

- have already **been implemented** in the Port of Hamburg and are in regular operation,
- are being tested as **pilot projects** in the Port of Hamburg,
- are currently **being discussed** in the Port of Hamburg and
- additional **good practices** with from other countries and ports.

In order to recommend a course of action for the Port of Hamburg different measures working towards the same goal were combined into twelve clusters. This approach helps to build on existing regional achievements while ensuring that the broadest possible overview can be used in terms of transferability to and from other ports.

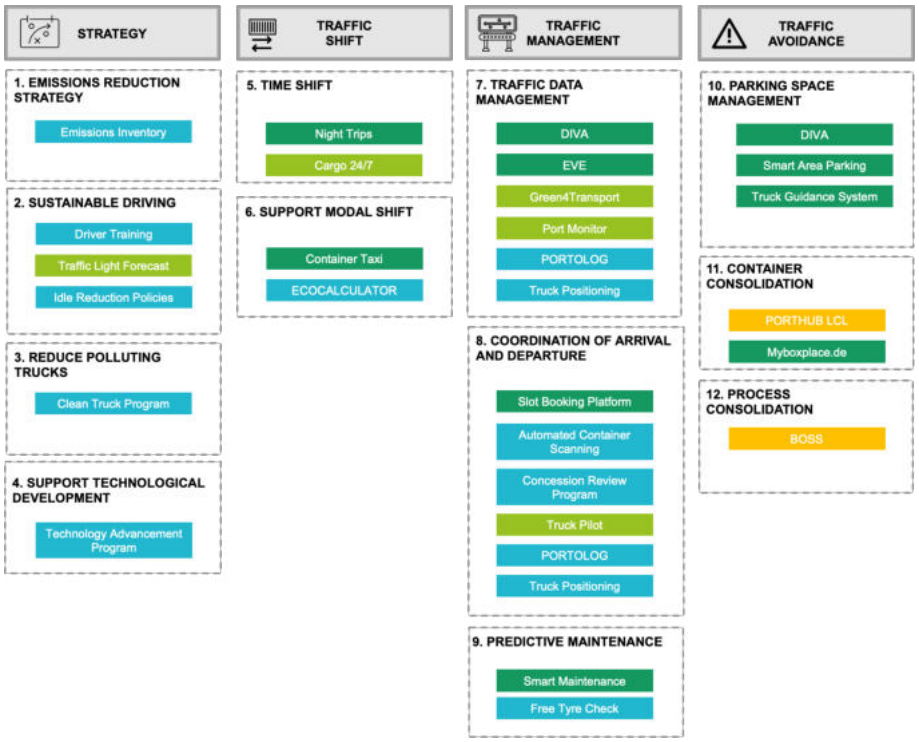

Figure 1 Classification of measures into categories and clusters

Each cluster has been assessed according to three aspects in order to recommend further action:

- **Impact (y axis)** refers to the assessment of the possible success that can be achieved by establishing the cluster.
- **Effort (x axis)** refers to the estimated contribution that is required for the implementation of the cluster.
- **Potential for the Port of Hamburg (bubble size)** describes the compatibility as well as applicability to the conditions in Hamburg.

Based on these variables the clusters are presented in a matrix to make them comparable in a comprehensive format and support the further decision-making processes.

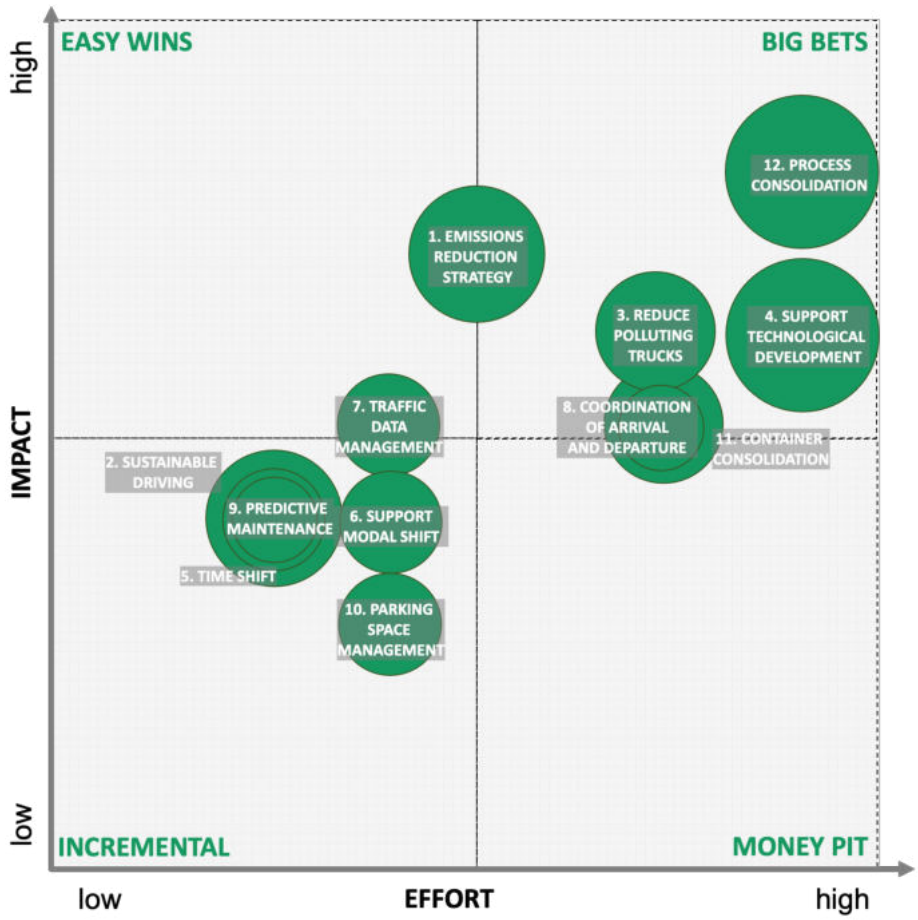

Figure 2 Cluster Analysis Summary

Continuous steering of these measures is of particular relevance to enable the best possible outcome. To reduce the risk that too many parallel initiatives emerge without benefiting from another, conflicts should be minimized by identifying the relevant gaps and potential synergies in advance. It is particularly important to develop a well-coordinated comprehensive strategy

and concept for the Port of Hamburg as a whole. A detailed and transparent data collection process plays a key role for a complete and effective evaluation of emissions. In general, the potential environmental impact is rarely quantitatively assessed or evaluated specifically when projects are considered, analyzed or rated. Therefore, it is recommended to adjust the data collection processes to allow a reliable and verifiable evaluation.

The four clusters with the highest potential to reduce CO_2 emissions in the Port of Hamburg are *Support Technological Developments (4), Process Consolidation (12), Emissions Reduction Strategy (1)* and *Sustainable Driving (2).*

As indicated by the quadrants, the matrix is divided into four categories. The individual clusters and related measures were assigned to the four quadrants and thus the prioritization of the different clusters can be quickly assessed:

Easy Wins (top left) give a high return based on the necessary effort.
Big Bets (top right) provide long term results but require planning and strategy.
Increments (bottom left) do not require a lot of effort but neither do they offer many benefits.
Money Pit (bottom right) are time- & money-consuming activities with low impact.

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ABBREVIATIONS

BWI	Ministry of Economy and Innovation (in German: Behörde für Wirtschaft und Innovation)
CO_2	Carbon Dioxid
DIVA	Dynamic information on traffic flow in the port (in German: Dynamisches Information zum Verkehrs-Aufkommen im Hafen)
ETV	European Union Environmental Technology Verification
EVE	Effective depiction of the traffic situation (in German: Effektive Verkehrslagedarstellung)
GHG	Greenhouse gas
GloMEEP	Global Maritime Energy Efficiency Partnerships
HBEFA	Handbook Emission Factors for Road Transport
HDV	Heavy-Duty-Vehicle
HHLA	Hamburg Hafen und Logistik AG
HPA	Hamburg Port Authority
NMVOC	non-methane volatile organic compounds
LCL	Less than Container Load
LIHH	Logistics Initiative Hansestadt Hamburg
LNG	Liquefied Natural Gas
PRM	Port Road Management
NABU	Nature and Biodiversity Conversation
SO2	Sulphur Dioxid
UBA	Umweltbundesamt
VHSp	Hamburg Freight Forwarders Association (in German: Verein Hamburger Spediteure e. V.)
VMT	Vehicle miles travelled
V2X	Vehicle-to-everything

1 PREFACE

As one of largest ports in Europe, the Port of Hamburg is an important hub for international transport and supply chains. Whereas a huge proportion of the long-distance transports to and from the port are railway-based, road transport is still the dominating mode when it comes to transports within the port area and short-distance haulage. On average 33,000 vehicles use the main port roads every day – a third of which are heavy-duty vehicles (HDV) which account for a large proportion of the port's annual produced CO_2 emissions.

In the Interreg Europe project "Smooth Ports", Hamburg represented through the Ministry of Economy and Innovation (BWI) partners with local authorities from four other European port cities in France, Italy and Bulgaria to jointly work on solutions that improve the traffic flow within the ports and potentially reduce CO_2 emissions. For Hamburg, the project is an important step within the execution of the climate plan and the necessary mobility transformation.

An essential part of the project are local studies prepared by each project partner. The aim is to determine CO_2 emissions caused by HDV in each port and identify ideas to reduce those emissions according to local conditions. The focus of the Hamburg-based study is to identify measures that increase efficiency in cargo handling and assess the potential to reduce emissions. In the final stage, the individual results of each study will be shared and discussed among all project partners.

2 STRUCTURE OF THE REPORT

Figure 1 gives an overview of the basic structure of this report consisting of the three work packages *Status Analysis, Identification of Measures* and *Analysis of Measures*. The proposed procedure is outlined and explained in terms of methodology and content. The individual work packages are not to be understood as independent units in the sense of silos. Rather, the intelligent networking of the findings from the individual work packages is key to a requirement-oriented assessment of relevant measures.

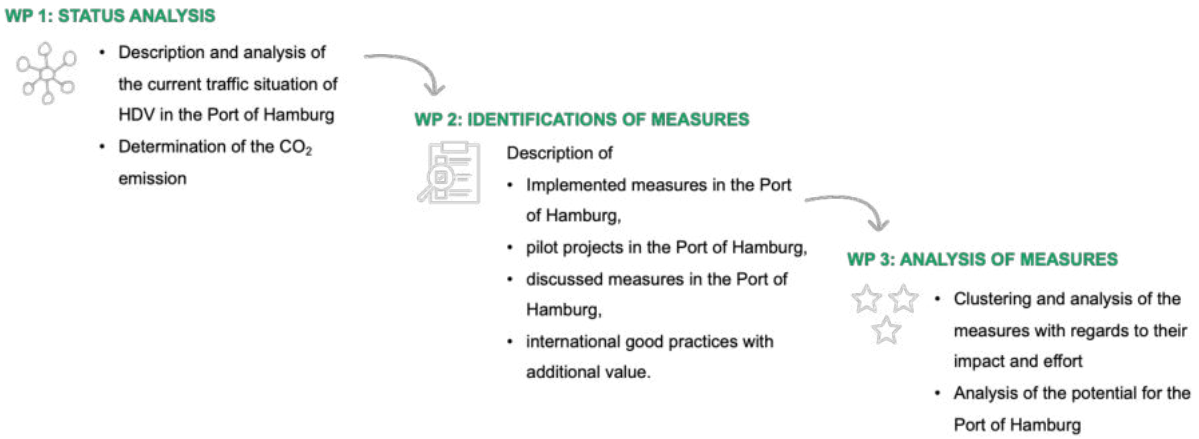

Figure 3 Approach

The information collected in work package 1 *Status Analysis* determined the CO_2 emissions of the HDV (Heavy-Duty-Vehicle) transports. According to the European Commission, HDV vehicles are defined as “freight vehicles of more than 3.5 tones (trucks) or passenger transport vehicles of more than 8 seats (buses and coaches)“ (European Commission, 2014).

In total 27 measures are being discussed in work package 2 *Identification of Measures*. They are grouped by their current project status in Port of Hamburg and international good practices. Based on this, the measures are clustered and analyzed in work package 3 *Analysis of Measures.* In the concluding chapter, the measures are prioritized and a recommendation for further actions is outlined.

3 STATUS ANALYSIS

Currently, there is no worldwide standardized process or formula for collecting the port emissions. In order to ensure comparability within the SMOOTH PORT project, the produced emissions were calculated by using the formula provided in the Port Emission Toolkit published in 2018 by GloMEEP Project Coordination Unit International Maritime Organization (GEF-UNDP-IMO GloMEEP Project and IAPH, 2018).

To estimate the emissions (E_i) caused by on-road HDV in the Port of Hamburg the formula (Figure 2) as well as the needed variables are explained in the following paragraphs. It is common practice to measure and/or determine emissions over the period of a year. For the purposes of the project's time constraints, the time frame has been specified for half a year.

The necessary background information and needed data for the assessment was obtained from the Hamburg Ports Authority (HPA) as well as site-specific studies such as the Border One Stop Shop Waltershof feasibility study. As a high-quality data basis is determining the quality of the assessment the available data was reviewed and analyzed through qualified expert interviews with relevant stakeholders such as the HPA, terminal operators and non-governmental organization like the Nature and Biodiversity Conversation (NABU). For further research the HPA's Sustainability Report (HPA, 2018) and Road Traffic Reports (HPA, 2019) were reviewed.

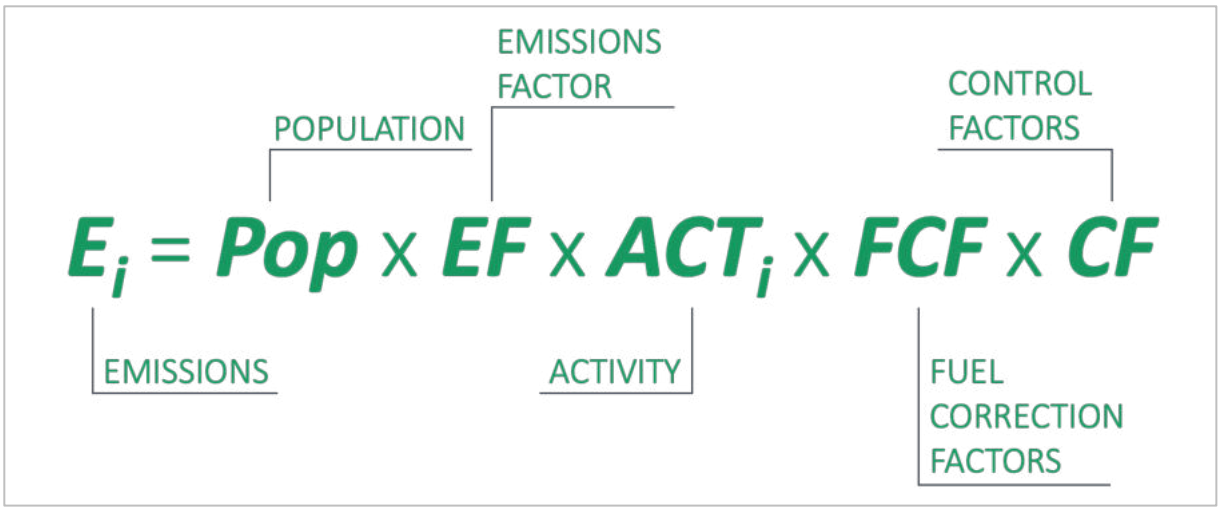

Figure 4 Equation to calculate CO_2 emissions from on-road heavy-duty vehicles (GEF-UNDP-IMO GloMEEP Project and IAPH, 2018)

Emissions (E_i): There are many different types of emissions that are produced during on-road heavy-duty transports. In addition to the well-known emission carbon dioxide (CO_2), particulate matter, nitrogen oxides (NO_2) and small amounts of sulphur dioxide (SO_2) as well as non-methane volatile organic compounds (NMVOC) are produced. With regards to the overall project goal and to ensure a cross-location comparability only CO_2 emissions are to be evaluated.

Population (Pop): The population includes all HDV vehicles accessing and exiting the Port of Hamburg. In the case of the Port of Hamburg, the traffic censuses from 2018 provided by the HPA will be used, as the data for 2019 is not available at the time of finalization of this study. As there is currently no data available on the specific truck models and their age-weighted distribution at the port, this initial estimate will be based on the data provided by the HPA so far, published data by the Federal Environment Agency and the publicly available reports of the Port of Hamburg.

Emissions Factor (EF): In Germany the emissions factor of HDV is calculated in the "Handbook Emission Factors for Road Transport" (HBEFA) by the German Ministry of Environment (in German Umweltbundesamt, short UBA). It is estimated in cooperation with different European governments and research institutes. As the emissions factor is published with an age-weighted distribution, the relevant emission factors can be applied without making additional assumptions.

Activity (ACT_i): The activity is broken down in three different areas: Vehicle miles travelled (VMT) per vehicle trip, on-terminal activity as well as number of starts after vehicle rests. The VMT per vehicle trip while in the port area are estimated based on expert statements within the HPA. Currently no valid estimations could be recorded for the on-terminal activities or the number of starts after certain vehicle rests.

Fuel Correction Factors (FCF): The fuel correction factor is dependent on the emissions factor and the type of fuel used by the fleet. As in Germany the fuel is already estimated based on standard average fleet estimations within the emissions factor of the HBEFA, the fuel correction factor is 1.

Control Factors: Control factors account for emissions reductions, such as from emissions control equipment installed by the manufacturer. Verified technologies for the European Union can be reviewed online (European Commission, 2020).

3.1 EMISSIONS IN THE PORT OF HAMBURG

The central location of the Port of Hamburg within the Hanseatic City increases the potential for conflict with regard to air emission values and thus future developments. In comparison to other European ports the rail share in hinterland traffic is quite high as more than half (51,3%) of cargo is handled by trucks in the Port of Hamburg.

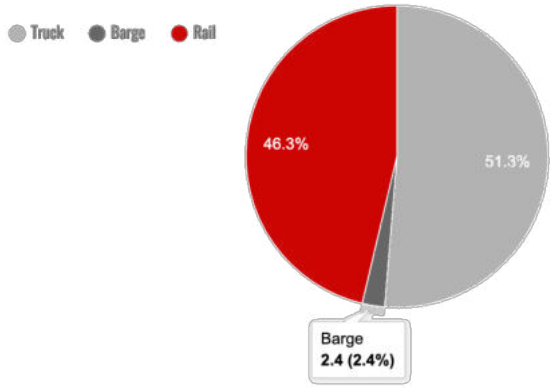

Figure 5 Modal Split in the Port of Hamburg (Port of Hamburg, 2019)

Additionally, many internal port transfers are conducted via the road as well. Due to the high proportion of HDV traffic, the reduction of CO_2 emissions from these transports is a critical factor for sustainable port development, especially in Hamburg. The main transport network covers 31 km and is divided into eight sections to enable a differentiated assessment. The HPA distinguishes between two categories of port roads: service roads as well as main and through roads. Most of the HPA's data collection focuses on the port's main and through road network.

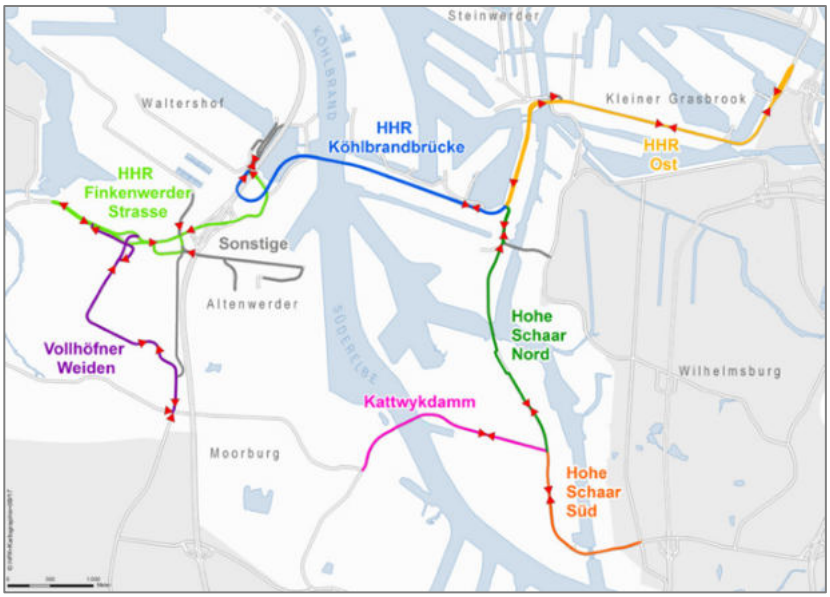

Figure 6 Most important roads and crossing in the Port of Hamburg (HPA, 2018)

Traffic data in the Port of Hamburg is collected selectively and recorded without destination-source relationships (Figure 5). Roughly around 17.100 HDV entry and exit the port area on a weekday. The HDV traffic consists of 61% articulated lorries, 33% trucks and trucks with trailers and 3% cars with trailers as well as 3% coaches and buses. It should be noted that there is a significant difference between working days and the weekend as only 2.000 HDV are counted on Saturday and even less on a Sunday. Based on this data it is estimated that 2,2 million HDV arrived in the main road network of the Port of Hamburg in half a year of 2018.

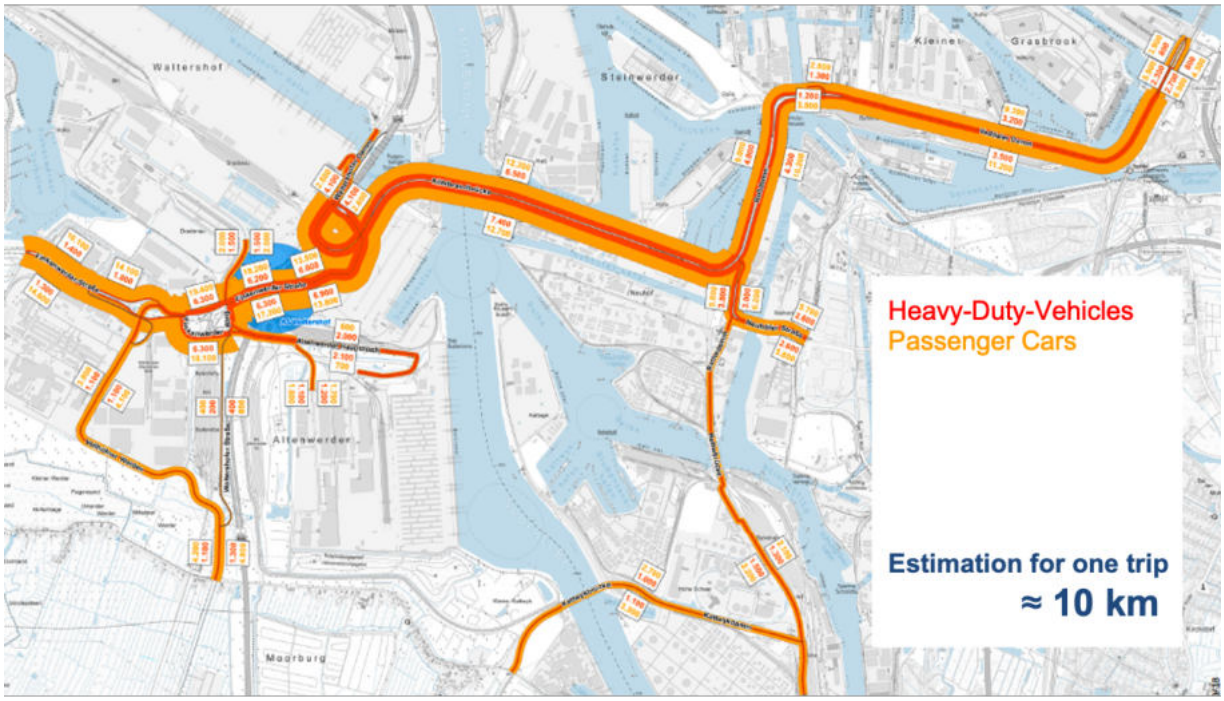

Figure 7 HDV Population in the Port of Hamburg on an average weekday (HPA, 2019)

An average round trip distance of 10 km is estimated.[1] The estimation is based on port area accesses and exits as well as distances travelled within the port for terminal operations. This means that a total of 21.46 million vehicle kilometers have been covered by HDV in half a year.

The German Federal Environment Agency assumes a pollution of nearly 815 grams CO_2 per travelled diesel driven HDV vehicle kilometer. No data could be generated regarding the terminal activities or the number of required starts after vehicle rest. The emission factor already includes a differentiated traffic composition for the area. Based on the provided data it can therefore be estimated that in the first half of 2018 around 17.500 tons of CO_2 were produced by HDV in the area of the Port of Hamburg.

[1] This assumption is based on statements from relevant stakeholders and was validated by reviewing the physical layout of the port.

4 IDENTIFICATION OF MEASURES

In order to identify potential sources for the reduction of HDV emissions, it is very important to review existing measures from the Port of Hamburg. Since the port has to be viewed holistically further developments in different port environments have to be taken into account when deriving measures by including projects in Hamburg and other ports worldwide. To give a brief description of the identified measures, they were divided into four categories:

Measures which …

- have already been implemented in the Port of Hamburg and are in regular operation,
- are being tested as pilot projects in the Port of Hamburg,
- are currently being discussed in the Port of Hamburg and
- additional good practices with additional value from other countries and ports.

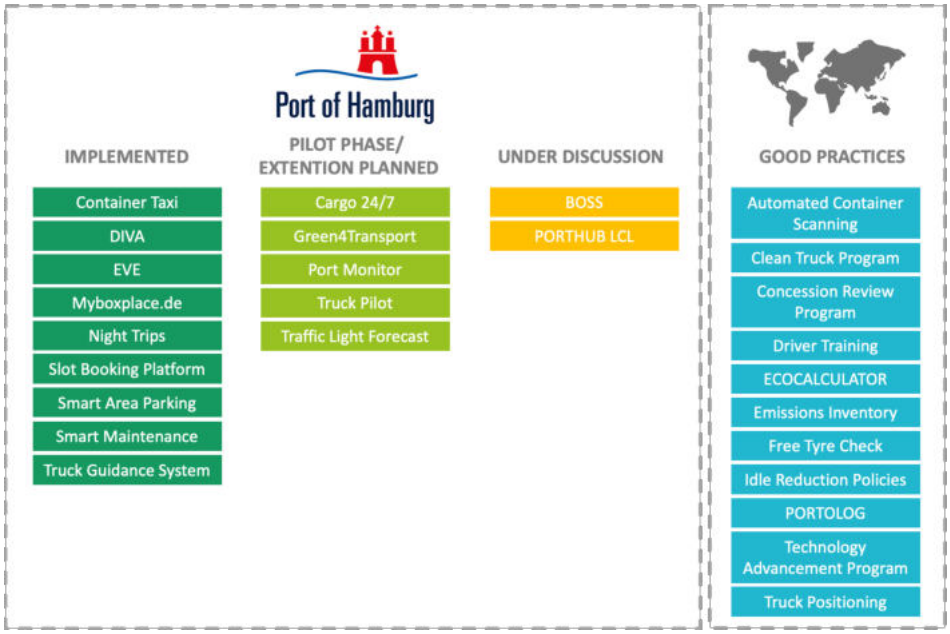

Figure 8 Summary of the Identified Measures

Although not all of these projects are aimed to reduce CO_2 emissions by HDV they directly or indirectly lead to reduction of emissions produced by HDV. The research was focused on projects and measures which reduce emissions in port areas in general, but a particular focus was placed on selected initiatives and individual ports that have been dealing specifically with the reduction of CO_2 emissions by HDV, for example “Heavy-Duty Vehicles” by the International Council on Clean Transportation, “Ports Initiative” by the United States Environmental Protection Agency, “Zero Emission Initiatives” by the Port of Los Angeles or the “Clean Truck Programs” (e. g. Port of Long Beach).

4.1 IMPLEMENTED PROJECTS

Implemented Projects describe projects that are currently being used in the operations of the Port of Hamburg. Although not all of these projects are aimed to reduce CO_2 emissions by HDV they directly or indirectly lead to the reduction of emissions by HDV traffic.

1 Container Taxi

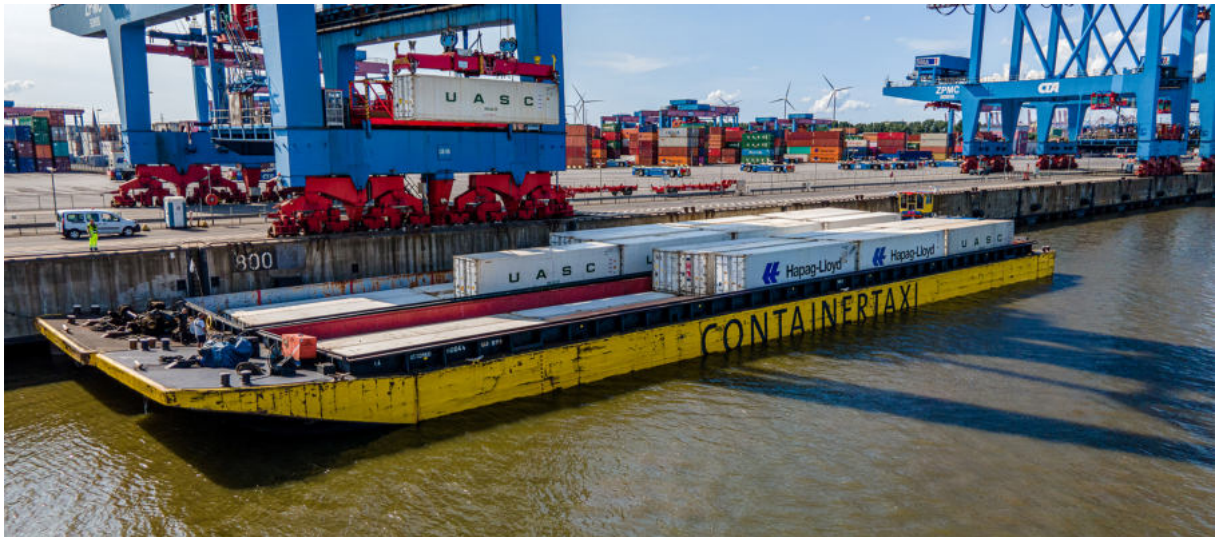

Figure 9 Container Taxi in Port of Hamburg (Eckelmann Group, 2020)

Topic	Container transport via waterways
Status	Project Start 2004
Details	Eckelmann currently uses six barges to transport containers in a regular service between 8 spots within the port incl. the major container terminals and empty depots. The barges have a capacity of 60 TEU (twin-use: 120 TEU) and allow the combination of separate shipments. The barges are operated 24/7 and can be chartered individually. Other barge operators like Walter Lauk offer similar services.
Involved Parties	Lead Eckelmann Group
Links	https://www.eckelmann.hamburg/index.php/en/transport-u-logistics/business-areas/container-taxi

2 DIVA

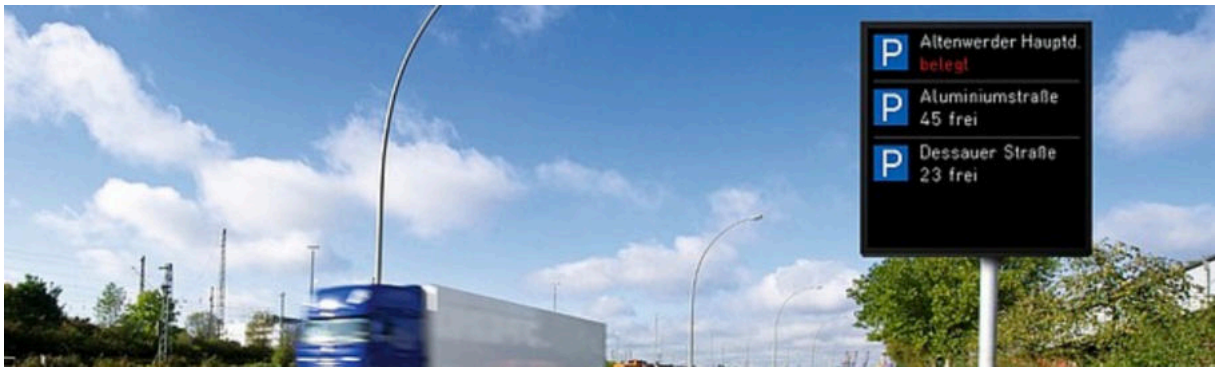

Figure 10 Dynamic parking space management for trucks (Port of Hamburg, 2016)

Topic	Digital boards for sharing information regarding congestion and closings
Status	Project Start 2014
Details	DIVA, the dynamic information on traffic flow informs road users about the traffic situation in the port on information boards with graphic and text displays along the roads and on the HPA website. About 300 detectors record congestions, closures or movable bridges Thus, disturbances can be displayed comprehensively as basis for alternative routings. DIVA also provides information on available parking spaces, distinguishing between small and big trucks. Currently 17 DIVA boards are being operated.
Involved Parties	Lead HPA
Links	https://www.hamburg-port-authority.de/fileadmin/user_upload/Flyer_Verkehrsmanagement_DIVA.pdf

3 EVE

Figure 11 The Port Road Management (Hamburg Port Authority, 2014)

Topic	Effective traffic situation display based on short-term and medium-term traffic data
Status	Project Start 2014 Since 2017 the interface is linked with the DIVA boards.
Details	The HPA traffic management system monitors the roads using Bluetooth, video detection and induction loops. In 2017 it was supplemented by a model-based solution for proactive traffic management which collects, compares, validates, and merges stationary data in real-time. The model-based approach thus fills the data gaps in the road network and creates a coherent and comprehensive picture of the traffic situation. Due to the forecasting capability HPA can react even more efficiently to disruptions in the road network and provide traffic information. Separate analysis of car and truck traffic allows for better parking space management within the port, a traffic control to/from the terminals via pre-gate parking spaces as well as dynamic traffic guidance.
Involved Parties	Lead HPA GeVAS
Links	https://gevas.eu/eve/ https://www.hamburg-port-authority.de/fileadmin/user_upload/140401_HPA_Broschuere_spl_web.pdf

4 Myboxplace.de

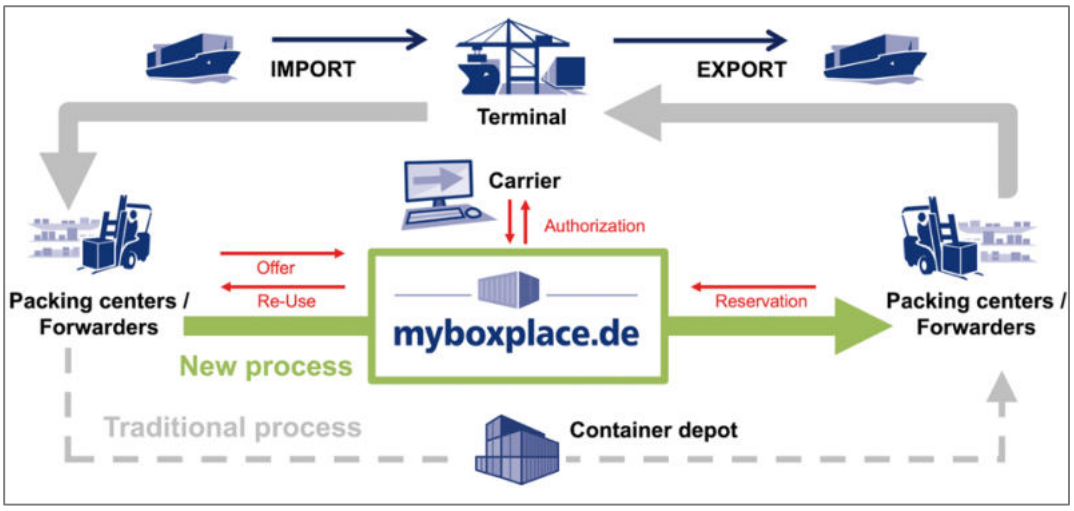

Figure 12 myboxplace.de - the digital exchange platform for empty containers (DAKOSY, n.d.)

Topic	Optimize the transport of empty containers between container terminals, packing companies and empty depots
Status	Project Start 2018 (2016) In 2016, HPA initiated the project Virtual Depot together with several partners. The technical implementation was commissioned to IBM. In 2018, the project was transferred to DAKOSY and then integrated into the myboxplace.de platform, which is used to arrange empty container transports from seaport terminals to the hinterland/depots.
Details	According to HPA more than one million trucks with empty containers travel in the Port of Hamburg every year. After a full container has been unpacked at a packing company, it is taken to an empty container depot. At a later stage, this very same box is often taken from the empty container depot to the same packing company e. g. for use in sea export. The aim of myboxplace.de is to provide a platform for different market players that usually do not communicate directly to reduce the number of truck journeys in empty container logistics. Contracts between the different market players are not affected.
Involved Parties	Lead DAKOSY
Link	https://www.dakosy.de/loesungen/logistics/intermodal/myboxplacede

5 Night Trips

Figure 13 Night Trips in Hamburg (Hamburg Port Authority, 2019)

Topic	Shifting traffic to night hours to reduce daytime peaks
Status	Project Start 2018
Details	CTD as one of major trucking company in the Port of Hamburg started to shift container traffic between terminals and depots to night hours to relieve the road infrastructure in the port and reduce the traffic volume during daytime peak periods. This results in 41 % (20,500) of all port internal truck transports were carried out in the period between 6 p.m. and 6 a.m. in 2018. For the trucking company this ensures a steady utilisation of the vehicle fleet and increased capacities for the daytime business. In addition, the vehicles are less likely to be stuck in traffic jams, which makes transport planning more reliable and at the same ecofriendly.
Involved Parties	CTD (HHLA subsidiary)
Links	https://hhla.de/unternehmen/news/detailansicht/nachtfahrten-entlasten-strassen-und-umwelt

6 Smart Area Parking

Figure 14 Guiding Truckers to available spaces in Port of Hamburg (Nedap, n.d.)

Topic	Implementation of systems to detect truck parking space
Status	Project Start 2016
Details	Currently Smart Area parking is implemented on four parking sites (Aluminiumstraße, Altenwerder Ost, Altenwerder West and Dessauer Straße). The occupancy rate of the parking sites is transferred automatically to the PRM, which then displays the capacities on the DIVA boards. This allows drivers to find free parking spaces more quickly and avoids unnecessary trips within the port.
Involved Parties	HPA
Links	https://www.smartcity-kompass.de/smartcity/smart-area-parking/ https://www.nedapidentification.com/cases/guiding-truckers-in-port-of-hamburg/

7 Smart Maintenance

Figure 15 Smart Maintenance (Smart City Kompass, n.d.)

Topic	Using mobile devices to monitor the infrastructure and therefore improve the maintenance process
Status	Project Start 2014 Roll Out 2015
Details	Mobiles devices such as tablets and smartphones are used to monitor and record data about the status of the port's transport infrastructure (incl. road and railway) In a first step the project focused on mobile infrastructures such as lifting or bascule bridges. and bridges. The solution supports HPA's service teams during on-site maintenance procedures. The data can automatically be processed and displayed as alerts, which can draw attention to emerging problems that bear a potential risk for the traffic flow.
Involved Parties	Lead HPA CISCO Systems, SAP, Microsoft
Links	https://www.smartcity-kompass.de/smartcity/smartmaintenance-intelligente-instandhaltung/

8 Slot Booking Platform

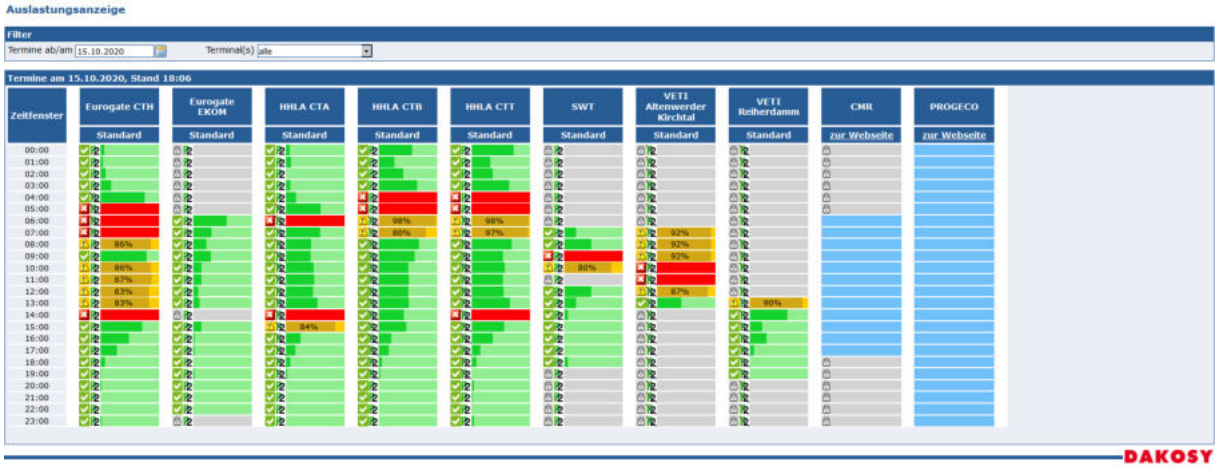

Figure 16 Slot-Booking for truck visits (HHLA, n.d.)

Topic	Slot-Booking for truck pick-up and delivery
Status	Project Start 2017 Roll Out 2019
Details	Since 2017 slot booking is mandatory for container deliveries or pickups by truck at the four major container terminals. In addition, three container depots and the Veterinary Office are participating in the procedure. Trucking companies need to book a time slot (always comprises one hour e. g. 8 – 9 a.m.) at one of the participating parties via the truckgate platform in advance. A slot has to be rebooked or exchanged if the trucker does not show up with a tolerance range of +/- 1.5 hour. The use of the service is not accompanied by any expenses for the truck operators.
Involved Parties	Lead Terminal Operators DAKOSY, Cargo Support
Links	https://www.truckgate.de/en

9 Truck Guidance System

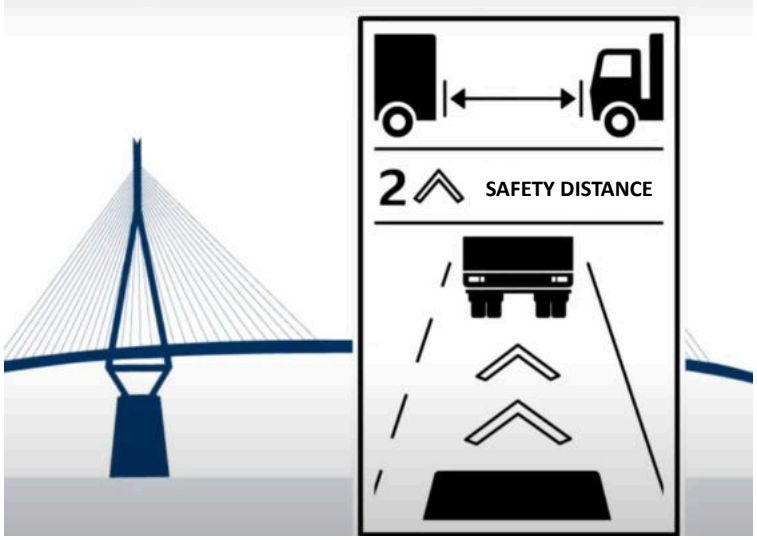

Figure 17 New Safety Signs (own presentation based on Port of Hamburg, n.d.)

Topic	Traffic guidance system to ensure an optimized traffic flow on the highly frequented Köhlbrandbrücke
Status	Project Start 2019
Details	Special lane markings on the entire bridge show truck drivers the ideal distance to the truck in front of them. If the driver always keeps the distance of two marked triangles, he is optimally guided to the distance requirements in the middle part of the bridge. The guidance system should prevent both, unnecessary braking maneuvers, and excessive distances between the trucks on the two ramps of the bridge and therefore optimizing traffic flow. The markings are based on shapes that have successfully been used in the Netherlands and Scandinavia.
Involved Parties	HPA
Links	https://www.hamburg-port-authority.de/de/aktuelles-presse/verkehrsfluss-optimiert-hpa-startet-neues-leitsystem-fuer-lkw-auf-der-koehlbrandbruecke/

4.2 PILOT PHASE AND IN DISCUSSION

This category includes measures that are currently either in the pilot phase or have already been implemented for other means of transport and are currently being extended to HDV transports.

10 Cargo 24/7

Figure 18 Truck Loading in the Night (HHLA, 2019)

Topic	Truck handling in the port and relevant hinterland around the clock
Status	Project Start 2016 Pilot Phase 2019
Details	Based on the initiative Port 24/7 which creates the possibility to handle trucks all day. In a second step, Cargo 24/7 is about integrating logistics, industrial and trading companies in the hinterland into the digital slot booking procedure at an early stage - and thus shifting transports into the low-traffic off-peak hours.
Involved Parties	Lead Logistik-Initiative Hamburg DAKOSY, HHLA, Eurogate Hamburg, Volkswagen, Cosco Shipping Lines, Hapag-Lloyd, WEETS Group and Schnellecke
Links	https://www.hamburg-port-authority.de/fileadmin/user_upload/port-development-plan2025.pdf

11 Green4transPORT

Figure 19 Intelligent Traffic Lights (HPA, n. d.)

Topic	V2X communication with light signal systems
Status	Project Start 2016 Pilot Phase 2019 - 2020 First results will be presented at the ITS Conference 2021.
Details	With V2X (vehicle-to-everything) communication between vehicles and infrastructure HPA is testing a dynamic traffic management. Therefore, different trucks are grouped, while speed and traffic light phases are adapted dynamically to the amount of a traffic at any time. The pilot phase focusses on two traffic lights near Kattwyk Dam and about 150 trucks. The system can also integrate information from other transport modes (rail, water) into the analysis to examine the effects on the flow of intermodal transport. The aim is reduce waiting times and thereby cut emissions. In the future it is planned to extend the technology to the main port routes to capture 50% of the traffic situation via on-board units.
Involved Parties	Lead HPA NXP Semiconductors Scania CV AB, Siemens Mobility GmbH and Technolution B.V.
Links	https://www.hamburg-port-authority.de/en/themenseiten/green4transport/

12 Port Monitor

Figure 20 The digital harbor (Hamburg Port Authority, n.d.)

Topic	Control room software to keep all stakeholders in the Port of Hamburg up-to-date
Status	Project Start 2012 Roll out 2017
Details	The Port Monitor gathers a variety of different information, e. g. electronic maps, vessel positions, water level data, current construction sites and bridge heights and widths. It can also be accessed remotely. The information is collected and evaluated from a various measurement and communication systems in the port and displayed in a graphical format. The aim is to provide a comprehensive overview of the current traffic situation and therefore enable proactive decision making with regard to traffic management.
Involved Parties	Lead: HPA Workplace Solutions GmbH and University of Hamburg
Links	https://www.hamburg-port-authority.de/en/hpa-360/smartport/

13 TruckPilot

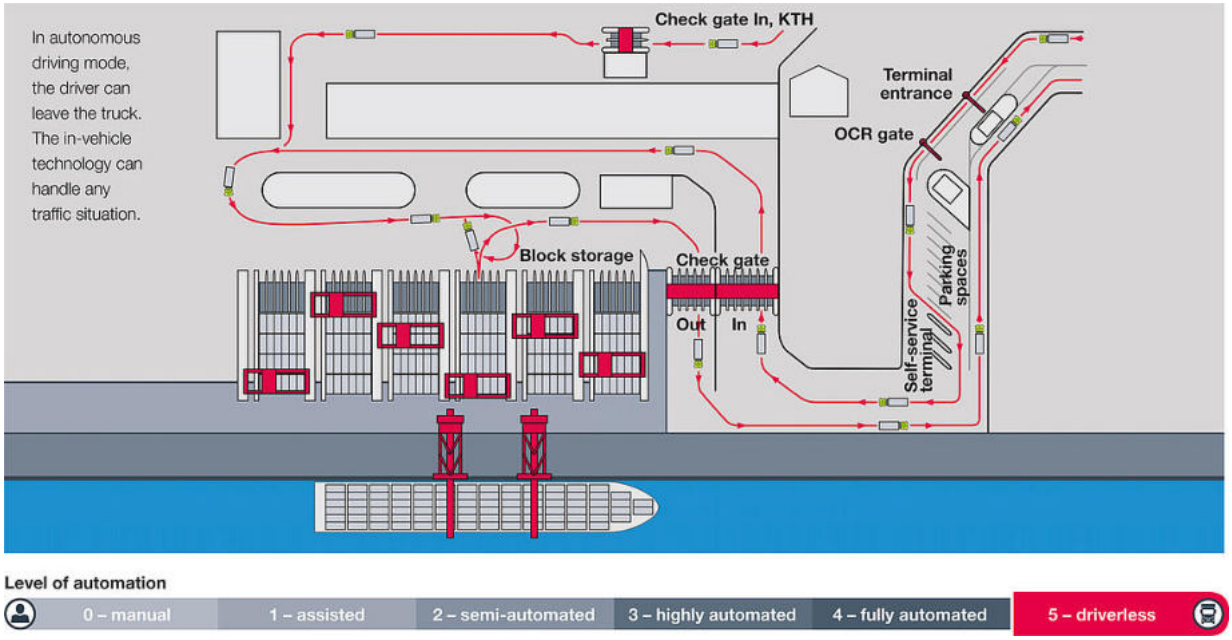

Figure 21 Driverless vehicles at the container terminal (HHLA, 2020)

Topic	Fully automated and autonomous terminal trucking
Status	Project Start 2018 Testing June 2020, on the MAN premises in Munich July – December 2020 Two trucks are tested at HHLA Container Terminal Altenwerder.
Details	The plan is to completely automate the truck loading and unloading procedure at container terminals to increase process efficiency and stability, and support truck drivers in their daily routine. The traffic flow on the terminal premises can be positively influenced by automation, which also offers potential for reducing fuel consumption. Additionally, a proactive driving style can help to reduce safety risks.
Involved Parties	Lead Free and Hanseatic City of Hamburg and MAN HHLA
Links	https://www.truck.man.eu/de/en/man-world/man-in-germany/press-and-media/MAN-and-HHLA-launch- Hamburg-TruckPilot -to-test-automated-and-autonomously-driving-trucks--345920.html

14 Traffic Light Forecast

Figure 22 "Green wave" with traffic light assistant for cyclist (City of Hamburg, 2020)

	Topic	Predicting driving patterns to smoothen traffic and reduce delays
	Status	Project Start 2015 Testing 2017
	Details	With its real-time data, the project is intended to contribute to anticipatory driving in the city of Hamburg. The results as well as the collected data of the pilot project will be available to the public. Since 2017, 70 traffic lights have been tested in Hamburg city center. The mobile app uses the collected data to recommend to the driver the optimal speed to get through the traffic without stop and go.
	Involved Parties	Lead German Federal Ministry of Transport and Digital Infrastructure State Office for Roads, Bridges and Waters, State Office for Geographical Information and Surveying, Hamburg Traffic Systems GmbH and Cisco Systems
	Links	https://www.smartcity-kompass.de/smartcity/pilotversuch-ampelassistent-traffic-light-forecast/

4.3 IN DISCUSSION

Measures in this category have already been reviewed for the Port of Hamburg or are currently still in discussion in various committees and/or authorities on regional and national level. These measures have not been tested yet and practical implementation plans do not exist.

15 Border One Stop Shop

Figure 23 The Port of Hamburg as a European sea customs port (Port of Hamburg, n.d.)

Topic	Relocating the border inspections for incoming goods
Status	Project Start 2019 Feasibility Study completed in 2020
Details	The idea is to combine veterinary, food control and phytosanitary import controls with customs controls at one single location to make the necessary inspection activities more customer friendly. The aim is to identify synergies between the different parties, become more cost-effective and lower emissions by reducing the number of truck journeys. Along with the physical consolidation, a significant number of port-internal transports could already be avoided through digitalization of processes and optimized IT interfaces.
Involved Parties	Lead General Customs Directorate Federal Agency for Agriculture and Food, Hamburg Ministry of Justice and Consumer Protection and BWI
Links	https://www.bdz.eu/fileadmin/dokumente/Bezirksverbaende/BV_Nord/BV_Nord_Medien/BV_Nord_Info/OV_HZA_Hamburg_aktuell_1_20_BOSS.pdf

16 PortHUB LCL

Figure 24 Container Hub (Logisitik Watchblog, 2020)

Topic	Optimization and digitization of bundling of LCL cargo
Status	Project Start 2019 Testing 2020 – 2021
Details	To avoid unnecessary traffic, the delivery and collection of LCL goods can be optimized and the corresponding processes digitized. For this purpose, a physical and digital HUB could be established where freight can be bundled in the port. The platform should be connected to existing interfaces in order to be able to react dynamically to changes e. g. customs clearance.
Involved Parties	Lead Association of Hamburg Forwarders e. V. LIHH, HPA and DAKOSY
Link	https://www.hamburg-logistik.net/fileadmin/user_upload/aktivitaeten/projekte/its/Projektsteckbriefe/200416_HafenHUB_kb.pdf

4.4 GOOD PRACTICES

Good practices describe approaches that are currently being pursued in other ports and other countries. The measures listed are all already in the pilot phase or are being implemented in various places.

17 Automated Container Scanning, Port of Rotterdam (NL)

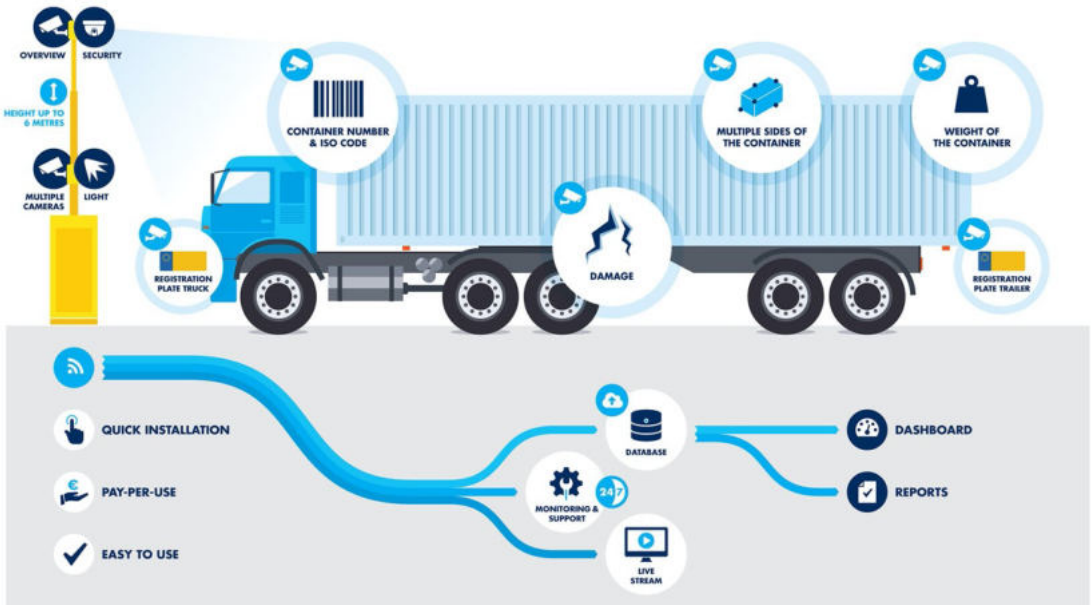

Figure 25 Mobile OCR (Port Technology, 2018)

Topic	Identification system that scans incoming trucks for registration details
Status	Pilot Phase 2018
Details	All arriving and departing trucks are scanned to record registration plate, container number, iso code as well as damage, and container weight. This way the entire gate process can be optimized as manual checks are reduced while performance and security are potentially increased.
Involved Parties	Lead Port of Rotterdam Barge Terminal Tilburg and Certus Port Automation
Links	https://www.porttechnology.org/news/rotterdam_pilots_new_container_scanning_system/

18 Clean Truck Program, Port of Los Angeles (US)

Figure 26 Clean Truck Program in Los Angeles (Port of Los Angeles, n.d.)

	Topic	Strategic program to reduce truck emissions
	Status	Project Start 2008
	Details	As part of the Clean Air Action Plan the Clean Truck Program is an initiative that deals with the strategic orientation of the ports regarding truck emissions. Various measures are being developed and established to reduce the heavy environmental pollution caused by trucks. The measures include banning HDV which did not meet the 2007 emission standards. Currently only new trucks produced after 2014 are allowed in the port area and trucks with alternative drive and fuel systems are being funded. Workshops involve the various stakeholders and reports ensure that measurable success can be identified. Several ports have introduced similar programs to take strategic action against truck emissions.
	Involved Parties	Lead Port of Long Beach and Port of Los Angeles
	Link	https://cleanairactionplan.org/strategies/trucks/

19 Concession Review Program, Port of Los Angeles (US)

Figure 27 San Pedro Bay Ports Clean Air Action Plan (The Port of Los Angeles, n.d.)

	Topic	Mandatory concession agreement for trucks in the port area
	Status	Project Start 2008
	Details	At the Port of Los Angeles, it is mandatory for over 900 licensed motor carriers to have a pending or approved concession agreement. This allows to track emissions standards, compliances with vehicle safety and maintenance standards as well as safety training for drivers, which are then periodically published.
	Involved Parties	Lead Port of Los Angeles
	Links	https://www.portoflosangeles.org/environment/air-quality/clean-truck-program https://kentico.portoflosangeles.org/getmedia/452bad8c-4e16-490f-bab6-155b061866bb/POLA-Monthly-Gate-Move-Analysis

20 Driver Training, Port of Vancouver (CA)

Figure 28 The Valley Driving School in Canada (Valley Driving School, 2017)

Topic	Policy to reduce idle operations and promote intelligent driving	
Status	Start	2016
Details	The Port of Vancouver supports the trucking companies in training their drivers for sustainable driving. The aim is to ensure that the Anti Idling Campagin is also lived by the drivers.	
Involved Parties	Lead	Port of Vancouver
Link	https://www.portvancouver.com/wp-content/uploads/2015/07/2017-03-08-NRDE-Fact-Sheet-Fuel-Efficiency-Plans-and-Idle-Reduction-Policy.pdf	

21 Idle Reduction Policies, Port of Vancouver (CA)

Figure 29 Idle Free in BC (BC Climate Action Toolkit, n.d.)

	Topic	Policy to reduce idle operations
	Status	Start 2015
	Details	The purpose of the policy is to establish guidelines for unnecessary idling of vehicles and other road equipments in the port area. Limiting idling times contributes to a healthier work environment, reduces noise as well as air pollution, reduces fuel consumption and extends the lifespan of the engine. Through the Truck Licensing System and the Smart Fleet Strategy, approx. 1,800 container trucks are tracked through GPS signals after entering the port and thus can be observed according to policy measures.
	Involved Parties	Lead Port of Vancouver
	Link	https://www.portvancouver.com/wp-content/uploads/2015/07/2017-03-08-NRDE-Fact-Sheet-Fuel-Efficiency-Plans-and-Idle-Reduction-Policy.pdf https://www.portvancouver.com/environment/air-energy-climate-action/container-trucking/

22 ECOCALCULATOR, Port de Barcelona (ES)

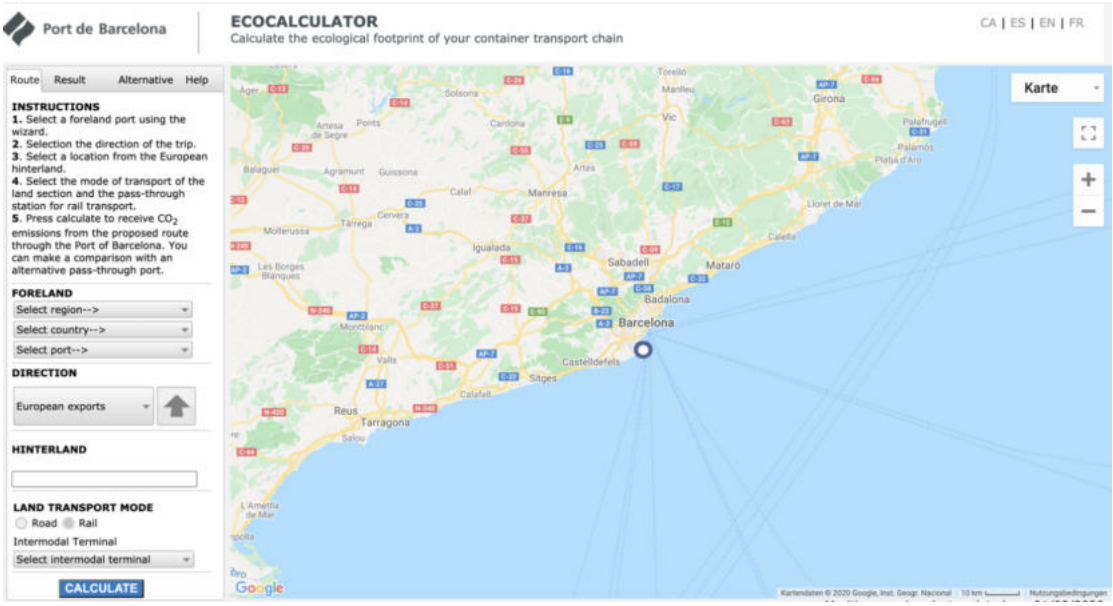

Figure 30 The Ecocalculator (Port de Barcelona, n.d.)

Topic	Software to inform about emissions for different transport modes
Status	Project Start 2012 Roll Out 2015
Details	The Port of Barcelona provides a tool that calculates the number of tons of greenhouse gases generated in specific logistics chains for each transported TEU based on a chosen set of parameters. Users can get a transparent and comprehensive overview, and compare the results provided by the web-based solution for different transport modes and routings. Additionally, the software proposes tailored alternatives with reduced emissions.
Involved Parties	Lead Port de Barcelona Technical University of Catalonia (BarcelonaTech) and Port de Barcelona Logistics Consultancy
Link	http://planol.portdebarcelona.cat/ecocalc/index.html?idioma=2

23 Emissions Inventory, Port of New York and New Jersey (US)

Figure 31 The Port Authority of NY & NJ (Port Authority NY NJ, 2020)

	Topic	Annual report for port related emissions
	Status	Project Start 2006
	Details	The Port Authority of New York and New Jersey provides a yearly emissions inventories concentrating on different air polluting emissions. A detailed reporting of emissions ejected by cargo handling equipment, heavy-duty diesel vehicles, railroad locomotives and commercial marine vessels is published to ensure transparency between stakeholders. By measuring their produced emissions, it is easier to ensure that goals are met and identify necessary next steps.
	Involved Parties	Lead Port Authority of New York and New Jersey
	Links	https://old.panynj.gov/about/pdf/PANYNJ-2017-Multi-Facility-EI-Report.pdf https://www.panynj.gov/port/en/our-port/sustainability/air-emissions-inventories-and-related-studies.html

24 Free Tyre Check, Port of Rotterdam (NL)

Figure 32 A green smiley for more safety (Presse Box, n.d.)

	Topic	Offering a free tyre check at two locations within the port
	Status	Project Start 2015
	Details	The Port of Rotterdam promotes safe and clean driving by installing an automatic measuring point for air pressure of truck tyres on a bridge within the port area. The check area can be accessed free of charge via a separate lane and takes one minute only. With the optimal tyre pressure fuel consumption and emissions decrease plus the safety risk can be reduced.
	Involved Parties	Lead Port of Rotterdam
	Links	https://www.portofrotterdam.com/sites/default/files/hbr_folder_bandenspanning_mei_2017.pdf?token=FQeLz24M

25 PORTOLOG, Port of Santos (BR)

Figure 33 Portolog (Santos Port Authorithy, n.d.)

Topic	Fully monitored arrivals of trucks and cargo
Status	Project Start 2015 Roll Out 2017
Details	PORTOLOG notices each truck that is loaded and envisaged for the port. The system puts all trucks and cargo in a virtual queue and every time a checkpoint is passed the system receives a signal to notify the predetermined terminal in the port. Currently it is focused on the port's public areas, terminals, and yards. But it will be extended to all main road corridors in Brasil.
Involved Parties	Lead Federal Data Processing Service Port of Santos, Terminal Operators
Link	https://www.portodesantos.com.br/operacoes-logisticas/portolog-sgtc/

26 Technology Advancement Program, San Pedro Bay Ports (US)

2019 ANNUAL REPORT AND 2020 PRIORITIES

Technology Advancement Program

Figure 34 Front page of the annual Technology Advancement Program Report (Ports, 2019)

	Topic	Promoting alternative fuels and developing technologies by supporting change
	Status	Project Start 2007
	Details	The Technology Advancement Program is an initiative that focusses on supporting clean technologies and the associated infrastructure within the San Pedro Bay port area. Several approaches are considered to identify and support potential projects. An Open Request for Information (RFI) is now available where a proposer may upload and submit a concept paper through an online portal at any time. Other approaches may include Requests for Proposals (RFP) and Port-Initiated Projects to encourage technology development or if there are multiple interests in demonstrating a certain technology.
	Involved Parties	Lead Port of Long Beach and Port of Los Angeles
	Links	https://cleanairactionplan.org/technology-advancement-program/

27 Truck Positioning Guidance, Duisport (DE)

Figure 35 The Integrated Truck Guidance (Duisport, n.d.)

Topic	Truck guidance system to ensure an optimized traffic flow prior to the port area
Status	Pilot Phase 2020
Details	Based on GPS tracking and a mobile app, which can be downloaded by truck drivers, all participating parties can be informed about the estimated time of arrival at the envisaged terminal. The truck is assigned to the next possible slot. If an immediate slot is not available – resulting in a delay – the app automatically informs the driver about available parking spaces within the port area and the driver is assigned a new destination slot. The aim is to reduce waiting times and minimize congestions within the port area.
Involved Parties	Lead Duisport Siemens
Link	https://www.duisport.de/hafeninformation/strassenservice-leitsystem/ https://assets.new.siemens.com/siemens/assets/api/uuid:4ff11208c253329e15b284d809991b12c1aa5d34/version:1500550767/brochure-integrated-truck-guidance-en.pdf

5 ANALYSIS OF MEASURES

In order to recommend a course of action for the Port of Hamburg while ensuring a certain degree of transformability for other ports, different measures working towards the same goals were combined into twelve clusters. In particular, the selection of established measures in the Port of Hamburg in combination with international good practices were taken into account. This approach helps to build on existing regional achievements while ensuring that the broadest possible overview can be given in terms of transferability for other ports. Some measures are relevant for different clusters, those appear twice in the overview. To reduce complexity the clusters and belonging measures are grouped into four categories:

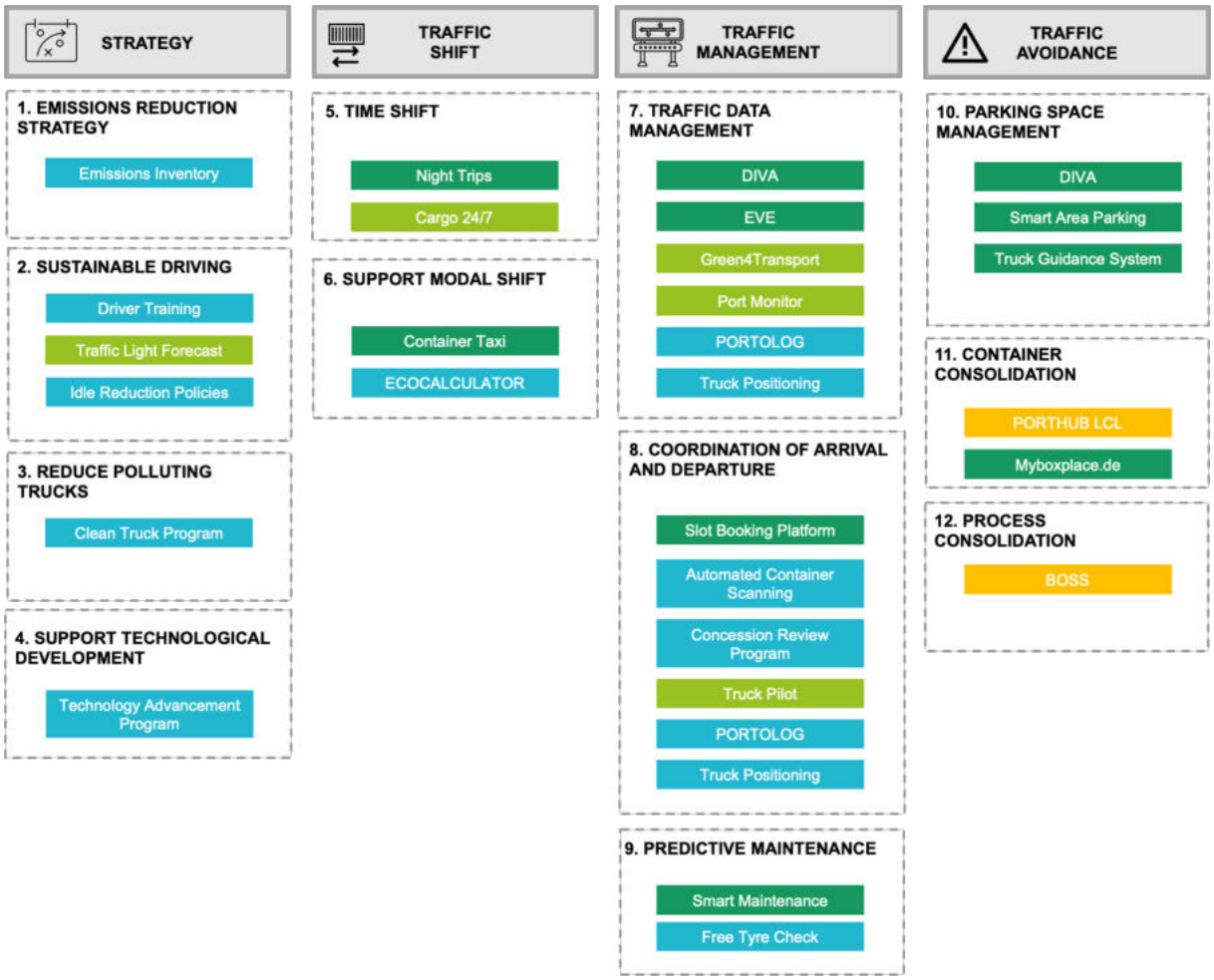

Figure 36 Classification of measures into categories and clusters

The subsequent derivation of the clusters is carried out with the objection that the measures developed in the previous section are described in more detail and examined with regard to their requirements. In order to determine the effect and therefore being able to recommend further action, each cluster is assessed according to three aspects:

- **Impact** refers to the assessment of the possible successes that can be achieved by establishing the cluster. These can be measured in different ways: The direct impact described the achieved effect in terms of CO2 emissions reductions for example caused due to traffic shift or traffic avoidance. The indirect impact can give information on further potentials arising from the establishment of the cluster for example in terms of the improved utilization of the given infrastructure, creating awareness for emissions or building the basis for other clusters.
- **Effort** refers to the estimated contribution that is required for the implementation of the cluster. This can involve various aspects such as time horizon, number of stakeholders to be involved, necessary technical requirements, data collection and availability, and financial needs.
- **Potential for the Port of Hamburg** describes the compatibility as well as applicability to the conditions in Hamburg. Therefore, reference is made to the available data for the current traffic situation, infrastructure, and general conditions within the port and preliminary projects that potentially can be used as starting point.

To ensure transferability to other port locations the first two aspects Impact and Effort are analyzed as broadly as possible while the third category explicitly focuses on the regional potential for the Port of Hamburg.

5.1 STRATEGY

Although the implementation of strategies and concepts does not reduce emissions directly for example by avoiding traffic, it can have an immense impact on a sustainable port-wide emissions reduction as it can form an encompassing directional guide for all means of transport.

1. Emissions Reduction Strategy

Impact: An emissions reduction strategy does not reduce emissions itself, but it can create the basis to develop further steps and policies. The purpose of an emissions inventory is to report and explain generated air emissions associated with specific GHG emissions. It can for instance enable a port authority as well as other relevant stakeholders to identify possible weak points in a long-term perspective and track progress towards emission reduction targets. Additionally, it can be used as a basis of argumentation or strategic foundation for possible useful or needed investments. In this context, it is especially important to increase the transparency and ensure comparability of the caused emissions by the different involved parties. This cluster can also be used to increase the awareness of the various stakeholders regarding the amount of emissions produced in different processes.

Effort: The effort is estimated as rather high, since many different stakeholders have to be cross-linked and a large amount of information and data has to be gathered. For a diligent emissions inventory the data collection processes must be refined to ensure a precise monitoring and reporting throughout the entire process. As there are already many scientific methodology reports (e. g. Port Emissions Inventory and Reduction Strategy by the United States Environmental Protection Agency, Task Force on Emission Inventories and Projections, European Environment Agency) and good practices (e. g. Port of London, Port of Oakland, Port of Seattle) on how to design an emissions inventory the effort could be reduced. The recording as well as the analysis have to follow a continuous approach. Many of the existing emissions inventories provide either yearly revisions or time frames between three to five years. A regular and minimum annual revision seems to be sufficient to flexibly follow up on changes and adapt measures accordingly.

Potential for Hamburg: The potential for the Port of Hamburg is considered to be very high while the effort can be kept relatively low, as the existing sustainability report by the HPA already provides a base. Major stakeholders in the port also publish own sustainability reports, but a methodological comparison of the collected data would be required. The different reports and the underlying data can be used to reduce the efforts for the different emission producers.

In addition, data that is currently mainly collected for other purposes, such as EVE, could be resorted too. An Emissions Inventory could be a valuable instrument to measure the achievement of CO_2 targets in the Port of Hamburg and establish an emissions reduction strategy. However, for a detailed and scientific preparation of the results an adaption of the current data collection processes has to be ensured as the quality and reliability of the data determines the degree of usefulness.

Table 1 Summarized analysis of the Cluster Emissions Reduction Strategy

	Impact	★★★★☆
	Effort	★★★⯪☆
	Potential for Hamburg	★★★★☆
	Relevant Measures	23 Emissions Inventory

2. Sustainable Driving

Impact: The impact that individual drivers have on overall vehicle emissions is limited. However, broad driver training can support a sustainable driving style nationwide. In relation to short trips it can be focused on three aspects which can increase fuel efficiency and thereby reduce both produced emissions and costs for the trucking company:

- reduce idling times as unnecessary idling wastes fuel,
- maintaining a consistent speed and
- preventing heavy breaks and unnecessary accelerations.

Nevertheless, it could also be conceivable to develop a campaign to make drivers aware of a sustainable driving style within the port area as idling is often a big cause of emissions. This would also enable drivers to reduce their emissions outside the port area. According to the ECO Training from Mercedes-Benz, fuel savings of up to 10 % can be achieved on long-distance routes (Mercedes-Benz, n.d.). Additionally, measures like the Traffic Light Forecast, which is currently being tested, aim to avoid unnecessary braking and approaching traffic lights by determining the optimal speed for drivers and communicating this via their mobile device.

Effort: This cluster can be implemented with relatively low investment as driving training is often already carried out by private companies on behalf of trucking companies as a sustainable driving is also economically reasonable. It is common to use classroom training and online classes. Some companies include simulator-based programs as a training technique. Additionally, the Port of Vancouver has established an idle speed reduction policy to allow trucks in the port to idle for over five minutes only in exceptional cases. Such arrangements with trucking companies can ensure that individual truck drivers must be made aware of their contribution. Measures which contribute to this cluster e. g. through a smart traffic management can support sustainable driving even further. However, such measures require a system landscape that is animated by sensors and can automatically analyze the collected information and transmit it in real time to mobile devises, which increases implementation efforts.

Potential for Hamburg: The potential for the Port of Hamburg is difficult to assess, as there is currently no data available on the driving efficiency within the main road network in the Port of Hamburg nor can information be provided on how many trucking companies are currently focusing on sustainable driving. It can be assumed that currently not all trucking companies are fully training their employees with regard to eco-driving or economical driving and therefore the measure could still create a significant impact. Until measures like the Traffic Light Forecast, which supports sustainable driving can be implemented to a majority of HDV, a campaign on sustainable driving could be beneficial. For this kind of campaign, the involvement of local stakeholders like the Hamburg Freight Forwarders Association (VHSp) could lead to a quick and easy implementation. Above all, this will ensure that all trucking companies that frequently operate in the port are involved.

Table 2 Summarized analysis of the Cluster Sustainable Driving

Impact	★★◐☆☆
Effort	★★☆☆☆
Potential for Hamburg	★★★★☆
Relevant Measures	14 Traffic Light Forecast 20 Driver Training 21 Idling Reduction Policy

3. Reduce Polluting Trucks

Impact: After it was launched in the Port of Los Angeles in 2004, many ports have adopted a Clean Truck Program to help trucking companies switch to environmentally friendly HDV. One option is to ban the use of old and thus more environmentally harmful trucks. Another option is the use of incentives to switch to newer and therefore environmentally friendly drives or alternative fuels such as LNG, CNG, hydrogen and fuel cell technology or electric drive.

Banning polluting trucks can have an immense impact on the reduction of emissions produced by HDV. A ban can be issued either for an entire port or specifically for certain areas and zones within the port. HDV which produce excessive emissions are either not allowed to enter the area or must pay extra pollution fees. It needs to be considered that these costs are usually shifted again on the customer. In either case, a gradual restriction for truck models according to their age is reasonable. Another approach is to support carriers with the implementation of more environmentally friendly fleets, if this does not take place through governmental funding. Especially in ports in which truck fleets are mainly characterized by older models, the implementation of this cluster can have a high impact.

Effort: The effort to implement this cluster is relatively low as no further infrastructure measures need to be implemented and only a few stakeholders need to be involved in the implementation process. However, an important factor for success is the control of the adopted regulations. Due to the emission standards for new HDV agreed to by the European Commission, the European Parliament and the European Council in 2019 this will be easier for future regulators.

Potential for Hamburg: Since 83% of the trucks in the Port of Hamburg already meet the Euro 5 and 6 standards, the potential for the Port of Hamburg in term of a ban of older trucks alone can be considered low (HPA, 2018). Even if these numbers do not relate directly to CO_2 emissions but to particulate and other pollutant emissions, they indicate that the truck port fleet used in the port is very modern - as the EURO 5 standard was only introduced in 2009 and EURO 6 in 2014. Innovations cycles in trucking business are lot shorter compared to rail or inland waterways. Additionally, many trucks are leased and therefore not older than three years.

Table 3 Summarized analysis of the Cluster Reduce Polluting Trucks

Impact	★★★⯪☆

Effort	★★★★☆
Potential for Hamburg	★★★⯪☆
Relevant Measures	18 Clean Truck Program

4. Support Technological Developments

Impact: The use of alternative fuels can make an important contribution to reducing emissions. Probably the best-known diesel alternative is Liquefied Natural Gas (LNG) but other alternative fuels such as CNG, electric, hydrogen are also partly implemented or tested for HDV. It is not the port's responsibility to push the trucking companies to change their fleet. For a future orientation in the port, it is rather necessary to contribute to the technical realization. Since the technical requirements in the market already exist, it is particularly important for ports to promote the technologies of the various fuels and drives within their port.

Effort: One of the biggest issues during the implementation of renewable fuels for all transport means is the lack of supply infrastructure. The Technological Advancement Program supports the development of technologies and plays an active role in the implementation of innovative pilot projects moving towards zero emissions. The projects as well as the impact they achieve are strongly dependent on the different local stakeholders, as they are responsible for the conception of ideas and project proposals. Therefore, the impact of this cluster depends on the willingness of the local stakeholders to innovate as well as the available resources and supply infrastructure.

Supporting the implementation of pilot projects is financially very straining, but requires less conceptual work, as most of the pilot projects are already well thought out and planned by the relevant stakeholders. The existing program in the United States not only provides financial support, but also connects relevant actors in the port and beyond. In addition, the program advises the project partners throughout the process and can also provide areas for development projects. Just like the achieved impact, the output that can be generated is highly dependent on local stakeholders. However, in order to achieve the greatest possible effect, a focus for such a program should be set beforehand.

Potential for Hamburg: Although currently only a fraction of HDVs are equipped with alternative drives, the market is growing steadily. Germany's first public LNG filling station was opened in Hamburg in 2018. The station is designed to handle 30 tons of LNG, which would enable almost 200 trucks to be filled per day. These and the many other innovative measures discussed above for the Port of Hamburg indicate that there is a great potential to further support these developments.

Table 4 Summarized analysis of the Cluster Support Technological Development

Impact	★★★◐☆
Effort	★★★★★
Potential for Hamburg	★★★★◐
Relevant Measures	26 Technology Advancement Program

5.2 TRAFFIC SHIFT

One of the most efficient ways to reduce HDV emissions is to shift existing traffic to more sustainable modes of transport or making use of off-peak times to reduce congestion and fuel consumption.

5. Time Shift

Impact: By shifting transports to off-peak hours, congestions on the port roads can be reduced and traffic flow as well as road safety can be increased. As the roads at night are less frequented than during the day disturbances like stagnant traffic can be avoided which leads to less fuel consumption and thus reduced emissions. This change also has an impact on the traffic during the day as the roads can be relieved. However, many transports within the port are time-sensitive or time-dependent and are influenced by e.g. loading windows inside and outside the port or regulated operating hours of companies. Nevertheless, a shift of not time-sensitive transports can lead to a more efficient use of the existing infrastructure.

Effort: The changeover for port-internal transfers at off-peak hours is relatively simple, since no further infrastructural or process changing measures have to be carried out. Nevertheless, it can be assumed that wage costs will increase significantly because a night surcharge must be paid to the drivers and workforce. To support the implementation of such a cluster, financial incentives can also be considered. Either time slots outside peak times could be made cheaper to increase the appeal of the booking or time slots at peak times could be made more expensive.

Potential for Hamburg: Traffic jams and congestions are a big problem on the main roads of the Port of Hamburg. According to the HPA 1,100 hours of congestions were registered in 2018. These congestion hours occurred mainly in the sections with a high proportion of truck traffic (HHR Ost, HHR Finkenwerder and Hohe Schaar Nord). HDV traffic in the Port of Hamburg mainly takes place between 6 a.m. and 7 p.m. Between 9 a.m. and 3 p.m., the traffic volume is even but at its highest with 2,500 to 2,600 HDV entering the port area per hour. In 2018 the CTD transferred approximately 20,000 port-internal trips to the night shift and thus outside of peak hours. This resulted in an increased efficiency of the day-to-day business and the utilization of their vehicle fleet. In the Cargo 24/7 pilot, travel times were reduced by 30 minutes (equivalent to approx. 18%) and processing times by 2 minutes (equivalent to approx. 8%). It can be assumed that a reduction in travel time also leads to a reduction in emissions. However, an exact analysis of these emissions is not possible on the basis of the available data. Due to the successful relocation of the traffic in both projects it can be assumed that there is also a high potential for further internal traffic.

Table 5 Summarized analysis of the Cluster Time Shift

	Impact	★★◐☆☆
	Effort	★★☆☆☆
	Potential for Hamburg	★★★☆☆
	Relevant Measures	5 Night Trips 10 Cargo 24/7

6. Supporting Modal Shift

Impact: By shifting traffic to lower-emission modes of transport, many emissions can be reduced. According to UBA, an average of 112 g GHG is emitted per tkm by truck, compared to 18 g/tkm by rail and 31 g/tkm by inland waterways (Umweltbundesamt, 2020). According to the Eckelmann Group, one of their barges (container taxis) alone can replace 60 trucks and thus reduce CO_2 emissions by 92% generating a big impact on internal port transports (Port of Hamburg, 2013). However, these figures highly depend on the emissions of the operated vessels fleet. Since the distances of internal port journeys are limited, transport shift to rail is not considered a feasible option and would potentially require additional trucking. Thereby the impact is limited to a certain amount of transports. As a first step awareness for the actual emission parameters must be created in order to support companies in their decision-making for alternative transport modes and the most sustainable routing. An ECOCALCULATOR can be a helpful tool. The Port of Barcelona uses the tool to support its customers in their decision-making. By providing a tool that calculates the CO_2 emissions cargo owners as well as logistics providers can identify the most environmentally friendly transport route. Similar tools have become widespread in recent years. For example, Kühne+Nagel's seaexplorer platform provides customers not only with schedules in container shipping, but also with an indication of CO_2 emissions.

There are several challenges regarding shifting port-internal transports to inland waterways. The major container terminals have dedicated their berths for large seagoing vessels, which complicates transport planning for barge operators. Since 2019 the Hamburg Vessel Coordination Center (HVCC) takes over the coordination part. Of course not all relevant parties in the port that receive or send cargo also have access to a berth and can be included in barge operations. However, focusing on the major terminals, packing companies and empty depots bears enough potential.

Effort: To implement an emission calculator, it is necessary that the emission parameters for the different transport modes are clearly evaluated and defined. An emissions inventory could primarily contribute to transparency in those processes. Nevertheless, the effort is strongly dependent on customer requests and expectations. Only if the customer is willing to change his supply chain, a change in the transport chain can be caused. For example, it must be ensured that a change also makes sense from an economic perspective.

Potential for Hamburg: In 2018, CTD decided to transfer some of its traffics to inland waterway vessels, which saved about 6,500 truck trips. These transports relate not only to internal port traffic but also to hinterland connections. Therefore, the evaluated emission

reduction of this project has to be evaluated just for the port area. As inland waterways and rail transport cause less emissions than road transport it can be deducted that the emissions overall have been reduced. It can be proportionally assumed that the CTD was able to save around 50 tons of CO_2. This only includes the saved emissions by avoiding road transport and not the emissions which were produced by the vessels caring the cargo. The potential for the Port of Hamburg is moderate as the maximum number of transports is limited to port-internal transports. Regardless it is assumed that a significant number of transports can be diverted to other transport routes.

Table 6 Summarized analysis of the Cluster Support Model Shift

	Impact	★★◐☆☆
	Effort	★★◐☆☆
	Potential for Hamburg	★★★☆☆
	Relevant Measures	1 Container Taxi 21 ECOCALCULATOR

5.3 TRAFFIC MANAGEMENT

This category includes three clusters and related measures that aspire a smooth traffic flow by increasing the efficiency and avoiding obstacles like congestions and therefore reducing emissions. Although some measures deal specifically with HDV many measures in this category have an effect on all road users.

7. Traffic Data Management

Impact: The aim of a *Smart Traffic Management* is to distribute traffic more efficiently by making the best possible use of the entire road network in a port. Sensors can be used to analyze the traffic flow and quickly indicate possible alternatives in the event of a traffic jam. In addition, traffic lights and movable bridges can be adapted and linked before registered or scanned trucks access the port area. Thereby traffic flow can be improved, fuel consumptions reduced and thus emissions avoided. The impact of this measure can be assessed as mediocre. Many ports are repeatedly confronted with congestion and stagnant traffic at certain

peak times, which generally leads to delays in traffic and process flows. On the other hand, due to the limited number of roads within a port, there are not always alternative routes and a long-distance bypass could lead to higher emissions. For this purpose, it is not only necessary to collect data from the ports, but also to evaluate the data and share information with road users as quickly as possible. A display of disturbances and bypasses can be realized, for example, by means of DIVA signs at the side of the road or by linking the information into navigation applications. Another added value is the collection of data generated by smart projects. By analyzing the data, sections can be identified that are often responsible for traffic jams. This can help optimize the traffic flow in the long-term.

Effort: Nevertheless, the effort required to implement this cluster should not be underestimated. A high number of stationary and mobile sensors is required to ensure comprehensive monitoring. At least on the main roads in a port this form of monitoring and guidance should be made available to generate a significant impact. If only individual street sections are examined, it is often not possible to fully evaluate the traffic situation. Ideally the traffic management system for a port is connected to the associated system for the neighboring road network. Because it is precisely by linking the means of transport with traffic monitoring that a significantly greater effect can be achieved. However, this cluster is characterized by a large number of different measures whose intelligent combination will most likely reduce the required effort.

Potential for Hamburg: The Port of Hamburg has already implemented many projects to record and control traffic movements. These projects have a value for the reduction of emissions. Further expanding these measures is extremely relevant in order to be able to provide data and information for other clusters such as Smart Maintenance or Parking Space Management in the future. It is likely that a smart combination of collected data of the different projects will generate synergies in other segments that can significantly increase the value of this cluster for example by using the data as a basis to develop process improvements.

Table 7 Summarized analysis of the Cluster Traffic Data Management

Impact	★★★☆☆
Effort	★★⯪☆☆
Potential for Hamburg	★★★☆☆

Relevant Measures	2 DIVA 3 EVE 11 Green4Transport 12 Port Monitor 25 PORTOLOG 27 Truck Positioning Guide

8. Coordination of Arrival and Departure

Impact: Truck appointment systems allow scheduling of arrival times and therefore avoid peak time overloads. Overall it is assumed that slot booking platforms can minimize waiting times at a terminal by up to 40% (Transporeon, n.d.). Another study established that unloading time can be reduced by 30% (Merk, 2014). By reducing waiting and loading times, especially idle times can be reduced which leads to emissions reductions. Additional process that can be automated lead to further emission reductions by allowing for example the handling of the terminal to be even better coordinated within the supply chain or reducing the time a truck spends idling. In the Port of Los Angeles, the slot booking procedure was combined with a Concession Review Program in which the contractual partners undertake to comply with prescribed limits and to carry out regular maintenance work. All container trucking companies and their trucks desiring to serve the port's marine container terminals must meet certain criteria to be eligible for an Access Agreement under the Truck Licensing System to gain access to the federally owned port property. Criteria includes minimum truck age, safety and environmental requirements.

Effort: Booking platforms are cloud-based solutions that can be introduced quickly and easily in a port community system to reduce the effort. However, for the effective reduction of emissions it is extremely relevant that the booking process is made mandatory for all trucks and is not carried out on a voluntary basis (Giuliano & O'Brien, 2007). In addition, an added value can be generated if different processes or even automatic slot booking systems can be combined. If this process is also automated and introduced to the entire transport route as seen in the Port of Santos this can make the entire process easier and even more efficient. On the other hand, effort for the full automation of the processes is notably higher as the necessary hardware i.e. infrastructure sensors, cameras as well as mobile devices must be provided. Overall, both partial and complete automation of the registration process for terminals or ports can save time and therefore reduce existing emissions.

Potential for Hamburg: The implemented slot booking procedure in the Port of Hamburg, which links the major container terminals, three empty depots and the Veterinary Office, already addresses a huge amount of daily trucking volume. This could be further expanded to smaller terminals, packing companies and customs authorities if feasible. Automated container scanning in particular is seen as a high potential for the Port of Hamburg as it can further simplify the arrival procedure at the terminal and reduce waiting times.

Table 8 Summarized analysis of the Cluster Coordination of Arrival and Departure

Impact	★★★☆☆
Effort	★★★◐☆
Potential for Hamburg	★★◐☆☆
Relevant Measures	8 Slot Booking Platform 13 TruckPilot 17 Automated Container Scanning 19 Concession Review Program 25 PORTOLOG 27 Truck Positioning Guidance

9. Predictive Maintenance

Impact: An important basis for efficient operations is the collection of traffic data. Especially the early recognition of essential maintenance works can be traced back to high traffic loads by using specific models. Due to the high daily traffic volume caused by HDV traffic in port areas, the infrastructure is heavily strained, which means that early detection of potential weak points is important to avoid downtime. In addition, the availability of the road network is elementary for the process flows in the port. If too much maintenance work has to be carried out at the same time, this can potentially lead to considerable losses in traffic volume for the whole port. For this reason, early detection of relevant weak points in the network is all the more important and can make a major contribution to smooth processes.

Effort: With a solid data foundation, this cluster can also have an extremely positive effect on the maintenance of the existing infrastructure. For instance, weak points can be detected earlier, and traffic can be diverted to avoid them.

Potential for Hamburg: Currently, the infrastructure in the Port of Hamburg is tracked by mobile devices through which information on roads, bridges and railways can be accessed. This collected information is already automatically sent, collected and evaluated. By improving the data quality, the potential of early predictive maintenance can also be exploited for the Port of Hamburg. This can be done by utlizing stationary sensors that can, for example, evaluate data on ideal tire pressure. In addition, an expansion of the Truck Guidance System can help reduce the load on the infrastructure at the various bridges and main roads.

Table 9 Summarized analysis of the Cluster Predictive Maintenance

Impact	★★◐☆☆
Effort	★★☆☆☆
Potential for Hamburg	★★◐☆☆
Relevant Measures	7 Smart Maintenance 9 Truck Guidance System 23 Free Tyre Check

5.4 TRAFFIC AVOIDANCE

The most effective way to reduce emissions is to avoid traffic. By intelligently linking cargo and connecting different economic players, capacities can be utilized and unnecessary journeys can be reduced. Therefore improving the overall traffic flow in the area.

10. Parking Space Management

Impact: An efficient and intelligent traffic management system is essential to support truck drivers in their search for a parking lot. In the port, additional traffic may occur as drivers are looking for available parking spaces in general or parking spaces that should be close to their destinations or starting positions. Traffic can be avoided by increasing the efficiency of the parking space search. Avoided traffic leads to an improvement in the overall traffic flow within the port.

Effort: An intelligent traffic data management can form a good basis for this cluster by pointing out available parking spaces, as in smart area parking. It is also conceivable that areas can be

booked in advance by the haulage companies or individual drivers. In the communication of these free parking spaces, it is possible to work primarily with boards, such as DIVA boards. For successful parking management, it is of primary significance to record the real-time traffic situation in the port. Only if it is possible to record exactly where HDV are they can be successfully steered. By linking different platforms, parking spaces could also be booked or allocated in advance by the trucking companies.

Potential for Hamburg: There are a total of 59 parking lots in the Port of Hamburg, which are used at varying degrees with peak times. In addition to the parking lots, the port also has approximately 200 to 300 truck parking slots in the side area of the main port network. This results to total of 1,200 to 1,800 available truck parking slots. In contrast to the parking spaces in the side area, the utilization of the parking spaces in the port area is recorded. In 2018, these parking spaces were used on average to 79% capacity. For several years now, the utilization rate has been increasing annually, from 2017 to 2018 the utilization rate rose by 3.5%. It should be noted, however, that during the night the utilization rate increases to 99%. It can be assumed that the higher the capacity utilization, the longer the search for a suitable parking space. Therefore, the potential for an efficient parking space management is given. The Port of Hamburg already uses intelligent control systems, but this system could be supported by using, for example, GPS systems and interlinking booking platforms.

Table 10 Summarized analysis of the Cluster Parking Space Management

Impact	★★☆☆☆
Effort	★★½☆☆
Potential for Hamburg	★★★☆☆
Relevant Measures	2 DIVA 6 Smart Area Parking 27 Truck Positioning Guidance

11. Container Consolidation

Impact: The avoidance of unnecessary transports in the port should be of highest priority. Consolidation of empty containers as well as consolidated cargo can play a role in this. In addition to savings in travel time storage space, equipment and personnel can be used more

efficiently. By developing a platform that includes a dynamic planning process in which disturbances and real time windows can be included, the impact can be increased. The chances of success stand and fall with the acceptance and use of the platform or service by the various users as some may prefer to use separate individual platforms. In 2019, 150,000 empty runs could be avoided in the Port of Antwerp (2020). However, it should be noted that the traffic volume is difficult to estimate and can therefore often only be planned spontaneously.

Effort: The effort is determined both by the costs that arise for the coordination of the various stakeholders and the costs that arise in regular operations, for example, for a real estate area or a digital platform. It is extremely relevant that both the involvement of a large number of stakeholders is continuously promoted and that the technology is kept up to date. A larger number of users makes the cluster more attractive for all users and therefore increases the chances for success.

Potential for Hamburg: Estimations in the Port of Hamburg assume that every year over one million empty containers are transported within the port area. According to the HPA, the predecessor project of the myboxplace in 2017 helped to avoid 4,000 truck transports in the Port of Hamburg, which lead to a reduction of almost 33 tons of CO_2. Since both the infrastructure and the process landscape in the Port of Hamburg are already designed for the consolidation of empty container transports, it can be assumed that the continuation of the project can further avoid traffic. However, the active involvement of as many participants as possible is crucial.

Table 11 Summarized analysis of the Cluster Container Consolidation

Impact	★★★☆☆
Effort	★★★★☆
Potential for Hamburg	★★★⯪☆
Relevant Measures	4 Myboxplace.de 16 PORTHUB LCL

12. Process Consolidation

Impact: By consolidating digital and non-digital processes between different stakeholders in the port, a significant number of internal port trips can be avoided. One process step that often leads to internal port movements are the procedures of authorities. For example, relevant process steps are located at different locations within the port area. The impact is mainly achieved by digitizing certain processes such as document control or reducing overlapping checks at different locations. By merging processes that deal with the same freight or containers, truck journeys can be avoided.

Effort: Since this cluster involves measures that involve infrastructural changes the effort is to be considered very high. When linking digital processes, a new IT system landscape is required, but this can lead to a large effect while the effort can be kept comparatively small. Far-reaching changes in the processes require a great deal of planning and must be carefully examined beforehand.

Potential for Hamburg: By linking the customs processes in the Port of Hamburg - both on a digital and physical level – around 150,000 vehicle kilometers per year could be avoided. However, this is a cluster which, in addition to ecological effects such as emission savings and improved traffic flow, can above all increase the competitiveness of the location. As already established in the feasibility study for the Border One Stop Shop, the measure leads to high potentials for the Port of Hamburg.

Table 12 Summarized analysis of the Cluster Process Consolidation

Impact	★★★☆☆
Effort	★★★★★
Potential for Hamburg	★★★◐☆
Relevant Measures	15 Border One Stop Shop

6 RECOMMENDATION

In the previous two chapters 27 different measures grouped in 12 clusters and 4 categories were identified, which either directly or indirectly could lead to a reduction of CO_2 emissions produced by HDV. Based on the determined impact and effort the clusters are presented in the following matrix in order to make them comparable in a comprehensive format and assist with the further decision-making processes. In addition to impact (y axis) and effort (x axis), the size of the bubbles represents the potential for the Port of Hamburg.

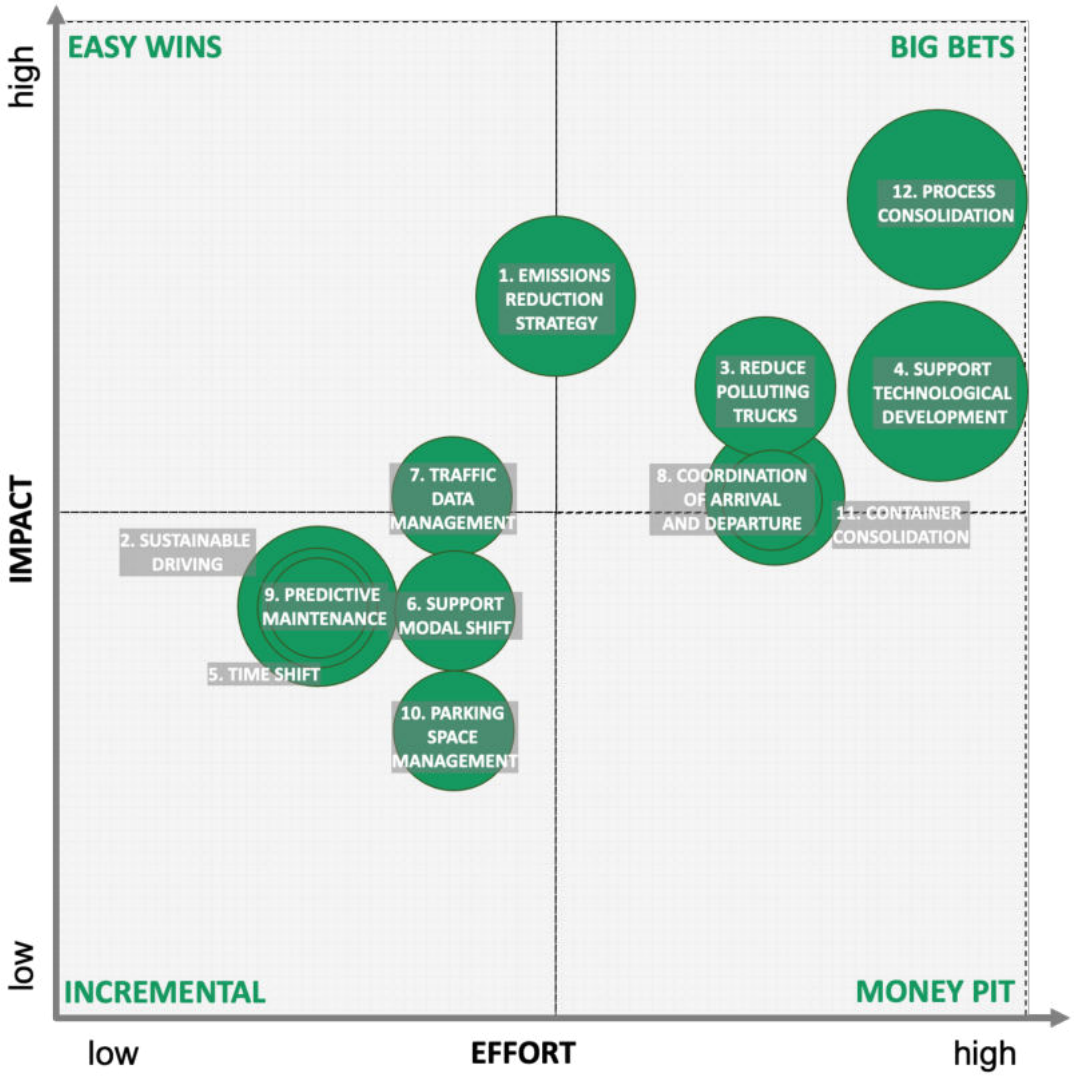

Figure 37 Cluster Analysis Summary

Out of the total 27 identified measures 16 measures have already been implemented or discussed specifically for the Port of Hamburg. Continuous steering of these measures is of particular relevance to enable the best possible outcome. Obviously, there is a risk that too many parallel initiatives without joint coordination emerge. This can lead to process

uncertainty, unclear responsibilities, insufficient commitment of involved parties. Overlaps must be minimized, gaps must be identified to benefit from synergies between different measures. It is particularly important to develop a well-coordinated and comprehensive strategy and concept for the Port of Hamburg as a whole. This should refer directly to existing programs like the Clean Air Plan Hamburg. It is therefore recommended that some sort of *Emissions Reduction Strategy (1)* is established for the entire port activities. Furthermore, it is important to clearly define responsibilities beforehand to simplify the coordination process. This could also assist the knowledge transfer between different stakeholders to exchange lessons learned, key takeaways etc.

A detailed and transparent data collection process plays a key role for a successful evaluation of emissions. The necessary basic data for a comprehensive analysis is often collected for other purposes already. In general, the environmental potential is rarely assessed and quantified when projects are considered, analyzed or rated. It is recommended to adjust these data collection processes to allow a reliable and verifiable evaluation. For this reason, it is currently not possible to make a quantifiable statement on how the identified measures and clusters can reduce the CO_2 emissions of HDV traffic in the Port of Hamburg by 10%. When establishing new projects, it must be emphasized to not only quantify the economic success but also the ecological benefits.

The four clusters with the highest potential for reduction of CO_2 emissions in the Port of Hamburg are *Support Service Infrastructure (4), Process Consolidation (12), Emissions Reduction Strategy (1)* and *Sustainable Driving (2).*

The cluster **Support Technological Developments (4)** can support and simplify the management of essential technological efforts of stakeholders in the Port of Hamburg. The focus should not solely be on financial support but also intelligently combining and structuring different project approaches concerning technological innovations. Measures like number 26 - Technology Advancement Program supports the implementation of alternative fuels while it also promoted other technological innovations und pilot projects within the port.

The **Process Consolidation (12)** cluster contributes to a large extent to the avoidance of existing traffic and therefore is considered the most effective strategy for emission reductions. The evaluation of customs processes in the Port of Hamburg seen in measure number 15 - Border One Stop Shop shows, that synchronizing processes effectively can highly contribute to sustainable transport.

As mentioned before, an **Emissions Reduction Strategy (1)** is a fundamental starting point. The first step is to implement measure 1 - Emissions Inventory for the entire port involving as many stakeholders as possible into a comprehensive data collection process.

Since only a certain number of truck journeys can really be avoided, it is equally important that transports take place as fuel-efficient as possible. The cluster **Sustainable Driving (2)** can be achieved on individual level through measures such as number 20 - Driver Training, which aims to support haulage companies in obtaining a fuel-efficient driving style. An example for a large-scale measure would be number 21 - Idling Reduction Policy which results into an agreement for truckers to reduce their idling times within the port. In addition, future-oriented technological developments such as the establishment of measure like number 14 - Traffic Lights Forecast can lead to relevant changes towards a fuel-efficient and therefore emissions-reduced driving style.

In addition to their potential individual benefits for Hamburg as a business location, these four clusters offer great potential, as they deal with future developments. They can have a lasting impact as they bear the potential to expand the knowledge in different fields while connecting various stakeholders.

With a behavioral change of individuals, a bigger impact can be generated than by changing a system. As many of the measures are dependent on the demand and expectations of different customers, it is particularly important to keep a customer-focused approach in mind while planning new projects. Incentive programs and methods, which increase the awareness for emissions and their reduction should be considered early in the process.

For further recommendations the Impact/Effect matrix is analyzed in-depth. As indicated by the quadrants in the background, the matrix is divided into four categories. The individual clusters and related measures can be assigned to the four quadrants and thus the prioritization of the different clusters can be quickly assessed:

- *Easy Wins* give a high return based on the necessary effort.
- *Big Bets* provide long term results but require planning and strategy.
- *Increments* do not require a lot of effort but neither do they offer many benefits.
- *Money Pit* are time- & money-consuming activities with low impact.

Easy Wins are the most attractive and rewarding clusters, as they can achieve a high impact with comparably small effort. These clusters should be implemented first. All the identified

measures are projects and concepts that have already been used in one form or another to reduce emissions of HDV. Since these are measures that often lead to process, infrastructure or even technological changes, it is not surprising that only a small number of measures would be realizable with little effort and a big impact.

- *Identified Cluster: (partially 1. Emission Reduction Strategy and 7. Traffic Data Management)*

Big Bets are the most effort-consuming clusters with a decent return rate. Especially technological and infrastructure projects are often associated with high costs. In the port many different stakeholders and processes depend on each other. Connecting these is always accompanied by a high effort. The clusters and individual measures should be considered perspectivally but must be well-prepared before implementation.

- *Identified Cluster: 3. Reduce Polluting Trucks, 4. Support Technological Development and 12. Process Consolidation (partially 1. Emissions Reduction Strategy, 8. Coordination of Arrival and Departure and 11. Container Consolidation)*

Increments are clusters that should be considered as non-crucial but efficient improvements. Although they are often not the most innovative clusters, they play an important role as fill-ins. It is recommended that clusters and measures in this category are prioritized, in consideration of possible synergies with regards to future projects.

- *Identified Cluster: 2. Sustainable Driving, 5. Traffic Shift, 6. Support Modal Shift, 9. Predictive Maintenance and 10. Parking Space Management (partially 7. Traffic Data Management)*

Money Pit are the cluster which are the least desirable to implement as they mean low impact while spending a lot of effort. Limited resources should not be spent on these clusters, but they can still be necessary. Individual considerations are necessary for these.

- *Identified Cluster: (partially 8. Coordination of Arrival and Departure and 11. Container Consolidation)*

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APPENDIX

Summary Cluster Analysis

CLUSTER NAME	IMPACT	EFFORT	POTENTIAL
1. Emissions Inventory	4	3,5	4
2. Sustainable Driving	2,5	2	4
3. Reduce Polluting Trucks	3,5	4	3,5
4. Support Technological Development	3,5	5	4,5
5. Time Shift	2,5	2	3
6. Supporting Modal Shift	2,5	2,5	3
7. Traffic Data Management	3	2,5	3
8. Coordination of Arrival, Handling and Departure	3	3,5	2,5
9. Predictive Maintenance	2,5	2	2,5
10. Parking Space Management	2	2,5	3
11. Container Consolidation	3	4	3
12. Process Consolidation	3	5	4,5