Appendix A – Transport Sector Methodology

April 2024

EGDC ICT Methodology

EUROPEAN GREEN DIGITAL COALITION

Funded by the European Union

EUROPEAN GREEN DIGITAL COALITION

Deliverable name: Transport Sector Methodology

Dissemination Level: Public

Published: April 2024

The European Green Digital Coalition (EGDC) is an initiative of companies, supported by the European Commission and the European Parliament, based on the request of the EU Council, which aims to harness the enabling emission-reducing potential of digital solutions to all other sectors.

The secretariat of the European Green Digital Coalition is managed by the consortium of the European Parliament Pilot Project for the EGDC, funded by the European Commission, namely the leading associations GeSI, the European DIGITAL SME Alliance, DIGITALEUROPE, ETNO and GSMA, working together with Carbon Trust, Deloitte, Sustainable ICT.

This deliverable has been produced by the consortium of the European Parliament Pilot project for the EGDC.

Global Enabling Sustainability Initiative (Coordinator)

DIGITALEUROPE

European Telecommunications Network Operators' Association

European DIGITAL SME Alliance

SUB-CONTRACTORS

Carbon Trust

Deloitte

GSMA

Sustainable ICT Consulting

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EUROPEAN GREEN
DIGITAL COALITION

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In addition, the case studies used in this methodology were received from the following organisations: AddSecure, Ericsson and University of Valencia

Introduction

To ensure the digital transition reinforces the green transition, the European Green Digital Coalition (EGDC) was formed in March 2021 supported by the European Commission and the European Parliament, based on the request of the EU Council. The main aim of the EGDC is to maximise the sustainability benefits of digitalisation within the ICT sector, while supporting sustainability goals of other key sectors such as energy, transport, agriculture, and construction. EGDC members commit to contributing to the success of the green digital transformation of the EU and beyond by taking action in the following areas:

- To invest in the development and deployment of greener digital technologies & services that are more energy and material efficient,
- To develop methods and tools to measure the net carbon impact of green digital technologies on the environment and climate by joining forces with NGOs and relevant expert organisations,
- To co-create with representatives of other sectors recommendations and guidelines for green digital transformation of these sectors that benefits environment, society, and economy.

As a cross-cutting sector, the EGDC recognises that the ICT sector can deliver emissions reductions in other sectors through the development and deployment of new solutions that would otherwise not be possible and replace existing solutions with high associated emissions.

In order to affirm, communicate and maximise the intended impact of the solutions that are being enabled by digital technologies, it is crucial that their impact is being measured in a robust and consistent way. Responding to this need and following from the EGDC Declaration, the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions" was developed to provide a methodology for the ICT sector to develop methods and tools to measure the net impact of ICT solutions on the environment and climate.

While this methodology is sector agnostic and aims to provide a set of requirements for assessing the net carbon impact of ICT solutions in any implementation context, there are many sector-specific challenges and specificities that need to be considered. This document aims to support users of the EGDC methodology with developing net carbon impact assessments for ICT solutions implemented across different sectors, by offering a demonstration of how the individual requirements from the EGDC methodology can be applied using practical examples from sector specific case studies.

The aim of this document is therefore to demonstrate the application of the EGDC methodology for ICT solutions implemented in the transport sector. To achieve this aim, the following ICT solutions that have been developed into case study calculators as part of the EGDC Pilot Project will be used:

- **AddSecure, Fleet management** – Logic TMS is a transport management system offered as an end-to-end solution for carriers. Logic TMS brings the entire order management process to a modern cloud-based platform, providing real-time control and insights that help optimize every stage of the transport process, including fleet and fuel utilization and order management. The AI-enabled AutoPlanner tool helps calculate best route combination, highlighting associated fuel and cost savings.
- **Ericsson, Port Optimisation** – This ICT solution was submitted to be developed into a case study calculator by Ericsson as part of the EP Pilot project. This solution uses 5G technologies to enhance the exchange of real-time information among actors in a port's terminal process (in this case Port of Livorno in Italy). This activity can lead to a reduction in movements of cargo handling, significantly optimizing the process overall and lowering fuel consumption. The Port of Livorno case was originally developed in collaboration between the Port of Livorno, Ericsson, Fondazione Eni Enrico Mattei (FEEM) and the National Inter-University CNIT as part of the EU H2020 project **COREALIS**. 1st order effects were not quantified as part of this case study as they were out of scope of the original COREALIS study. As a result, this case study is not fully aligned with the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions".
- **PREDRI, Fleet management** - PREDRI is a fleet optimisation solution that leverages on-board monitoring with Artificial Intelligence to optimise routes and encourage efficient and safe driving. Continuous reporting of mechanical parameters helps to anticipate failures and prevent high damage, ultimately extending the life of various mechanical parts. As a result, PREDRI both increases fuel efficiency, and reduces the need to replace exhaustive spare parts.

While these case studies do not necessarily illustrate best practice applications of the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions", they provide a realistic application that aims to demonstrate how the methodology can be used under different circumstances. Furthermore, this document highlights where a case study has not fulfilled the criteria and details steps that would need to be taken in order for the criteria to be fulfilled.

How to use this document

This document mirrors for the most part the requirements laid out in sections 3, 4 and 6 of the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions". As such, it should be used in conjunction with the requirements and guidance laid out in the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions" and used as a reference point to illustrate how each requirement can be applied in practice for solutions in the transport sector. Note that while the examples provided in these documents could be applied to other ICT solutions in this sector, they are not prescriptive and other approaches to meeting the requirements in the "Net Carbon Impact Assessment Methodology for ICT Solutions" can be applied if appropriate.

Methodology Application in the Transport Sector

This section outlines all requirements in the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions" for ICT solutions that impact emissions in the transport sector. The application for each requirement is shown using three ICT solutions that impact the emissions in the transport sector. Certain requirements are combined if it made sense to illustrate the application of these requirements together. This may also affect the order of the requirements in some cases.

Defining the Assessment

Assessment Objective

The assessor shall define the following:

(A) Assessment aim: Describe the intended use of the output from the assessment

AddSecure, Fleet management

The assessment intent is to determine to what extent the AddSecure fleet management solution can have a net positive impact on the transport sector when implemented in a specific context. Furthermore, the aim of the assessment was also to test the EGDC ICT Sector Guidance for Net Carbon Impact Assessments and identify sector-specific methodological considerations.

PREDRI, Fleet management

The assessment intent is to understand the net carbon impact of the implementation of the PREDRI solution in a pilot group of medium sized buses.

Ericsson, Port Optimisation

The assessment intent is to understand the net carbon impact of the implementation of the Ericsson 5G-enabled solution in pilot study at Port of Livorno, Italy.

(B) Assessment type: Define if the assessment will consider a single implementation context or if multiple contexts will be carried out.

AddSecure, Fleet management

The assessment considers the implementation of the solution in multiple contexts, namely in two different fleets operating across different European countries mostly in Central, Western and Southern Europe.

PREDRI, Fleet management

The assessment only considers one implementation context, which is a fleet of medium-sized buses typically operating on a fixed route in Mexico.

Ericsson, Port Optimisation

The assessment only considers one implementation context, which is a fleet of forklifts operating within the Port of Livorno.

(C) Assessment perspective (actual / potential effect): Determine if an ex-post or ex-ante assessment is to be carried out.

AddSecure, Fleet management

The assessment is ex-post, as it determines the actual effect of the ICT solution by considering the impact of the ICT solution over two 10-month periods after the implementation of the solution.

PREDRI, Fleet management

The assessment is ex-post, determining the actual effect of the ICT solution by analysing two years of data after the implementation of the solution.

Ericsson, Port Optimisation

The assessment is ex-post, determining the actual effect of the ICT solution by analysing four years of implementation data.

Solution Description & Boundary

The ICT solution to be assessed shall be clearly defined including:

(A) A description of the ICT solution and its functionality.

AddSecure, Fleet management

Logic TMS is a transport management system that combines a fleet's order management process with a cloud-based platform. This allows for real-time control and insights that help optimise fleet and fuel utilisation and order management. Using Artificial Intelligence, Logic TMS helps to calculate best route combinations.

PREDRI, Fleet management

PREDRI – failure PREvention and DRIving optimisation for vehicles – is a fleet management system that leverages on-board monitoring with Artificial Intelligence to optimise routes and encourage efficient and safe driving. Continuous reporting of mechanical parameters in vehicles helps to anticipate failures and prevent high damage, ultimately extending the life of various mechanical parts. As a result, PREDRI increases fuel efficiency and reduces the need to replace exhaustive spare parts.

Ericsson, Port Optimisation

Ericsson 5G-enabled RTPORT is a logistics management solution that combines a digital registration platform with 5G connectivity. This enables real-time digital registrations of incoming cargo to optimise loading/unloading processes and movement of goods via forklifts.

(B) The key mechanism(s) by which the ICT solution is expected to result in changes to GHG emissions.

AddSecure, Fleet management

Optimising routes: Logic TMS's AutoPlanner tool uses Artificial Intelligence to calculate the most efficient combination of routes for freight transporters. By reducing the distance driven without freight, fleets reduce their fuel usage, which cuts their GHG emissions.

Improving driver behaviour: Additionally, the AutoPlanner improves overall driving patterns by identifying unnecessary fuel usage and bad driving habits, such as excessive idling and poor throttle usage, which on average cuts combustion (L/100km). This results in fewer litres of fuel required for the same distance.

PREDRI, Fleet management

Optimising routes: PREDRI optimises routes by combining path key-points with "driving events" such as real-life congestion data, bumps, and dangerous areas according to the current weather. This increases the fuel efficiency and therefore results in a decrease in GHG emissions incurred along the route.

Mechanical part monitoring: Continuous reporting of mechanical parameters helps to anticipate failures and prevent high damage, ultimately extending the life of various mechanical parts. This reduces the GHG emissions related to manufacturing spare parts (embodied emissions) due to the reduction in replacements.

Ericsson, Port Optimisation

Optimising movement of goods: 5G enabled digital solution allows goods to be registered digitally in real time, replacing the previous off-line procedure (manual forklift delivery of waybills to the terminal offices. Online system allows forklift yard movements to be optimised, resulting in a decrease in forklift fuel usage for the same amount of freight processed.

(C) The sector(s) in which the ICT solution is expected to be implemented in.

AddSecure, Fleet management

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The Logic TMS solution is expected to have an impact in the freight transport sector.

PREDRI, Fleet management

The PREDRI solution is expected to have an impact in the vehicle fleet transport sector.

Ericsson, Port Optimisation

Ericsson 5G Port solution is expected to have an impact in the marine freight transport sector.

(D) Any limitations to the use of the solution (e.g., geographical, technical, operational, etc.).

AddSecure, Fleet management

The solution requires an intermittent connection to the internet and therefore is limited to locations where this infrastructure is available. Furthermore, the solution requires an understanding of how to action the insights from the solution, both from the operators of the solution and the drivers of the vehicles.

PREDRI, Fleet management

The solution requires a 4G mobile connection to function (for the GPS trackers).

Ericsson, Port Optimisation

Ericsson 5G port solution has potential to be deployed in other ports processing cargo freight which have the infrastructure required to implement a 5G network and whose operations involve the use of vehicles such as forklifts.

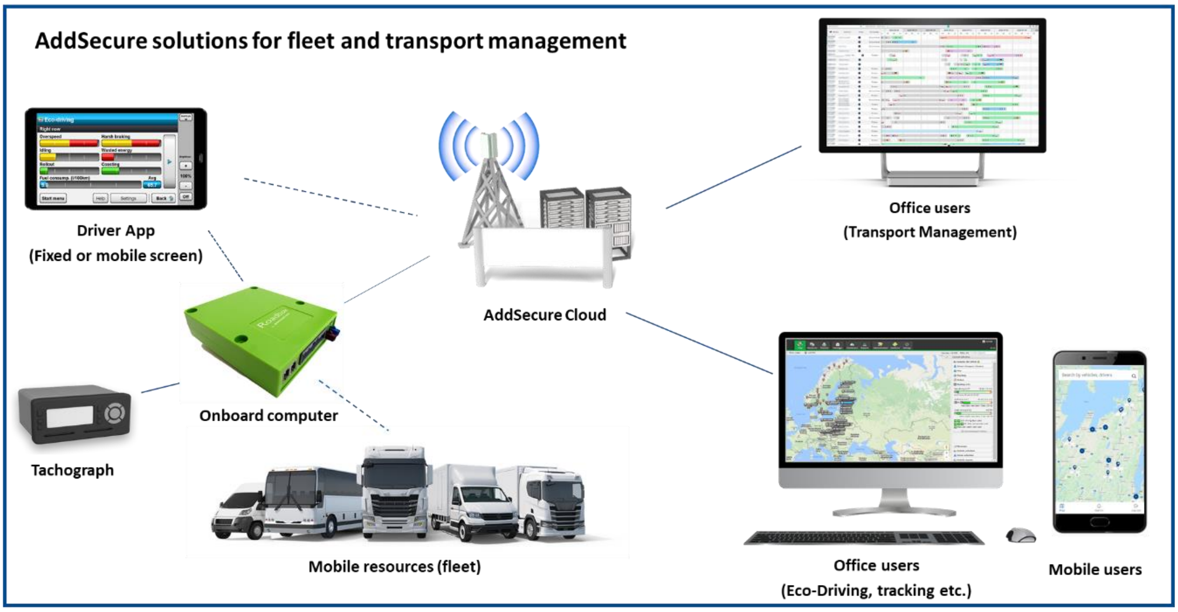
(E) The ICT solution boundary as a description of all components comprising the solution.

AddSecure, Fleet management

The ICT solution requires cloud-based storage provided by servers hosted by Hetzner in Germany. The data transfer required for the solution is provided by 4G and 2G network providers across Europe. Furthermore, the ICT solution requires laptops, mobiles and in-vehicles interface devices for informing the operators of the solution and drivers of the vehicles.

When hardware is installed, every vehicle is equipped with a minimum of one black box with a SIM-card.

The black boxes are delivered to the customers by in-house technicians who use diesel-fuelled vehicles, carrying over 50 black boxes, wires and other equipment needed for installation. The black boxes are shipped from the manufacturers using popular courier brands like UPS, FedEx and DPD.



PREDRI, Fleet management

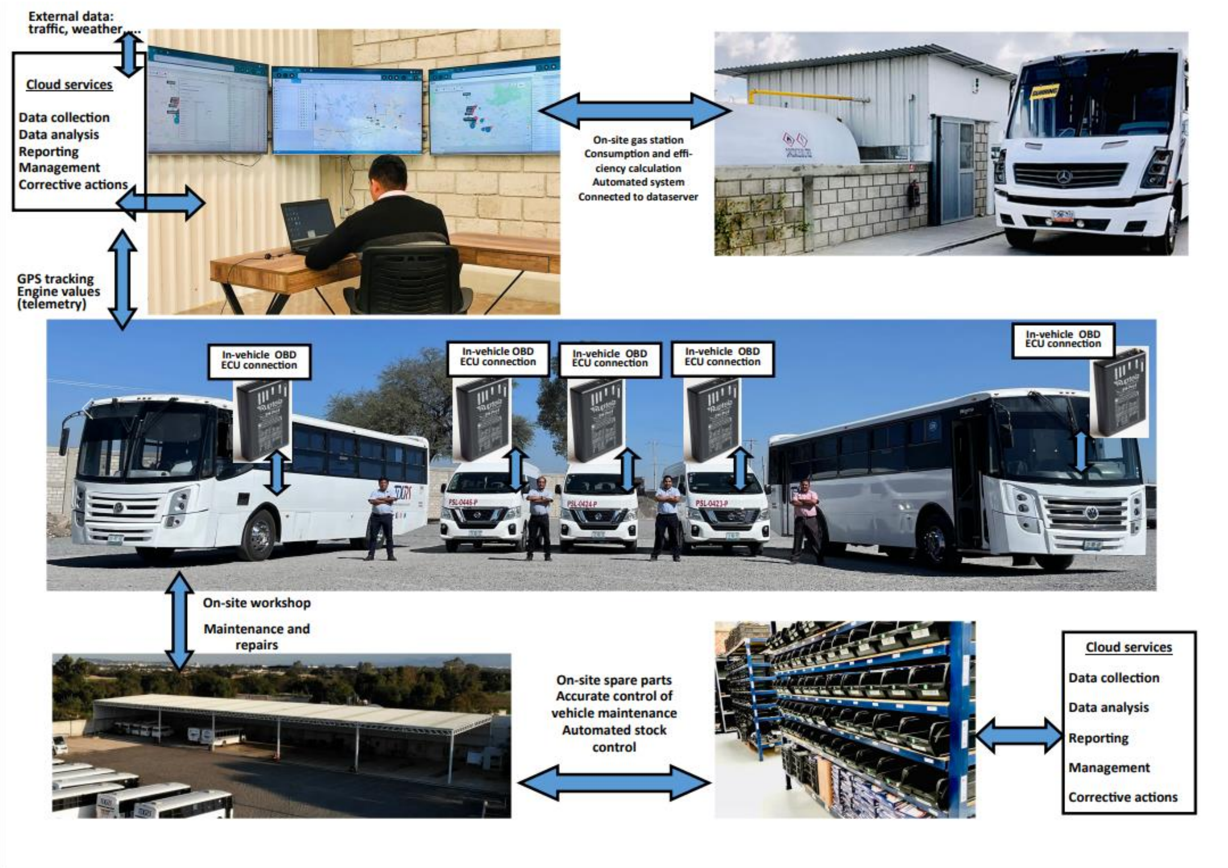
Digital components:

The solution requires a GPS tracker with 4G mobile communication system and connection to the vehicle control unit (VCU) using CAN, digital and analogue GPIOs, provided by Ruptela. DeviceCenter configuration software is used for the Ruptela GPS trackers. The solution requires a GPS Platform Server and 4G connection, provided by Wialon. An Omron refuelling station is used in the base camp, based on Programmable Logic controller (PLC). This is an automated control system that during refuelling and/or maintenance matches the vehicle to the data registry using bar codes. Siemens cloud logging based on IOT gateway is used for refuelling and spare part stock and repair control. A Raspberry module is used for spare part control use and shock, which is also managed by software.

Furthermore, the ICT solution requires local personal computers for administration and Google servers.

Non-digital components:

Pipes, tubes and conducts for gas refuelling at the base camp.



Ericsson, Port Optimisation

Digital components:

RTPORT software provides real-time processing capabilities and a staging environment for online registrations. The 5G network enables the implementation of the RTPORT logistics management software and real-time data processing. The 5G network presents key characteristics of speed, increased capacity and reliability which would not have been achieved through a 4G network. The RTPORT software interacts with:

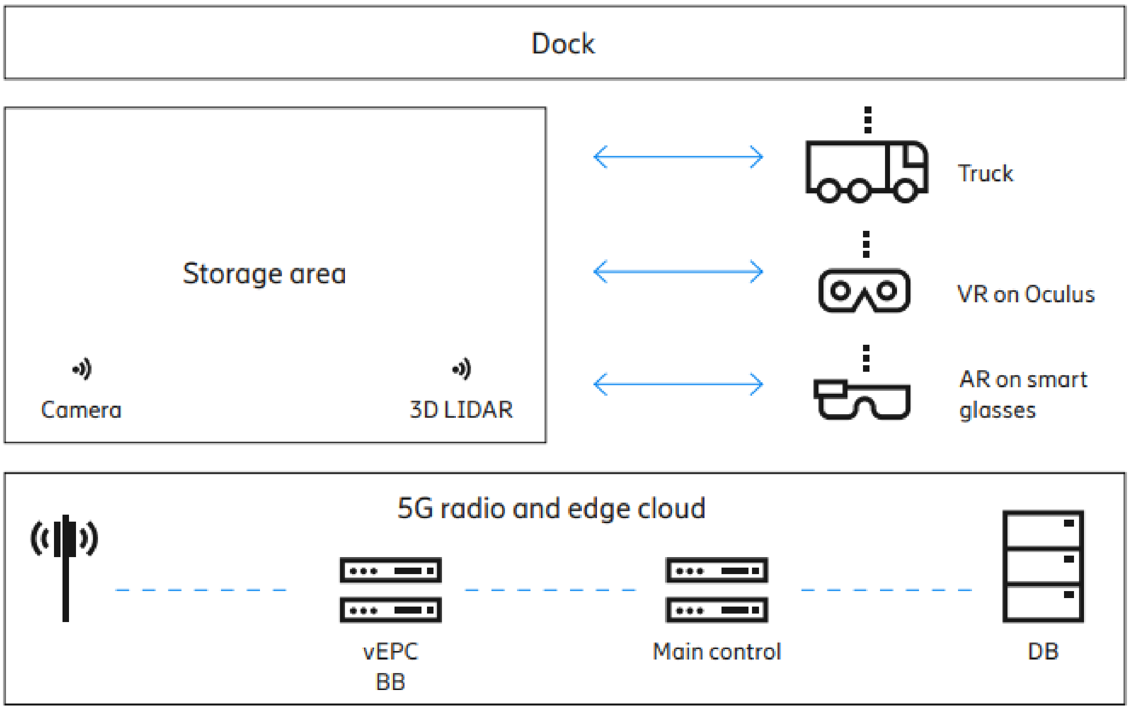
- oneM2M plateform for forklifts and data collection;
- Port Monitoring System (MonI.C.A) for the visulation of available forklifts, their status and the assigned cargo. Interaction between RTPORT and MonI.C.A optimises the vehicle-call process. This is achieved by reducing the total number of movements per general cargo unit and reducing the time to find a forklift on the yard to carry out the required operation;
- Tablets used by the forklift drivers, connected to 5G network.

VR simulations are additionally used to acquire statistics on loading operations and test the software for the positioning of the freights.

Non-digital components:

Yard vehicles (forklifts)

The 5G-based control module manages cargo operations in real-time



Functional Unit

(A) The functional unit for the assessment shall be defined including descriptions of its:

(i) Function relevant to both reference and ICT solution scenarios

(ii) Unit quantity

(iii) Performance

AddSecure, Fleet management

The functional unit for the solution is **kilogrammes of CO2 equivalent saved per 100 kilometres driven by fleet.**

The unit of 100 kilometres was chosen to allow for a comparison across fleets of different sizes.

The function that the ICT solution is aiming to deliver is the efficient delivery of products or services.

The unit quantity in this instance is the number of products or services delivered.

The performance would be around the speed and efficiency with which the products or services are delivered within a year.

PREDRI, Fleet management

The functional unit for the solution is **kilogrammes of CO2 equivalent saved per 100 kilometres driven by fleet.**

The unit of 100 kilometres was chosen to allow for a comparison across fleets of different sizes and this aligns with the common market practice of measuring fuel efficiency in litres per 100 kilometres.

The function that is being fulfilled in the reference and ICT enabled scenario is the transport of passengers.

The performance is maintaining a well-operating vehicle fleet and completing schedule passenger transport trips successfully during the year.

The unit quantity in this instance is per 100 km driven.

Ericsson, Port Optimisation

The functional unit for the solution is **kilogrammes of CO2 equivalent saved per freight ton per year.**

The unit per ton of freight was chosen to allow for comparison across ports of different capacities. This has a direct impact on the fuel consumed by the forklifts.

The function that solution is aiming to deliver is efficient processing of freight goods, through optimised forklift operations.

The unit quantity in this instance is the unit per ton of freight.

The performance is about the efficiency with which freight tonnage is processed (through optimised forklift operations) within a year.

Assessment Boundary

The assessment boundary determines which activities should be included in the net carbon impact assessment and therefore which emissions are included in the calculation.

(A) All GHGs covered by the Kyoto Protocol shall be included in the assessment and reported in a single CO_2e value in alignment with common greenhouse gas reporting standards.

AddSecure, Fleet management

The emission factors used to calculate the net carbon impact of the ICT solution cover all GHG emissions covered by the Kyoto Protocol and are reported in terms of CO_2e. Furthermore, the well-to-tank emissions are also included in the emission factor.

PREDRI, Fleet management

The emission factors used to calculate the net carbon impact of the ICT solution cover all GHG emissions covered by the Kyoto Protocol and are reported in terms of CO_2e. Furthermore, the well-to-tank emissions are also included in the emission factor.

Ericsson, Port Optimisation

The emission factors used to calculate the net carbon impact of the ICT solution cover all GHG emissions covered by the Kyoto Protocol and are reported in terms of CO_2e.

(B) The assessor shall define the time boundary for the assessment.

AddSecure, Fleet management

The time boundary for the assessment is over two 10-month periods (equalling 20 months).

PREDRI, Fleet management

The time boundary for the assessment is a 24-month period for analysing the fuel efficiency impacts whilst the part replacement impacts are assessed over a time period of 16 months.

Ericsson, Port Optimisation

The time boundary for the assessment is over the period 2017-2020/2021 for the implementation scenario.

(C) The assessor shall define the geographical boundary for the assessment.

AddSecure, Fleet management

The geographical boundary for this assessment is EU-wide and the fleets have a dominant presence in Germany, the Benelux countries and Poland.

PREDRI, Fleet management

The geographical boundary for this assessment is Mexico.

Ericsson, Port Optimisation

The geographical boundary for this assessment is a single port (Livorno) in Italy.

(D) The assessor shall define the implementation context for the assessment.

AddSecure, Fleet management

The solution has been implemented in 356 diesel lorries across 2 fleets that deliver products across European countries. These included over sixty different types of lorries from Mercedes, DAF, Scania, Volvo, Renault and MAN.

PREDRI, Fleet management

The solution has been implemented across a fleet of diesel powered medium-sized buses operating in Mexico. The buses hold 20 to 40 people. The assessment considered 85 buses out of a total fleet of 214 buses; buses were eliminated from the data set due to lack of data, erroneous/outlier data, and lack of activity during parts of the assessment period. These buses typically operate on a fixed route, with options to divert. They are mainly used to transport private company workers, from factories to areas in the metropolitan area.

Ericsson, Port Optimisation

The solution has been implemented at the Lorenzini terminal of Port Livorno, in Italy. It is one of the largest maritime ports in the Mediterranean with an annual freight capacity of around 30 million tons. Ericsson 5G-enabled solution applies across vessel and truck loading and unloading activities and yard movements by forklifts. However, scope of activity was limited to forklift movements as deemed higher potential impact (no observed change in forklift performance for other activities).

Reference Scenario Definition

(A) The reference scenario shall be determined as what the most likely alternative scenario in the event the solution is not/was not implemented, and it shall:

(i) Have equivalent or less functionality than the ICT solution.

(ii) Be relevant to the given implementation context.

(iii) Be relevant to the time in which the ICT solution is being assessed.

(B) The most likely scenario is determined as either:

(i) Continued use of the known system that was previously in place.

(ii) Use of the average alternative solution/method that solution users would select to achieve the same service.

AddSecure, Fleet management

The assumed reference scenario is the manual management of the fleet without a fleet management system in place. This is supported by statistics for the European fleet management market, which states that in 2021 around 13.2 million active fleet management systems had been deployed[1]. This represents around 38% of the current volume of commercial vehicles (vans and medium and heavy commercial vehicles) in-use across Europe, which is estimated to be around 35.2 million in 2020[2]. It is not known if any solution was used in the reference scenario. As the market average across Europe is still to manage a fleet without a digital fleet management system, this is taken as the reference scenario. It is assumed the fleets in the reference scenario had no assessment of driving behaviour and no real-time data to support decision-making. Moreover, it is assumed they used a standard navigation system, including in-vehicle interface devices informing the operators of the solution and drivers of the vehicles.

PREDRI, Fleet management

The reference scenario is a fleet of 85 medium-sized buses operating in Mexico. They hold 20 to 40 persons per bus and drive on diesel. It is not clear if there was any other optimisation system in use in the reference scenario, but it may be assumed software like Google Maps routing was used.

Ericsson, Port Optimisation

The reference scenario is the manual delivery/management of waybills by forklift drivers manually moving between yard and the terminal offices to register the unloaded freight. This scenario was chosen in accordance with the data measured by Ericsson in the context of the COREALIS project in 2017.

(C) The reference scenario shall include multiple scenarios if necessary to accurately represent the most likely alternative scenario.

AddSecure, Fleet management

[1] https://www.berginsight.com/the-installed-base-of-fleet-management-systems-in-europe-will-reach-25-million-by-2026 [Accessed: 09/11/23]

[2] https://www.acea.auto/publication/report-vehicles-in-use-europe-2022/#:~:text=There%20are%20more%20than%206.2,by%20far%20%E2%80%93%20see%20page%206. [Accessed: 09/11/23]

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While the solution has been implemented across two different fleets operating across several European countries, it has not been possible to split the data for the assessment by country or other regions, that could have different reference scenarios. Therefore, a European average was used to derive the reference scenario.

PREDRI, Fleet management

This requirement is not relevant for this assessment because the assessment only considers the implementation of the solution across one fleet, which is assumed to have the same reference scenario.

Ericsson, Port Optimisation

This requirement is not relevant for this assessment because the known reference scenario for the specific implementation context is used.

(D) The assessor shall describe how the function is fulfilled in the reference scenario.

AddSecure, Fleet management

In the reference scenario it is assumed that the managing and optimisation of the fleet is manual and there is no real-time data to support decision making. Furthermore, there is no assessment of driving behaviour in the reference scenario. Moreover, it is assumed they used a standard navigation system, including in-vehicle interface devices informing the operators of the solution and drivers of the vehicles.

PREDRI, Fleet management

In the reference scenario, there is no technology-enabled route optimisation and there is no detailed, real-time data about mechanical part condition to support decision making. Moreover, it may be assumed that a software like Google Maps routing was used.

Ericsson, Port Optimisation

In the reference scenario, there is no network-enabled digital registration software and no detailed, real-time data processing to support optimised forklift activity. The 5G network presents key characteristics of speed, increased capacity and reliability which would not have been achieved through a 4G network. A 4G network would not enable the same functionalities for the application of the RTPORT software which requires instant data transfer and connectivity of on-field equipment, hence is not considered as the market-average.

Identifying Effects

Identifying Reference and ICT Solution Scenario Activities and Emission Sources

(A) Identify the activities under the reference and ICT solution scenarios.

AddSecure, Fleet management

The following activities were identified as activities under both the reference and ICT solution scenarios.

Reference scenario	ICT solution scenario
Fleet goods collection	Fleet goods collection
Fleet goods delivery	Fleet goods delivery
Fleet maintenance	Fleet maintenance
Fleet operations management	Fleet operations management
	Driver behaviour improvement

PREDRI, Fleet management

The following activities were identified under the reference and ICT solution scenarios:

Reference scenario	ICT solution scenario
Passenger collection	Passenger collection
Passenger drop off	Passenger drop off
Fleet maintenance	Fleet maintenance
Fleet operations management	Fleet operations management

Ericsson, Port Optimisation

The following activities were identified as activities under both the reference and ICT solution scenarios.

Reference scenario	ICT solution scenario
Forklift usage timings	Forklift usage timings
Forklift yard activity (distance)	Forklift yard activity (distance)
Forklift fuel consumption per hour	Forklift fuel consumption per hour

(B) Identify potential GHG emissions sources related to the activities.

AddSecure, Fleet management

Reference scenario	Potential emission sources	ICT solution scenario	Potential emission sources
Fleet goods collection	Transport emissions	Fleet goods collection	Transport emissions
Fleet goods delivery	Transport emissions	Fleet goods delivery	Transport emissions
Fleet maintenance	Site emissions from workshop Electricity and process emissions from maintenance activities	Fleet maintenance	Site emissions from workshop Electricity and process emissions from maintenance activities
Fleet operations management	Office emissions	Fleet operations management	Office emissions

	Hardware embodied and in-use emissions of Standard Navigation System in-vehicle interface Network emissions		Hardware embodied and in-use emissions (Black box, SIM Card, in-vehicle interface) Network emissions (4G/2G) Laptop/mobile emissions Data centre processing and storage emissions
		Driver behaviour improvement	Hardware embodied and in-use emissions (interface, Black box, SIM card) Network emissions (4G/5G) Data centre processing and storage emissions

PREDRI, Fleet management

Reference scenario	Potential emission sources	ICT solution scenario	Potential emission sources
Passenger collection	Transport emissions	Passenger collection	Transport emissions
Passenger drop off	Transport emissions	Passenger drop off	Transport emissions

Fleet maintenance	Site emissions from workshop Electricity and process emissions from maintenance activities Embodied emissions of replacement parts	Fleet maintenance	Site emissions from workshop Electricity and process emissions from maintenance activities Embodied emissions of replacement parts
Fleet operations management	Office emissions Network emissions (use of Google Maps)	Fleet operations management	Office emissions Hardware embodied and in-use emissions (GPS tracker, refuelling station based on Programmable Logic Controller, Raspberry module, GPS platform server) Software emissions Network emissions (4G mobile) Personal computer emissions Data centre processing and storage emissions

Ericsson, Port Optimisation

Reference scenario	Potential emission sources	ICT solution scenario	Potential emission sources

Forklift fuel consumption per hour	Transport emissions	Forklift fuel consumption per hour	Transport emissions
Freight operations management	Assumed negligible as manual processing	Logistics management - digital registration software	Hardware embodied and in-use emissions (Tablets used by forklift drivers) Software emissions Network emissions (5G mobile and fixed) Data centre processing and storage emissions – RTPORT software, Port Monitoring System, oneM2M platform.

Identifying Potential Effects of Solution Implementation

(A) Identify the potential effects generated by the implementation of the ICT solution.

AddSecure, Fleet management

Reference scenario	Potential emission sources	ICT solution scenario	Potential emission sources	GHG emission impacts
Fleet goods collection	Transport emissions	Fleet goods collection	Transport emissions	Yes, reduction in transport emissions
Fleet goods delivery	Transport emissions	Fleet goods delivery	Transport emissions	Yes, reduction in

				transport emissions
Fleet maintenance	Site emissions from workshop Electricity and process emissions from maintenance activities	Fleet maintenance	Site emissions from workshop Electricity and process emissions from maintenance activities	No change to emissions from workshop or maintenance activities, as solution does not provide information on required repairs
Fleet operations management	Office emissions Hardware embodied and in-use emissions of Standard Navigation System in-vehicle interface Network emissions	Fleet operations management	**Software only:** Office emissions Network emissions (4G/5G) Laptop/mobile emissions Data centre processing and storage emissions **Including hardware:** Hardware embodied and in-use emissions (Black box, SIM Card, in-vehicle interface)	No change to office emissions Increase in emissions from hardware, laptop, mobile and data centre

		Driver behaviour improvement	**Software only:** Network emissions (4G/5G) Data centre processing and storage emissions **Including hardware:** Hardware embodied and in-use emissions (interface, Black box, SIM card, in-vehicle interface)	No change to office emissions Increase in emissions from hardware, laptop, mobile and data centre

PREDRI, Fleet management

Reference scenario	Potential emission sources	ICT solution scenario	Potential emission sources	GHG emission impacts
Passenger collection	**Transport emissions**	**Passenger collection**	**Transport emissions**	**Reduction in transport emissions**
Passenger drop off	**Transport emissions**	**Passenger drop off**	**Transport emissions**	**Reduction in transport emissions**
Fleet maintenance	**Site emissions from workshop** **Electricity and process**	**Fleet maintenance**	**Site emissions from workshop** **Electricity and process emissions**	**No change in workshop emissions**

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	emissions from maintenance activities Embodied emissions of replacement parts		from maintenance activities Embodied emissions of replacement parts	Reduction in electricity and process emissions from maintenance activities; reduction in replacement parts therefore embodied emissions
Fleet operations management	Office emissions Network emissions (use of Google Maps)	Fleet operations management	Office emissions Hardware embodied and in-use emissions (GPS tracker, refuelling station based on Programmable Logic Controller, Raspberry module, GPS platform server) Network emissions (4G mobile and fixed) Personal computer/software emissions Data centre processing and storage emissions	No change in office emissions Increase in emissions from hardware, PC/ software, and data centre use

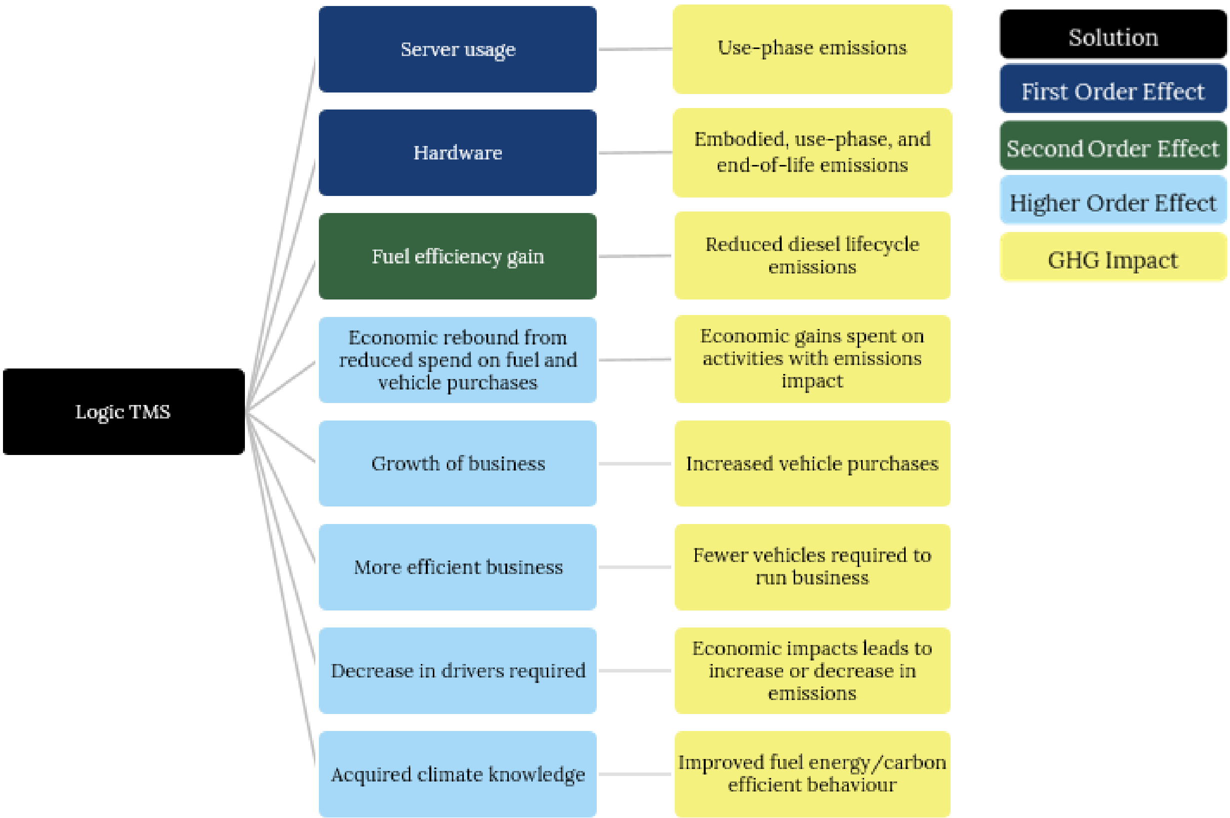
Ericsson, Port Optimisation

Reference scenario	Potential emission sources	ICT solution scenario	Potential emission sources	GHG emission impacts
Forklift fuel consumption per hour	Transport emissions	Forklift fuel consumption per hour	Transport emissions	Reduction in transport emissions
Freight operations management	Assumed negligible as manual processing	Logistics management - digital registration software	Hardware embodied and in-use emissions (Tablets used by forklift drivers) Software emissions Network emissions (5G mobile and fixed) Data centre processing and storage emissions – RTPORT software, Port Monitoring System, oneM2M platform.	Increase in emissions from hardware, network, tablet/ software, and data centre use

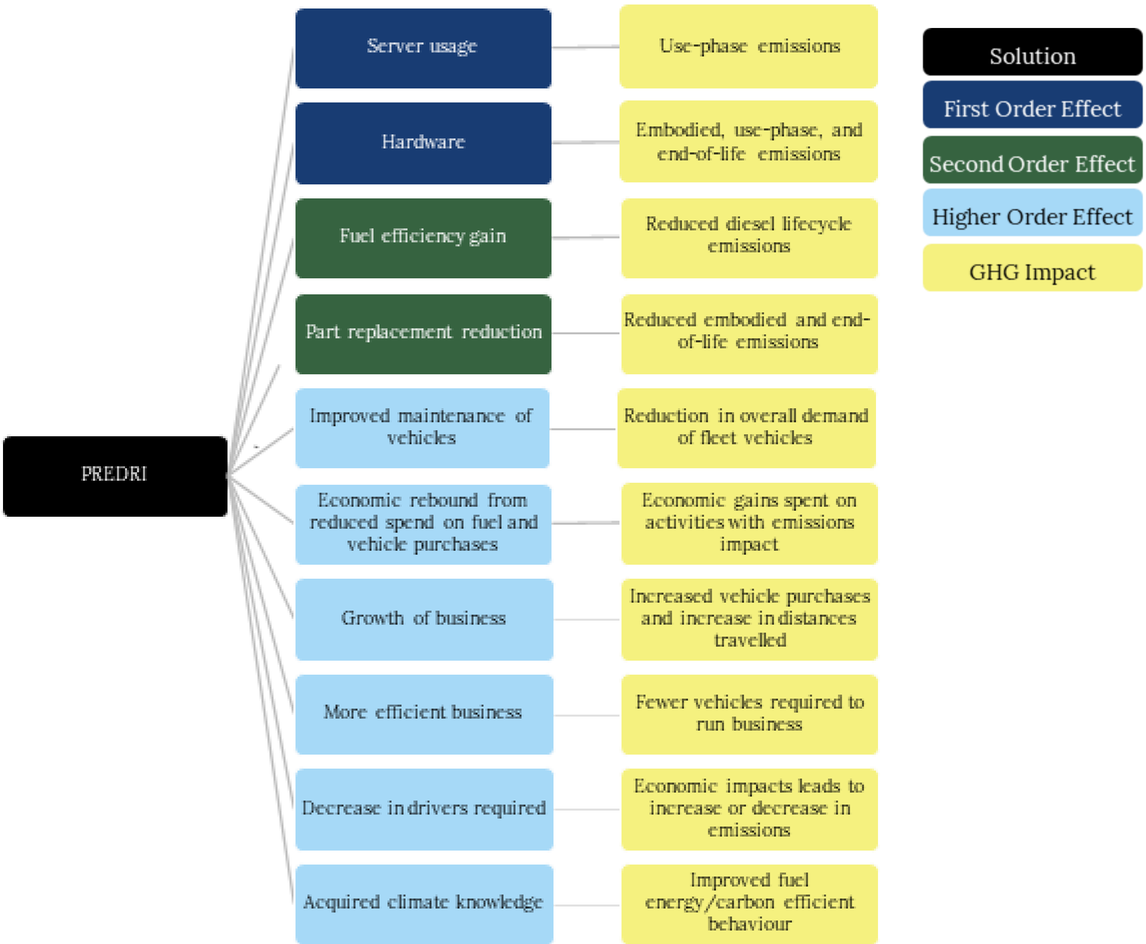
Mapping Effects in a Consequence Tree

(A) Map out all first, second, and higher order effects and GHG impacts in a consequence tree.

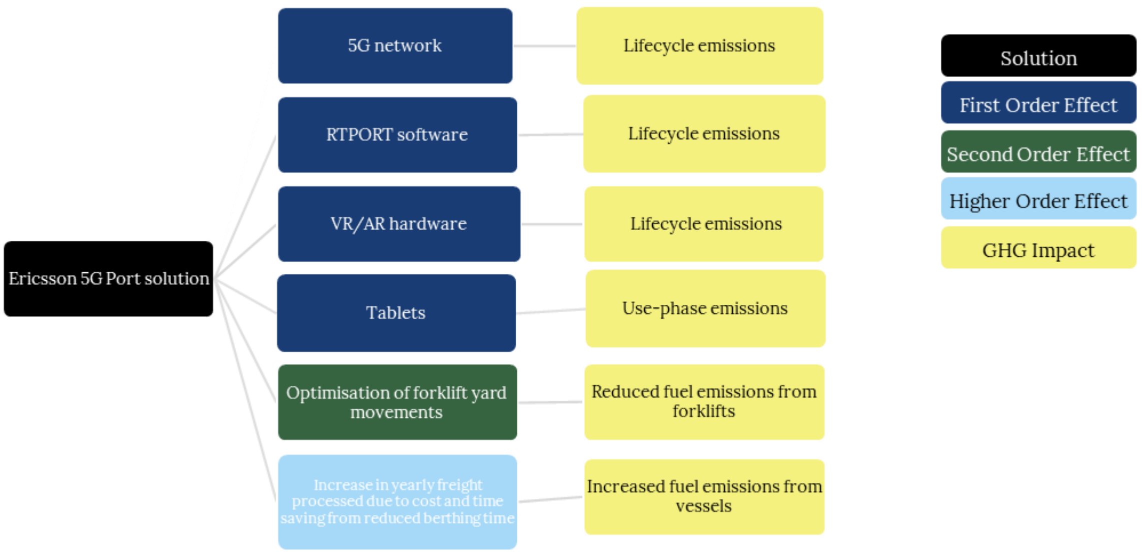
AddSecure, Fleet management



PREDRI, Fleet management


PREDRI
Server usage
Use-phase emissions
Hardware
Embodied, use-phase, and end-of-life emissions
Fuel efficiency gain
Reduced diesel lifecycle emissions
Part replacement reduction
Reduced embodied and end-of-life emissions
Improved maintenance of vehicles
Reduction in overall demand of fleet vehicles
Economic rebound from reduced spend on fuel and vehicle purchases
Economic gains spent on activities with emissions impact
Growth of business
Increased vehicle purchases and increase in distances travelled
More efficient business
Fewer vehicles required to run business
Decrease in drivers required
Economic impacts leads to increase or decrease in emissions
Acquired climate knowledge
Improved fuel energy/carbon efficient behaviour
Solution
First Order Effect
Second Order Effect
Higher Order Effect
GHG Impact

Ericsson, Port Optimisation



Identify First Order Effects

(A) All first order effects shall be identified that occur within the boundary of the ICT solution as defined in section 3.2.2 of the "Net Carbon Impact Assessment Methodology for ICT Solutions".

(B) The GHG impact of first order effects shall consider the full life cycle emissions of the ICT solution, that are not excluded by (C). This includes upstream emissions relating to solution's manufacture and transportation (embodied emissions), life cycle emissions from use and maintenance, and end of life treatment.

(C) Embodied and end-of-life emissions from ICT equipment or hardware that can be justified as already in existence without the solution implementation can be excluded from the calculation of first order effects with justification.

AddSecure, Fleet management

The following emissions were identified to not be part of the reference scenario and must therefore be considered as first order effects:

- **Embodied (incl. transport), end-of-life and in-use emissions of hardware** (Black box, SIM Card) – as the Black box and SIM card hardware were not required before the implementation of the solution and they are not part of the reference scenario, both the embodied and in-use emissions of these devices should be considered for the calculation of first order effects.

  - It is assumed that an alternative navigation system was used in the reference scenario. Therefore, the lifecycle emissions of the in-vehicle interface have been excluded from the calculation of first order effects.

- **Network emissions (4G/5G) -** It is assumed that an alternative navigation system was used in the reference scenario. Therefore, the lifecycle emissions of the network have been excluded from the calculation of first order effects.

- **Laptop/mobile emissions**

  - The marginal increase in **in-use emissions from laptops and mobiles used to operate the solution** are not part of the reference scenario and therefore should be considered as first order effects.

  - It is assumed that the **embodied (incl. transport) and end-of-life emissions of the mobile and laptop devices** are already in existence even without the implementation of the solution in place, as they are unlikely to be purchased solely for this solution. These emissions are therefore excluded from the calculation of first order effects.

- **Data centre processing and storage emissions**

  - The marginal increase in **in-use emissions from data centre processing and storage** are not part of the reference scenario and therefore should be considered as first order effects.

  - It is assumed that the **embodied (incl. transport) and end-of-life emissions of datacentres used for processing and storage** are already in existence even without the implementation of the solution in place, as they are unlikely to be built solely for this solution. These emissions are therefore excluded from the calculation of first order effects.

PREDRI, Fleet management

The following emissions were identified to not be part of the reference scenario and must therefore be considered as first order effects:

- **Embodied (incl. transport), end-of-life and in-use emissions of hardware (Ruptela GPS tracker)** – as this hardware was not required before the implementation of the solution and is not part of the reference scenario, the embodied, in-use, and end-of-life emissions and should be considered for the calculation of first order effects.

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- **Network emissions (4G mobile)**
    - The marginal increase in **in-use network emissions** is assumed to be the same across the reference scenario and implementation scenario as another optimisation system like Google Maps would likely be operating in the absence of PREDRI solution. Therefore, network emissions have been excluded from the calculation.
    - The **embodied (incl. transport) and end-of life emissions of the network** are already in existence even without the implementation of the solution in place, as the network is unlikely to have been upgraded solely for this solution. These emissions are therefore excluded from the calculation of first order effects.
- **Personal computer/software emissions**
    - New software associated with the ICT solution (DeviceCenter configuration software for GPS trackers, spare part stock control system software) was not present in the reference scenario. The marginal increase in **in-use emissions from personal computers used to operate the solution** is not part of the reference scenario and therefore should be considered as first order effects.
    - It is assumed that the **embodied (incl. transport) and end-of-life emissions of the PC devices** are already in existence even without the implementation of the solution in place, as they are unlikely to be purchased solely for this solution. These emissions are therefore excluded from the calculation of first order effects.
- **Data centre processing and storage emissions**
    - The marginal increase in **in-use emissions from data centre processing and storage** is not part of the reference scenario and therefore should be considered as first order effects.
    - It is assumed that the **embodied (incl. transport) and end-of-life emissions of datacentres used for processing and storage** are already in existence even without the implementation of the solution in place, as they are unlikely to be built solely for this solution. These emissions are therefore excluded from the calculation of first order effects.

Ericsson, Port Optimisation

The following emissions were identified to not be part of the reference scenario and must therefore be considered as first order effects:

- **Network emissions (5G mobile)**

- The marginal increase in **in-use network emissions** is not part of the reference scenario and therefore should be considered for the calculation of first order effects.
- The **embodied (incl. transport) and end-of life emissions of the network** are already in existence even without the implementation of the solution in place, as the network is unlikely to have been upgraded solely for this solution. These emissions are therefore excluded from the calculation of first order effects.

- **Personal Tablet / Software emissions**
    - Software associated with the ICT solution (RTPORT software, Port Monitoring System, oneM2M platform) was not present in the reference scenario. The marginal increase in **in-use emissions from personal tablets used to operate the solution** is not part of the reference scenario and therefore should be considered as first order effects.
    - It is assumed that the **embodied (incl. transport) and end-of-life emissions of the tablet devices** are already in existence even without the implementation of the solution in place, as they are unlikely to be purchased solely for this solution. These emissions are therefore excluded from the calculation of first order effects.
- **Data centre processing and storage emissions**
    - The marginal increase in **in-use emissions from data centre processing and storage** is not part of the reference scenario and therefore should be considered as first order effects.
    - It is assumed that the **embodied (incl. transport) and end-of-life emissions of datacentres used for processing and storage** are already in existence even without the implementation of the solution in place, as they are unlikely to be built solely for this solution. These emissions are therefore excluded from the calculation of first order effects.

Identify Second & Higher Order Effects

(A) All second order effects shall be identified.

(B) All higher order effects shall be identified.

AddSecure, Fleet management

The following second and higher order effects were identified:

Second order effects:

- A reduction in fuel consumption due to improved driver behaviour and an increase in fuel efficiency due to an improvement in driver behaviour.

Higher order effects:

- Optimisation of vehicle fleet for goods collection and delivery results in an increase in operations and distance travelled.
- Potential decrease of fleet vehicles when a business can dispose of them.
- Potential decrease of drivers needed, and the economic impacts associated with lower income of these drivers, which could lead to an increase/decrease in GHG emissions.
- Reduction in cost of delivering products/services and associated economic impacts, which could lead to an increase/decrease in GHG emissions.
- Acquired knowledge of climate and fuel efficiency can improve fuel usage/energy consumption in other areas, reducing emissions.

Given the potential system-wide scope of higher order effects, it should be acknowledged that this is not necessarily an exhaustive list and other higher order effects may be identified.

PREDRI, Fleet management

The following second and higher order effects were identified:

Second order effects:

- An increase in fuel efficiency due to route monitoring and optimisation.
- A reduction in embodied emissions from replacement parts that are replaced less frequently, only, when necessary, due to on-board monitoring of mechanical parts.

Higher order effects:

- Improved fuel efficiency and improved monitoring of replacement parts may result, in the medium to long term, in vehicles themselves being replaced less frequently. This would reduce the demand for new vehicles, saving GHG emissions associated with the manufacturing process.
- Reduced spend on new vehicles and fuel can cause an economic rebound effect as financial capital can be reallocated to activities that reduce or increase carbon emissions.
- Optimisation of vehicle fleet results in an increase in operations and distance travelled.
- A more efficient fleet in terms of fuel and spare part replacements may also allow a company to increase its profit margins and grow, thus increasing the number of vehicles on the roads emitting more GHGs. Alternatively, improved efficiencies may allow the business to operate with fewer vehicles.

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the European Union

- Another higher order effect results from the decrease of drivers needed. The economic impacts associated with the lower income of these drivers could lead to an increase or decrease in GHG emissions. The reduction in costs of delivering products and the associated economic impacts could lead to an increase or decrease in GHG emissions.
- Finally, the acquired knowledge of climate and fuel efficiency can improve fuel usage in other areas, reducing emissions.

Given the potential system-wide scope of higher order effects, it should be acknowledged that this is not necessarily an exhaustive list and other higher order effects may be identified.

Ericsson, Port Optimisation

The following second and higher order effects were identified:

Second order effects:

- An increase in fuel efficiency of forklifts due to optimised freight cargo processing and operations.

Higher order effects:

- Improved efficiency of forklift operations from 5G-enabled solution, in the medium to long term, could result in time saving that could increase productivity (more vessels calling at the port. This increase in yearly freight processed would result in higher associated cargo emissions.

Given the potential system-wide scope of higher order effects, it should be acknowledged that this is not necessarily an exhaustive list and other higher order effects may be identified.

Calculating Effects

Estimating the Relative Magnitude of Effects

(A) An estimation of the magnitude of effects included in the assessment should be carried out for all identified GHG impacts resulting from first, second, and higher order effects.

AddSecure, Fleet management

First order effects:

Embodied (incl. transport), end-of-life and in-use emissions of hardware (Black box, SIM Card) – these emissions were estimated to be small, considering the weight of the devices and the relatively small power consumption (~33W based on similar devices[3]). The calculations should still aim to include this effect but may rely on secondary or proxy data if necessary.

Data centre processing and storage emissions, and laptop/mobile emissions marginal increase in **in-use emissions –** the in-use emissions from laptops and mobiles are assumed to be relatively small given that the calculations only account for the marginal increase in emissions caused by the use of the software needed to operate the solution. The data centre and network emissions on the other hand, while also assumed to be relatively small, are considered to be more significant, given the amount of data being transferred.

Second order effects:

Initial results show a fuel saving of around 5%, which amount to around 8,800 litres of fuel for the assessment boundary. Given the high carbon intensity of diesel, it is assumed that the reduction in transport emissions from route optimisation and improving driver behaviour is likely to account for a large part of the GHG savings from second order effects, and high data quality should therefore be a priority for this effect.

Higher order effects:

- **Optimisation of vehicle fleet for goods collection and delivery results in an increase in operations and distance travelled.** – this direct higher order effect could have a significant impact as it could negate the impact of the second order effect. It should therefore be assessed using high data quality. It is also likely that the same data as provided for the second order effect will demonstrate this higher order effect.
- **Potential decrease of fleet vehicles when a business can dispose of them** – the emissions from this higher order effect could be relatively significant to the overall net carbon impact but they are dependent on the end-of-life fate of the vehicles and the percentage of materials that are recyclable. While the end—of-life emissions from vehicles typically only account for 3-5%[4] of the lifecycle emissions of ICE vehicles, the emissions could still be significant in the context of the net carbon impact of this assessment.
- **Potential decrease of drivers needed, and the economic impacts associated with lower income of these drivers, which could lead to an increase/decrease in GHG emissions.**
- **Reduction in cost of delivering products/services and associated economic impacts, which could lead to an increase/decrease in GHG emissions.**

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[3] https://www.blackboxgps.net/products-blackbox-gps-india/blackbox-fleet-management-system/blackbox-tm33-gps-vehicle-tracker/ [Accessed: 26/11/2023]

[4] https://www.mckinsey.com/capabilities/sustainability/our-insights/the-zero-carbon-car-abating-material-emissions-is-next-on-the-agenda [Accessed: 26/11/2023]

- **Acquired knowledge of climate and fuel efficiency can improve fuel usage/energy consumption in other areas, reducing emissions.**

It is extremely difficult to assess the magnitude of these higher order effects as their impact is highly uncertain. The impact for the first two effects could be both positive, if the reduction in income for drivers and/or the reduction in costs change expenditure to lower carbon activities or negative, if the reverse was the case. Furthermore, for all three higher order effects it will be very difficult to establish the extent to which the solution will cause this effect, as this may also vary across individuals and companies.

PREDRI, Fleet management

First order effects:

The hardware that is introduced as part of the solution is a GPS 4G module. Its weight is known, and associated lifecycle emissions are determined to be low materiality. In contrast, because the solution uses AI, the energy consumption related to administering the solution via the PC, data transmission across the network, and data centre processing and storage is likely to account for most of the first order effects. Therefore, these should be the focus areas for obtaining high quality data within the first order effects.

Second order effects:

Previous studies on efficient routing and fleet management solutions indicate fuel savings in the range of 2-25%[5]. Therefore, the expected reduction in transport emissions from route optimisation is likely to account for a large part of the GHG savings from second order effects, and high data quality should be a priority for this effect. The reduction in electricity and process emissions from maintenance activities as well as the reduction in embodied emissions from fewer replacement parts will likely make up a smaller share of the GHG savings impact, given that parts take time to wear out and it will take a longer time period for savings to materialise.

Higher order effects:

The identified potential higher order effects (vehicles replaced less frequently; increase in distance travelled; growth in fleet) are generally speculative and evidence of their existence would take longer time periods to materialise than the first and second order effects. Given the long lifespan of vehicles, the reduction in new vehicle demand would have an immaterial impact in this context. The potential direct and economic rebounds from an optimised fleet are limited by the savings achieved but may be material if the savings are large enough to enable additional trips or new vehicles for the fleet. Therefore, effort should be made to track these impacts and their drivers in order to understand if any rebound is experienced.

[5] https://www.gsma.com/betterfuture/wp-content/uploads/2019/12/GSMA_Enablement_Effect.pdf

Ericsson, Port Optimisation

First order effects:

1st order effects were not quantified as these were out of scope of the original COREALIS study. The scale of proxies required to cover these data gaps was such that first order effects have been excluded from the calculator. As it was not possible to ascertain whether the excluded 1st order effects are below a 5% materiality, this case study is not fully aligned with the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions".

Factors which would need to be considered to calculate first order emissions of a similar use case are included below:

Data centre processing and storage emissions, network emissions (5G) and laptop/mobile emissions marginal increase in **in-use emissions –** the marginal increase in in-use emissions from tablets that interface the digital solution is assumed to be relatively small given that the calculations only account for the marginal increase in emissions caused by the use of the software needed to operate the solution. The data centre and network emissions on the other hand, while also assumed to be relatively small, are considered to be more significant, given the amount of data being transferred across the digital components of the solution (RTPORT, oneM2M platform, Port Monitoring system). However, it was not possible to determine whether the excluded 1st order effects are below a 5% materiality.

Second order effects:

Initial results show a fuel saving of around 19%, which amount to around 43 m3 reduction in diesel fuel consumption for the assessment boundary. Given the high carbon intensity of diesel, it is assumed that the reduction in annual fuel emissions from optimised forklift operations is likely to account for a large part of the GHG savings from second order effects, and high data quality should therefore be a priority for this effect.

Higher order effects:

Improved efficiency of forklift operations from 5G-enabled solution drives an increase in productivity – this was assessed qualitatively by Ericsson who deduced that the marginal gains in productivity would be negligible. They evaluated that the time saved in forklift activity does not result in substantial increases in cargo ship processing activity (the time saved decreases the daily shifts for forklifts from 14h to 12h for the same amount of cargo). Thus, forklift daily activity decreases rather than observing an increase in number of cargo ships processed.

Data Collection

Identifying Key Activities for each Effect

(A) For all effects identified under section 3.3 of the “Net Carbon Impact Assessment Methodology for ICT Solutions”, suitable activities and activity emission intensities should be identified that can be used to estimate the GHG impact of each effect.

AddSecure, Fleet management

Effect	Description	Activities
First Order	Embodied (incl. transport), end-of-life and in-use emissions of hardware Black box SIM Card	• Number of devices per functional unit • Cradle to grave footprint of hardware devices • Material breakdown of hardware devices (type and weight of material) • Likely disposal method of devices • Material and end-of-life emission factors • Location of origin and destination, likely transport modes • Energy usage per device over lifetime • Power consumption of device and usage profile • Electricity emission factors
First Order	In-use emissions from laptops and mobiles used to operate the solution	• Marginal energy consumption of laptops/mobiles due to operation of Logic TMS • Electricity emission factors
First Order	In-use emissions from data centre processing and storage	• Marginal energy consumption of data centres due to Logic TMS • Electricity emission factors

Second order	A reduction in fuel consumption due to improved driver behaviour and an increase in fuel efficiency due to an improvement in driver behaviour.	• Fuel consumption by fuel type in fleets before and after the implementation of Logic TMS. • Fuel emission factors
Higher order	Optimisation of vehicle fleet for goods collection and delivery results in an increase in operations and distance travelled.	• Fuel consumption by fuel type in fleets before and after the implementation of Logic TMS, several years after implementation. • Distance travelled in fleets before and after implementation of Logic TMS, several years after implementation. • Fuel emission factors
Higher order	Potential decrease of fleet vehicles when a business can dispose of them.	• Number of vehicles before and several years after implementation of Logic TMS. • Products/services delivered before and several years after implementation of Logic TMS.
Higher order	Potential decrease of drivers needed, and the economic impacts associated with lower income of these drivers, which could lead to an increase/decrease in GHG emissions.	• Number of drivers before and several years after implementation of Logic TMS. • Income and likely spending habits of drivers before and several years after implementation of Logic TMS. • Products/services delivered before and several years after implementation of Logic TMS.
Higher order	Reduction in cost of delivering products/services and associated economic impacts, which could	• Products/services delivered before and several years after implementation of Logic TMS.

	lead to an increase/decrease in GHG emissions.	• Cost of delivering product and services before and several years after implementing Logic TMS. • Likely Spending habits of customers before and several years after implementing Logic TMS.
Higher order	Acquired knowledge of climate and fuel efficiency can improve fuel usage/energy consumption in other areas of the users, reducing emissions.	• Total fuel consumption of users before and several years after implementation of Logic TMS. • Likely spending habits of customers before and several years after implementing Logic TMS. • Personal carbon footprints of customers before and several years after implementing Logic TMS.

PREDRI, Fleet management

Effect	Description	Activities
First Order	Embodied (incl. transport), end-of-life and in-use emissions of hardware: ○ GPS 4G module	Number of devices per solution implementation Cradle to grave GHG emissions footprint of GPS 4G module Material breakdown of GPS 4G module (type and weight of material) Likely disposal method of devices Material embodied and end-of-life emission factors Energy usage per device over lifetime Power consumption of device and usage profile

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		Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use emissions from personal computers / software used to operate the solution	Marginal energy consumption of personal computers due to operation of solution
First Order	In-use emissions from data centre processing and storage	Marginal energy consumption of data centres due to solution Dedicated server energy consumption Data centre PUE Electricity grid emission factor (GHG emissions per kWh)
Second order	A reduction in fuel consumption due to an increase in fuel efficiency	Fuel consumption by fuel type in fleets before and after the implementation of the solution Kilometres travelled by fleet over the same time period Fuel emission factors
Second order	A reduction in embodied emissions from fewer replacement parts	Part replacement records for each fleet vehicle before and after the implementation of the solution, across multiple years Embodied emissions of replacement parts Material breakdown of replacement parts (type and weight of material) Material embodied emission factors
Higher order	Improved fuel efficiency and monitoring of replacement parts results in lower demand for new	Data on rates of vehicle replacement before and after implementation of the solution (across many years)

	vehicles and therefore lower manufacturing emissions	Data on other variables which affect vehicle replacement (e.g. financial) Vehicle embodied emissions
Higher order	Optimisation of vehicle fleet results in an increase in operations and distance travelled	Fuel consumption by fuel type in fleets before and after the implementation of solution, several years after implementation. Distance travelled in fleets before and after implementation of solution, several years after implementation. Data on other variables which affect distance travelled (e.g. number of customers/trips per year)
Higher order	Optimisation of vehicle fleet reduces costs, allowing company to grow fleet size.	Number of vehicles before and several years after implementation of solution Cost of operating fleet before and several years after implementation of solution, identifying cost savings attributable to solution Data on other variables that would impact growth in fleet size
Higher order	More efficient business reduces the need of number of vehicles	Fuel consumption by fuel type in fleets before and after the implementation of solution, several years after implementation. Distance travelled in fleets before and after implementation of solution, several years after implementation. Data on other variables which affect distance travelled (e.g. number of customers/trips per year)

Higher order	A decrease of drivers needed and the effect of reduced income of drivers	Income and spending patterns of all drivers before and after implementation of solution.
Higher order	Acquired knowledge of climate and fuel efficiency	Spending patterns or carbon footprints of all users of the solutions before and several years after implementation of solution.

Ericsson, Port Optimisation

Effect	Description	Activities
First Order	In-use network emissions	Marginal energy consumption of 5G network due to solution Amount of data transfer over the network Network energy intensity (kWh energy use per GB data transfer) Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use emissions from personal tablets/ software used to operate the solution	Marginal energy consumption of personal tablets due to operation of solution Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use emissions from data centre processing and storage	Marginal energy consumption of data centres due to solution Dedicated server energy consumption Data centre PUE Electricity grid emission factor (GHG emissions per kWh)

Second order	An increase in fuel efficiency (reduced fuel consumption) of forklifts due to optimised freight cargo processing and operations.	Fuel consumption by forklift vehicles over their activity hours (litres/hour) before and after the implementation of the solution.
Higher order	Improved efficiency of forklift operations leading to time saving and increased productivity (more vessels calling at the port. This increase in yearly freight processed would result in higher associated cargo emissions.	Data on rates of time saved in daily forklift operations per unit of cargo processed before and after implementation of the solution (across many years). Data on other variables which affect increased productivity (e.g. financial cost saving)

Data Quality and Availability Assessment

(A) A data availability and quality assessment should be carried out for all activities and activity emission intensities identified for each effect included in the assessment. The assessment shall be used to select the most appropriate data sources for the assessment.

(B) The data availability and quality assessment can then be used to select relevant data sources for the net carbon impact assessment by considering the following:

(i) The data quality and availability for each activity under both the reference and ICT solution scenario.

(ii) The ITU L1410 guidance for data quality and data quality review guidance.

(iii) The relative magnitude of the effect.

(C) All data sources and assumptions used when selecting applicable data should be documented and reported.

AddSecure, Fleet management

Effect	Activities	Data for activity available?	Data Quality

Embodied (incl. transport), end-of-life and in-use emissions of hardware **Black box** **SIM Card**	• Number of devices per functional unit • Cradle to grave footprint of hardware devices • Material breakdown of hardware devices (type and weight of material) • Likely disposal method of devices • Material and end-of-life emission factors • Location of origin and destination, likely transport modes • Energy usage per device over lifetime • Power consumption of device and usage profile • Electricity emission factors	• Number of devices per functional unit (assumed 1 per vehicle) • Weight of device and main material	• Good • Good – weight and main material used to estimate embodied emissions
In-use emissions from laptops and	• Marginal energy consumption of	• Not available	• N/A

mobiles used to operate the solution	laptops/mobiles due to operation of Logic TMS • Electricity emission factors		
In-use emissions from data centre processing and storage	• Marginal energy consumption of data centres due to Logic TMS • Electricity emission factors	• Total kWh electricity consumed by reference platform divided by number of active units/vehicles • Electricity emission factors	• Fair/Good– information from a similar AddSecure Fleet Management solution (FMS) over 1 year served as a reference. • Very good
A reduction in fuel consumption due to improved driver behaviour and an increase in fuel efficiency due to an improvement in driver behaviour.	• Fuel consumption by fuel type in fleets before and after the implementation of Logic TMS.	• Fuel consumption for 10-months directly after Logic TMS implementatio n • Fuel consumption 10-months in the following year	• Poor - 10-month measured data immediately after implementation of solution is used as proxy for data before implementation . • Good – measured data for 10-month period after

			implementation.
Optimisation of vehicle fleet for goods collection and delivery results in an increase in operations and distance travelled.	• Fuel consumption by fuel type in fleets before and after the implementation of Logic TMS, several years after implementation. • Distance travelled in fleets before and after implementation of Logic TMS, several years after implementation.	• No, data not available for several years after implementation of Logic TMS.	• Not applicable
Potential decrease of fleet vehicles when a business can dispose of them.	• Number of vehicles before and several years after implementation of Logic TMS. • Products/services delivered before and several years after implementation of Logic TMS.	• No, data not available for several years after implementation of Logic TMS.	• Not applicable
Potential decrease of	• Number of drivers before	• No, data not available for	• Not applicable

drivers needed, and the economic impacts associated with lower income of these drivers, which could lead to an increase/decrease in GHG emissions.	and several years after implementation of Logic TMS. • Income and likely spending habits of drivers before and several years after implementation of Logic TMS. • Products/services delivered before and several years after implementation of Logic TMS.	several years after implementation of Logic TMS. • No data/information on spending habits available and information would be difficult to get.	
Reduction in cost of delivering products/services and associated economic impacts, which could lead to an increase/decrease in GHG emissions.	• Products/services delivered before and several years after implementation of Logic TMS. • Cost of delivering product and services before and several years after implementing Logic TMS. • Likely Spending habits of customers	• No, data not available for several years after implementation of Logic TMS.	• Not applicable

	before and several years after implementing Logic TMS.		
Acquired knowledge of climate and fuel efficiency can improve fuel usage/energy consumption in other areas of the users, reducing emissions.	• Total fuel consumption of users before and several years after implementation of Logic TMS.	• No, data not available for several years after implementation of Logic TMS.	• Not applicable

PREDRI, Fleet management

Effect	Activities	Data for activity available?	Data Quality
Embodied (incl. transport), end-of-life and in-use emissions of hardware: **GPS 4G module**	• Number of devices per solution implementation • Cradle to grave GHG emissions footprint of hardware devices • Material breakdown of hardware devices (type and weight of material) • Likely disposal method of devices • Material embodied and end-of-life emission factors	• Weight of device and main material • Generic electrical emission factor (incl. end-of-life) • Energy usage for GPD module and hours active • Electricity emission factor for Mexico	• Good • Good/Fair • Good • Good

	• Energy usage per device over lifetime • Power consumption of device and usage profile • Electricity grid emission factor (GHG emissions per kWh)		
In-use emissions from personal computers / software used to operate the solution	• Marginal energy consumption of personal computers due to operation of solution • Electricity emission factors	• Power consumption for PCs and active hours • Electricity emission factor for Mexico	• Very good • Good
In-use emissions from data centre processing and storage	• Marginal energy consumption of data centres due to solution • Dedicated server energy consumption • Data centre PUE • Electricity grid emission factor (GHG emissions per kWh)	• Spend on Wialon GPS server, 4G data connection and data location analysis software • Spend on Google Server • Server emission conversion factor	• Good • Good • Poor
A reduction in fuel consumption due to an increase in fuel efficiency	• Fuel consumption by fuel type in fleets before and after the implementation of the solution • Kilometres travelled by fleet over the same time period	• Fuel consumption for 2-year period, capturing before and after solution implementation • Kilometres travelled over same time period	• Good – measured data • Good – measured data

A reduction in embodied emissions from fewer replacement parts	• Part replacement records for each fleet vehicle before and after the implementation of the solution, across multiple years • Embodied emissions of replacement parts • Material breakdown of replacement parts (type and weight of material) • Material embodied emission factors	• Data for oil, break pad and tyre replacements in 2022 and 2023 • Lifecycle conversion factor for break pads • Oil conversion factor • Tyres conversion factor	• Good/Poor • Good • Good • Good
Improved fuel efficiency and monitoring of replacement parts results in lower demand for new vehicles and therefore lower manufacturing emissions	• Data on rates of vehicle replacement before and after implementation of the solution (across many years) • Data on other variables which affect vehicle replacement (e.g. financial) • Vehicle embodied emissions	• No, data not available for several years after implementation of solution	• N/A
Optimisation of vehicle fleet results in an increase in operations and distance travelled	• Fuel consumption by fuel type in fleets before and after the implementation of solution, several years after implementation. • Distance travelled in fleets before and after implementation of	• No, data not available for several years after implementation of solution	• N/A

	solution, several years after implementation. • Data on other variables which affect distance travelled (e.g. number of customers/trips per year)		
Optimisation of vehicle fleet reduces costs, allowing company to grow fleet size.	• Number of vehicles before and several years after implementation of solution • Cost of operating fleet before and several years after implementation of solution, identifying cost savings attributable to solution • Data on other variables that would impact growth in fleet size	• No, data not available for several years after implementation of solution	• N/A
More efficient business reduces the need of number of vehicles	• Fuel consumption by fuel type in fleets before and after the implementation of solution, several years after implementation. • Distance travelled in fleets before and after implementation of solution, several years after implementation. • Data on other variables which affect distance	• No, data not available for several years after implementation of solution	• N/A

	travelled (e.g. number of customers/trips per year)		
A decrease of drivers needed and the effect of reduced income of drivers	• Income and spending patterns of all drivers before and after implementation of solution.	• No, data not available for several years after implementation of solution	• N/A
Acquired knowledge of climate and fuel efficiency	• Spending patterns or carbon footprints of all users of the solutions before and several years after implementation of solution.	• No, data not available for several years after implementation of solution	• N/A

Ericsson, Port Optimisation

Effect	Activities	Data for activity available?	Data Quality
In-use network emissions	• Marginal energy consumption of network due to solution	• No data available	• N/A
In-use emissions from tablets/computers used to operate the solution	• Marginal energy consumption of tablets/computers due to operation of solution	• No data available	• N/A

In-use emissions from data centre processing and storage	• Marginal energy consumption of data centres due to solution	• No data available	• N/A
An increase in fuel efficiency of forklifts due to optimised freight cargo processing and operations.	• Reduction in diesel fuel consumption of forklifts	• Forklift fuel usage (m3/year) is primary data from Livorno pilot study	• Very good
Improved efficiency of forklift operations from 5G-enabled solution, in the medium to long term, could result in time saving that could increase productivity.	• Increase in productivity of freight cargo processed and associated emissions	• Partial data on productivit y rates and qualitative justification s of likely impact provided by Ericsson.	• Fair

First Order Effects

(A) The GHG impact of all first order effects shall be calculated for each implementation context within the boundary conditions except for those excluded by the cut-off criteria.

(D) First order effects shall be calculated for all life cycle phases of the solution.

(i) Embodied and end-of-life emissions shall be allocated equally across the lifetime of the solution and included according to the time period of the assessment

(ii) Use-phase emissions shall be calculated for the time period of the assessment.

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(E) First order effects shall be calculated in relation to the functional unit and for the level of activity defined by the functional unit performance. If the functional unit requires multiple units of the solution or its components for the level of activity, as many units as required will be calculated.

(F) A conservative approach should be applied for all calculations of first order effects, i.e. emissions should rather be overstated than understated.

AddSecure, Fleet management

Whilst Logic TMS is most often employed using software and hardware components, it is possible to use the solution with software only. In that case, AddSecure estimates that the associated GHG reduction is 20% lower than if used with software and hardware. That is because using only software gives customers the improvement in planning and the elimination of empty kilometres. However, if customers also use hardware, it allows them to measure and monitor additional driving behaviour, including driving style, and a more detailed view on fuel consumption.

The lifecycle and in-use emissions of the hardware components that are installed in the lorries have been included into the calculation. It is unclear how long the hardware should last. Taking a conservative approach, the production and disposal emissions have been calculated for the entire lifespan.

The cloud-based server used to power the software consumes some electricity. No direct data from the server host could be obtained, but information from a similar AddSecure Fleet Management solution (FMS) served as a reference. Whilst the server was powered by renewable energy, this has been included in the calculations as a conservative approach. The electricity grid conversion factor used aligns to the top three geographies selected in the optional adjustments section.

PREDRI, Fleet management

Embodied emissions of the GPS 4 module are calculated by multiplying the weight of each module with the number of vehicles in the fleet and the production carbon conversion factor to obtain GHG emissions. Additionally, a conversion factor for end-of-life is used. Taking a conservative approach, it is assumed the device ends up in landfill.

Emissions related to energy consumption of the GPS 4 module and the 4 local PCs are calculated by multiplying their power consumption with the Mexican electricity grid emission factor to obtain GHG emissions.

Emissions related to the use of servers is estimated by multiplying the spend on server usage with the relevant carbon conversion factor to obtain GHG emissions (see the sections on assumptions and key areas for improvement for the relevant caveats and limitations). Emissions related to energy consumption are calculated by multiplying the on-board energy requirements with the conversion factor of diesel to electricity. The off-board energy requirements are multiplied with Mexican grid carbon conversion factor to obtain GHG emissions.

Ericsson, Port Optimisation

The first order effects calculation captures the embodied emissions for the digital solution. These were excluded in the first iteration of the Ericsson calculator as these were not included in the context of the COREALIS study. The COREALIS study is based on data captured up to 2021, at which point the pilot of the solution at Livorno port ended. No further data collection was possible for the purpose of the EGDC case study, beyond the historical COREALIS data provided by the solution developer. These were captured in a qualitative manner in the methodology document in the Components of the solution and 1st order effects section. As we are unable to ascertain whether the excluded 1st order effects are below a 5% materiality, this study does not fully align to the EGDC ICT methodology. All results should be treated as illustrative.

(B) Cut-off criteria for first order effects:

(i) Solution components common between the reference and solution scenarios where the GHG impact has not been modified.

(ii) Where data availability prevents calculation of the GHG impact, first order effects may be excluded from the net carbon impact assessment if they can be demonstrated to be less than 5% of the total net carbon impact or net carbon impact per functional unit.

(iii) If multiple first order effects are considered for cut-off, the total effect must remain less than the 5% threshold.

(C) Exclusions of any first order effects from net carbon impact assessments shall be supported by clear justification and supporting calculation.

AddSecure, Fleet management

The impacts for the following first order effects were estimated to justify their exclusion from the calculations:

- Laptop and mobile in-use emissions – using an assumed in-use carbon impact of 72kgCO2e for a laptop[6] and around 11kgCO2e for a mobile phone[7], the total impact of these devices would be 2,848 kgCO2e, assuming there is 1 laptop and mobile for each vehicle (with 250 vehicles). This is assumed to be a conservative estimate, as it is likely that multiple vehicles would be operated from 1 laptop/mobile. Based on this conservative assumption, the in-

[6] https://static.lenovo.com/ww/docs/regulatory/eco-declaration/pcf-thinkpad-e15-2nd-intel.pdf

[7] https://www.apple.com/environment/pdf/products/iphone/iPhone_14_PER_Sept2022.pdf

use emissions from laptops and mobiles would contribute 0.045% to the total net carbon impact.

The excluded first order effects are estimated to be less than 5% of the total net carbon impact of Logic TMS.

PREDRI, Fleet management

No identified first order effects were excluded from the calculations.

Ericsson, Port Optimisation

All first order effects were excluded from the case study, due to lack of data. As it was not possible to ascertain whether the excluded 1st order effects are below a 5% materiality, this study does not fully align to the EGDC ICT methodology. All results should be treated as illustrative.

Second Order Effects

(A) The GHG impact of all identified second order effects (positive and negative changes to the reference scenario) shall be calculated for the same implementation context except for those excluded by the cut-off criteria.

(C) The GHG impact of second order effects shall be calculated with a life cycle perspective.

(D) The second order effect calculation shall exclude additional rebound usages in the quantification of the GHG impact.

(E) The second order effect calculation shall exclude existing occurrence of the second order effect from other similar ICT solutions.

(F) Second order effects shall be calculated in relation to the functional unit and for the level of activity defined by the functional unit performance.

(G) If a net carbon impact assessment is to be used for public claims of a solutions' impact (including annual reporting) primary data should be used for either the reference or ICT solution scenario, or both.

(H) A conservative approach should be applied for all calculations of second order effects i.e. net positive emissions should rather be understated than overstated.

AddSecure, Fleet management

The second order effects calculation captures the reduction in GHG emissions achieved through the solution, by optimising transport routes and improving driving patterns.

Whilst Logic TMS is most often employed using software and hardware components, it is possible to use the solution with software only. In that case, AddSecure estimates that the associated GHG reduction is 20% lower than if used with software and hardware. That is because using only software gives customers the improvement in planning and the elimination of empty kilometres. However, if customers also use hardware, it allows them to measure and monitor additional driving behaviour, including driving style, and a more detailed view on fuel consumption. According to AddSecure it is very well possible 100% efficiency can be achieved without hardware but reducing it by 20% for software only is a conservative approach.

To calculate the GHG savings from the solution, the calculator measures the average fuel efficiency and the proportion of empty kilometres, before and after the solution. By multiplying those numbers with the proportion of fleet vehicles in different European countries, respective distance reduction factors and combustion reduction factors were calculated for each of the countries where data exists, i.e. Germany, Poland, the Czech Republic, France, Austria, Italy, Switzerland and the Benelux countries.

By multiplying the associated reduction factors with the provided kilometres driven without freight and the default fuel efficiency, the new overall distance and new fuel efficiency are calculated. The calculated new distance is then multiplied with the calculated new fuel efficiency to find the new consumption of fuel. The well-to-wheel emission factor of diesel is applied to calculate the associated reduction of GHG emissions.

PREDRI, Fleet management

The new fuel efficiency is calculated by multiplying the selected fuel efficiency before the solution with the reduction factor obtained from the solution's data. Given the irregularities in the data, the reduction factor was approximated using a trendline. This is multiplied with the overall distance driven by the fleet to obtain the reduction in fuel usage, which is multiplied with the carbon conversion factor for diesel to obtain saved GHG emissions.

For the reduction in spare parts and oil, similar calculations are performed. Default turnover of parts is calculated using the percentage of replacements from the solution per kilometre driven. The respective reduction factors were obtained by dividing the number of replacements (or litres of oil) over the total distance driven by the entire fleet that year and comparing the data from 2022 with the data from 2023. The selected turnover of parts is multiplied with the respective reduction factor and with the relevant carbon conversion factor to obtain saved GHG emissions.

The GHG emissions are deducted from the GHG savings to obtain the amount of overall carbon savings.

Ericsson, Port Optimisation

The second order effects calculation captures the reduction in GHG emissions achieved through the solution, by optimising freight cargo processing and improving fuel efficiency of forklifts in port yard.

To calculate the carbon saving from the solution, the calculator measures the difference in activity hours per year of the forklifts before and after the implementation of 5G. To the total time saving we apply the hourly diesel consumption of forklifts (13L/h) to capture the diesel saved from the solution implementation. Finally, an emissions factor for the forklift diesel (2.6 t/m3) was applied to reach the final figure of 148 CO_2 ton/year saved at Port Livorno.

(B) Cut-off criteria for second order effects:

(i) GHG impacts from identified second order effects may be excluded from the net carbon impact assessment if they can be demonstrated to be less than 5% of the total net carbon impact or net carbon impact per functional unit. Positive second order effects of any magnitude may also be excluded (typically due to data availability).

(ii) If multiple second order effects are considered for cut-off, the total effect must remain less than the 5% threshold.

(iii) Cut-offs of any second order effects from net carbon impact assessments shall be supported by clear justification and supporting calculation.

AddSecure, Fleet management

No second order effects that were identified were excluded from the calculation.

PREDRI, Fleet management

No second order effects that were identified were excluded from the calculation.

Ericsson, Port Optimisation

No second order effects that were identified were excluded from the calculation.

Higher Order Effects

(A) A qualitative assessment shall be undertaken for all identified higher order effects, including how and where they would occur, within what timeframe, the expected magnitude, and the likelihood of the effect occurring. The strength of the relationship between the solution and the higher order effect should be considered and ideally be demonstrated by academic research.

AddSecure, Fleet management

Qualitative assessment of identified higher order effects:

Higher order effects	How and where they would occur	Timeframe	Expected magnitude	Likelihood of effect occurring	Causal relationship to solution?
Optimisation of vehicle fleet for goods collection and delivery results in an increase in operations and distance travelled	Would happen if business is able to leverage the solution to further business aims	Medium term	Medium	Medium	Many factors of influence
Potential decrease of fleet vehicles when a business can dispose of them.	Would happen if business is able to leverage the solution to further business aims	Medium term	Medium	Medium	Many factors of influence
Potential decrease of drivers needed, and the economic impacts associated with lower income of these drivers, which could lead to an increase/decrease in GHG emissions.	Would occur if companies decide to lay off workers and they would not be able to find an alternative job with a similar income	Long term	Low	Low	Many factors of influence
Reduction in cost of delivering products/services and associated economic impacts, which could lead to an	Would occur if the customer is able to save significant costs and is able to redivert capital elsewhere	Medium term	Medium	Low	Many factors of influence

increase/decrease in GHG emissions.					
Acquired knowledge of climate and fuel efficiency can improve fuel usage/energy consumption in other areas of the users, reducing emissions.	Would occur if drivers are actively engaged in the climate benefits of the solution and decide to use acquired knowledge elsewhere in their lives	Long term	Low	Low	Difficult to ascertain

PREDRI, Fleet management

Higher order effects	How and where they would occur	Timeframe	Expected magnitude	Likelihood of effect occurring	Causal relationship to solution?
Improved fuel efficiency and monitoring of replacement parts results in lower demand for new vehicles and therefore lower manufacturin g emissions	PREDRI's effect on driving behaviour, as well as the more precise monitoring of replacement parts may mean that in the long term, vehicles themselves (rather than the parts in them) can be replaced less frequently. On a system-level this could reduce the demand to	Long term	Low	Medium	Yes

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	produce new vehicles, saving GHG emissions during the manufacturing process.				
Optimisation of vehicle fleet results in an increase in operations and distance travelled	A more efficient fleet in terms of fuel and spare part replacements may also allow a company to increase its profit margins and grow, thus increasing the number of vehicles on the roads emitting more GHGs.	Long term	Medium	Medium	Difficult to ascertain as it depends on many other variables (e.g. business performance /decisions) which makes it difficult to determine causality
A decrease of drivers needed and the effect of reduced income of drivers	Would occur if companies decide to lay off workers and they would not be able to find an alternative job with a similar income	Long term	Low	Low	Many factors of influence
Acquired knowledge of climate and fuel efficiency	Would occur if drivers are actively engaged in the climate benefits of the solution and decide to use acquired knowledge	Long term	Low	Low	Difficult to ascertain

	elsewhere in their lives				
Optimisation of vehicle fleet reduces costs, allowing company to grow fleet size.	Would happen if business is able to leverage the solution to further business aims and is intent on growing	Medium term	Medium	Medium	Many factors of influence
More efficient business reduces the need of number of vehicles	Would happen if business is able to leverage the solution to further business aims	Medium term	Medium	Medium	Many factors of influence

Ericsson, Port Optimisation

Higher order effects	How and where they would occur	Timeframe	Expected magnitude	Likelihood of effect occurring	Causal relationship to solution?
Improved efficiency of forklift operations from 5G-enabled solution drives an increase in productivity.	Rebound effect could in theory occur within the solution's system boundary, increasing cargo output at the Port. In this instance the solution optimises forklift operations,	Medium to Long term	Immaterial - Ericsson indicated that the time saved in forklift activity does not result in substantial increases in cargo ships processing activity. The	Ericsson analysis suggests likelihood of occurrence is low (see justification, under Expected magnitude)	Yes – solution's optimisation of operations would lead to productivity rebound.

	resulting in time saving that could increase productivity (more vessels calling at the port and increased in yearly freight processed.		time saved decreases the daily shifts for forklifts from 14h to 12h for the same amount of cargo. Thus, forklift daily activity decreases rather than observing an increase in cargo ships processed.			

(B) Where a quantitative assessment is possible, the GHG impact of all identified higher order effects (positive and negative) should be calculated for each implementation context within the boundary conditions.

> (i) Significant effects shall not be excluded from quantitative assessment if robust data and knowledge of the effect exist.
>
> (ii) Effects deemed significant but not quantifiable shall be supported by clear justification and reported alongside the net carbon impact quantitative results.
>
> (iii) Effort should be made to collect necessary data or carry out necessary studies with the intention of quantitatively assessing the effect in the future and the exclusion shall be re-evaluated during the recalculation assessment**Error! Reference source not found.**.

(C) The GHG impact of higher order effects shall be calculated with a life cycle perspective, where it is feasible.

(D) Higher order effects shall be calculated in relation to the functional unit and for the level of activity defined by the functional unit performance.

(E) A conservative approach should be applied for all calculations of higher order effects, i.e. net positive emissions should rather be understated than overstated.

AddSecure, Fleet management

No identified higher order effects were included in the calculation, due to lack of data availability and as it would be impossible to predict which business decisions will be made post implementation.

PREDRI, Fleet management

No identified higher order effects were included in the calculation due to limited data availability.

Ericsson, Port Optimisation

No identified higher order effects were included in the calculation.

The identified higher order effect (productivity rebound) was excluded as the time saved in forklift activity does not result in increased cargo ships processed, as informed by Ericsson. This is because the time saved decreases the daily shifts for forklifts from 14h to 12h for the same amount of cargo. This brings the duration of daily shifts for forklifts to match that of the tower cranes. Therefore, as a result of their increased efficiency, forklifts see a decrease in daily activity rather than an increase in the number of cargo ships processed.

Net Carbon Impact Calculation

(A) The total net carbon impact of the solution shall be calculated including all quantified first, second, and higher order effects included in the assessment, for the time boundary of the assessment

AddSecure, Fleet management

Results for 356 vehicles driving 15.7Mn km, using software and hardware using EU average reduction factors.

Total carbon saved for the 2 customers: 636 tCO_2e / year

1st order effects: 0.22 t CO_2e / year

2nd order effects: 636 t CO_2e /year

Saving per functional unit: 4.05 kg CO_2e / 100km

PREDRI, Fleet management

For the reference scenario (Tours Ejecutivos' buses), the following carbon reductions were noted:

Total carbon saving impact: 169 t CO2e / year

1st Order effects: 2 tCO2e

2nd Order effects: 171 tCO2e

Savings from reference scenario: 3.8%

Saving per functional unit: 2.2 kg CO2e / 100 km

Ericsson, Port Optimisation

Total carbon saving impact: 111 tCO2e / year

1st order: Not calculated

2nd order: 111 tCO2e / year

Savings from reference scenario (%): 19% forklift fuel saved

Saving per functional unit: 3.48 tCO2e/freight mil tonnage/year

(B) Significant changes to the calculated GHG impacts of first, second, or higher order effects during the time period of the assessment shall be included in the assessment.

AddSecure, Fleet management

Any changes during the time period of the assessment, such as changes in emission factors, have been considered in the calculation.

PREDRI, Fleet management

Any changes during the time period of the assessment, such as changes in emission factors, have been considered in the calculation.

Ericsson, Port Optimisation

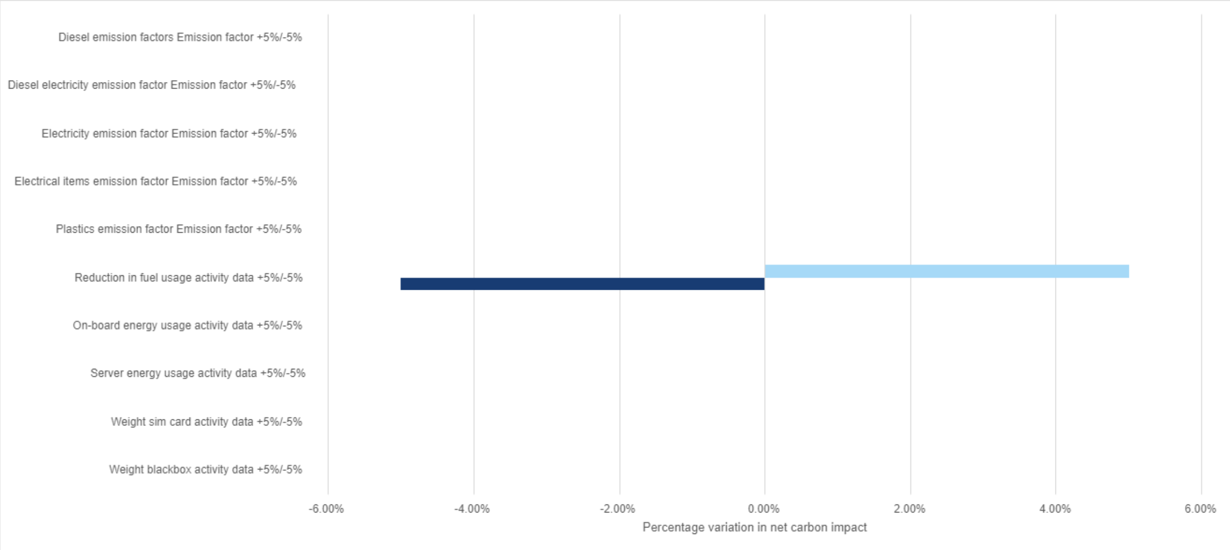
Any changes during the time period of the assessment, such as changes in emission factors, have been considered in the calculation.

Uncertainty and sensitivity analysis

(A) A sensitivity analysis should be carried out for all key parameters as part of the net carbon impact assessment.

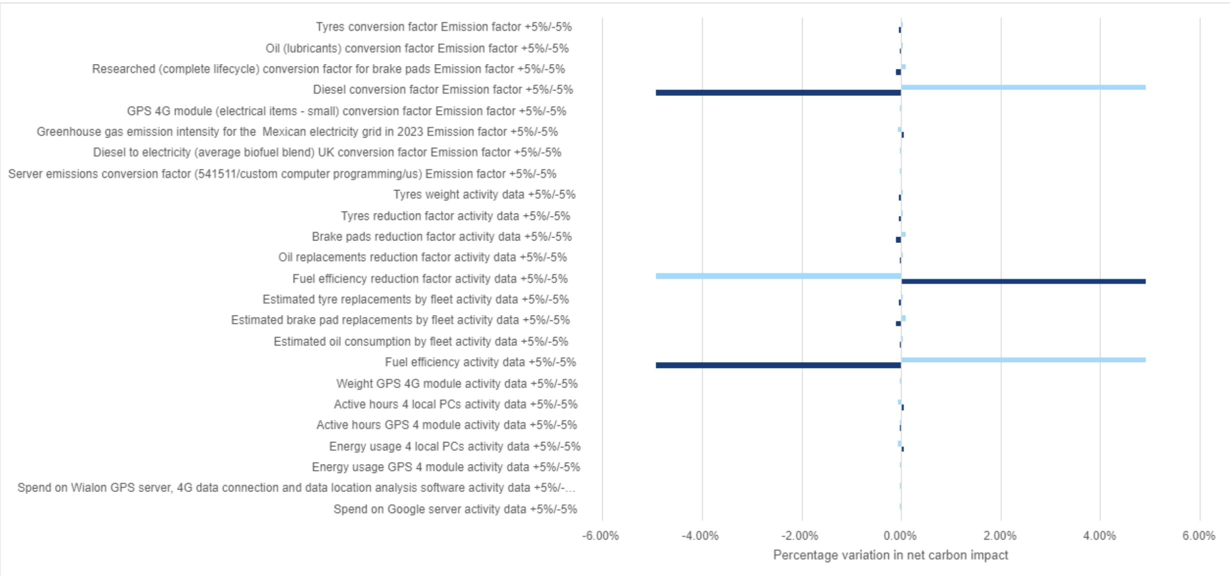
AddSecure, Fleet management

The sensitivity analysis demonstrates that the first order effects have a very low sensitivity (<1%). The second order effects have a high sensitivity of around 5%. This reaffirms the importance that the data quality of the second order effects should be high.



PREDRI, Fleet management

The sensitivity of specific datapoints to the overall outcome is relatively low. Data related to tyres is relatively important in terms of sensitivity, scoring between 5% and 10%.



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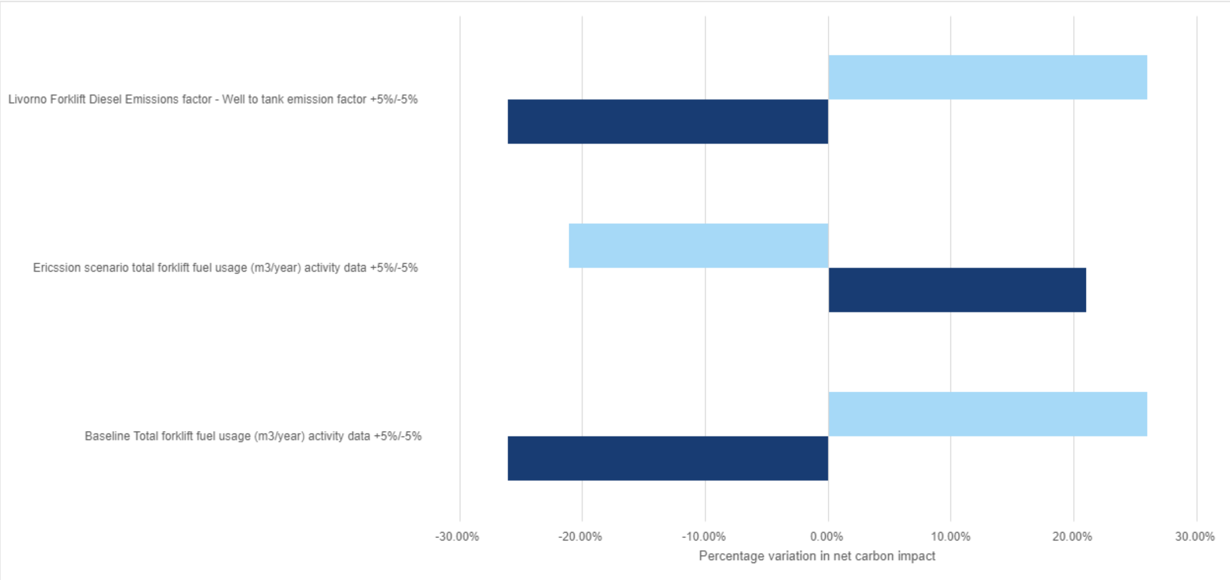
The sensitivity of specific datapoints to the overall outcome is relatively low. Data related to the 2nd order effects is relatively important in terms of sensitivity, scoring around 5%.

Ericsson, Port Optimisation

The sensitivity of second order effects has a high sensitivity to forklift fuel usage and associated emissions factor.



(B) A net carbon impact assessment should include an uncertainty analysis of the results.

AddSecure, Fleet management

The data obtained is of relatively good quality which decreases the uncertainty around the results. Especially the data for the highly material second order effects scores well.

Data type	Description of effect		Activity	Time	Geography	Reliability	Completeness
Activity Data	First order	Weight of hardware	Very good	Very good	Very good	Very good	Very good
		Server usage	Good	Fair	Good	Very good	Very good
		On-board energy usage	Very good	Very good	Very good	Good	Good
	Second order	Fuel efficiency readings	Very good	Very good	Very good	Very good	Very good
		Empty kilometre readings	Good	Very good	Very good	Very good	Very good
Emission factors	First order	Emission factors hardware material use	Good	Very good	Very good	Good	Very good

		Electricity conversion factors	Good	Very good	Very good	Good	Very good
		On-board electricity conversion factor	Fair	Very good	Very good	Good	Very good
	Second order	Diesel conversion factors	Good	Very good	Very good	Good	Very good

It should be noted that the analysis performed is not a quantitative uncertainty analysis. By providing a more granular view of data quality, which builds on the data quality assessment, this analysis highlights areas of uncertainty within the calculation using a qualitative assessment framework. It can however be used to feed into a quantitative uncertainty analysis using guidance from the Greenhouse Gas Protocol on Quantitative Inventory Uncertainty: https://ghgprotocol.org/sites/default/files/2022-12/Quantitative%20Uncertainty%20Guidance.pdf

PREDRI, Fleet management

The overall data quality for first order emissions is good, with relatively precise energy consumption data. The second order emission data quality for fuel consumption is good but it is poor for part replacements. This is because of the limited timeframe for measurements and poor completeness.

Data type		Description of effect	Activity	Time	Geography	Reliability	Completeness
Activity Data	First order	Spend on Google server	Very good	Good	Good	Very good	Good
		Spend on Wialon GPS server, 4G data connection and data location analysis software	Very good	Good	Good	Very good	Good
		Energy usage GPS 4 module	Very good	Very good	Very good	Very good	Very good
		Energy usage 4 local PCs	Very good	Very good	Very good	Very good	Very good
		Active hours GPS 4 module	Very good	Fair	Good	Fair	Fair
		Active hours 4 local PCs	Very good	Fair	Good	Fair	Fair
		Weight GPS 4G module	Very good	Very good	Good	Very good	Very good
	Second order	Fuel efficiency	Good	Very good	Fair	Good	Fair
		Estimated oil consumption by fleet	Very good	Fair	Good	Good	Poor
		Estimated brake pad replacements by fleet	Very good	Fair	Good	Good	Poor
		Estimated tyre replacements by fleet	Very good	Fair	Good	Good	Poor
		Fuel efficiency reduction factor	Good	Very good	Fair	Good	Fair
		Oil replacements reduction factor	Very good	Poor	Good	Good	Poor

		Brake pads reduction factor	Very good	Poor	Good	Good	Poor
		Tyres reduction factor	Very good	Poor	Good	Good	Poor
		Tyres weight	Very good	Very good	Good	Good	Very good
Emission factors	First order	Server emissions conversion factor (541511/custom computer programming/us)	Poor	Poor	Poor	Poor	Poor
		Diesel to electricity (average biofuel blend) UK conversion factor	Good	Very good	Very good	Good	Very good
		Greenhouse gas emission intensity for the Mexican electricity grid in 2023	Good	Good	Very good	Good	Good
		GPS 4G module (electrical items - small) conversion factor	Fair	Very good	Very good	Good	Very good
	Second order	Diesel conversion factor	Good	Very good	Very good	Good	Very good
		Researched (complete lifecycle) conversion factor for brake pads	Very good	Good	Good	Good	Good
		Oil (lubricants) conversion factor	Good	Very good	Very good	Good	Very good
		Tyres conversion factor	Good	Very good	Very good	Good	Very good

It should be noted that the analysis performed is not a quantitative uncertainty analysis. By providing a more granular view of data quality, which builds on the data quality assessment, this analysis highlights areas of uncertainty within the calculation using a qualitative assessment framework. It can however be used to feed into a quantitative uncertainty analysis using guidance from the Greenhouse Gas Protocol on Quantitative Inventory Uncertainty: https://ghgprotocol.org/sites/default/files/2022-12/Quantitative%20Uncertainty%20Guidance.pdf

Ericsson, Port Optimisation

The overall data quality is fair to good. Due to the reliance on primary data, reliability, activity and geography representativeness is largely good. As actual data collection was run over limited timeframes, temporal representativeness and completeness of data set are fair to poor.

Data type	Impact effect	Description of effect	Activity	Time	Geography	Reliability	Completeness
Activity data	2nd order	Ericsson scenario total forklift fuel usage (m3/year)	Good	Good	Good	Good	Good

	2nd order	Baseline Total forklift fuel usage (m3/year)	Good	Good	Good	Good	Good
Emission factors	1st order	Livorno Forklift Diesel Emissions factor - Well to tank	Very good	Good	Fair	Good	Good

It should be noted that the analysis performed is not a quantitative uncertainty analysis. By providing a more granular view of data quality, which builds on the data quality assessment, this analysis highlights areas of uncertainty within the calculation using a qualitative assessment framework. It can however be used to feed into a quantitative uncertainty analysis using guidance from the Greenhouse Gas Protocol on Quantitative Inventory Uncertainty: https://ghgprotocol.org/sites/default/files/2022-12/Quantitative%20Uncertainty%20Guidance.pdf

Recalculation

(A) It may be suitable that an assessment calculated for one year can be repeated in following years without changes, however, the reference scenario, implementation context, assumptions, exclusions, methods, and data used shall be reviewed annually to be applicable before continuing to use the results of an assessment.

(B) If the review identifies necessary changes to the assessment that could change the results by more than 5%, recalculation in whole or part will be necessary.

(C) Recalculation of the assessment should take place at a maximum of three years after the original assessment to ensure its validity.

AddSecure, Fleet management

As the solution is nearly market average across Europe, the assessment will need to be reviewed annually to determine whether the reference scenario needs to be updated. This would change the results by more than 5%.

PREDRI, Fleet management

As the solution is nearly market average across Europe, the assessment will need to be reviewed annually to determine whether the reference scenario needs to be updated. This would change the results by more than 5%.

Ericsson, Port Optimisation

First order effects were not included within this assessment. Their inclusion has the potential to change results by 5%, therefore, the assessment should be reviewed annually to determine the contribution of first order effects to the solution's net carbon impact.

Other considerations for a net carbon impact assessment

Do No Significant Harm

AddSecure, Fleet management

The solution is not expected to cause significant harm in other ESG areas. Potential longer-term effects of the solution could be a reduction in the required number of vehicles/drivers, which could have an impact on employment.

PREDRI, Fleet management

The solution is not expected to cause significant harm in other ESG areas. PREDRI's focus on more efficient driving, as well as its effect on non-GHG emissions (fine particle pollution) mean PREDRI may influence other ESG areas positively (e.g. human health).

Ericsson, Port Optimisation

The solution is not expected to cause significant harm in other ESG areas. In line with the UN Sustainability Framework, it has been assessed (as part of COREALIS project) that the 5G Port solution does not negatively impact other areas such as ecosystems, management of resources, communities and livelihoods or working conditions.

As part of the COREALIS Port of the Future project, Ericsson has assessed the impact of the Livorno Living Lab digital solutions against the Sustainable Development Goals:

- The 5G-enabled transformations of the port processes directly influence:
- SDG 8 (Decent Work and Economic Growth),
- SDG 9 (Industry, Innovation and Infrastructure), - SDG 11 (Sustainable Cities and Communities),
- SDG 12 (Responsible Consumption and Production) and,
- SDG 13 (Climate Action).

Other impacts are:

- SDG 4.4 (Vocational Skills) relevant to the port workforce, where the transformative role of 5G can enhance job tasks, tools and competence profiles.
- SDG 14 (Life below water) addressed as part of the port's ambition to protect the marine and coastal ecosystems.
- SDG 17 (Partnerships for the Goals) relevant to the Port of Livorno approach on public-private partnerships and cooperation.

Using Results in Other Implementation Contexts

(A) The new implementation context shall have the same ICT solution scenario and reference scenario as the original net carbon impact assessment.

(B) The parameters of the original net carbon impact assessment should be adjusted to reflect the new implementation context.

(C) Where it is not possible to adjust the assessment parameters, the results should only be used in other implementation contexts if a review determines that the changes are not expected to significantly change the results or overestimate a positive impact.

AddSecure, Fleet management

The following includes a list of implementation parameters that may need to be adjusted in different implementation contexts:

- **Fuel efficiencies of vehicles** – if the fuel efficiencies of vehicles differ considerably to the fuel efficiency of the fleets in the assessment, this could impact the second order effects. Adjustments would therefore be needed and could be addressed by using the differences in fuel used per km to adjust fuel usage data before and after the implementation of the solution.
- **Carbon intensity of fuel –** this will change as the biomass content of diesel changes, as well as the well-to-tank emissions associated with the fuel (i.e., emissions from extracting, transporting and distributing fuel), as processes become more or less efficient. While the carbon intensity of transport fuels has been decreasing, it is uncertain whether and how this will continue in the future, as demand for biofuel in other areas increases and the demand for fossil-based transport fuels decreases with a growing number of zero emission vehicles.
- **Fuel type of vehicles** – the fleets currently assessed are diesel vehicles. If assessing a different fleet, the fuel type of vehicles may be different. Especially in the future, it is likely that vehicles will be replaced by zero emission vehicles like EVs, given the policies to end the sale of CO_2 emitting vehicles across Europe. Therefore, an adjustment would need to

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be made to the emission factors used. This would also impact the fuel efficiencies of the vehicles.

- **Type of vehicles** – A different composition of vehicle types would change the overall saving potential of the solution. Furthermore, a replacement of vehicles with autonomous vehicles would further optimise the operation of the vehicles, while also negating the impacts of the improvement in driver behaviour from the fleet management solution.
- **Driving conditions** – driving conditions may differ across locations and they may also change over time, especially as impacts from climate change become more severe. Different conditions on the road can make it easier or more difficult for drivers to adjust their behaviour, which would impact the effectiveness of the solution.

PREDRI, Fleet management

The following includes a list of implementation parameters that may need to be adjusted in different implementation contexts:

- **Fuel efficiencies of vehicles** – if the fuel efficiencies of vehicles differ considerably to the fuel efficiency of the fleets in the assessment, this could impact the second order effects. Adjustments would therefore be needed and could be addressed by using the differences in fuel used per km to adjust fuel usage data before and after the implementation of the solution.
- **Carbon intensity of fuel –** this will change as the biomass content of diesel changes, as well as the well-to-tank emissions associated with the fuel (i.e., emissions from extracting, transporting and distributing fuel), as processes become more or less efficient. While the carbon intensity of transport fuels has been decreasing, it is uncertain whether and how this will continue in the future, as demand for biofuel in other areas increases and the demand for fossil-based transport fuels decreases with a growing number of zero emission vehicles.
- **Fuel type of vehicles** – the fleets currently assessed are diesel vehicles. If assessing a different fleet, the fuel type of vehicles may be different. Especially in the future, it is likely that vehicles will be replaced by zero emission vehicles like EVs, given the policies to end the sale of CO2 emitting vehicles across Europe. Therefore, an adjustment would need to be made to the emission factors used. This would also impact the fuel efficiencies of the vehicles.
- **Type of vehicles** – A different composition of vehicle types would change the overall saving potential of the solution. Furthermore, a replacement of vehicles with autonomous vehicles would further optimise the operation of the vehicles, while also negating the impacts of the improvement in driver behaviour from the fleet management solution.

Driving conditions – driving conditions may differ across locations and they may also change over time, especially as impacts from climate change become more severe. Different conditions on the road can make it easier or more difficult for drivers to adjust their behaviour, which would impact the effectiveness of the solution.

Ericsson, Port Optimisation

The following includes a list of implementation parameters that may need to be adjusted in different implementation contexts:

- **Fuel efficiency of forklifts (m3/year)** – if the fuel efficiencies of other forklift fleets differ considerably to the fuel efficiency of the fleet in the assessment, this could impact the second order effects. Adjustments would then be needed and could be addressed by using the differences in fuel used per km to adjust fuel usage data before and after the implementation of the solution.
- **Fuel type of vehicles** – if the solution was applied in a forklift fleet using different fuel types. In order to take this into account, the emission factor would need to be adjusted and for EV fuel usage may need to be converted into kWh used.
- **Port size and activity** – Port size and the level of activity (cargo processed annually) could directly impact forklift activity (hours per year) and thus the associated fuel emissions. Additionally, for other ports the higher order effect identified in the assessment may need to be considered, where the increased efficiency of forklift activity would lead to more cargo freight being processed annually at the port.

Communicating and Documenting Outcomes of a Net Carbon Impact Assessment

Communicating and documenting outcomes of a single ICT solution

Organisations communicating results from a net carbon impact assessment of a single ICT solution should disclose:

(A) The total net carbon impact, as well as a breakdown by first order, second order, and higher order effects included in the quantitative assessment.

(B) The qualitative assessment of all higher order effects deemed to be likely and/or of significant magnitude and any actions undertaken to mitigate the effect.

(C) Any other environmental impacts identified from the do no significant harm assessment and any actions undertaken to mitigate their effect.

(D) A description of the ICT solution and assessment including the reference scenario, assessment perspective (actual/potential), implementation context(s), and time period.

(E) The organisation's contribution to the ICT solution and limitations to the calculation.

Organisations communicating results from a net carbon impact assessment of a single ICT solution are encouraged to disclose or provide on request:

(F) Documentation for the assessment including the boundary, calculation methodology, rationales (e.g. justification of reference scenario), assumptions, data sources and uncertainty of the results.

(G) A relative metric for the net carbon impact in relation to the business operations, e.g. percentage of total revenue associated with the solution.

AddSecure, Fleet management

The results of the assessment have been documented in a combined methodology document, which can be found here.

PREDRI, Fleet management

The results of the assessment have been documented in a combined methodology document, which can be found here.

Ericsson, Port Optimisation

The results of the assessment have been documented in a combined methodology document, which can be found here.

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