SUSTAINABLE LOGISTICS:

ROADMAPPING AND CARBON FOOTPRINTING AS TOOLS FOR REALIZATION OF ENVIRONMENTAL GOALS

TNO innovation for life

As part of the overall transition towards a low- or zero-carbon economy by 2050, the logistics sector needs to develop and implement effective strategies for decarbonising freight transport. Roadmapping and monitoring are important activities to achieve confidence in the attainability of the medium- and long-term CO_2 reduction targets. They are means to identify action perspective for all involved stakeholders, and for creating some level of control on the transition towards sustainable logistics. Roadmapping bridges the gap between long-term visions and targets on the one hand and short-term action plans and strategies on the other. Since there are many uncertainties along the pathway towards low-carbon transport, roadmapping should include some form of a plan-do-check-act cycle to adjust action plans and allow for adaptive programming by governments or sectors (see Figure 1). Ex ante assessments of possible options and measures, ex durante monitoring of progress and impacts and ex post evaluations are important tools for roadmapping and adaptive programming. In this process carbon footprinting is an essential instrument for defining and analysing the baseline situation and monitoring the impacts of implemented measures on the CO_2 emissions of transport and wider logistic operations. The carbon footprinting method used to monitor progress in the *action* phase should be consistent with the methodology used in the *planning* phase for assessing impacts of considered measures.

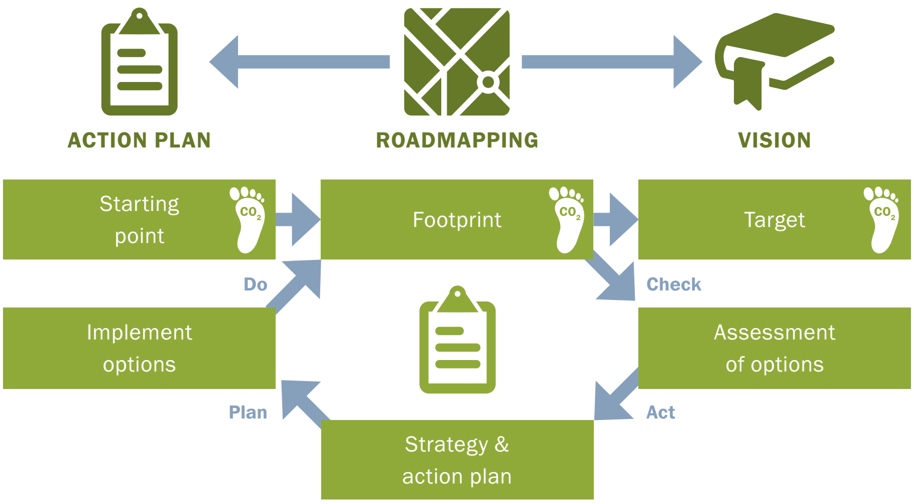

Figure 1: Roadmapping and carbon footprinting as elements in an adaptive programming approach to achieving sustainable transport.

TARGET SETTING: STRIVING FOR DECARBONISATION OF THE LOGISTICS SECTOR

This paper discusses the role of roadmapping, monitoring and carbon footprinting in defining and implementing effective government and sectoral policies as well as company strategies for reaching ambitious greenhouse gas reduction targets, focussing on the freight transport and logistics sector.

TARGET SETTING: STRIVING FOR DECARBONISATION OF THE LOGISTICS SECTOR

Roadmapping starts with target setting: defining where one needs to go and when this target is to be reached. Until the 2015 Paris Agreement, climate policies of the European Commission and Member States were based on the ambition to limit average global temperature rise to 2 °C. To realize this ambition the EU Member States agreed that by 2050 greenhouse gas (GHG) emissions in the EU would need to be reduced to around 80% below the 1990 level. In its 2011 white paper[1] the European Commission translated this into a specific reduction target of 60% for the transport sector, meaning that other sectors would have to achieve higher relative reductions. Under such a relatively relaxed target for the transport sector the required reduction from freight transport could even be significantly less than 60%, given the around one third share of freight transport in the total transport sector's CO_2 emissions and the fact that progress in electric vehicles suggests that reduction potentials way above 60% can be realised in passenger transport.

In the 2015 Paris Agreement participating countries defined limiting average global temperature rise to 2 °C as a binding target, but also agreed to strive for 1.5 °C as maximum increase by the end of the century. The 1.5 °C target has been adopted in EU policy and requires GHG emissions from the entire economy to be reduced by 95% or more in 2050 relative to 1990. Under such a stringent target there is little room for an uneven distribution of reduction efforts. Concrete implications of this ambition are currently being translated into EU policy. A specific target for the transport sector has not yet been set.

Transport performance and CO_2 emissions from EU 28 freight transport sector

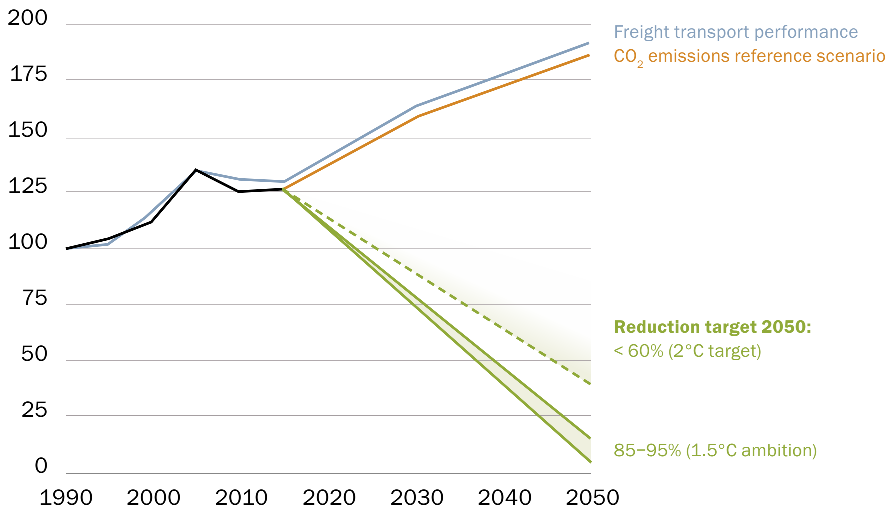

Figure 2: Implications of the long-term climate change mitigation targets on reduction of CO_2 emissions from the EU 28 freight transport sector in 2050 relative to 1990.

1 See https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en

2 Non-ETS sectors are sectors that are outside of the EU emissions trading system (ETS). Transport is one of these sectors.

In this paper we work under the assumption that an overall ambition to reduce GHG emissions by 95% requires all sectors to achieve similar reduction levels. Depending on the extent to which electric and hydrogen-fuelled vehicles and other measures allow decarbonisation of passenger transport beyond the 95% target, the reduction goal for freight transport is likely to be between 85 and 95%. This means that going from a 2 °C to a 1.5 °C target drastically alters the perspective for the freight transport sector's contribution to mitigating climate change. This is illustrated in Figure 2. Intermediate targets, e.g. for 2030, have not been set for the freight transport sector at the EU level. Under current EU policy the freight transport sector is part of the 30%-by-2030-relative-to-2005 target that applies to the combined non-ETS sectors[2].

Instead of defining the amount of emission reduction that needs to be realized, the challenge for the freight transport sector can also be defined in terms of a required increase in the sector's carbon efficiency, i.e. the amount of transport performance (in tonne.km) delivered per unit of CO_2 emitted. This aligns better with the sector's continuous strive for efficiency improvement. In 2017 Connekt[3] and TNO developed the "Factor 6" paradigm as a motivating target for the sector. This paradigm translated a 60% reduction target for the transport sector's absolute GHG emissions, based on the 2 °C ambition, into the need to increase the sector's carbon efficiency by a factor 6 in 2050 relative to 1990. It is clear that under an 80 – 95% target, in line with the more recently adopted 1.5 °C ambition, this factor would need to be significantly higher. The factor obviously also depends on expectations for the autonomous growth in the freight transport performance.

The challenge for the coming years is to translate the sector's ambitions with respect to emission reduction or improvement of the carbon efficiency into a roadmap for actions to be taken in short and medium term, and to develop government policies and company strategies for implementing the necessary measures. For developing strategies and action plans for the logistics sector as a whole or for specific subsectors it is important to know all available GHG reduction measures, their potential in specific applications, and whether or not their combined impacts add up to the overall target.

ROADMAPPING FOR MEETING THE CO_2 TARGETS IN FREIGHT TRANSPORT

Further improvements in vehicle energy efficiency, the use of sustainable biofuels and electrification are important measures to decarbonize transport. These measures alone, however, will not achieve the required improvement in carbon productivity required for reaching the 2050 target. From the magnitude of the ambition it is evident that reaching this requires a wide set or combination of decarbonization measures. These include options that relate to the efficient use of vehicles, a shift to more sustainable transport modes, a reduction of the number of vehicle kilometres by improving logistic operations, changes in spatial organization of production and product sourcing, adjustments in supply chain design and organization, and development of value adding logistic solutions. Such a decomposition of the reduction target in terms of the contributions of different levers is illustrated in Figure 3 and Figure 4. Of these graphs Figure 3 shows the decomposition of the CO_2 emissions of logistic operations into different determinants that act at the level of fuel, vehicle, logistics and supply chain, and production system. How reduction potentials associated with these different levers, which can be seen

3 https://www.connekt.nl

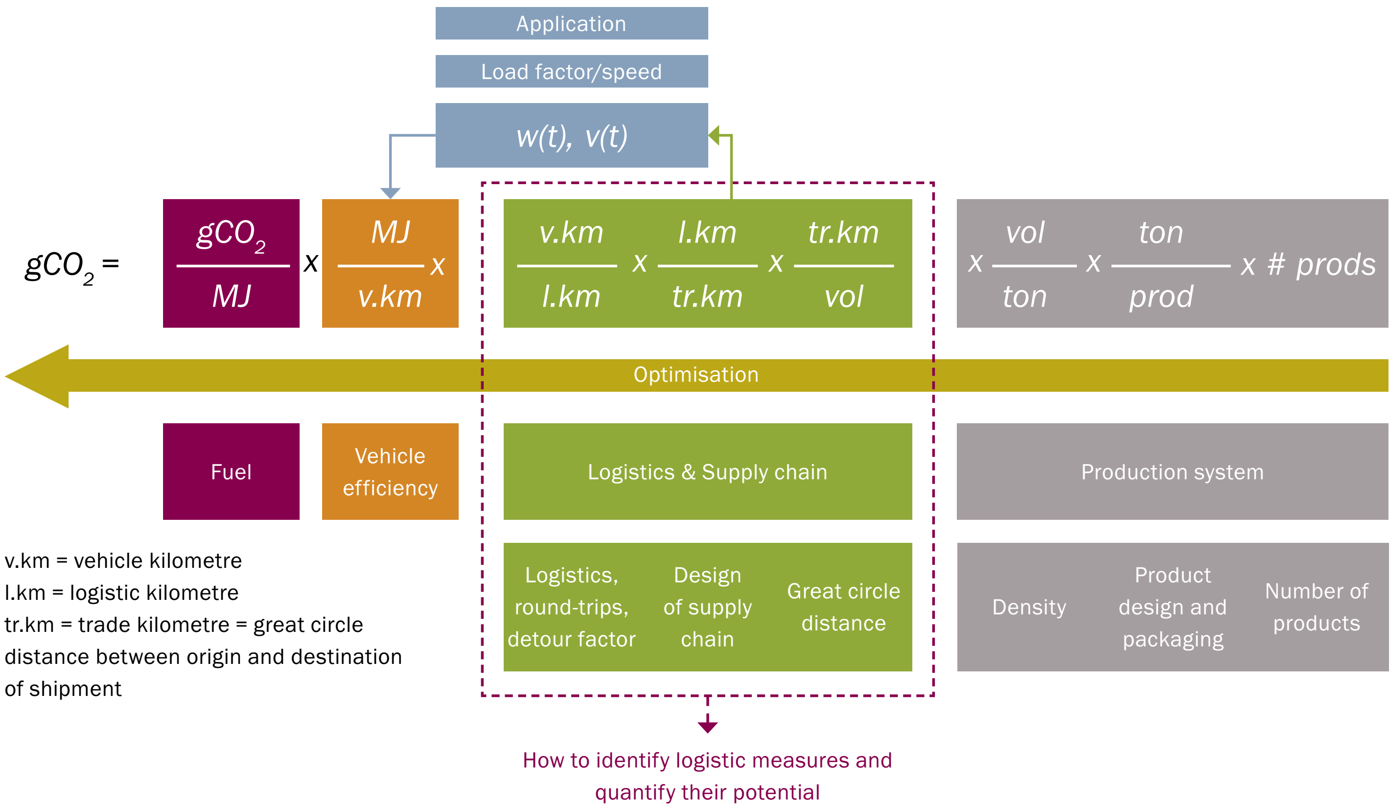

Figure 3: Decomposition of determinants of the CO_2 emissions of logistic operations.

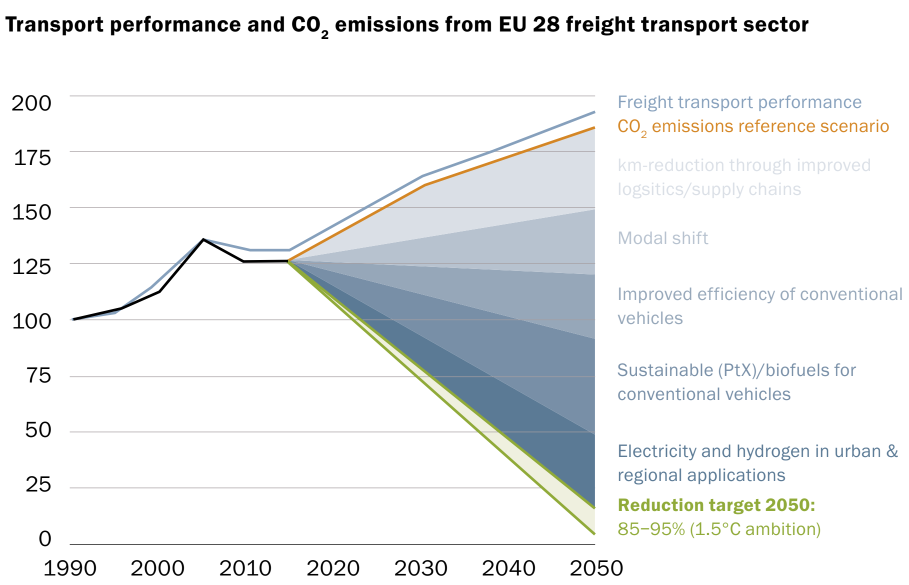

Figure 4: Exploring the low-carbon "building blocks" towards zero-emission freight transport (relative to the reference scenario for freight transport in the EU).

as low-carbon "building blocks", add up to a total reduction of CO_2 emissions from freight transport is illustrated by a hypothetical example in Figure 4.

INNOVATIONS IN LOGISTICS AND SUPPLY CHAINS ARE NEEDED

Although it is likely that a large share of the reduction target can be achieved by "technical" measures related to vehicles and energy carriers, it is becoming more and more evident that also improvements in the efficiency of the logistic organization will have to contribute in a significant way to achieving the medium- and long-term GHG emission reduction targets. Besides adopting technical innovations developed by the vehicle and energy industry, the logistics sector will have to utilize and strengthen its own innovative power, as illustrated in Figure 5. In addition innovations in products, production geography and processes, as well as packaging may help by reducing the demand for freight transport.

Besides improving the logistic efficiency within companies, the required logistic innovations include advanced forms of collaboration between companies. Examples are horizontal collaboration between carriers to reduce empty running and increase load factors, and the further development of synchromodality to facilitate the use of more sustainable modes. Logistic innovations are also needed to facilitate the large scale implementation of sustainable vehicle technologies, such as electric vehicles for zero-emission city logistics. Vertical cooperation in the supply chain also offers potential for further logistic optimization and reduction of GHG emissions. Besides logistic innovations such cooperation should also include innovations in business models. These are needed to achieve a fairer distribution of costs, benefits and risks associated with the investments, e.g. in electric vehicles, that need to be made by carriers to meet the demands of suppliers for more sustainable logistics.

Given the large number of measures that are or at some point will or need to become available for reducing GHG emissions in freight transport and logistics, roadmapping is needed to develop cost-effective strategies. What can be done now, what needs to be done in the medium and longer term, and what needs to be developed and tested in the meantime? Given the large number of subsectors with specific characteristics in terms of vehicle fleet, operations, and business cases this roadmapping needs to have a certain level of sophistication to create a motivating action perspective for all involved stakeholders.

AN APPLICATION-SPECIFIC SYSTEMS APPROACH TO ROADMAPPING

Sophisticated roadmapping requires an application-specific systems approach (see Figure 6) that combines proper decomposition of sectoral data (to enable realistic estimates of reduction potentials and to make assessment results recognisable and acceptable to specific stakeholders) and acknowledgement of trade-offs and synergies between abatement options and interactions between the transport system and other systems (including e.g. energy supply and road and urban infrastructures)[4].

A HOLISTIC APPROACH TO THE WHOLE TRANSPORT CHAIN IS REQUIRED

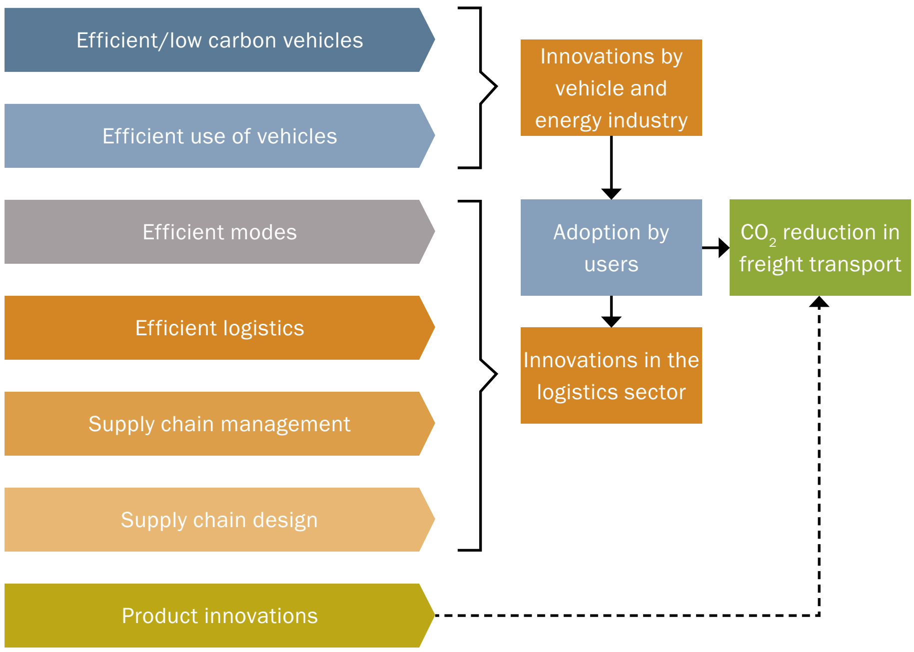

Figure 5: Combining technological and logistic innovations for achieving CO_2 emission reduction in freight transport.

4 *This systems approach was introduced earlier in Smokers et al, 'Decarbonising Commercial Road Transport'. TNO 2017 R10951, September 2017. http://publications.tno.nl/publication/34625511/QQDdeN/smokers-2017-decarbonising.pdf*

For developing sustainable logistic innovations and assessing their impact on CO_2 emissions of the supply chain, a decomposition in terms of the determinants of CO_2 emissions can be used, as already illustrated in Figure 3.

Roadmapping is not only relevant for identifying applicable reduction measures but also for determining their optimal timing. This is important from a cost perspective but also in view of the long lead times before measures take effect. Although it is different for different segments, renewal of entire fleets takes many years. For example, for tractor-semi-trailers the average economic lifetime is generally much shorter than for light commercial vehicles. For tractor-semitrailers huge steps forward should be feasible within a ten year timeframe since new vehicle sales constitute approximately 10% of the total vehicle fleet. On the contrary, once all newly sold light commercial vehicles would become zero emission, it would still take approximately 20 years before the entire vehicle stock is turned into a zero-emission fleet. In this sense long-term targets are actually not so far away and the next 5 to 10 years are probably critical for making sure that we get on track to meeting the 2050 climate targets.

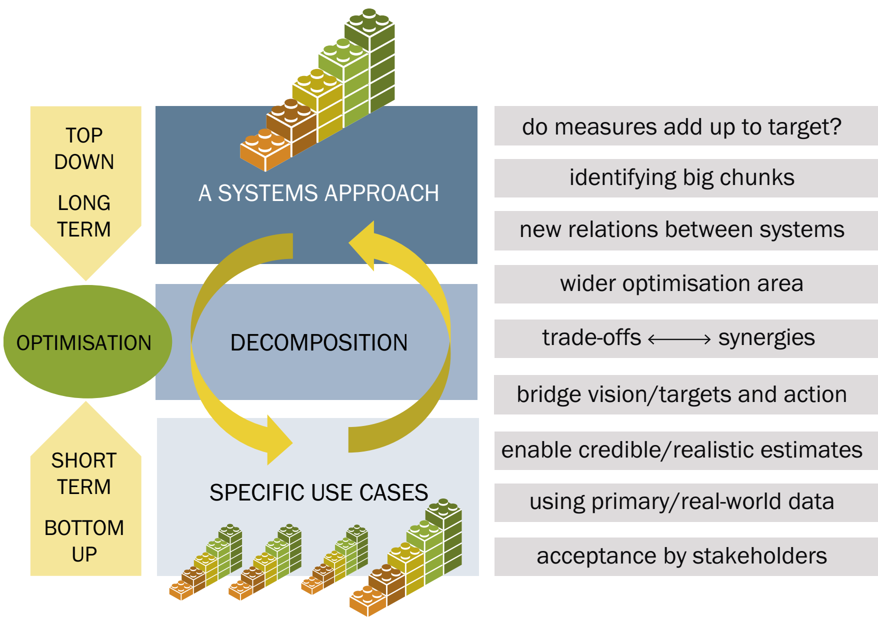

Figure 6: The need for and benefits of a systems approach.

CARBON FOOTPRINTING AND REPORTING AS A TOOL FOR ASSESSMENT AND MONITORING

In addition to the system-oriented assessment tools described above carbon footprinting and carbon reporting are valuable tools to assess the GHG impact of the logistic activities of shippers, logistics service providers (LSPs) and transport carriers. It defines the baseline and helps to identify promising reduction options and monitor the impact of measures.

Where carbon reporting generally relates to the total, absolute CO_2 emissions associated with the operations of a company, carbon footprinting in the logistics sector usually reports the specific CO_2 emissions per unit of transport performance.

As indicated in the simplified formula below, the carbon footprint of a shipment or of the logistic operations of a company is defined as the amount of CO_2 emissions attributed to the transport of an amount of goods divided by the transport performance. The latter is defined as the sumproduct of the amount of goods and the distances over which they are transported.

$$\textit{carbon footprint} = \frac{\sum \textit{amount of } CO_2}{\sum \textit{amount of goods x distance}}$$

$$\text{in} \left[\frac{\text{g}}{\text{tonne km}}\right] \text{ or } \left[\frac{\text{g}}{\text{m}^3\text{ km}}\right]$$

The above formula is valid from a *logistics service provider (LSP) or carrier perspective*. Results can be used to compare and benchmark companies or operations, provided that similar logistic operations are compared. For comparing the sustainability of shippers on the basis of their specific carbon footprint the following formula should be used (*shipper perspective*):

$$\textit{carbon footprint} = \frac{\sum \textit{amount of } CO_2}{\sum \textit{amount of goods}}$$

$$\text{in} \left[\frac{\text{g}}{\text{tonne}}\right] \text{ or } \left[\frac{\text{g}}{\text{m}^3}\right]$$

Carbon reporting or footprinting can also be applied to specific shipments. Comparison of shipment- or client-specific footprints can help a company to identify transport activities that are inefficient from a sustainability perspective. Improving these inefficiencies will in most cases not only reduce CO_2 emissions but also save costs.

For many shippers, logistics service providers (LSPs) and carriers carbon footprinting is becoming increasingly important. Reduction of CO_2 emissions not only leads to a more efficient operation, but also helps to meet the increasing demands of product users, customers, shareholders or other stakeholders with respect to the sustainability of the services or supply chain of companies. For example, nowadays many LSPs and transport carriers have started to participate in carbon reduction programmes, thereby step-by-step increasing their insight in the carbon footprint of their operations as well as taking action to decrease it. An example of this is the Dutch carbon footprinting and reduction programme “Lean & Green”[5].

Key factors for determining carbon footprints and carbon reporting are data on the transport activity, determined by the origin, destination and size of shipments, and data on the related CO_2 emissions (and/or fuel consumption) of the vehicles performing the transport services. The methodology used to attribute these emissions to individual shipments, operations or clients will have an impact on the quantification of the footprint.

APPROPRIATE METHODOLOGIES FOR CARBON FOOTPRINTING

A standardized methodology for the full process of determining the carbon footprint of logistics does not yet exist. The EN 16258 standard prescribes a methodology for attributing emissions to shipments, but does not cover all steps for determining a carbon footprint. Moreover it contains a number of methodological shortcomings. Different programmes and initiatives for sustainable logistics have developed their own approaches, which generally also have limitations in scope and/or methodology. Improvement and harmonisation are necessary to arrive at a correct and widely accepted methodology that can be applied to often international if not global supply chains. In that process a careful balance needs to be struck between stakeholder acceptance and methodological correctness in order to achieve widespread adoption of the proposed methods.

In the EU-funded LEARN project[6] a network of leading global industry, government and civil society stakeholders has been established to promote harmonisation and application of a method that builds on the approach developed by the Global Logistics

5 See: http://www.lean-green.nl/ or http://lean-green.eu/

6 See: www.learnproject.net/

FOR CARRIERS CARBON FOOTPRINTING IS A WAY TO DISTINGUISH THEMSELVES FROM THE COMPETITION

Emission Council (GLEC)[7]. In addition next steps to improve the approach will be defined on the basis of experience with implementation and use of the initial approach and knowledge from prior work in the EU-funded COFRET project.

Accurate carbon accounting requires that all relevant emissions that are associated with the shipping of goods are taken into account for determining the numerator in the above formula. Besides the emissions during transport of the goods this includes emissions related to e.g. empty vehicle kilometres, transshipment and warehousing. For attributing these emissions to individual shipments (e.g. containers on a ship or different parcels in a van used for urban delivery) different methodological options are available. Limiting the scope of emissions included in the calculation may result in more favourable carbon footprint figures, but also makes them insensitive to a number of meaningful CO_2 reduction measures such as the reduction of empty kilometres.

For determining the transport performance in the denominator of the formula it is essential that it is calculated on the basis of the Great Circle Distance (GCD) between origin and destination of the shipment and not on the actual driven distance or shortest feasible distance. Using one of the latter leads to methods that cannot adequately compare different modes or that do not reward meaningful reduction measures. Therefore, it is important to ensure that in the ongoing standardization process a methodological shift is made from the actual distance travelled allocation method to the one based on the great circle distance allocation.

BENEFITS OF USING PRIMARY DATA

Calculation of carbon footprints is ideally embedded in a company's ICT systems, and based on primary data, i.e. actual recorded data from a company's operations. The benefits of using primary data are best illustrated by applying the above formula to determine the carbon footprint of the complete operation of a carrier company. In that case the numerator is calculated on the basis of the total amount of consumed diesel (for the vehicle fleet) and electricity (for warehousing). These numbers are available from the company's financial administration. The energy consumption is converted to CO_2 using applicable emission factors. For determining the transport performance in the denominator only the origin, destination and size of all shipments need to be known. These data should be available from the company's logistic ICT system. The transport distances can easily be calculated from the origin and destination of the shipments using a GCD-calculator. Information on actual routes of vehicles is not necessary. Obviously more detailed data and calculations, as well as an appropriate allocation method, are needed to calculate the carbon footprint of individual shipments or to report the emissions associated with specific shipments or operations to individual clients. But also that can be fully based on primary data.

In the absence of primary data on transport performance and CO_2 emissions of vehicles default values can be used. But these limit the ability of carbon footprinting to adequately monitor the impacts of various meaningful measures that can be taken to reduce a company's carbon footprint and also tend to make the assessment more complex and time consuming.

7 See: *http://www.smartfreightcentre.org/glecframework/glecframework*

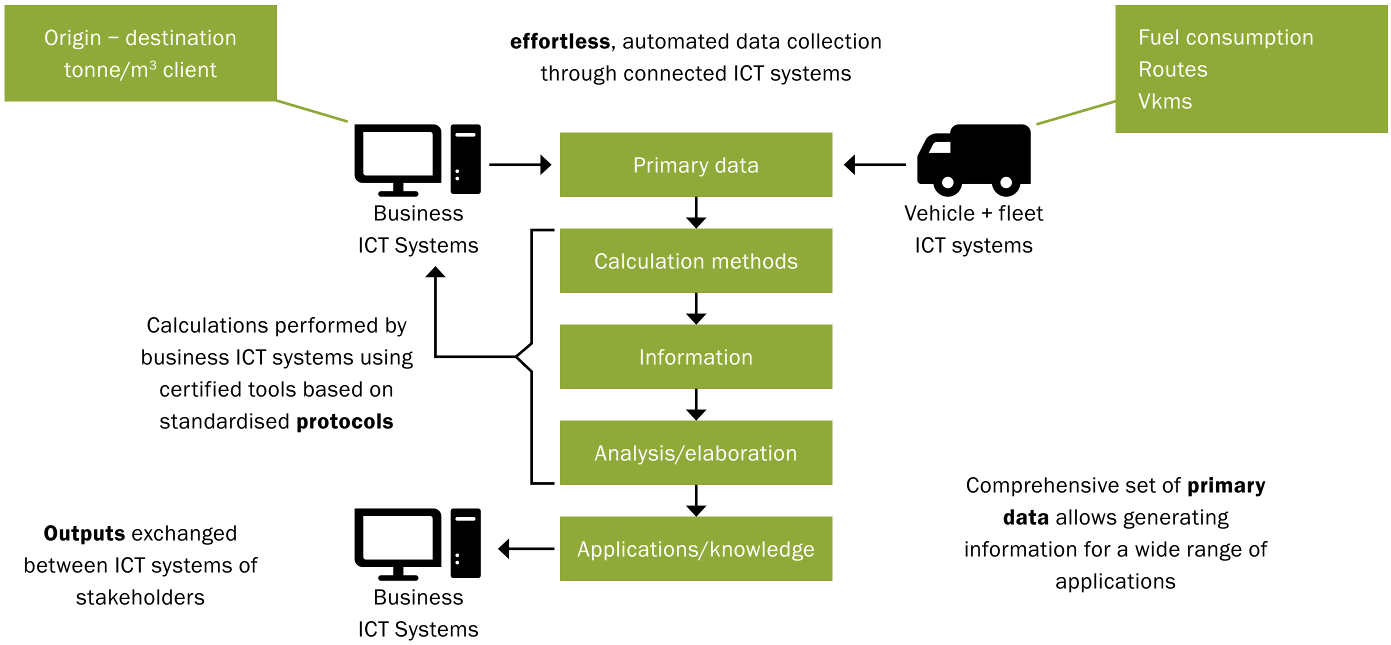

Figure 7: The role of ICT systems for logistic planning and fleet management in generating primary data for carbon footprinting.

With proper ICT systems for logistic planning and fleet monitoring primary data can be harvested without large efforts and converted to accurate and reliable carbon footprint results. This is illustrated in Figure 7. In this way carriers can easily generate carbon emission data that can be reported to shippers, who need these numbers to determine the carbon footprint for their entire supply chain. In complex multimodal logistic chains the emissions attributed to a shipment on individual transport legs need to be combined, as shown in Figure 8. This could be organized by data communication between (the ICT systems of) carriers, LSPs and shippers, but may in the future also be information that “travels” along with the shipment through the logistic or supply chain (see Figure 9). If GCD is used as a measure for the transport distance, as recommended above, carriers and LSPs operating individual legs in a complex supply chain only need to report a CO_2 figure for each shipment to the shipper. In attributing CO_2 emissions to shipments for different clients it is paramount that carriers and LSPs use a consistent attribution methodology.

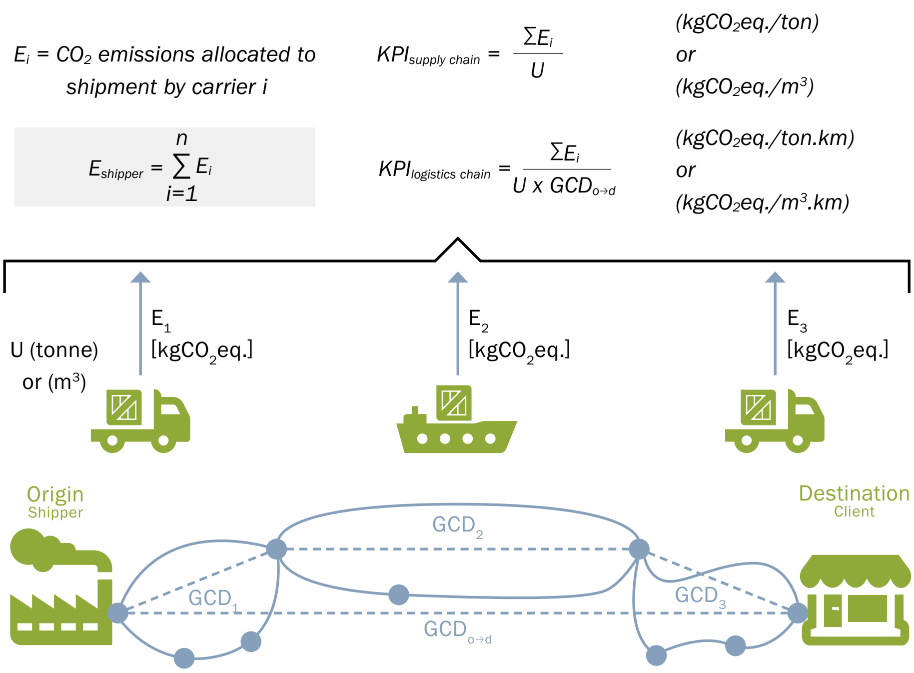

Figure 8: Adding the emissions attributed to a shipment on individual transport legs to determine the carbon footprint of complex multimodal logistic chains.

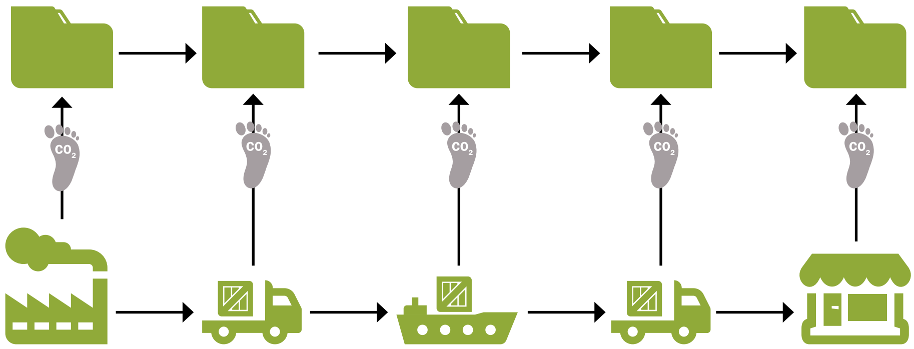

Figure 9: Developments towards logistic data travelling along with shipments can also be used to collect data for carbon footprinting.

CARBON FOOTPRINTING AS A TOOL FOR MAKING BETTER ENVIRONMENTAL CHOICES

Carbon footprinting is potentially a very useful tool for facilitating choices leading to a reduction of CO_2 emissions. Carbon footprinting essentially realizes the following three primary goals: 1) make CO_2 emissions measurable and "visible" in the logistic chains; 2) ensure awareness about CO_2 emissions resulting from the operations; 3) drive the change in operations leading to a reduction of CO_2 emissions. For a comprehensive realization of the available CO_2 reduction potential carbon footprinting based on ex post computations of emissions that have occurred in the chain provides the starting point. Subsequently action potential is identified by means of ex ante evaluations of emissions that would occur if certain choices are made. In this process a holistic approach to the whole transport chain is required, as optimization of only a part of logistic chain may have an adverse impact on the total emissions. During the process of improving the sustainability of the logistic operations (ex durante) carbon footprinting is used as an instrument for monitoring progress.

What currently drives carbon footprinting

On the business side, shippers are the main actor type driving the introduction of carbon footprinting in transport and logistic operations. Many shippers have their own, often voluntary, environmental targets. This is especially the case for the large publicly traded producers of goods, for whom transport- and logistics-related emissions form a part of sustainability reporting. These companies spend some effort and resources to make logistic operations less carbon-intensive, e.g. by requiring that their service providers use specific trucking equipment, such as young Euro 6/VI equipment, or to train their drivers in eco-friendly driving style. If the shipper does not have actual emission data at its disposal, it applies general average emission factors, which may not adequately reflect their sustainability performance and improvement efforts. Therefore, in order to verifiably achieve the environmental targets, it is in the interest of the shipper to implement a proper carbon footprinting scheme, which is based on actual fuel consumption data.

For carriers that perform transport activities on behalf of shippers, carbon footprinting is a way to distinguish themselves from the competition. Carriers get more and more requests from shippers to perform carbon footprinting: the business interest of the carriers involves satisfaction of such customer requests without sharing too much sensitive operational data.

Branch organizations representing interests of the transport and logistics industry are motivated to promote voluntary carbon footprinting schemes, which could be more beneficial (or at least less costly) for the transport sector than mandatory ones. Realization of the medium- and long-term CO_2 emission reduction goals will require a concerted effort from all parties involved in freight transport, so the sector's logic is to take initiative in their own hands and not to wait until governments come with some heavy-handed measures for CO_2 reduction in the sector.

All types of stakeholders agree on the need for a common standardized way of carbon footprint computation and emission data exchange. From a business point of view, it is important to introduce it once and to do it right. Once structurally implemented in a company's operations and accounting systems, it is costly to change the way in which emission data is computed. It is also costly to maintain numerous interfaces to exchange data with different service providers using different standards. From the point of view of knowledge organizations, and society as a whole, a common harmonised, and preferably standardized way of emission computation is necessary for a proper comparison of options, such as different transport modalities, and for facilitation of effective choices for making transport and logistics more sustainable.

Reporting and emission data exchange challenges
In complex transport and logistic chains, such as those presented in Figure 8 and Figure 9, a number of companies work on transportation of goods from the goods' origin to the final destination. It means that without certain emission data exchange or sharing mechanisms it is not possible to compute actual chain-wide emissions related to the shipment.

There is currently an ongoing discussion on how to design emission reporting in complex transport and logistic chains. The choice is essentially between the three primary designs: 1) the shipper computes emissions based on data provided by the carrier; 2) the carrier computes emissions and shares the result with the shipper; 3) the carrier shares the transport and fuel data with a third-party trusted platform, which computes emissions for the shipper. Each of these methods has advantages and disadvantages; it is a matter of reaching a consensus on the way emission data are reported. The mission-owner-emission-reporter mechanism, as presented in Figure 10, provides a conceptually elegant and implementable way for defining the hierarchy in emission reporting for the complex chains.

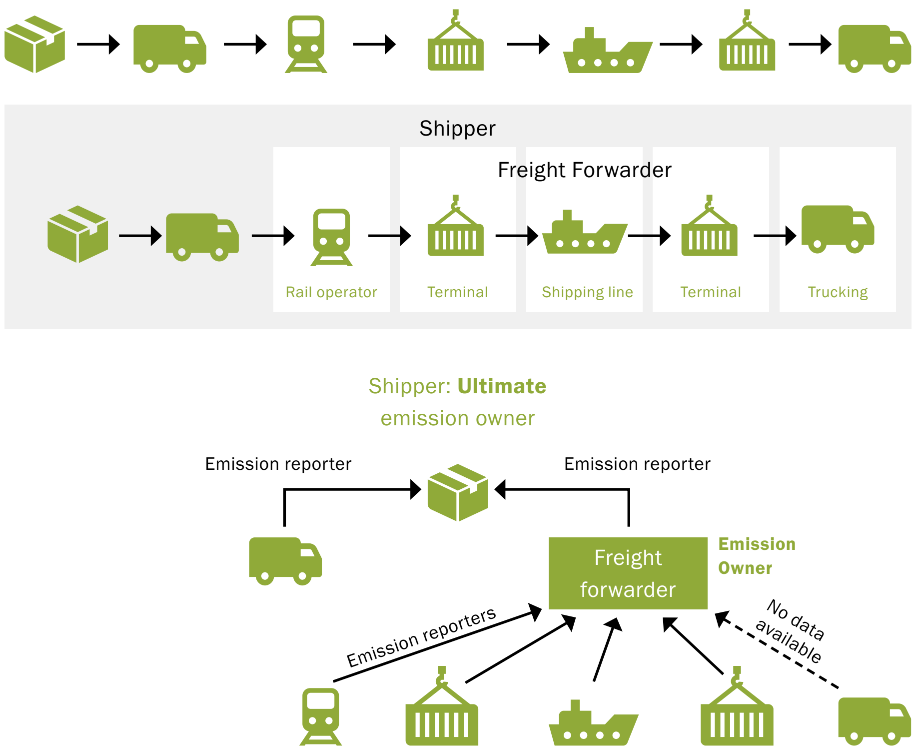

Figure 10: Hierarchical emission reporting mechanism.

Ex ante emission computation and default emission data

In practice a complete transport and logistic chain carbon footprinting can become difficult if one of the segments in the chain, as shown in Figure 10, cannot provide data. Also in case a choice is to be made between different transport options, there are often no emission data for all options in the choice set available at the moment the choice is to be made. In these situations default emission data can be used as a substitute for real-world emission data.

There are different databases available for estimation of transport CO_2 emissions. The emission factors generally convert tonne-kilometre transported by specific modes into CO_2 emissions. Although useful as a quick fix in case real-world primary data are not available, the emission factors are too general and do not allow for taking into account sustainability measures taken by the chain partners related to e.g. using efficient vehicles, efficient driving styles or improving load factors.

The toolset developed by TNO[8] bridges this gap by allowing for a more detailed decomposition of ex ante emission computations for new transport options and ex post emission computations for carbon accounting when the real primary data are not available. The toolset refines transport-related emission estimations taking into account vehicle type, mission profile (e.g. urban, rural, motorway), fuel type, energy saving measures (e.g. aerodynamics, ITS), payload and a set of other measures. It is a powerful tool for accurate ex ante assessments of reduction potentials in transport and logistics systems and for bridging data gaps in carbon footprinting.

DILEMMAS FOR COMPANY AND SECTOR INITIATIVES

One of the main challenges for the development and implementation of robust transition pathways towards a low-carbon freight transport sector is to align the motivation and direction resulting from short-term commercial stakeholder interests with the societal need to achieve ambitious long-term GHG reduction targets. As reducing CO_2 emissions results from the reduced consumption of fossil fuels, to some degree improving the sustainability of freight transport aligns with the desire to reduce costs. Nevertheless investments by carriers in cost-effective solutions, the low hanging fruit, are found to be hindered by the strong competition in the sector which puts pressure on carriers to fully pass on these cost reductions to their clients.

Furthermore reducing CO_2 emissions only to the point of optimal costs will most likely not be sufficient to meet the medium- and long-term targets. Also various solutions, that may become cost-effective in the longer term, require some level of market uptake in the short term for economies-of-scale to help them reach economic maturity. Front runner carriers investing in these solutions are generally not able to pass on the costs to their clients, and see their additional costs and associated risks only partially compensated by benefits in terms of increased market share or client loyalty. Also, carriers and shippers have difficulty in finding objective information upon which they can base their longer-term strategies and short-term investments.

The above examples are indicative of the dilemmas associated with getting the transition to sustainable logistics in motion. The current strategy for initiating and accelerating the transition is largely

8 The TNO toolset was also introduced in Smokers et al, 'Decarbonising Commercial Road Transport'. TNO 2017 R10951, September 2017. http://publications.tno.nl/publication/34625511/QQDdeN/smokers-2017-decarbonising.pdf

9 See e.g. the Dutch Green Deal on Zero-Emission City Logistics.

based on voluntary participation of companies in sustainable logistics programmes (such as the aforementioned Dutch programme "Lean & Green") and government-supported Green Deals[9] or other types of coalition agreements. This approach works well if voluntary action leads to sufficient competitive advantages for participating companies. Various on-going programmes are quite successful, with companies achieving impressive reduction percentages and using the programmes as a platform to showcase the feasibility of options. But these programmes are also starting to feel the tension between rewarding frontrunners and getting the early majority on board. It is clear that in the long run, when all companies have to become significantly more "green" to reach the required long-term improvement in carbon efficiency, competitive advantages can no longer be the driver.

For many companies and other stakeholders in the logistics sector it would therefore be a very helpful if government policies could provide more clarity about the long-term direction and would provide means to better align short-term company interests with long-term targets. This could start with developing a more clear and detailed roadmap for the sector.

THE ROLE OF POLICIES AT DIFFERENT GOVERNMENT LEVELS

For developing effective policy packages for sustainable mobility and logistics it is necessary to identify which abatement options can typically be influenced by European, national, regional or local policy measures and which abatement options in which areas of the transport sector may contribute in significant proportions.
To take an example for the passenger transport sector: Passenger cars make up a large share of the CO_2 emissions (Figure 11), but the strongest driver for CO_2 abatement in passenger car transport is European CO_2 emission regulation. The availability of low-carbon technologies is therefore largely driven by EU regulation, with fiscal policies in Member States playing a strong role in stimulating demand for these technologies. For applying electric and fuel cell vehicles in a sustainable way, there is also a need for energy policies aimed at reduction of carbon emissions in the electricity generation process. The mass adoption of electric, zero-emission vehicles furthermore requires appropriate development of local charging infrastructure, besides the supply of vehicles with a competitive total cost of ownership compared to conventional vehicles. That is where local government policies play a dominant role, possibly stimulated or coordinated through EU or national policies.

LONG-TERM TARGETS ARE ACTUALLY NOT SO FAR AWAY

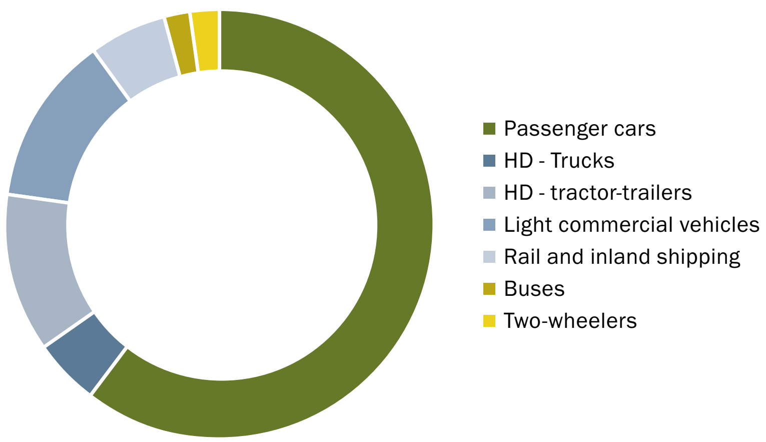

Figure 11: CO_2 emissions by inland passenger and freight transport in the Netherlands in 2015.

For defining effective policy packages it is important to understand to what extent CO_2 abatement potentials will be achieved by autonomous developments, sectoral initiatives, and by current and planned policies at the EU, national and local level, and to what extent new policies and action are needed.

For the freight transport sector European CO_2 emission regulation may also stimulate the availability of more energy-efficient or even zero-emission vehicles. CO_2 standards already exist for some time for light commercial vehicles and will enter into force for heavy-duty vehicles by 2025. But given the complex and competitive nature of the freight transport sector stimulating the uptake of these vehicles and augmenting that with accelerated improvements in logistic efficiency will require a more differentiated approach than is the case for passenger transport. Working out that differentiated approach entails mapping the characteristics of the different subsectors, calculating their footprint, identifying possible decarbonisation measures and application-specifically assessing their potential. Based on that, appealing roadmaps can be developed for each subsector, which will give guidance to further voluntary actions within the sector and possible policy interventions that are needed to resolve market dilemmas.

CARBON FOOTPRINTING AND ROADMAPPING ARE ESSENTIAL MEANS, BUT COOPERATION IS KEY

As this paper clearly shows the logistics sector is facing a major and complex transition towards full decarbonisation, involving sustainable transport fuels, efficient conventional and zero-emission vehicles and increased logistic and operational efficiency. Reaching CO_2 emission reductions of the order of 95% by 2050 requires logistic innovations ranging from a modal shift to more sustainable transport modes, a reduction of the number of vehicle kilometres by improving logistic operations, changes in spatial organization of production and product sourcing, adjustments in supply chain design and organization, and development of value adding logistic solutions.

Finding and implementing feasible, effective and affordable pathways for realising a sustainable logistics system requires a systems approach, as it operates in a complex environment with stringent requirements for costs and profitability and strict operational boundary conditions set by demands and interests of customers and a wide range of other stakeholders.

The integral systems approach combined with the carbon footprinting or carbon accountancy tool that TNO is developing can help the logistics sector to identify acceptable and cost-effective solutions. But no transport company, logistics service provider, government body, or research institute can realise this on its own. Cooperation is key for achieving the challenging climate goals.

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TRAFFIC AND TRANSPORT

In a changing world full of global challenges such as urbanisation, ageing, digitisation, automation and energy transition, our ambition is to boost the competitiveness of business and improve the well-being of society by increasing the safety, efficiency and sustainability of traffic and transport.

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Rapportnummer: TNO 2019 R10104

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