

CONCEPTUAL FRAMEWORK FOR IMPACT ASSESSMENT OF DISTANCE-BASED ROAD PRICING FOR HEAVY GOODS VEHICLES

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SUMMARY

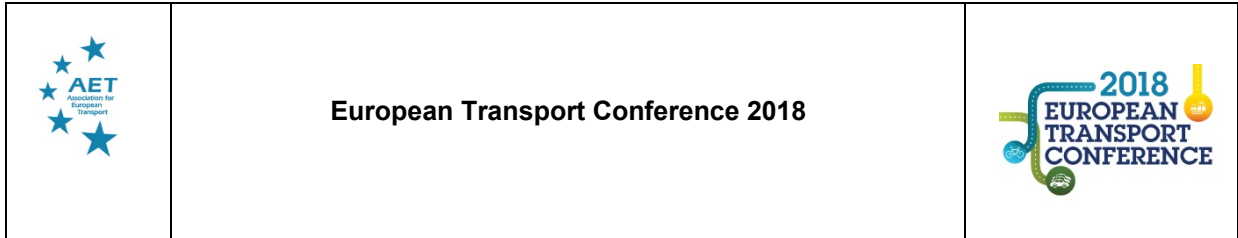
What are the potential effects of distance-based heavy good vehicle road pricing? With an eye toward implementation in the Netherlands, the KiM Netherlands Institute for Transport Policy Analysis devised a conceptual framework based on relevant literature. Moreover, a supplementary infographic provides an overview of how heavy good vehicle road pricing would impact the various segments of the freight transport system, revealing the effects on transport and traffic, the economy and living environment. The conceptual framework was developed on behalf of the Dutch Ministry of Infrastructure and Water Management and serves as a foundation for further analyses of heavy good vehicle road pricing.

Conceptual framework

The KiM conceptual framework provides a clear overview of all the potential effects on the micro- and macro-level, and how as a result of heavy good vehicle road pricing they correlate to:

- Transport and traffic (effects on decrease in heavy good vehicle kilometres, number of trips and transported tons of freight by road, hours of delay, routes, logistic efficiency, the distribution structure (from longer to shorter distances), route choice, fleet composition (including delivery vans), modal split and logistics flows);
- Environment and living environment (effects on emissions of CO₂, particulate matter and nitrogen oxides, as well as on noise, traffic safety and road wear);
- Economy (effects on competitiveness, welfare and the costs and revenues of heavy good vehicle road pricing).

The conceptual framework distinguishes between the various markets (or layers) where supply and demand converge: the transport market, traffic market, logistics market and goods market. It describes the behavioural reactions of the actors engaged in the various markets: drivers/carriers, shippers/logistics providers, producers and consumers. Negotiations and agreements about pricing, quality standards, delivery terms and quantities transpire in these markets. The expectation is that the costs will initially be passed on to customers. Should that prove impossible, other measures are then required, including cost savings, enhanced and/or improved collaboration or profit margin adjustments.



1. INTRODUCTION

In the latest Dutch cabinet coalition agreement from October 2017, 'Confidence in the future', a specific text passage states that a heavy goods vehicles kilometre charge (HGV km-charge) will be implemented by 2023 (VVD, CDA, D'66 and CU, 2017):

"A kilometre charge for freight traffic ("Maut") will be introduced as soon as possible, following neighbouring countries. The registration and payment system will be the same as in neighbouring countries, so that no additional equipment is required for trucks. The revenues will be recycled to the transport sector in consultation with the sector by lowering the motor vehicle tax on lorries and money for innovation and sustainability"

The Netherlands Ministry of Infrastructure and Water Management (IenW) has initiated an impact assessment of a distance-based HGV road pricing system in the Netherlands, investigating how an HGV km-charge will impact:

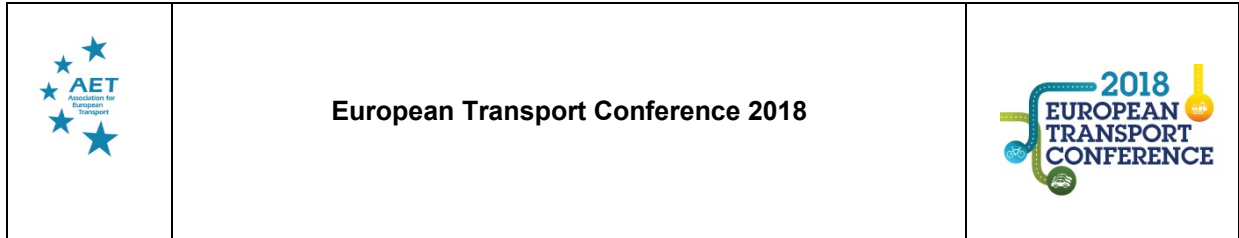
- Transport (e.g. efficiency, fleet composition including delivery vans, modal split and logistic chains);
- Traffic (e.g. number of kilometres, vehicle hours of delay);
- Environment (e.g. CO₂, NO_x, noise, traffic safety);
- Economy (e.g. income, competitive position).

In order to thoroughly analyse the impact of an HGV km-charge, IenW's impact study distinguishes between various 'policy buttons':

- Charge level;
- Differentiation by location (e.g. main road network versus local road network);
- Differentiation according to time period (day/night, peak/rest of day);
- Differentiation by environmental class;
- Differentiation by weight;
- Differentiation by number of axles;
- Scope of heavy vehicles fleet (buses, vans).

The study primarily focuses on the first two policy buttons ('charge level and location'), as they are likely to have the greatest impact. Other buttons could be used for fine tuning. For the time being, the manner in which the revenues will be used is not identified as a separate button; the details about such revenue spending have yet to be determined. The assumption is however that the Eurovignette will be abolished in the Netherlands and the motor vehicle tax reduced to a minimum level.

IenW asked the KiM Netherlands Institute for Transport Policy Analysis to devise a conceptual framework that structurally maps how an HGV km-charge could impact the various segments of the freight transport system.



The conceptual framework and strength of the relationships therein are based on an international literature review. Additionally, KiM tested a first draft version of the conceptual framework in an expert session, focusing on the behavioural reactions of the various actors involved, including transporters, shippers and logistics service providers, producers and consumers. Little is known about the behavioural reactions occurring the micro-level. The available literature primarily deals with the HGV km-charge's macro-effects on traffic and transport (number of kilometres and tonnes) and emissions, for example.

Chapter 2 describes the conceptual framework in broad outline. Chapter 3 explains the micro-behavioural reactions of transporters, shippers and consumers. Chapter 4 examines the macroeconomic effects of an HGV km-charge. Finally, Chapter 5 denotes which effects can or cannot be assessed using Dutch strategic traffic and transport models like the National Model System (LMS), and the BASGOED freight model.

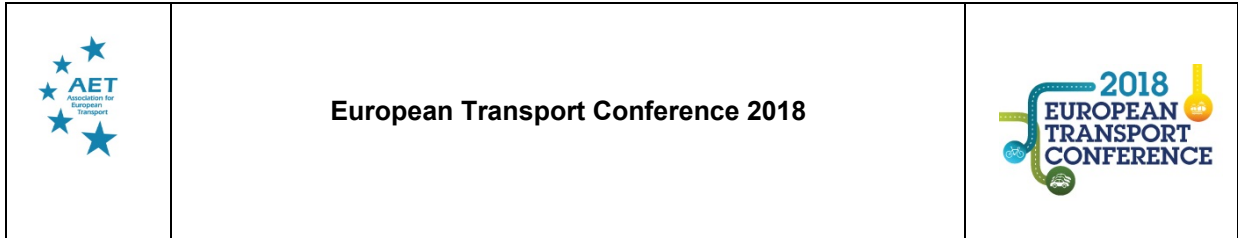
2. BROAD OUTLINE CONCEPTUAL FRAMEWORK

In the conceptual framework (see Figure 2.1) we distinguish between markets (or layers) where supply and demand converge together (Schoemaker et al., 1998, Van Binsbergen & Visser, 2001). The market parties (actors) make choices and agreements based on the characteristics (price and quality) of the product or service.

In accordance with Ecorys (2007), we placed the 'policy buttons' on the left side of Figure 2.1. The starting point is a future 'equilibrium situation', in which the introduction of an HGV km-charge leads to subsequent changes. All other circumstances remain the same. The policy buttons that can be differentiated are:

- Charge level (including abolishing Eurovignette and reducing motor vehicle tax);
- Location (e.g. main road network vs. local road network);
- Time period (e.g. day/night, peak/night/rest of day);
- Environmental class (e.g. EURO norm);
- Vehicle weight;
- Number of axles;
- Vehicle type (e.g. trucks, buses, vans).

Government measures can impact the variable and/or fixed costs. The Eurovignette is an example of a fixed cost, where the price depends on the number of days, the environmental class and the number of axles, but which is not differentiated according to number of kilometres driven on Dutch territory. An HGV km-charge directly impacts the variable costs.



A price incentive, such as an HGV km-charge, subsequently influences the behaviour of the various interdependent actors:

- Infrastructure operator;
- Driver/carrier;
- Shipper/logistics service provider;
- Producer;
- Consumer.

At the top are the four markets/layers in which the actors interact with each other: traffic, transport, logistics and goods. Negotiations and agreements on price (p), quality and delivery conditions (p & q) and quantity (q) occur in these markets.

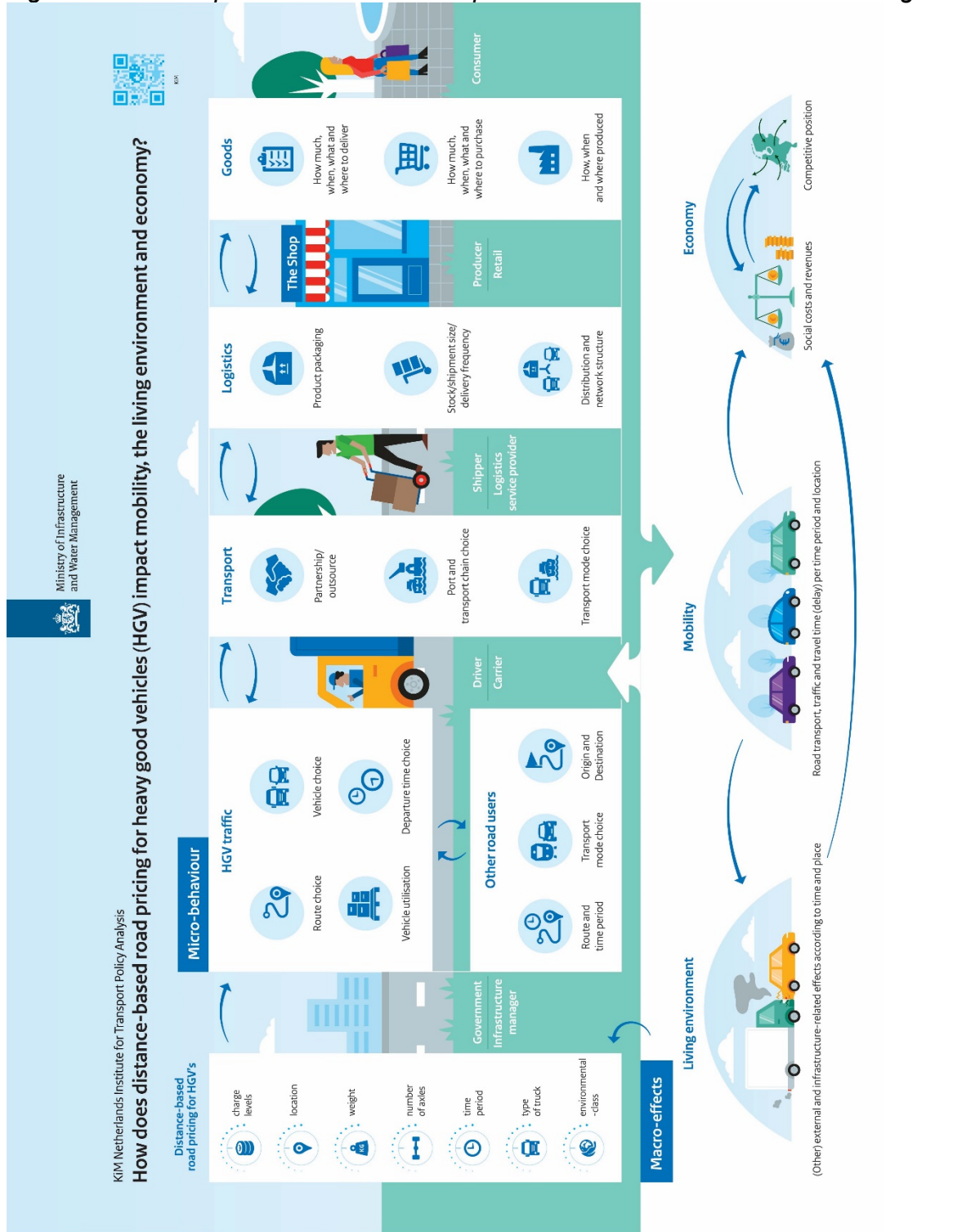
The first behavioural response of the actors in the various markets will be to fully pass on the cost increase of an HGV km-charge to customers through higher prices. The extent to which these costs can be passed on depends on the relationships between the buyers and suppliers in the relevant markets. If it is not possible to fully pass on the extra costs, then other measures are required such as, saving costs, enhanced/improved collaboration or accepting lower profit margins, for example. It is often difficult for many small road transport companies to pass on cost increases to their customers; these small-scale firms have less market power and therefore often lower profit margins compared to larger companies. Consequently, it could be that small transport companies will go bankrupt and/or be taken over by larger companies that can more easily absorb and/or pass on the extra costs. The behavioural responses described below are from the actors active in the various markets: driver/carrier, shipper/logistics service provider, producer and consumer. If possible we distinguish in the descriptions between behavioural responses in the short-, medium- and long-term. By long term we mean 2030.

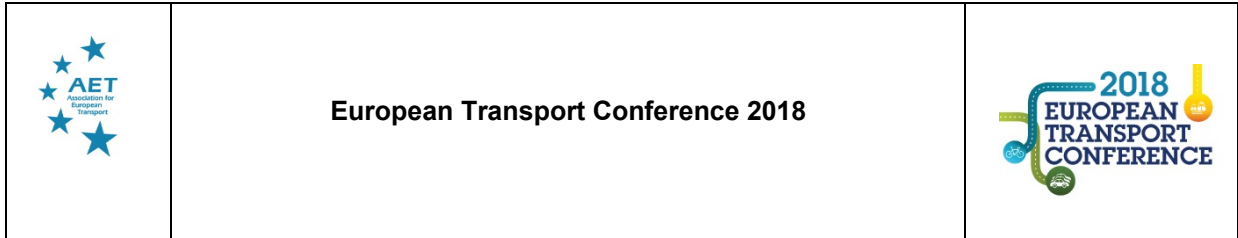
A conceptual framework structures the actors and relationships between them, and is a simplified representation of reality. Important considerations behind the choices for simplification and presentation are detailed below.

Actors versus markets

The markets were chosen as the starting point in the conceptual framework. The behavioural responses of the actors active in these markets are described (carrier, shipper, producer and consumer). As previously stated, the actors' reactions are often the result of negotiations and agreements with other actors. Such agreements and negotiations occur in markets where supply and demand meet. In the mobility domain, the various markets or layers are distinguished in a functional system description where supply and demand converge. In passenger mobility, the so-called 'three-market model' (Schoenmaker et al., 1998) is a well-known term, and in freight transport and logistics it is called a layer model (Van Binsbergen & Visser, 2001).

Figure 2.1: Conceptual framework for impact assessment of an HGV km-charge.





In this case we have four markets or layers, namely, the traffic market, the transport market, the logistics market, and the goods market.

Linear view

Despite the use of feedback relations, the conceptual framework could give the impression that a strong sequence exists in the choices and relations between actors. In reality however the situation is more complex, and carriers often cannot make choices without consulting with shippers and vice versa. In the long term, the HGV km-charge will likely lead to other choices and agreements between the actors in the various markets.

Nature and strength of relationships

To keep the model as clear as possible, we limited the number of relationships within the model. Within the markets/layers, for example, there are also relations and behavioural choices in the short-, medium- and long-term (see also NEA, 2001). In terms of type of relationships, direct or first-order and feedback/rebound or second-order relationships are distinguished in Figure 2.1. No difference is made between the strengths of the relationships.

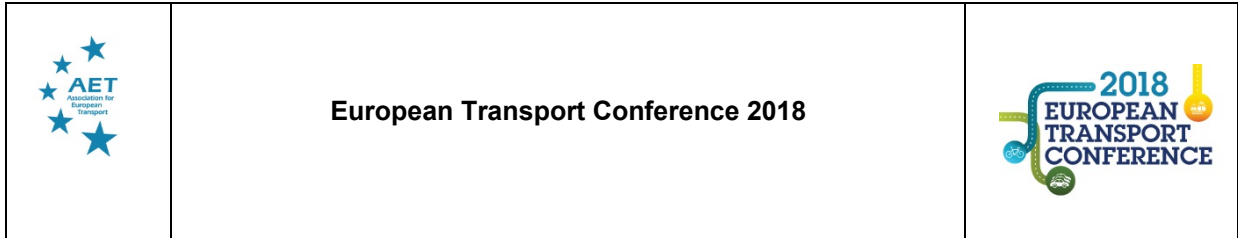
3 Behavioural responses of carriers, shippers and consumers

3.1 Carrier

The carrier will initially try to charge as much of the extra costs as possible to the shipper. The market in which the carrier and shipper operate is in theory a perfect competition situation. A carrier that does not charge the extra costs of an HGV km-charge to his shipper will in theory go bankrupt in the long-term. However, the situation in practice is often different. Due to market imperfections and ineffective government action, the long-term outcome may be that the cost increase is not fully passed on. If it is not possible to pass on the costs of the HGV km-charge, the carrier can opt to lower profit margins or save costs by adjusting its behaviour. Various choices are possible in the short-, medium- and long-term, with simple and inexpensive adjustments are made in the short term while complex adjustments requiring major investments are made in the longer term.

Short-term

The driver or carrier choosing an alternate route is an example of a behavioural response in the short-term. When an HGV km-charge applies to all roads, the carrier can choose a shorter, and thus cheaper, route that will take longer to travel and have possible implications for the quality of life and safety of the local road network. If the HGV km-charge is differentiated by type of road for example only highways, then the route choice effect is probably greater as a result of avoidance behaviour. Border effects can also occur: shorter routes through neighbouring countries once again become more attractive when an HGV km-charge is introduced in the Netherlands,



as it has been in Germany and Belgium. Consequently, Dutch HGV drivers will be more inclined to drive through Germany or Belgium, and foreign HGV's will use the Dutch road network less frequently.

Medium-term

Multiple responses are possible in the medium-term. One consequence of higher costs due to an HGV km-charge is that carriers will aim to cut costs by loading their trucks more efficiently and by making fewer empty trips. In addition, other efficiency improvements are possible, including more fuel-efficient driving and the outsourcing of transport to other cheaper and/or foreign carriers. If the HGV km-charge is differentiated according to time periods, such as higher surcharges during peak-hours and/or lower night rates, changes may also occur to the time of driving.

Long-term

In the longer term, carriers can choose other vehicle types. This may involve the purchase or leasing of more economical or larger vehicles with higher payloads or, for example, using smaller vehicles that do not need to pay an HGV km-charge, vans for instance. This has implications for the shipment size. Leasing could be more flexible than purchasing, but such contracts will also have minimum durations of several of years or likely longer.

Outcome behavioural choices carrier

The behaviour of the carrier ultimately has consequences for the transport tariffs, as well as possibly for the time at which the transport occurs and the frequency of the trip. Behavioural responses can also lead to more or less flexibility (for example through the use of larger or smaller vehicles) or impact other level-of-service factors. Many of the aforementioned behavioural responses play a role in the traffic market, yet also have consequences for the transport market in which the carrier's supply and the shipper's demand converge, thus also impacting the traffic market (see feedback relationship in Figure 2.1).

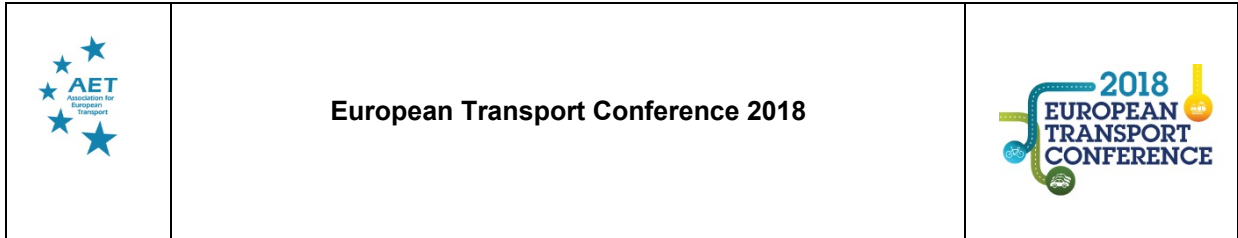
3.2 Shipper

The shipper, which can be the producer or the buyer of goods or a logistics service provider, will initially aim to pass on additional costs to carriers or buyers of the products, such as the consumer. If this fails, they can also choose to capitalise on profits or save costs by adjusting their behaviour. Here, as with the carrier, various choices are possible, both in the shorter and longer term.

Short-term

Just like the carrier, the shipper can adjust the shipment size. In addition, they may or may not additionally opt for a modal shift using another modality, such as by rail or ship, for example.

Medium-term



In addition to changes in modal choice, shippers can also opt to adjust the transport and logistics chain; this can occur in the transport chain, for example, by changing from unimodal (HGV-only) to multimodal transport (such as a combination of inland navigation and HGV pre- or end-haulage), and in the logistics chain by choosing a foreign port. Changes may also eventually occur in the choice of product (higher or lower quality) and type and quality of the packaging.

Long-term

In the long run, shippers - both sending and receiving - can also choose to adjust their spatial patterns; for example, they can change the production location or location of their distribution centres. Additionally, changes can occur in the purchasing and sales market.

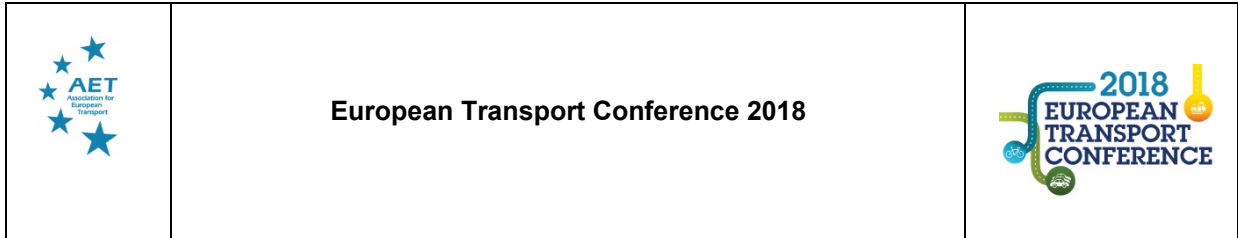
Outcome behavioural choices shipper

The behaviour of the shipper or logistics service provider ultimately has consequences for the product price, product quality and the delivery conditions that impact the choices made in the goods market. In this context, feedback occurs between the goods market and the logistics market, and between the logistics market and the transport market (see feedback relations in Figure 2.1).

3.3 Consumer and traveller

The consumer, or buyer of products, which can also be a company, can aim to avoid higher product prices by choosing other cheaper products, examples of which include purchasing cheaper products or products that are transported less by trucks, or purchasing products elsewhere, such as abroad, for example. These consumer decisions can in turn determine the shippers' behaviour and choices on the macro-level.

If the HGV km-charge results in less freight traffic on roads, this will impact the travel times of the other road users, see macro-level in Chapter 4. Consequently, other road users will in turn adjust their behaviour (see 'Other road users' in Figure 2.1). If, for example, a time-differentiated charge leads to substantially less HGV traffic during peak hours, this can lead in the *short-term* to other road users filling up the resulting 'gaps' with a 'back to the peak effect'. In the *medium-term* this may also result in a change of mode choice; for example, a modal shift from public transport to private cars, because travel times on roads have decreased. In the *long-term*, trip origins and destinations could be adjusted by choosing another place to work, shop or reside.



4. Macro-effects of an HGV km-charge

The behavioural responses of the individual carriers, shippers, producers and consumers in the various micro-markets impact the scale and composition of traffic and transport on the macro-level, the external effects, costs and revenues, and ultimately the competitive position of the Netherlands. Desired or undesirable macro-implications can then lead to the government making other choices, such as for example adjusting the structure of the HGV km-charge shown in the feedback loop in Figure 2.1.

Transport, traffic and travel time by hour and location

On the macro-level adjustments to individual traffic and transport choices result in traffic intensities changing per hour and per segment of the road network. For reference, see the arrow in Figure 2.1 between the block detailing micro-behaviour and macro-effects. This can lead to changes in traffic congestion and hours of delay, and therefore to carriers and other road users making different behavioural choices.

Traffic and transport effects can be expressed in various output indicators, such as number of vehicle-trips, transported weight (tonnes), number of vehicle kilometres and number of tonne kilometres. In Figure 2.1 the mutual relationship between such indicators and the HGV km-charge is explored conceptually.

These impacts on transport and traffic in turn impact the (other) external and infrastructure-related costs, the revenues and costs, and ultimately (directly or indirectly) the competitive position of the Netherlands.

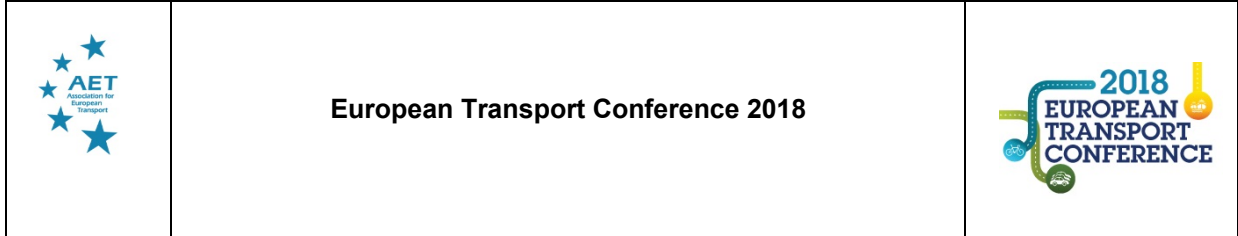
Other external and infrastructure-related effects by hour and place

The behavioural choices of the carriers and shippers in the various markets and of the other road users directly or indirectly impact the external effects as a result of the traffic and transport effects. This pertains to changes in:

- road safety, a relationship with the number of kilometres per location and hour of driving, weight of vehicles;
- environment, a relationship with kilometres per location and hour of driving, type and environmental class of HGV's, mode of transport;
- wear and tear, a relationship with the number of kilometres per location and hour of driving, type of vehicles, load factor, etc..

Changes in the external costs due to an HGV km-charge impact the revenues and costs of the actors involved and hence indirectly, or possibly also directly, the competitive position of the Netherlands.

Costs and benefits and competitive position of the Netherlands



The introduction of an HGV km-charge leads to social benefits and costs for specific groups and for the Netherlands as a whole. Consequently, the Netherlands' competitive position in relation to other countries may also change hypothetically. Moreover, changes to the competitive position can also impact the costs and benefits of carriers, shippers, the government and consumers.

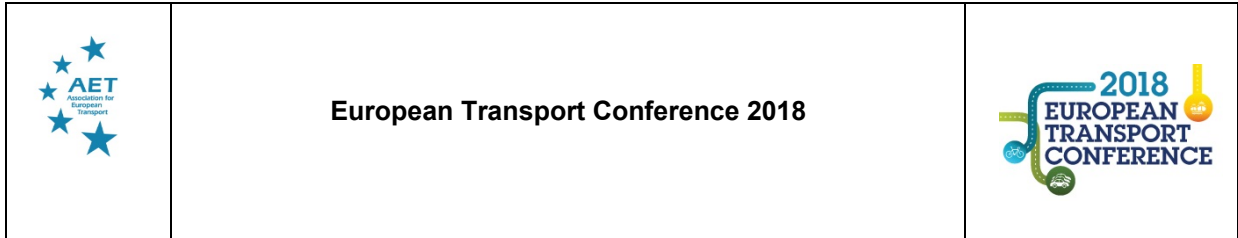
Relationship between the various output indicators

The impact of an HGV km-charge will vary according to the diverse physical traffic and transport indicators, such as absolute *weight lifted or transported weight*, road freight *tonne kilometres*, number of *HGV-trips*, and the *HGV-kilometres*. This is not easy to validate, however, especially because the impacts occur in different markets (traffic, transport, logistics and goods markets) as described. The ratios between these absolute physical indicators reveal something about the efficiency of the freight transport system, such as:

- the average transport distance, calculated as tonne kilometres/weight transported;
- the average load factor, calculated as tonne kilometres/HGV-kilometres or alternative weight transported/HGV-trips;
- the average trip distance, calculated as the HGV-kilometres/HGV-trips.

Generally, on the micro-level, the direct effect of higher costs per kilometre due to an HGV km-charge will lead to reductions in average transport and trip distances and to an increase in the average load factor. However, an opposite effect can also occur; for example, when a different transport mode, port or logistic chain is chosen, the road freight transport will shift to other modes over longer distances. Long-distance HGV-traffic is more sensitive to variable distance costs and hence is often conducted using larger HGV's with better loading factors. Consequently, the average load factor will be slightly lower due to a modal shift on the macro-level.

- The effect on the *weight transported* by road in tonnes is likely smaller than on the number of *HGV-trips* resulting from the use of larger HGV's and improved loading of HGV's. This effect will partly be compensated by a modal shift. Larger HGV's are often used on longer trips, which usually have higher loading factors. Especially for longer distances, other modes of transport, such as inland shipping and railways, are more competitive.
- The effect on the *tonne kilometres* by road is expected to be greater than on the *weight transported* by road. This is because the average distance over which the goods are transported decreases. The total weight transported by road remains the same, but it requires less kilometres. A carrier or driver who must pay an HGV km-charge will check whether they can complete the same trip in less kilometres by driving a shorter route. In addition, by buying or selling goods nearby, the average transport distance will also decrease.
- The effect on the number of *HGV-kilometres* is assumed to be greater than on the number of *HGV-trips*. This is comparable to the relationship between the



tonne kilometres and weight transported using a shorter route and by buying and selling nearby. In addition, as described above, the probability of a modal shift is higher for long distance HGV-trips. Consequently, the number of HGV-kilometres will also decrease relatively more than the number of HGV-trips.

- The number of *HGV-kilometres* will likely decrease more than the number of *tonne kilometres* by road. This is mainly due to an improved load factor, which results in fewer HGV-trips and therefore less HGV-kilometres for the same transport performance in terms of weight transported and tonne kilometres.

To summarise: an HGV km-charge is expected to have the greatest impact on the number of *HGV-kilometres*, followed by the number of *tonne kilometres* by road and the number of *HGV-trips*. The smallest impact will likely be on the *weight transported* by road in tonnes.

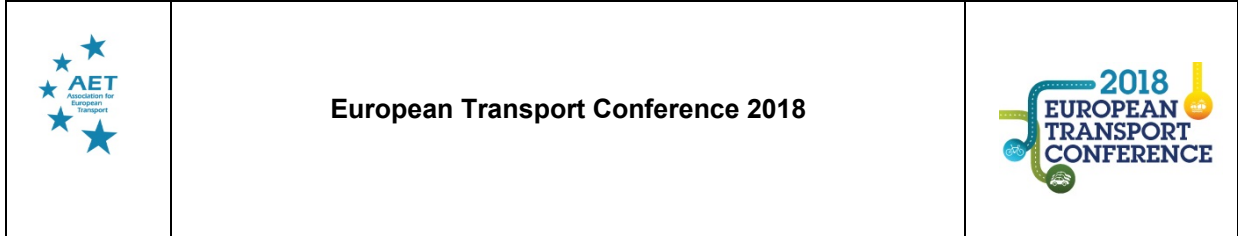
5. What can be assessed using BasGoed and LMS?

A model is a simplified representation of the real world and this can also be a model's strength. Concurrently, the main behavioural choices must be modelled, for if they are not, the model's results will be less realistic. The BasGoed freight transport model and the National Model System (LMS) are two strategic models used in the Netherlands on the national level to simulate the effects of policy measures. In this chapter we use previously derived insights to determine which potentially key behavioural effects of an HGV km-charge can or cannot be simulated using the BasGoed and LMS strategic models.

5.1 Key behavioural effects within the scope of BasGoed and LMS

At present BasGoed and LMS can be used to assess the following key behavioural responses to an HGV km-charge:

- *Modal split*: an HGV km-charge can render other modes, such as inland shipping and rail, more attractive. This is included within BasGoed.
- *Distribution structure*, from longer to shorter distances: the more expensive it becomes after the HGV km-charge's introduction to buy products from far away, the more products will be purchased locally. BasGoed uses the distribution module to simulate the effect of buying more products locally or from the producer's perspective: more local sales of products. It is assumed that the total supply and demand per region remains the same. Within BasGoed, no account is taken of a possible shift between domestic and foreign purchasing and sales as a result of an HGV km-charge.
- *Route choice*: an HGV km-charge on certain roads will lead to alternative route choices. LMS is suitable for simulating this on a national level.



- *Traffic and transport indicators:* using BasGoed and LMS, the effects of an HGV km-charge can be determined for various output indicators, including weight transported in tonnes, number of trips, tonne kilometres and vehicle kilometres. Additionally, insights can be provided into hours of delay and congestion.
- *External effects:* based on the BasGoed and LMS output indicators, - e.g. number of vehicle kilometres per network segment and key figures for emissions, noise, traffic safety and wear and tear, - the changes in external effects occurring as a result of an HGV km-charge can be estimated. A possible point of attention here is to what extent the effects can be differentiated into roads within built-up areas, where the external effects are likely greater due to the higher building density. Local roads are included in less detail within LMS than the main road network.

5.2 Key behavioural effects outside the scope of BasGoed and LMS

Various behavioural responses that may be of interest are outside the direct scope of BasGoed and LMS. This involves:

- *Logistic efficiency:* an HGV km-charge could in theory lead to higher efficiency: the bundling of goods flows through the increasing use of distribution centres, the use of more efficient vehicles, reductions in the number of empty return trips, and adjustments of shipment sizes. Changes in logistical efficiency fall outside the scope of BasGoed, outside the endogenously modelled behavioural effects. However, this could be taken into account by modifying the model input or editing the model output. Little is known about the extent of the possible logistical efficiency improvement.
- *Competitive position:* generally, little is known about the impact that an HGV km-charge would have on competition. However, the limited insights seem to indicate a very modest effect. BasGoed cannot determine such effects, because it is assumed that the total production and consumption of each region remains the same as the situation without an HGV km-charge. Examples of effects on the competitive position include:
 - *Between carriers:* an HGV km-charge could lead to small companies/carriers going bankrupt or being taken over, because they cannot pass on the cost increases to their customers. This is called company consolidation. The extent of this effect is unknown. In Belgium, the number of bankruptcies seems to have increased in the last two years mainly among small carriers/companies; however, it is difficult to inevitably attribute this increase to the HGV km-charge.
 - *Between ports:* an HGV km-charge can change the competitive position between ports if shippers decide to adjust their logistic chains and transport more products via foreign seaports. This effect is likely relatively small, however, because transport costs resulting from an HGV km-charge only increase partially and additional costs can be (partly) mitigated by 'simpler' behavioural changes, such as route choice and mode of transport choice.

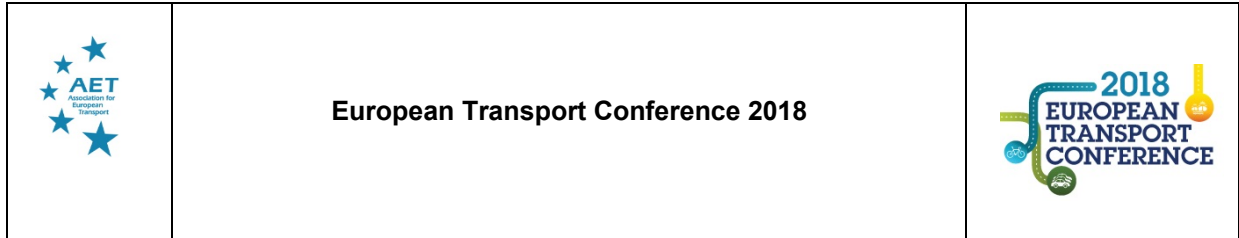
- *Between regions*: an HGV km-charge could be less favourable for peripheral (contraction) areas than for the Randstad (Amsterdam, Rotterdam, The Hague and Utrecht conurbation). The competitive position could deteriorate and (some) companies could relocate. Little is found in the literature pertaining to the spatial effects of cost price increases resulting from an HGV km-charge and the implications for the competitive position of regions. The extent of this effect is unknown.
- *Between countries*: The competitive position between countries can also change. In neighbouring countries, such as Germany and Belgium, an HGV km-charge has already been introduced. When such a tax is also introduced in the Netherlands, a level-playing field will (once again) have been created. This is therefore likely to impact the competitive position of the Netherlands.
- Consumer price increase: Various studies have shown that consumer prices are slightly higher due to an HGV km-charge.
- Drop in demand: Due to possible price increases, the consumption and therefore production of certain goods could also be reduced.

5.3 Summary overview

The table below summarises the various effects resulting from an HGV km-charge. Additionally, we examine the various forms of differentiation of an HGV km-charge. The middle column shows the expected size of the effect (+/-: small effect; +: average strong effect; ++: strong effect). The right column indicates whether a certain effect can be simulated using the BasGoed and/or LMS models.

Table 5.1: Summary of effects and link to BasGoed and LMS

Type of effect and/or differentiation	Direction and magnitude of effect	Simulation with LMS and/or BasGoed
Effects on traffic, transport and logistics		
• Route choice	+	Yes
• Modal split	+	Yes
• Distribution structure (buying/selling nearby)	+	Yes, partly
• Logistic efficiency	+	Not directly but indirectly using elasticities
External effects	+	Yes
Economics		
• Competitive position	+/-	No
• Product price	+/-	No
• Demand drop	+/-	No
HGV km-charge and differentiation possibilities		
• Charging level	++	Yes
• Location	++	Yes
• Time period (rush hour/night/other)	+	No
• Vans	+/- . In theory the effect is expected to be small but it depends on the specific market: kind of goods, distance, shipment size.	Not yet, a specific module is being build
• Emission class	+/- . Depending on the differentiation but it is expected to have little impact in 2023.	No
• Weight of number of axles of HGV	+/- . Depending on the differentiation but it is expected to have little impact on HGV fleet and on emissions.	No



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