INTELLIGENT ACCESS AND GEOFENCING
– CHALLENGES AND OPPORTUNITIES IN SWEDEN

Sten Wandel
Professor Emeritus in Engineering Logistics at Lund University, Sweden.
MBA from Stockholm University, M.Sc. in Electrical Engineering from KTH, Stockholm and Ph.D. in Industrial Engineering from Stanford University, USA

Thomas Asp
Working both as a head of a section at Swedish Transport Administration (STA) and as a project leader for the research program on High Capacity Transport at CLOSER/Lindholmen Science Park. M.Sc. in Civil Engineer from Chalmers, Gothenburg.

Abstract

The purpose is to report on news since HVTT15 regarding HCT (High Capacity Transport) in Sweden. The framework for HCT reforms in Sweden consists of four parts: roads, vehicles, operations, and legal framework as well as purpose, access schemes, and compliance assurance schemes. This can enable the use of all road sections at their maximum capacity and/or accelerate a shift to carbon free road freight by mandating a maximum CO2 emission per ton-km only for HCT vehicles.

In many countries HCT reforms have not been implemented despite that clear benefits to the society have been foreseen. In Sweden, benefits up to 13 times the cost of upgrading the infrastructure is expected if the maximum length is increased from 25.25 to 34.5 m. Therefore, barriers and drivers perceived by the most important stakeholders were identified and some strategies to mitigate these barriers were proposed.

Finally, an overview of ongoing HCT projects in Sweden is presented, focusing on HCT-City.

Keywords: Intelligent access, Geofencing, Connected vehicles, Telematics, High productivity vehicles, High capacity transport, Smart logistics, Infrastructure access, Pavement and bridge loading, Standards and regulations, Compliance and enforcement, Fleet management, Digital infrastructure, Satellite positioning, Environmental zones, Road use charging, Weight control, Decarbonization, and Green transport.

1. Background

Over the years, investments in infrastructures have made it possible to increase the sizes of vehicles without premature destruction of the infrastructure for all modes of transport resulting in lower energy demand, higher labour and capital productivity, and thereby lower transport cost. For example, in Sweden the maximum allowed gross weight for trucks for general access increased from around 3 tons 1920 to 64 tons 2015. For sea and air transport the increase in productivity has been even larger. Lower transport cost has enabled growth in trade which enabled specialization and economy of scale and thereby economic growth.
The concept High Capacity Transport, i.e. to permit larger trucks on dedicated roads than allowed for general access.

2. Framework for HCT reforms

In our literature review we found that most HCT reforms consist of the following four parts:

1. Roads, bridges, and streets adapted for allowing specific HCT vehicles
2. Performance and technical specifications of these specific HCT vehicles
3. Requirements on operating these specific HCT vehicles on specific HCT road network
4. A legal, institutional, and telematics framework for the above parts, including support to drivers and operators, monitoring of compliance, and sanctions for violations

In most cases this means that an operator can increase payload only if she accepts:

- Stricter vehicle specifications, e.g. PBS – Performance Based Standards
- Only drive on HCT approved road networks, for example with stronger bridges, longer turning lanes
- Stricter means for compliance assurance
- Legal framework, including stricter enforcement with sanctions

2.1. Purposes and impacts of HCT reforms

According to OECD/ITF 2019 and Asp 2019 many countries have implemented HCT and a reduction of CO2, cost, and infrastructure space by 15-50% on a vehicle level and 8-15% on a road freight systems level have been achieved, with the same or reduced wear and tear of the roads and number of accidents. A system analyses estimated expected benefits of introducing HCT vehicles in Sweden to be up to 13 times the cost of upgrading the infrastructure over a 40-year period (Pålsson 2017) and even higher if only the length and of the road train is increased from 25.25 m to 34.5 m while keeping the gross weight to 64 tons.

Urban Construction
42 ton GW
50% less CO2

Long Haul
80 ton GW
30% less CO2

Figure 1 - Typical HCT Vehicles, gross weight, and CO2 savings

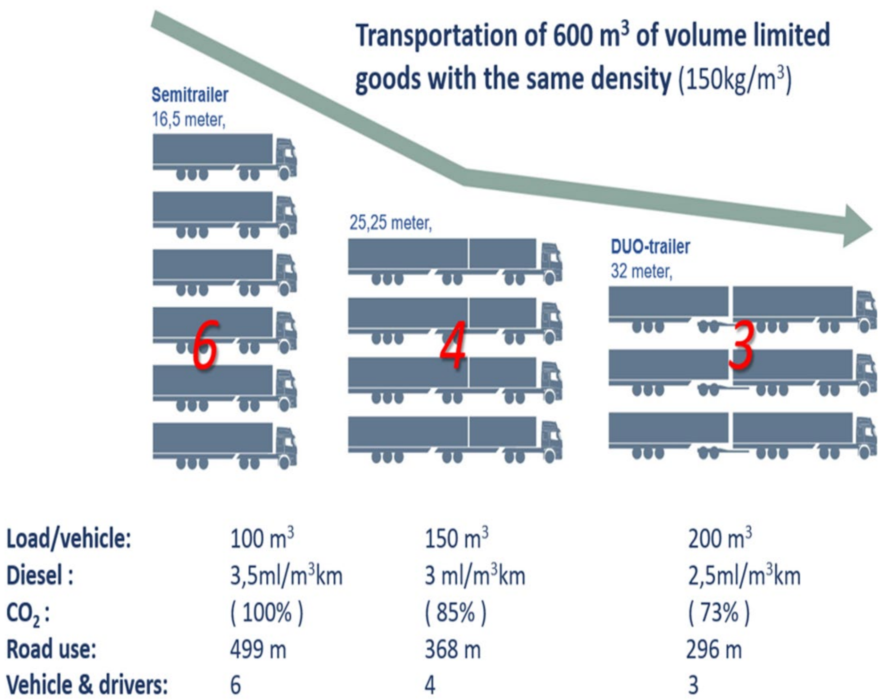
We found that deploying HCT reforms were expected to contribute to five groups of challenges shown in Table 1

Table 1 - Challenges were HCT can contribute

Challenges	HCT contribution
Climate, Emissions	Less energy/ton-km -> less CO2
Traffic, Lane space	Fewer trips -> less traffic
Accidents	Less traffic (vehicle-km) Stricter truck standard Better rule compliance
Road wear Bridge life	More axels & No overloads -> Lower axel loads
Productivity, Cost	Less drivers, trucks, lower energy consumption

The main driver for HCT reforms varies between countries and over time. According to our understanding there is a constant quest from transport buyers and operators for increased productivity, particularly in the forest and mining industries. The aim to use all road sections to their maximum capacity has been the major driver in Australia, Canada, South America, Sweden, and Finland. While reduction of accidents has been important for South Africa, reduction of congestion and road ware have been important for the Netherlands and most European countries, and reduction in road wear and increased productivity have been the aim in New Zealand. Reduction in fuel consumption and thereby impact on climate change has been measured in most pilots and used as an argument, probably for being politically correct, while the real agenda has been lower cost. In the resent years, the emerging climate crises calls for radical and fast reduction in CO2 emissions. An accelerated shift to carbon free road freight could be accomplished by mandating a graduate reduction of CO2 emission per ton-km for accepting HCT vehicles. For example, replacing single trailer with double trailer combinations will reduce cost with about 30%. This cost savings can be shared by involved stakeholders to stimulate a fast shift to electrical power trains without subsidies from taxpayers and as a bonus a reduction in road space by 40% as shown in figure 2.

Figure 2 - Performance of three different vehicle combinations



In a study in Finland (Liimatainen et al. 2020) estimated the benefits of increasing the maximal gross weight from 60 to 76 ton that was implemented 2013 to be 3 times the cost over a 20-year period based on time series data from 2013 to 2017. On average 79% of ton-km with over 60 tons vehicles had used at least some of the extra capacity provided by the new regulation in 2017. However, only four commodities out of 20 had a larger share than the average 46%. These commodities were forestry (91%), mining and quarrying (64%), chemical products (51%), and coke and petroleum products (61%). This resulted in about 3% less CO2 emissions from trucking in Finland after taking to account a small modal shift from rail to road

2.2. Access schemes for HCT vehicles

In the road map for HCT implementation in Sweden (CLOSER 2019), which is based on (Asp, Åkesson and Wandel 2019), which is an update of the first HCT road map (Kyster-Hansen, et al. 2013).the following access schemes for HCT are proposed:

A. **New road class**: on a limited appointed road network for a specific class of HCT vehicles. E.g. BK4 with max 74 tons/25.25 m was introduced 2018 in Sweden in addition to BK 1-3. Finland does not yet have different bearing capacity classes, but Norway and Australia have more than the four in Sweden.
B. **Permanent permit**: specific type of HCT vehicles on specific dedicated roads for an extended period. E.g. PBS certified vehicles for transport of ore.
C. **Time limited permit**: Specific vehicle individuals on specified roads during a limited time period. E.g. for research purpose, temporary construction site, forest harvesting every 50 years, and waiting for a road or bridge to be strengthened.
D. **Situation adapted permanent permit or restriction:** Dynamically adjusted to changed conditions. E.g. more loads when frozen and less loads when wet road body, shift from diesel to electric power train when entering an environmental zone, type of goods, speed over vulnerable infrastructure; at road works; and in pedestrian zones.
E. **Permit for one specific trip:** non-divisible goods, heavy mobile cranes, and detour if accident or road works.

Following the HCT reform to open up a dedicated new class of roads for up to 74 ton/25.25 m on July 1, 2018 the HCT research has focused on the next foreseen reform, a dedicated road network for 64 ton/34.5 m to allow for two EU-trailers following the prime mover. The proposal for that reform, without requiring Intelligent Tillträde och Kontroll (ITK, Intelligent Access and Control), was delivered by the Swedish Transport Administration to the Government in April 2019 but over two years later the Government had still not proposed a reform to the Parliament or taken any other decision towards a reform allowing longer vehicle combinations, similar to the 34.5 m reform in Finland that was introduced in January 2019.

Research was also done to promote combining road HCT with other transport modes to make these modes more competitive and to considerably reduce the CO2 from the whole logistics system. Still there are some stake holders that have concerns about safety, despite that most research has indicated that HCT will make the roads safer. Therefore, investigations are underway with regards the impact on safety of more HCT vehicles, especially on non-divided roads.

2.4. Compliance Assurance Scheme

Recent studies (ITF 2017, ITF 2018 and ITF 2019) indicate that HCT adoption in most countries is not happening despite the fact that clear benefits to the society have been proven, e.g. in (Pålsson et al 2017). They recommend using ITS technologies, including vehicle tracking, route planning, and geofencing to ensure political and public acceptability and minimise costly infrastructure upgrades (Aronietis and Voege 2018), which is in line with observations by Moore, Regehr and Rempel (2014), that most HCT reforms have required additional compliance mechanisms over and above the requirements for vehicles under general access regimes.

Hence, it is important to get an overview of what compliance mechanisms are used and how well they perform. Which one to choose depends mainly on the risks involved, the perceived barriers, and the thrust required, and thereby the level of assurance needed. Higher assurance level is however more expensive. In Australia the monitoring schemes (TCA 2020) offered within their National Telematics Framework are classified into three assurance levels (TCA 2018).

Most vehicles have GPS and Internet connection via mobile network installed from the factory and the rest can easily be retrofitted. Australia introduced IAP (Intelligent Access Program) 2003 for school busses in Tasmania and 2009 for HCV (TCA 2020), Estonia started experimenting with VELUB 2010 (Tönts 2018), and Sweden has developed and tested prototypes of ITK (Intelligent Access Control) for HCV and geofencing for busses and lately also for trucks in pilots. All these systems are based on already installed fleet-management systems, where authorities get access to data for compliance checking.

In this paper we suggest the following classification of means for managing and controlling compliance:

1. Self-regulation schemes, e.g. the Road Transport Management System (RTMS) for PBS permits in South Africa.
2. Traditional monitoring means with fixed weight stations, Bridge WIM (Weigh In Motion), and inspections at the roadside. These means could not be extended in Sweden since there is a shortage of policemen and too costly. Hence, automatic, and digital options are called for. Data from Bridge WIM show that some years ago over 30% of the loaded vehicles were overloaded with more than 3 tons, and 40% drove faster than the speed limit of 80 km/h. The share of overloaded sank to 15% but have in the last years increased to over 20%.
3. Driver support & warning, e.g. geofencing and as in Finland mandatory display of actual axel loads in the driver cabin.
4. Report position and weight data without IDs only for statistical purposes, e.g. RIM in Australia, VELUB in Estonia, and ITK-statistics in Sweden. TCA assurance level 1.
5. Report position and weight data with IDs. Combined with other data sources independent audit of operators with high risk scores are performed, e.g. ITK1.0 in Sweden, TMA in Australia and tachograph audits in EU. TCA assurance level 2.
6. Independent certification of on-board equipment and oversight of telematics provider with 100% audit using non-compliance reporting afterwards where the data is valid in court, e.g. IAP in Australia. TCA assurance level 3.
7. The speed of the vehicle is reduced, or the vehicle is forced to stop when dangerous violation of access rules occurs.

2 is the most common one but very labor intensive, expensive, and easy to bribe
3-7 are often called Intelligent or Smart Access Schemes.

Another way of classifying compliance management is by who acts: the vehicle itself (7 above), the driver, the operator (1 above), the transport buyer, the road manager (4 above) or the enforcement agency (5-6 above). One or more of these control loops can be combined with one or more of the compliance mechanisms above. It is often recommended that the contracts between the driver, the operator and the transport buyers include incentives and monitoring to encourage compliance. This practice has been stimulated by the introduction of stricter chain of responsibility legislation in many countries.

2.5. Combining an HCT Access Scheme with a Compliance Assurance Scheme

All HCT reforms and access schemes have so far mandated some extra means for compliance assurance to avoid accidents and road damages. This can be illustrated in a matrix with access schemes on one axel and compliance assurance schemes on the other.

Some examples:

a. PBS (B) permits in South Africa requires RTMS (compliance #1)
b. Temporal permit (C) to take more loads when moving earth and rocks when building the subway under Sydney in Australia requires RIM (#4).
c. Stopping a vehicle (#7) entering a pedestrian zone (E) or even a sidewalk was demonstrated in Stockholm in 2018 as a policy response to the terrorist attack killing five the year before. Now that active speed control system, an application of geofencing, is used for busses to allow them to drive with reduced speed over a vulnerable bridge in Gothenburg and in several other use cases.

3. Barriers and drivers for compliance assurance schemes by stakeholder

The ITK access and monitoring system, presented in Wandel and Asp 2018, was proposed by the Swedish Transport Administration to the Government to be mandatory for trucks larger than the 64 ton/25.25 m currently allowed on most roads. However, in 2018 the government launched a dedicated road system for 74 ton/25.25 m trucks, without any monitoring requirements. To understand why ITK not was implemented we identified, in a series of workshops and interviews, the barriers and drivers perceived by the most important stakeholders, as summarized in Table 2.

Table 2 - Barriers and drivers for ITK for different stakeholders.

Stakeholder	Barriers	Drivers
Transport Buyer	**Higher transport prices** since less cheating	**Lower transport prices** if more HCT due to ITK Less risk for sanctions due to cheating operators
Operator	Buy ITK serv. €20/month, Administration 1 h/week **Higher cost** since no overloads, illegal routes, speeding, or illegal vehicle modules	Less risk for sanction for overloads Less accidents Always full loads **Larger HCT network** if lower safety factors for bridges

Driver	Time to key in data More difficult to cheat with the tachograph and with speeding	Warning if noncompliance **Not forced by customers to break laws** Fewer inspection stops Less risk for sanctions Prove innocence if in an accident
Telematic Industry	Costly to develop ITK service only for Sweden	Sell ITK and other services on the same platform
Vehicle Industry	Cost to adapt vehicles to ITK On board weight systems are expensive **Not incriminate customers**	Extended vehicle business model Better international competitiveness More export
Police	At roadside inspection, an additional item to check but **no budget**	Inspections: Faster, Fewer, Risk based
Transport Agency	Request and analyse ITK & Tachograph data More work but **no additional budget**	Less job if automatic non-compliance reports direct to court as in Australia
Vehicle Register	Develop & operate the database **Problem with foreign vehicles**	Can better assure all vehicles combinations on the roads are safe
Road Owner	Cost to update maps in real time with all restrictions on weight, length, speed, time, detour etc Cost to develop & operate statistics and analyses	**Less infrastructure damages** Lower safety factor for bridges allows for larger HCT network Better statistics for maintenance Situation Specific Access
Society	Cost to develop telematics infrastructure and services covering all locations	Level playing field. Fair transport. Safety. **Thrust. Assurance** drivers follow regulations Platform for other reforms
Government	Too complicated. **Risk not compliant with EU 96/53.** Many stakeholders & voters against.	**First step to a Telematics Framework** for all road users for: geofencing, environment zones, antiterror, road pricing, speed control,

Based on these strategies to overcome the barriers were developed and partly implemented. We noticed that these barriers and drivers were quite different from the barriers and drivers for allowing High Capacity Vehicles (HCV) in Sweden, and that ITK lowered some of the barriers against HCVs. We expect that barriers and drivers are situation specific and hence each country has to do its own investigation.

4. Projects in Sweden that include intelligent access for HCV

4.1. Overview of ongoing projects in Sweden

1. Joined forces with the EU project (AEROFLEX., 2021) and ACEA (European car manufacturers) to make the EU commission aware of the need to change the legal framework to be more flexible to allow high capacity vehicles (ACEA 2019)
2. Completed the detailed specifications for the ITK statistical service. Data from the ITK back-end servers, where all IDs have been removed, are sent to the Transport Administration that uses the data for statistics to improve infrastructure maintenance management, and to evaluate regulatory compliance, without being able to identify and sanction individual drivers or operators.
3. Started a project, called Digi-Disp, to adapt and implement the ITK-system for monitoring over-size transport with indivisible loads and mobile cranes that operates with permits. This application of ITK is expected to be met with lower resistance and will require far less amendments to the laws and regulations than ITK for a new class of roads.
4. Participated in the Nordic way projects 1, 2 and now 3.(Nordic way, 2021) This EU project focuses on the digital ecosystem and several geofencing concepts regarding trucks are being tested.

5. Joined the governmental geofencing commission. This was set up after the terrorist attack in Stockholm in 2017. The terrorist stole a truck and drove it at high speed in a pedestrian only street in Stockholm killing five persons. Similar attacks using vehicles as a weapon have taken place in several cities in Europe. A whole set of new tools are being developed to control vehicles, e.g. automatically manage speed with both engine power and brakes and even stop when entering a pedestrian zone, distance keeping, lane control, advanced sensors, driver assistance, and switching from diesel to electric engine when entering an environmental zone, a tunnel or at night.
6. Following the deployment of new policy instruments as Urban Vehicle Access Regulations (UVAR) (Ricci, A. et al 2017) and Sustainable Mobility Plans (SUMP). The EU-commission now urges for including the freight dimension to a larger extent. (ReVeAL, 2021 and ELTIS, 2021). Since the first and/or last mile and sometimes the whole HCT trip is in urban areas, HCT reforms must adapt.
7. Started the project HCT-City regarding issuing permits and monitoring compliance of HCT for transport of excavated materials to/from construction sites in urban areas.

4.2. The HCT - City project

Roughly 25% of all heavy goods transports in cities are excavated material from housing or infrastructure projects. Earlier research (Triber and Bark 2016 and Triber and Bark 2018) shows that CO2 could be reduced by 40% and the number of trucks can be reduced by 50% if the HCT-concept is adapted to be used also in cities. In urban areas there are also more issues to consider than on highways, e.g. noise in residential areas, emissions of particles and NOX, safety of pedestrians and cyclists, rush hour traffic, vibrations that destroy pipes under the streets, sharp corners, and narrow streets. This calls for other regulations for operations and other performance and technical specifications for the HCT vehicles compared with HCT for highways. As part of the project two new urban truck designs will be tested and evaluated. Two test sites,

- Varberg: digging a 3,6 km tunnel and 2 km open trough for a railway
- Stockholm, N. Djurgårdsstaden: excavation to make room for a new residential area

In contrast to most previous research on HCT, the impact on the performance and productivity for the whole construction site is studied, not only on moving masses from A to B. E.g. switch to HCT may change the daily schedules and synchronisation between blowing the rock, excavator and truck operations, which may result in increased or decreased waiting times and overall productivity.

The access scheme D above will be used, and several different compliance assurance schemes described above will be tested as well as new tools from the geofencing toolbox. This requires additions to the IT architecture for ITK described in Wandel, Asp 2018 as depicted in Figure 3. The system uses already installed fleet, excavation, and construction management systems. The on-board truck computer registers GPS position, axel loads, fuel consumption and provide driver support and communicates with a server at the telematics service provider. Data can be made available, based on agreements, also for driver, operator, transport buyer, and road owner. Two FMS standard interfaces developed by ACEA are used. Since the telematic systems are already in place in all vehicles sold the last 7 years, the extra cost is less than 20 € per month. Older vehicles can be retrofitted with a "dong". In addition, also most construction equipment using the AEMP standard, weight-in-motion sensors in bridges and in the pavement at entrances, as well as noise and vibration sensors will be used to collect data that is reported to the "cloud".

The project will try to answer several research questions, e.g.:

- Impact on vulnerable infrastructure of specific HCV and their operation, e.g. speed and load
- What level of compliance assurance the local municipalities will require to allow a specific type of HCV and operation?
- How to digitalize the essential process? Needs for standards?

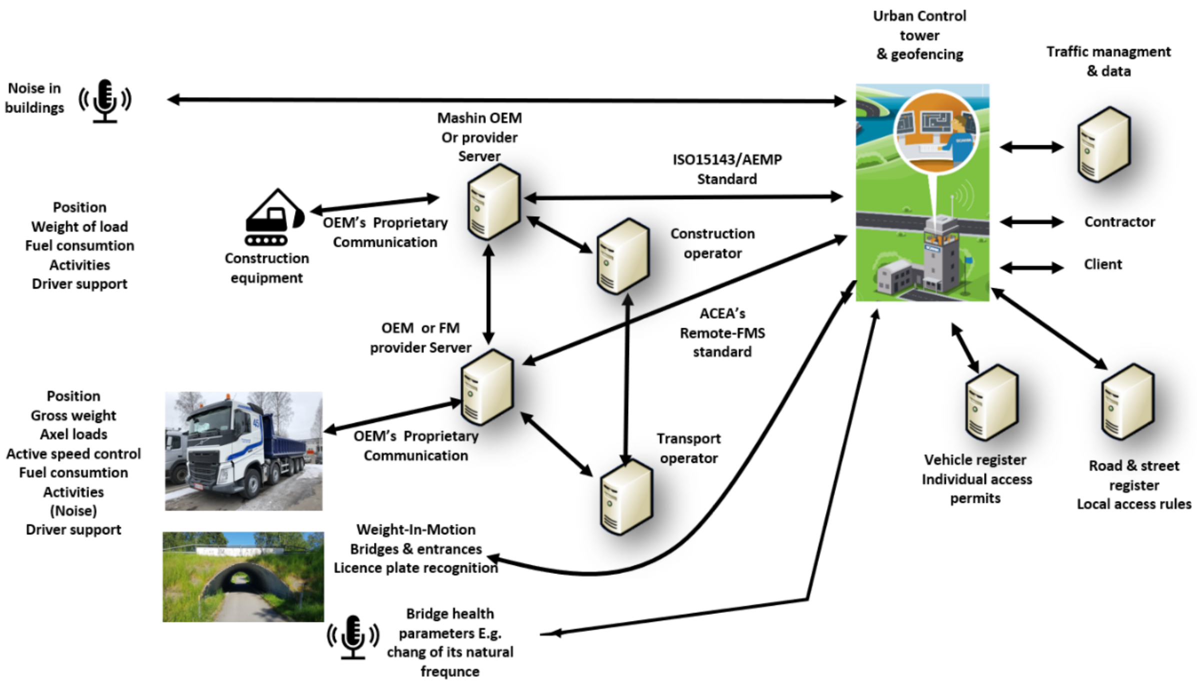


Figure 3 - Suggested IT architecture for HCT- City project

5. Discussion and conclusion

We will try to consider and implement the emerging new business models for data collection and sharing reported in Vejo, 2021 and at TCA, 2021, where data is collected from many different sources and sensors, not only from the truck, and then analysed using big data and AI tolls to provide information for decisions by an array of stakeholders. The ownership and sharing of data era essential legal issues that must be resolved.

HCT with Intelligent Access means differentiated, dynamic and intelligent access to roads based on e.g. weight, length, load type, engine, noise, fuel, emissions, time, speed, place, road condition or weather. The telematic set up can preferable also be used for differentiated road charging for even better allocation of limited capacity and generate finance for maintenance and capacity expansion. In this way ultimately all road sections can be used to their maximum capacity without causing premature brake down of the road construction or increased accidents.

HCT reduce costs. Other things equal, this may lead to lower prices for road transport which in its turn tend to result in additional freight demand, yet the effect is likely to offset only a small part of environmental (Pålsson 2017, Liimatainen 2020). Where there is head-to-head competition, HCVs will enjoy a greater advantage over competing modes than standard trucks. However, positive impacts on rail freight have also been observed in intermodal markets, as HCVs can extend the reach of rail services and serve as backup when the train is full, goods arrive late, or the rail operation gets delayed. Such intermodal operations generally require innovative business models and contracts between all parties to be successful. (Berling, Eng-Larsson, 2017). Additional research on intermodal freight, where trucks both at the ends and parallel are an essential component, and related policies are needed.

It has become more and more clear that all four parts of the HCT policy concept are needed and that intelligent access is necessary but not sufficient to overcome all barriers. Additional policy tools are needed to get all stakeholders on board.

HCT has the potential to reduce CO2 with up to 33% by allowing 34.5 m road trains while keeping the current engines and fuel. This reform can be implemented in the next couple of years which is much faster that most alternative actions to reduce carbon emissions from freight. However, this is not enough to reduce CO2 with 70% by 2030 as the Swedish parliament has decided.

One suggestion is to stipulate a maximal allowed CO2 emissions per ton-km in the performance and technical specifications for the 34.5 m road trains and that this maximum is lowered each year ahead the operator gets a strong incentive to invest in clean power trains as electric engines with batteries or with fuel cells and a hydrogen tank. The cost for an EMS2 (one prime mower with two trailers) is about 30% less compared to the standard work horse (one prime mover with one trailer) if internal combustion engine is used. These cost saving could be shared among the stake holders. For example, the operator keeps 15% to compensate for the extra cost to buy and operate the low emission vehicle, the road owner gets 10% to finance the necessary adaption of the infrastructure including electric and/or hydrogen infrastructure, and the government gets 5% to compensate for less taxes from fossil fuels and for subsidies to shift from road to rail and water transport. As an extra benefit EMS2 vehicle uses 40% less road space and wear the road less compared to single trailer vehicles, which means less time lost due to congestions and it enables postponement of investment in new road capacity and road maintenance. All this can be achieved at no cost to the taxpayers and all stakeholders will gain something on such reform, which reduces blockages and barrier for its introduction.

Bundling of CO2 strategies with Intelligent Access and HCT in the same reform package has a very high potential to accelerate a shift away from combustion engines and implement new innovations. Such decarbonization measure can quickly be scaled up after a few short pilots to find the proper mix of policy instruments, suitable parameters for different contexts, and evolution of parameters over time.

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