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Low carbon smart mobility & green logistics

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Low carbon smart mobility & green logistics

[Älyliikenteen keinot kasvihuonepäästöjen hillitsemiseksi]. **Juho Kostiainen.** Espoo 2012. VTT Technology 39. 34 p. + app. 3 p.

Abstract

This review is intended as an overview of European and Finnish targets for greenhouse gas emissions from transport and logistics, and of performed and proposed measures for achieving these targets through intelligent transport systems (ITS).

It was found that the impacts of different solutions are evaluated by expert estimates or models but seldom measured directly. The reason for the use of estimates is mainly the difficulty of differentiating one source from an overall change in emissions.

The impact of ITS usually arises from increased usage of public transportation (decreased use of private vehicles), reduced congestion (improved traffic flow and alternative routing), and improved eco-driving (automatic solutions or information based on analysis, such as speed suggestions).

The influence of ITS is, typically, realized more from being an enhancing tool rather than a complete solution. The use of ITS does help in reducing emissions. However, other measures such as technological advances in fuel efficiency, alternative energy, regulatory and financial guidance and more well-planned land use may be more direct and powerful. Combining ITS and ICT with the abovementioned alternatives is recommended.

Avainsanat ITS, greenhouse gas emissions, ICT, transport, logistics

Liikenteen ja logistiikan kasvihuonekaasupäästöt

[Low carbon smart mobility & green logistics]. **Juho Kostiainen.** Espoo 2012.
VTT Technology 39. 34 s. + liitt. 3 s.

Tiivistelmä

Tämän katselmuksen tarkoitus on luoda yleiskuva Euroopan ja Suomen asettamista tavoitteista liikenteen ja logistiikan kasvihuonekaasupäästöille ja esitellä näiden tavoitteiden saavuttamiseksi toteutettuja sekä ehdotettuja älykkään liikenteen (Intelligent Transport Systems, ITS) keinoja.

Katselmus esittää olennaiset kasvihuonekaasupäästötavoitteet ja esimerkkejä toteutetuista ITS-pohjaisista ratkaisuista sekä niiden arvioidut vaikutukset. Myös ehdotettuja menetelmiä ja niiden vaikutusarvioita ja -ennusteita esitetään.

Eri ratkaisujen vaikutukset ilmaistaan useimmiten joko asiantuntija-arvioihin tai malleihin pohjautuen ja vain harvoin suoraan mitattuina tuloksina. Arvioiden käyttö johtuu lähinnä vaikeudesta erottaa yhden ratkaisun osuus päästöissä tapahtuneesta kokonaismuutoksesta.

ITS:n keinot pohjautuvat usein kasvaneeseen julkisen liikenteen osuuteen (henkilöautojen käytön vähentyminen), ruuhkien vähentymiseen (sujuvampi liikenne ja vaihtoehtoiset reittiratkaisut) sekä edistyneempään eko-ajamiseen (automaattiset ratkaisut vai analysointiin pohjautuva informointi, kuten nopeussuositukset).

ITS-keinojen vaikutukset ovat tyypillisesti ennemmin tehostavana työkaluna toimimista kuin selkeä ratkaisu yksinään. ITS:n hyödyntämisellä on selvä vaikutus päästöjen vähentämisessä. Muut keinot, kuten polttoainetehokkuuden kehitys, vaihtoehtoiset energiamuodot, taloudelliset ja määräykselliset ohjauskeinot ja tehokas maankäyttö, voivat olla suoraviivaisempia ja tehokkaampia ratkaisuja. Älykkään liikenteen ja tietotekniikan hyödyntäminen yhdessä edellä mainittujen keinojen kanssa on suositeltavaa.

Avainsanat ITS, greenhouse gas emissions, ICT, transport, logistics

Contents

1. Context and background

Transport is the second largest source of greenhouse gas (GHG) emissions, just behind energy, producing more than a fifth of GHG emissions in the EU (European Environment Agency, 2011b; International Transport Forum, 2010). In Finland, for example, transportation has been responsible for 18–20% of the total GHG emissions each year between 2005 and 2010 (Statistics Finland, 2012). This review was done in order to report the impacts of different actions taken to reduce the GHG emissions from transport and logistics and to analyse how the effectiveness of these actions have been assessed. Special emphasis is placed on actions associated with intelligent transport systems (ITS) and utilization of information and communications technology (ICT).

First the background is provided, then the scope of this review and methods applied are defined (Ch. 1.1 and 1.2). The European and Finnish GHG emission reduction targets are listed in Chapter 2. Chapter 3 provides examples and results of attempts to reduce emissions by use of ITS. Proposed ITS-based solutions, along with their estimated impacts, are presented in Chapter 4. In Chapter 5 the results are summarized and analysed. Finally, Chapter 6 presents the conclusions of this review and offers several recommendations.

1.1 Background

The most significant factor in the amount of emissions from transport is the quantity of traffic. Other components, such as mode of transportation, fuel type, fuel efficiency, route efficiency, and idling time, define the amount of emissions per distance travelled. An interpretation by the International Transport Forum illustrates how transport emissions are composed in Figure 1.

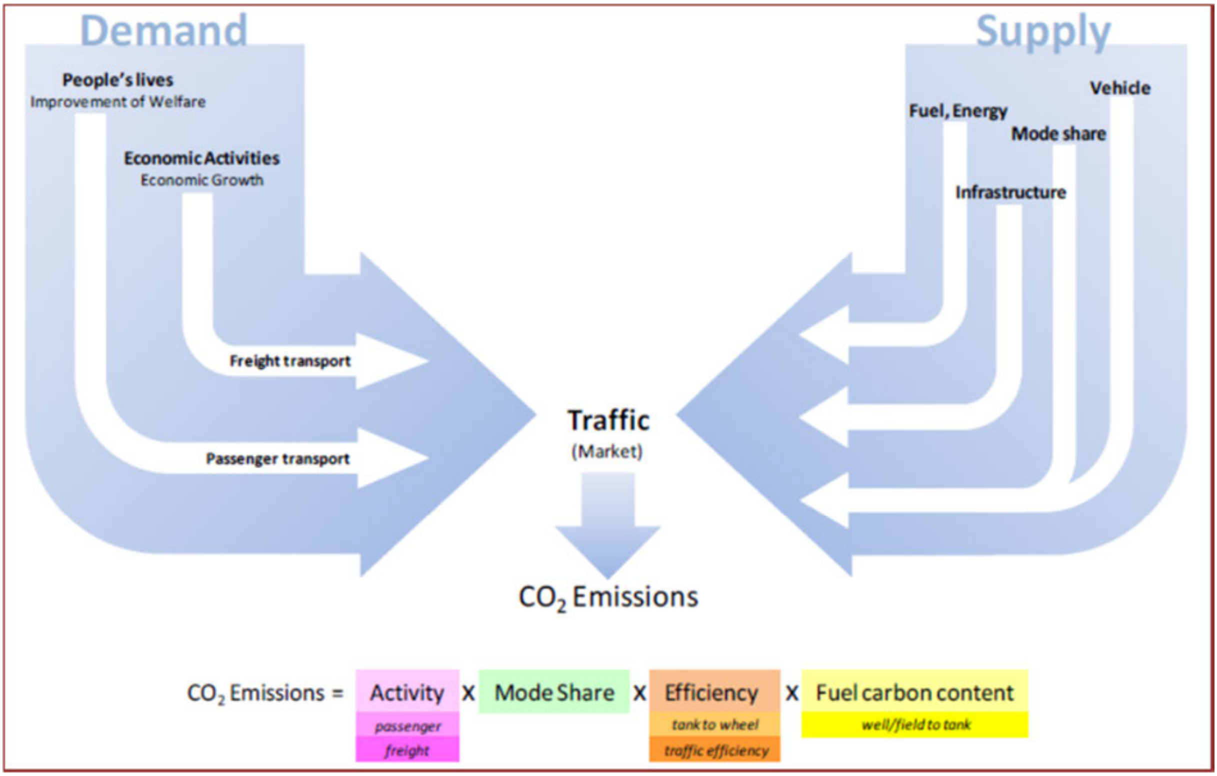

Figure 1. An evaluation framework for addressing transport emissions (International transport forum, 2009).

Of the total inland freight transport in EU-27[1] in 2009, 77.5% was over road and 16.5% over rail (Eurostat, 2011a). In 2008, in EU-27, passenger cars accounted for 83.3%, buses and coaches for 9.4% and rail transport for 7.3% of inland passenger transport (Eurostat, 2011b). Being by far the most used mode of transport, road transportation accounts for over 70% of transport GHG emissions, as shown in Figure 2. Railways, on the other hand, account for significantly lower emissions in relation to their use (although indirect emissions from electricity consumption are not taken into account in Figure 2).

[1] EU-27 Countries: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:EU-27

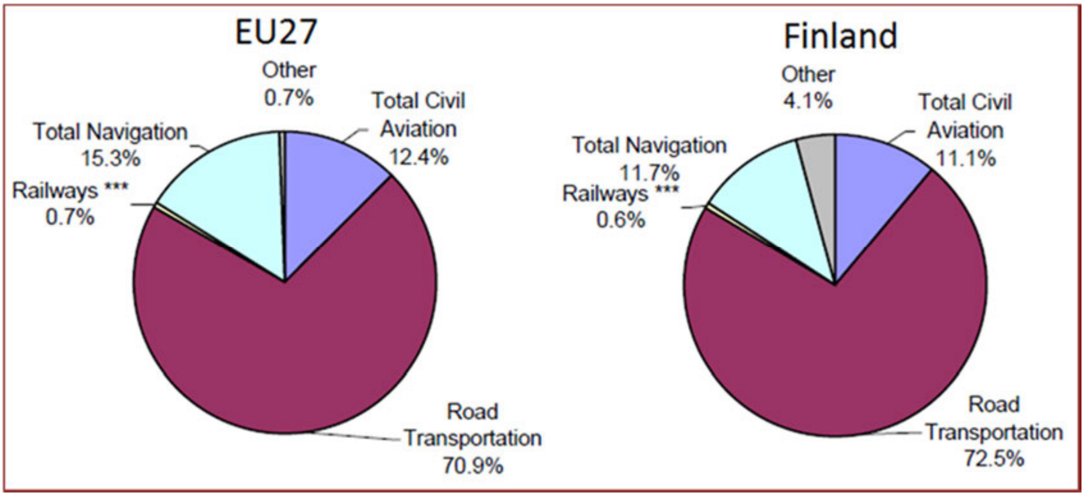

Figure 2. Total transport GHG emissions in 2007 by mode (European Commission, 2010).

Not only is the mode relevant in considering transport emissions, but also the type within that mode plays an important role. The use of public transportation is highly encouraged as the emissions per person are significantly lower compared to using a personal vehicle, as illustrated in Figure 3.

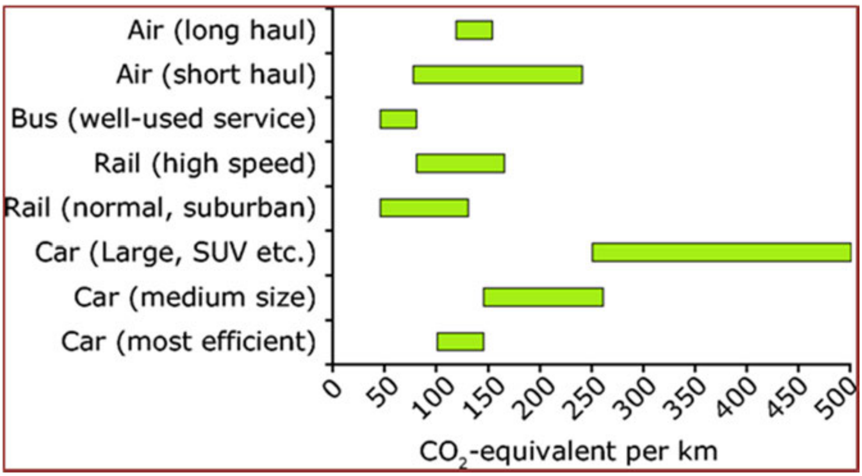

Figure 3. Approximate greenhouse gas emissions across different modes of transportation (European Environment Agency, 2008).

The European Commission's White Paper states developing new transport models that make the most of combining the most efficient modes of transport in transporting large amounts of goods and passengers as one of the important goals for a competitive and sustainable transport system (European Commission, 2011b). The use of ICT is highlighted as a key factor in enabling simpler and more reliable transitions. Shifting transport from roads to other modes will reduce congestion and, therefore, GHG emissions. Intelligent transport and logistics solutions and services can – and are expected to – take advantage of data, such as traffic flow, interruptions and conditions, to provide valuable information in new ways (Ministry of Transport and Communications Finland, 2012).

1.2 Scope and method of the study

Technical improvements on vehicle efficiency, fuel consumption and fuel efficiency are widely researched and very important for reducing GHG emissions. The fuel efficiency of passenger car transport is considered the main reason for CO_2 emission decrease in road transport since 1995 (European Environment Agency, 2011c).

The impact of, for example, electric vehicles is significant. Trials and studies have found replacing gasoline vehicles with electric vehicles to reduce GHG emissions by at least 25–40% (Zulkarnain;Leviäkangas;Tarkiainen;& Kivento, 2012).This review, however, is focused on the effects of utilizing ITS to reduce GHG emissions from transport and logistics. Other means of improving environmental friendliness (such as fuel efficiency and alternative energy, aerodynamics, tyre friction, and so on) are, therefore, excluded.

Different modes of transportation are reviewed in terms of their varying emission targets and solutions. The most relevant set of carbon emission targets are listed in this research. Different implemented solutions are then gathered with their results and assessment presented. Based on the results of measures taken and expert estimates and recommendations, conclusions and recommendations are formed.

2. Greenhouse gas emissions reduction targets

2.1 European targets

The European Environment Agency (EEA) presented a concise list of concrete GHG emission reduction targets for transport up to 2050 in a 2011 report (European Environment Agency, 2011a), based mostly on the European Commission's policies and regulations, such as the White Paper[2]. We expanded this list to have a more comprehensive set of European targets. The revised target lists, categorized by mode of transportation, are shown in the tables below. The relevant TERM indicators (cf. 2.3) for the targets, when listed, are defined by the European Environment Agency.

Table 1. European targets for reducing GHG emissions from transportation – general.

Greenhouse gas emission target	Target year	Indicator (cf. 2.3)	Source
GHG emissions in transport sector: 20% compared to 2008 60% compared to 1990	 2030 2050	TERM 002	(European Commission, 2011b)
Major urban centre city logistics to be CO_2-free	2030		(European Commission, 2011b)
Renewable energy to have a 10% share in transport in each state	2020	TERM 031	(European Commission, 2009b)

[2] *White Paper* is an authoritative report by the European Commission that provides a roadmap for a single European transport area and defines environmental targets (European Commission, 2011b).

Table 2. European targets for reducing GHG emissions from transportation – roads.

Greenhouse gas emission target	Target year	Indicator (cf. 2.3)	Source
Share of conventionally fuelled cars in urban transport: 50% 100%	 2030 2050	TERM 034	(European Commission, 2011b)
Modal shift for long distance (> 300 km) road freight to rail/water: 30% shift 50% shift	 2030 2050	TERM 013a/b	(European Commission, 2011b)
Road transport fuel life-cycle GHG emissions to be reduced by 6–10% (compared to 2010 fossil fuels) by fuel suppliers	2020	TERM 031	(European Commission, 2009c)
Type-approval emission average for new passenger cars (percentage of new cars by each manufacturer to take into account): 130 g CO_2/km (65%) 130 g CO_2/km (75%) 130 g CO_2/km (80%) 130 g CO_2/km (100%) 95 g CO_2/km (100%)	 2012 2013 2014 2015– 2020	TERM 027 and TERM 034	(European Commission, 2009)
Type-approval emission average for new light commercial vehicles (percentage of new vehicles by each manufacturer to take into account): 175 g CO_2/km (70%) 175 g CO_2/km (75%) 175 g CO_2/km (80%) 175 g CO_2/km (100%) 147 g CO_2/km (70%)	 2014 2015 2016 2017– 2020	TERM 027 and TERM 034	(European Commission, 2011c)
Increased efficiency (including fuels) for long-distance trucks (compared to 2011): + 20% tonne-km/g CO_2 + 45% tonne-km/g CO_2 + 60% tonne-km/g CO_2	 2015 2020 2025		(European Commission, 2011a)
Transport efficiency – load factors: 65% 75% 85%	 2015 2020 2025		(European Commission, 2011a)
Carbon emissions from transport and logistics: 230 million tonnes 200 million tonnes 162 million tonnes	 2015 2020 2025		(European Commission, 2011a)

Table 3. European targets for reducing GHG emissions from transportation – waterways.

Greenhouse gas emission target	Target year	Indicator (cf. 2.3)	Source
Reduction of 40% in CO_2 emissions of maritime bunker fuels in the EU (compared to 2005)	2050	TERM 002	(European Commission, 2011b)
Improved efficiency for new maritime ships. Reduction factor compared to Energy Efficiency Design Index (EEDI) reference line (lower for smaller ships, cf. source) 10 15–20 30	 2015 2020 2025		(International Maritime Organization, 2011)

Table 4. European targets for reducing GHG emissions from transportation – aviation.

Greenhouse gas emission target	Target year	Indicator (cf. 2.3)	Source
Share of 40% for low carbon sustainable fuels in aviation	2050	TERM 031	(European Commission, 2011b)
CO_2 emission cap (under the EU Emission Trading Scheme (EU ETS)) compared to the average in 2004–2006: 97% 95%	 2012 –2020		(International Emissions Trading Association, 2012)
Cap on CO_2 emissions: Carbon-neutral growth	2020		(International Air Transport Association, 2009)
Average annual fuel efficiency improvement of 1.5%, starting from 2009	2020		(International Air Transport Association, 2009)
CO_2 emissions reduced by 50% compared to 2005	2050		(International Air Transport Association, 2009)
Fuel consumption and CO_2 emissions reduced by 50% per passenger kilometre (compared to 2000)	2020		(Advisory Council for Aeronautics Research in Europe, 2001)

Table 5. European targets for reducing GHG emissions from transportation – railways.

Greenhouse gas emission target	Target year	Indicator (cf. 2.3)	Source
Medium-distance passenger transport mostly by rail	2050	TERM 012a/b	(European Commission, 2011b)

2.2 Finland's targets

Some of the European goals for transport emissions have specific targets defined for each member state. The targets for Finland, as well as national targets set in Finland, are presented in Table 6.

Table 6. Finland's Targets for Reducing GHG Emissions from Transportation.

Greenhouse gas emission target	Target year	Indicator (cf. 2.3)	Source
Maintain transport emissions at 1990 levels or below	2012		(European Environment Agency, 2002)
Reduction of 16% compared to 2005	2020		(European Commission, 2009a)
Maximum emissions of 11.4 million tonnes (15% reduction compared to 2005)	2020		(Ministry of Transport and Communications Finland, 2009), (Finnish Government, 2008)
Passenger car stock emissions at or below			(Prime Minister's Office Finland, 2009)
80–90 g CO_2/km	2030		
50–60 g CO_2/km	2040		
20–30 g CO_2/km	2050		

2.3 Indicators, metrics, and criteria

The definitions of the Transport and Environment Reporting Mechanism (TERM) indicators related to the targets given in Tables 1–6 are provided in Appendix I.

Measuring the emissions from different modes is based mostly on estimates of the type average emissions and traffic volumes. Shift from one transport mode to another is indirectly monitored by the mode shares.

3. Impacts of actions taken

The main means for reducing transportation GHG emissions are technological advances (e.g. more fuel efficient engines), management of mobility and demand (promoting and incentivizing public transportation, cycling and walking) and improving the flow of traffic (reducing congestion). The benefits of ITS, typically, fall on the latter two, which makes it more difficult to estimate its impact. The technological improvements are more likely to be directly measurable whereas mobility management, for example, consists of many different contributing factors.

As an example, transport CO_2 emissions have declined in Germany and Japan and stabilized in France as a result of various measures (International Transport Forum, 2009). The different measures include improved vehicle fuel efficiency, reduced travel speeds, stabilized travel volume, tax exemption and quota system for biofuels, higher taxes on fossil fuels, heavy duty vehicle road pricing, differentiated vehicle excise taxes, improved load factors in road freight transport, increasing number of hybrid cars, and so on. Evaluating the role of a certain solution is, clearly, very challenging but also important. This chapter describes various ITS measures that have been taken around the world and their impacts on the GHG emissions from transport and logistics.

3.1 Actions taken and the estimated impacts

3.1.1 Reducing congestion

In the UK, traffic management solutions, under the term “Managed Motorways”, includes using variable speed limits to smooth the flow of traffic as well as using the hard shoulder of some highways as an extra lane during busy times (UK Department for Transport, 2011). The results are a steadier stream of traffic and less stopping. Even non-dynamic, but rigidly enforced, speed regulations aiming at improving traffic flow and safety and reducing congestion and air pollution were estimated to result in CO_2 reductions of 15% in Rotterdam, the Netherlands (Kroon, 2005).

Dynamic road information panels can reduce congestion by providing localized traffic information to end-users (UK Department for Transport, 2011). More effectively, providing the information in real-time prior to leaving, if reliable and easily accessible enough, could persuade up to 35% of travellers to change their plans (route, time or modality), leading to less congestion (Ministry of Infrastructure and the Environment the Netherlands, 2011). Parking place information, often displayed in information panels, can be provided by web servers to have the information beforehand. Awareness of available parking places, and ability to reserve them, is one of the ITS priorities in Spain, for example, for improving merchandise and fleet management (National ITS Report: Spain, 2011).

With efficient incident management (e.g. detecting and reporting accidents), significant congestion reductions (up to 30%) are possible. A reduction of 5% in vehicle hours lost for eCall[3] alone is claimed by initial estimates (Ministry of Infrastructure and the Environment the Netherlands, 2011).

In Rome, Italy, an integrated traffic and mobility management system, the Traffic Control Centre, monitors, manages and controls urban traffic through several subsystems to improve traffic flow. The ITS system includes functions such as mobility management, traffic light regulation, traffic flow monitoring, user information via variable message signs, restricted traffic area access monitoring, video surveillance, monitoring and communicating parking spaces, and providing traffic information. Along with reduced travelling times and accidents, the amount of emissions have fallen by 15% in areas managed by the Traffic Monitoring Centre (National ITS Report: Italy, 2011).

Congestion charging – paying to drive in a defined zone – can reduce congestion and encourage the use of bicycles in urban areas. Transport for London have estimated an impact of 16% CO_2 emission reductions resulting from changes in the amount and flow of traffic due to the introduction of a charged central zone in London, UK (Transport for London, 2007).

3.1.2 Eco-friendly driving habits

Lower driving speeds, and avoiding accelerating (therefore, avoiding full stops) produces less emissions (Rakha & Ding, 2003). Enforcing reduced speed limits near inhabited areas by the use of automatic number plate recognition can reduce the environmental impact (Ministry of Infrastructure and the Environment the Netherlands, 2011).

A programme called “Ecodrive” in the Netherlands in 2004 found eco-driving training to reduce fuel consumption by 4.2–4.5%, amounting from 97,000 to 222,000 tonnes of CO_2 emissions avoided (European Environment Agency, 2008). Studies have estimated CO_2 emission reductions of 34.9% for typical passenger vehicles by using intelligent adaptive speed systems that advise the driver (Servin;Boriboonsomsin;& Barth, 2006).

[3] eCall: http://ec.europa.eu/information_society/activities/esafety/ecall/index_en.htm

Upgrading of road networks and infrastructure contributes to CO_2 emissions by improving the traffic flow and therefore making driving more eco-friendly and efficient. In Japan, the impact of increased average vehicle speeds over a 7.1 km section called “Oji” of the Tokyo Metropolitan Expressway was quantitatively evaluated and estimated to result in 20,000–30,000 tonnes less emissions annually (Japan Automobile Manufacturers Association, Inc., 2007; Japan Automobile Manufacturers Association, Inc., 2006).

Intelligent traffic lights (or approaching traffic lights intelligently) to create a “green wave” can reduce a vehicle’s emissions by reducing the amount of stops and accelerations (Dobre;Szekeres;Pop;& Cristea, 2012). Various adaptive systems to time the traffic light cycle to fit the vehicles are in place around the world (Fehon & Peters, 2010). Studies have shown that the adaptive traffic lights can reduce CO_2 emissions by up to almost 30%, although results vary greatly based on the location, time of day, and amount of traffic (Hutton;Bokenkroger;& Meyer, 2010). Yearly CO_2 emission savings as high as 2.4 million tonnes across the EU have been estimated from substituting half of the current traffic lights with modern dynamic ones that would optimize traffic flow (Kompfner & Reinhard, 2008).

A dynamically adjusting speed suggestion system (dynamic road signs or in-car display) for hitting traffic lights when they are green (ODYSA[4]) is implemented on some roads in the Netherlands (Ministry of Infrastructure and the Environment the Netherlands, 2011). The system gives the end-user speed advice based on the time of day, car in front, place in queue, place on the road, and possible congestion at an upcoming intersection. Carbon dioxide emissions were found to be reduced by 17% compared to vehicle-adaptive cycle time controllers in a limited number of emission measurements (DTV Consultants).

Studies have shown that a high engine load during a small portion of a trip can be responsible for a significant amount of the total emissions of the trip, and therefore significant air quality improvements are achievable by educating drivers (Anh & Rakha, 2008).

In Finland, more advanced traffic light controlling systems have been found to improve traffic flow and reduce delays by creating “green waves”, even though specific results are not available (Ministry of Transport and Communications Finland, 2011).

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[4] ODYSA: http://www.i-mobilitynetwork.com/odysa-

3.1.3 Promoting public transportation

Journey planning services5 enable users to find efficient ways to use public transportation, and raise environmental awareness by often providing carbon emission estimates for using public transportation and using a private passenger car. The availability of door-to-door route planning services has contributed to a change from car to public transport (UK Department for Transport, 2011).

Incentive schemes, such as Pay-As-You-Drive insurances, can reduce the amount of unnecessary driving and help persuade people into choosing public transportation, cycling or walking by either punishment or reward based on how eco-friendly a person is (Kompfner & Reinhard, 2008). Pilot testing of a Pay-As-You-Drive project has found that a significant amount (37%) of pilot survey respondents reduced the distance driven and that the incentives would make them consider carpooling or using public transportation (Progressive County Mutual Insurance Company & The North Central Texas Council of Governments, 2008).

3.2 Evaluation methods

Typically, impact evaluations are carried out with traffic flow models that estimate emissions for different traffic situations and behaviour, such as using intelligent speed adaptation (Servin;Boriboonsomsin;& Barth, 2006) or evaluating the effects of eco-driving penetration rates (Qian & Chung, 2011).

Measuring actual emissions in the environment before and after implementing a solution will have various factors affecting the result. As an example, GHG emissions from transport increased in the EU by 29% between 1990 and 2009 regardless of improvements on vehicle efficiency and implemented measures, while emissions from other sectors fell by 24%. The exception for rising emission amounts was 2007–2009, generally considered to result from the global recession (Smokers;Skinner;Kampman;Fraga;& Hill, 2012).

3.3 Recommendations based on the reviews

Kompfner and Reinhardt reviewed a wide range of ITS measures (some of which are used as examples in 3.1) and their impact on road transport energy efficiency and emissions (Kompfner & Reinhard, 2008). Based on their review, they provided a number of recommendations directed at different stakeholders, described briefly as follows:

- Eco-driving support

[5] Example public transport journey planners with emission estimates:
in Finland: http://www.reittiopas.fi/en, Sweden: http://reseplanerare.trafiken.nu, and
UK: http://www.transportdirect.info

- Research into automated on and off board services for eco-driving
- Campaigns for awareness and acceptance of eco-driving measures
- Additional eco-driving support functions (e.g. feedback display, reporting and analysis, on-line coaching etc.)
- Promoting on-line services that support eco-driving behaviour (comparing performance to peers, competitions and incentives, etc.).

- Eco-traffic management
    - Research and development into urban traffic control systems that could optimize the operation according to environmental criteria (e.g. fuel consumption or emissions)
    - Adaptive urban traffic and parking management systems should be encouraged
    - Compiling a guidebook for best practice on energy-efficient traffic management strategies and measures
    - Exploring new public–private partnership models for cooperative system deployment.
- Eco-information and guidance
    - Enhancing digital maps (road slope, speed limits, truck-specific restrictions, historic traffic data, etc.) and authorities with such data should offer it to map providers
    - Enhanced information (incl. critical weather conditions and multi-modal journey alternatives) should be offered by real-time traffic information service providers
    - Data collection, processing and delivery should be promoted in a joint stakeholder effort to improve real-time traffic information quality and coverage.
- Eco-mobility services
    - Promoting public acceptance of eco-friendly modes of mobility
    - Research into environmental benefits and fuel savings of ride-sharing, car-sharing and multimodality concepts and end-to-end traveller support services
    - Deployment support and large scale demonstrations to build stakeholder acceptance of technologies and standards.
- Eco-demand and access management
    - Harmonized technologies and framework for demand and access management.

- Eco-freight and logistics management
    - Research into ICT solutions for higher freight load factors and cargo technologies
    - Research into developing a standards-based open platform offering a range of fuel economy and environmental impact improving services to vehicle fleet operators
    - Support for demonstration and deployment of intelligent cargo concepts
    - A common European approach to city logistics.
- Eco-monitoring and modelling
    - Integrated tools for air quality, energy efficiency, CO_2 emissions and traffic modelling need to be developed and tested in a real life environment.

3.4 Summary of ITS-related emission reductions

ITS-based solutions often have an indirect impact on the environment by affecting the behaviour of people. For example, improved public transportation, along with sufficient information and promotion, reduces the use of private vehicles. However, the use of ITS can also have a more direct impact on emissions when it enables the same amount of traffic to perform more efficiently. The efficiency comes from avoiding traffic and maintaining a more constant speed throughout the distance travelled.

The effects of different ITS solutions can work well together, producing greater results than the sum of individual measures. For example, alternative routes can reduce congestion, which in turn can amplify the effects of eco-driving.

There is not much accurately measured data available about the impacts of ITS solutions on carbon emissions. The benefits of using ICT in a variety of ways for improving efficiency and eco-friendliness of traffic seem clear, however.

4. Proposed ITS-based solutions

ICT has great potential in making transport more efficient and environmentally friendly. Intelligent systems can play a big part by forming intelligent solutions and providing information to improve and alter the means of transport and logistics.

This chapter provides examples of ITS measures with estimates on the impact on emissions (4.1) as well as other solutions (4.2). The conclusions from the solutions are summarized in 4.3.

4.1 Estimates of emission savings

The CO_2 abatement potential from the use of ICT in transport has been studied by, e.g. Penttinen et al. (Penttinen;Paloheimo;Landau;Lees;& Chen, 2012). They used a model to evaluate the impact of higher uptake rates of ride sharing/carpooling, public transport, car sharing and eco-driving based on data from various developing and developed countries. They estimated eco-driving and public transport to be the most significant of the application areas, as shown in Figure 4.

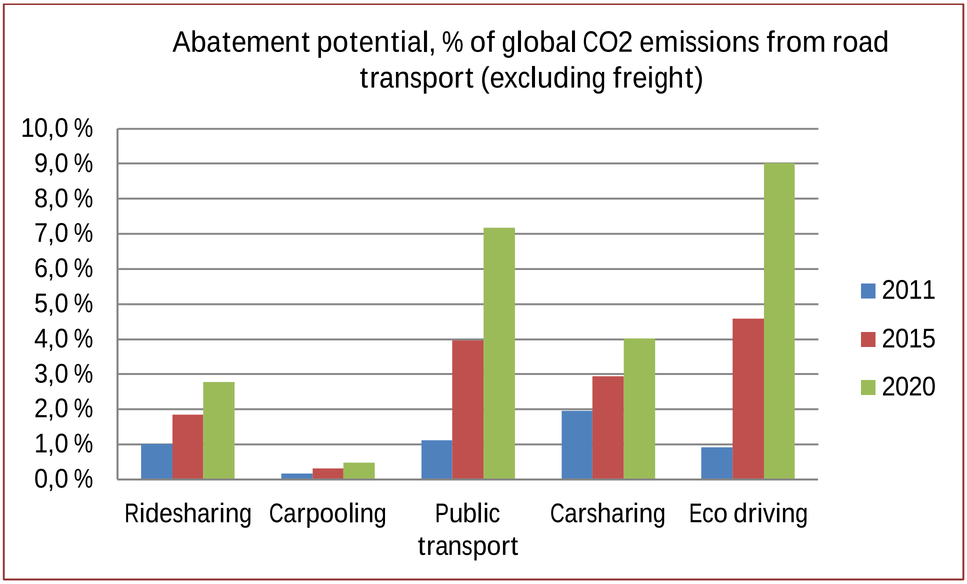

Figure 4. Global CO_2 abatement potential from road transport (excluding freight) (Penttinen;Paloheimo;Landau;Lees;& Chen, 2012).

Smart logistics – efficiency improvements in transport and storage – are estimated to have the potential for 225 $MtCO_2e$ worth of fuel[6], electricity and heating savings in 2020 in Europe, and 1.52 $GtCO_2e$ globally (The Climate Group, 2008). Using ICT to optimize logistics could, then, globally result in emission reductions of 16% in transport and 27% in storage. ICT could improve efficiency in a number of ways, such as improved transport network design, seamless and centralized distribution networks and flexible management systems for delivery services.

Increased utilization of vehicle capacity, reduced empty running, and driver training are considered significant factors in improving logistics and performing freight operations more efficiently. Such improvements could achieve significant CO_2 reductions by cutting the distance travelled by trucks by 10–40% (SE Consult, 2009).

The next generation of driver coaching systems combining Vehicle-to-Infrastructure (V2I) communication systems to support drivers and fleet managers to improve fuel efficiency are believed to have a fuel saving potential of 20%, while existing systems could result in 10–12% fuel saving according to a report from 2008 (Kompfner & Reinhard, 2008).

Based on experience, it is estimated that 25 million tonnes of CO_2 could be saved by replacing 20% of business travel in the EU by video-conferencing (WWF

[6] Carbon Dioxide Equivalent (CO_2e) is used to compare emissions based on their impact on global warming (http://www.epa.gov/climatechange/glossary.html)

& ETNO). By estimate, dematerialization measures could result in savings of 0.46 $GtCO_2e$ in 2020, more than half of which would come from telecommuting (The Climate Group, 2008).

A few lists of ITS-based measure–impact assessments, as gathered from different sources, are presented in the tables below. The potential effects are based on expert estimates and estimation models.

Table 7. Potential CO_2 Impact of ITS-Based solutions (TNO, 2009).

Solution	Potential CO_2 Effect (EU27)
Eco-driving coaching	15%
Eco-driver assistance	10%
Pay-As-You-Drive	7%
Platooning	6%
(Adaptive) cruise control	3%
Fuel-efficient route choice	2%
Dynamic traffic light synchronization	2%
Automatic engine shutdown	2%
Tip-departure planning (freight)	2%
Type pressure indicator	1%
Congestion charging	0.5%
Slot management	0.05%
Lane keeping	0.008%
Emergency braking	0.007%

Table 8. Potential CO_2 Impact of ITS-Based solutions (The Climate Group, 2008).

Solution	Potential CO_2 Effect (Global)
Optimized logistics network (Assuming 14% reduction in road transport and 1% reduction in other transport modes)	0.340 $GtCO_2e$
Intermodal shift (Assuming 1% reduction in road transport owing to shift towards rail and water)	0.020 $GtCO_2e$
Reduction in inventory (Assuming 24% reduction in inventory levels, 100% of warehouses and 25% of retail used for storage)	0.180 $GtCO_2e$
Optimization of truck itinerary planning (Assuming 14% reduction in road transport)	0.330 $GtCO_2e$
Optimization of truck route planning (Assuming 5% reduction in road transport carbon intensity)	0.100 $GtCO_2e$
Eco-driving (Assuming 12% reduction in carbon intensity)	0.250 $GtCO_2e$
In-flight fuel efficiency (Assuming 1% reduction in fuel consumption)	0.002 $GtCO_2e$
Reduction in ground fuel consumption (Assuming 32% reduction for 80% of flights)	0.002 $GtCO_2e$
Reduction in unnecessary flight time (Assuming 3% reduction in flight time)	0.007 $GtCO_2e$
Maximization of ship load factor (Assuming 4% reduction in marine transport)	0.030 $GtCO_2e$
Optimization of ship operations (Assuming 3% increase in fuel efficiency)	0.020 $GtCO_2e$
Minimization of packaging (Assuming 5% reduction in packaging material, leading to 5% reduction in transport and storage)	0.220 $GtCO_2e$
Reduction of damaged goods (Assuming 0.2% reduction in damaged goods)	0.010 $GtCO_2e$

Table 9. Potential CO_2 Impact of ITS-Based Solutions (in Finnish Conditions) (Kulmala & Schirokoff, 2009).

Solution	Potential CO_2 Effect
Roadside warnings	0.5 – 3%
Fluency reporting	0.5 – 2%
Information on alternative ways to travel	1 – 2%
Traffic light advantage for public transportation	1 – 3%
Intelligent urban road use charging	10 – 20%
Management of interruptions	5 – 15%
Management of transport equipment	3 – 6%

4.2 More emission-saving solutions

Navigation applications can provide alternative routes with significant emission reductions. Digital maps with slope and curvature information can estimate fuel consumption and emissions using various route options. Implementing this kind of map and position-based solutions widely to in-car systems could result in significant savings in emissions with relatively low costs. However, motivation and incentives, in the form of policies, for manufacturers and companies to implement the systems are lacking (Denaro & Blervaque, 2011). The need for policies arise from the fact that, while alternative routes may produce significantly less emissions, the travel time may also increase, which tends to be financially negative for companies.

Lack of public transportation and it not being available at the right time are key issues for people opting to use private vehicles for commuting and other trips. Efforts are put into combining the development of land use and transportation to support the use of public transportation and reduce congestion (Ministry of Transport and Communications Finland, 2009). Efficient multimodal passenger transport hubs around services and work places can encourage the use of public transportation. The role of ICT is often emphasized (e.g. in the White Paper) in providing reliable and accurate information in an easily accessible way to enable seamless transitions from one mode of transport to another. Local and regional mobility management policies contribute considerably to travel behaviour and, therefore, CO_2 emissions (International Transport Forum, 2009). The use of centralized intermodal hubs or nodes for freight transport can lead to reduced emissions by economies of scale. The use of geospatial information can be used in planning the locations for those hubs efficiently (Comer, 2009) and traffic information systems have a role in improving the effectiveness.

Market economy based strategies for transportation emission reductions have been presented by Litman (Litman, 2012). He argues that the balance between personal vehicles and public transportation is distorted. People are neither significantly being rewarded for using public transportation nor punished for using personal vehicles. Solutions for fixing the market include providing viable coverage of public transportation, both time and route-wise, and pricing the use of public and private transportation fairly based on the amount used. Litman suggests that many of the available solutions are not only ecologically but also economically worthwhile. ITS-based solutions can act as leverage in guiding behaviour by increasing the favourability and effectiveness of public transportation.

Easy access to reliable information increases the favourability of public transportation. Customized route-planning and adaptive timetables make public transportation more attractive, while relevant services, such as wireless internet connection, make it a more viable solution for longer commutes (Erdmann;Hilty;Goodman;& Arnfalk, 2004).

A short list of different ways to utilize ITS to reduce transport emissions is presented in Appendix II.

4.3 Impact potential summary

Various ITS-based solutions have been suggested and the opportunities of applying ICT to improve transportation and logistics are evident. Impact estimates are, typically, based on uptake or penetration rates of the solutions and the resulting changes in amount or flow of traffic of different modes and types.

The effects of eco-driving and reducing congestion clearly have potential in reducing emissions. Analysing user behaviour and informing and giving advice or automatically assisting (e.g. cruise control) can result in significant fuel savings and less pollution. Interruptions (e.g. car crashes) are the cause of a substantial amount of delays and idling time. Intelligent navigation and route planning to avoid interruptions or to simply take a less congested route can not only reduce the emissions from the individual vehicle but also help by not increasing congestion.

Since reducing the amount of vehicles is the most straightforward way to reduce emissions, the role of public transportation is significant. Land use to create multi-modal transportation hubs or nodes around densely populated or travelled areas can be a significant factor. Easily accessible and accurate information about the transportation options, lines, and routes add to the favourability of public transportation by allowing seamless and reliable transitions.

ITS can help increase the favourability of public transportation, but the most significant way to reduce the amount of private vehicles is accomplished by enforcing limits and guidance (e.g. financial reward or charging based on behaviour).

5. Conclusions and recommendations

More research is focused on road transport than on other modes. Results and evaluations of ITS measures for waterborne, aviation and rail transport are scarce. Also, the amount of proposed solutions is much higher for road transport, which is understandable since it is responsible for a major portion of all transport and transport-related emissions.

The role and potential of ITS is often highlighted as a powerful tool in reducing emissions from transport and logistics. Typically, the impacts of ITS-based measures are evaluated based on models or evaluations estimating changes in amount and mode share of traffic. Measured data is uncommon, not least because identifying the effects of a particular solution from a dynamic environment is challenging.

The policies and regulations, such as emission limits and reduction targets, set by authorities have an important role in incentivizing and driving the markets towards more environmentally friendly solutions and practices. The need for regulations is, clearly, higher if the measures require financial investments. Often, however, ecologically beneficial energy efficient solutions can lead to financial savings also.

Carbon emission savings from ITS measures are relatively small compared to the regulatory action, such as charging more for driving in urban areas, and act more as an assisting tool rather than a final solution. Alternative solutions, such as electric vehicles, can also deliver a more distinct impact on emissions. The combined use of ITS and other solutions is recommended. The prevalence of smart phones and other mobile technology increases the accessibility and opportunities of using information and intelligence while mobile.

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Appendix I: Term indicator definitions

Table 1. Transport and environment reporting mechanism (term) indicators, defined by EEA[1]

Indicator	Definition
TERM 002	"Total Greenhouse Gas emissions, CO_2, CH_4 and N_2O from transport, are analysed in this indicator. Total transport emissions can be split into road transport, rail transport, navigation, domestic aviation and other transport. All transport related GHG emissions exclude emissions from international aviation and maritime transport (not included in the Kyoto Protocol)."
TERM 012a/b	"Passenger transport demand is defined as the amount of inland passenger-kilometre travelled every year in the EEA32. Inland passenger transport includes transport by passenger cars, buses and coaches, and trains. There is no agreement among the EU Member States on how to attribute the passenger-kilometres of international intra-EU flights, therefore data for air passenger travels are deemed unreliable and not included. Modal split is defined as the proportions of total passenger-kilometre allocated to different transport modes every year. The decoupling indicator is defined as the annual changes of the ratio between passenger-kilometres (inland modes) and GDP (Gross Domestic Product in constant 2000 EUR) growth."
TERM 013a/b	"Freight transport demand is defined as the amount of inland tonne-kilometre travelled every year in the EEA32. According to the latest metadata Inland freight transport includes transport by road, rail and inland waterways: rail and inland waterways transport are based on movements on national territory ('territoriality principle'), regardless of the nationality of the vehicle or vessel; road transport is based on all movements of vehicles registered in the reporting country. The ratio of annual growth of inland freight transport to GDP, measured in 2000 prices, determines the amount of coupling between GDP and transport. The decoupling indicator is defined as unity minus the coupling ratio. The modal split of freight transport is defined as the percentage share of modes (road and rail) to total inland transport. It includes transport by road, rail and inland waterways."
TERM 027	"Specific CO_2 emissions are defined as emissions of CO_2 per transport unit (passenger-km or tonne-km), specified by mode (road, rail, inland, maritime, air)."
TERM 031	"Shares of low and zero sulphur fuels, and biofuels in total fuel consumption by road transport (in % of fuels sold for transport purposes). The shares of low and zero sulphur petrol and diesel are calculated by dividing the consumption of each fuel by the total fuel consumption of petrol and diesel respectively. The share of biofuels is based on their energy content and is thus calculated by dividing the energy consumption of biofuels by the energy consumption of all petrol and diesel sold for transport purposes."
TERM 034	"The vehicle category split in technology classes is defined as the percentage share of conventional, open loop, Euro 1, Euro 2, Euro 3, Euro 4 and Euro 5 vehicles of each vehicle category (petrol and diesel passenger cars and light duty vehicles, heavy duty vehicles, buses, coaches, mopeds and motorcycles). The vehicle activity split in technology classes is defined as the percentage share of the total activity (vehicle-kilometres) of conventional, open loop, Euro 1, Euro 2, Euro 3, Euro 4 and Euro 5 vehicles of each vehicle category (petrol and diesel passenger cars and light duty vehicles, heavy duty vehicles, buses, coaches, mopeds and motorcycles)."

[1] EEA Indicators and fact sheets about Europe's environment: http://www.eea.europa.eu/data-and-maps/indicators

Appendix II: Ways to utilize ITS to reduce transport emissions

Promoting Public Transportation:

- Passenger information systems indicating real-time environmental load
- Mobile payment
- Wireless internet connection in vehicles and terminals
- Traffic light advantage for public transportation
- Seamless and reliable transition from transportation mode to another.

Reducing Congestion (traffic management and ICT to improve traffic and infrastructure efficiency):

- Real-time information for the prevention of interruptions
  - Congestion
  - Interruptions
  - Weather and conditions
  - V2V, V2I and V2X information to avoid traffic and provide new route alternatives
  - Car park occupancy metering.
- Real-time passenger information
- Improved traffic network capacity
  - Locating services (e.g. satellites and RFID in number plates)
- Advanced route planning
  - Taking into account congestion, road slope, speed limits, traffic lights, etc.
- Ramp metering to remove bottlenecks
- Variable speed limits to improve traffic flow
- Intelligent/coordinated traffic light systems
- Variable message signs on roadside and on board displays
- Journey time measurement systems (e.g. by automatic number plate recognition)
- Restricted zones
  - Activating rising barriers or bollards
  - Monitoring (cameras, wireless connections, etc.)
  - Number plate recognition for charging.

Eco-Driving:

- Monitoring and adjusting tyre pressure
- Optimized energy efficiency for auxiliary systems (e.g. cooling)
- Automated eco-driving
- ITS-based convoy driving
- Speed advice coordinated with traffic lights.

Logistics:

- More efficient delivery chain
- Seamless and reliable transition from one transportation mode to another
- Unmanned and driverless vehicles
- Paperless tools for document handling
- Intelligent routing (preferred routes, height/weight limits, access/load regulations, truck parks).

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Title	**Low carbon smart mobility & green logistics**
Author(s)	Juho Kostiainen
Abstract	This review is intended as an overview of European and Finnish targets for greenhouse gas emissions from transport and logistics, and of performed and proposed measures for achieving these targets through intelligent transport systems (ITS). It was found that the impacts of different solutions are evaluated by expert estimates or models but seldom measured directly. The reason for the use of estimates is mainly the difficulty of differentiating one source from an overall change in emissions. The impact of ITS usually arises from increased usage of public transportation (decreased use of private vehicles), reduced congestion (improved traffic flow and alternative routing), and improved eco-driving (automatic solutions or information based on analysis, such as speed suggestions). The influence of ITS is, typically, realized more from being an enhancing tool rather than a complete solution. The use of ITS does help in reducing emissions. However, other measures such as technological advances in fuel efficiency, alternative energy, regulatory and financial guidance and more well-planned land use may be more direct and powerful. Combining ITS and ICT with the above-mentioned alternatives is recommended.
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Nimeke	**Älyliikenteen keinot kasvihuonepäästöjen hillitsemiseksi**
Tekijä(t)	Juho Kostiainen
Tiivistelmä	Tämän katselmuksen tarkoitus on luoda yleiskuva Euroopan ja Suomen asettamista tavoitteista liikenteen ja logistiikan kasvihuonekaasupäästöille ja esitellä näiden tavoitteiden saavuttamiseksi toteutettuja sekä ehdotettuja älykkään liikenteen (Intelligent Transport Systems, ITS) keinoja. Katselmus esittää olennaiset kasvihuonekaasupäästötavoitteet ja esimerkkejä toteutetuista ITS-pohjaisista ratkaisuista sekä niiden arvioidut vaikutukset. Myös ehdotettuja menetelmiä ja niiden vaikutusarvioita ja -ennusteita esitetään. Eri ratkaisujen vaikutukset ilmaistaan useimmiten joko asiantuntija-arvioihin tai malleihin pohjautuen ja vain harvoin suoraan mitattuina tuloksina. Arvioiden käyttö johtuu lähinnä vaikeudesta erottaa yhden ratkaisun osuus päästöissä tapahtuneesta kokonaismuutoksesta. ITS:n keinot pohjautuvat usein kasvaneeseen julkisen liikenteen osuuteen (henkilöautojen käytön vähentyminen), ruuhkien vähentymiseen (sujuvampi liikenne ja vaihtoehtoiset reittiratkaisut) sekä edistyneempään eko-ajamiseen (automaattiset ratkaisut vai analysointiin pohjautuva informointi, kuten nopeussuositukset). ITS-keinojen vaikutukset ovat tyypillisesti ennemmin tehostavana työkaluna toimimista kuin selkeä ratkaisu yksinään. ITS:n hyödyntämisellä on selvä vaikutus päästöjen vähentämisessä. Muut keinot, kuten polttoainetehokkuuden kehitys, vaihtoehtoiset energiamuodot, taloudelliset ja määräykselliset ohjauskeinot ja tehokas maankäyttö, voivat olla suoraviivaisempia ja tehokkaampia ratkaisuja. Älykkään liikenteen ja tietotekniikan hyödyntäminen yhdessä edellä mainittujen keinojen kanssa on suositeltavaa.
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