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INSIGHTS SERIES 2018

Saving oil in a hurry

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This report provides a toolbox for governments on how to effectively reduce oil demand in an emergency involving a sudden restriction in oil supplies. The work was started by Jan Bartos and completed by Lucie Girard with the objective of writing a publication with a new set of actionable recommendations to save oil in a hurry. The authors would like to thank Jacob Teter and Jason Elliott for the valuable comments and Aad van Bohemen, head of the Energy Policy and Security Division, for his expert guidance and advice.

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Executive summary

Oil supply security is a core mission of the International Energy Agency (IEA). In addition to the requirement to hold emergency oil stocks equivalent to 90 days of net imports, each IEA member country must maintain a programme of demand restraint measures that are able to bring about a rapid reduction in oil consumption by 7%, and as much as 10% in the case of a severe supply emergency. While emergency oil stocks remain the primary response measure for an IEA collective action, demand restraint is an effective tool that could be introduced as a complementary measure to stock draw, particularly during severe or extended supply disruptions.

The 2005 IEA publication *Saving Oil in a Hurry (SOIAH)*[1] presented a number of transport demand management measures and assessed their potential effectiveness when implemented in a crisis. This report, based on work that started in 2015, provides an updated set of actionable recommendations for governments on how to effectively reduce oil demand in a sudden restriction in oil supplies. As in the original study, this report is meant as a toolbox for countries in determining the most appropriate short-term measures to save oil rapidly in a crisis, given their national circumstances.

Measures covered in this report are summarised in Table 1 below. These are classified into impact categories ranging from very small to very large, according to the potential for oil savings. The total potential savings range from less than 50 000 barrels per day (very small) to more than 2 million barrels per day (very large) if all IEA countries implemented the measures within the given impact category. The feasibility of each measure is also assessed on institutional, technical and political aspects. Finally, the report presents the levels of costs for implementation of these measures in low/medium and high categories.

Emergency response measures are generally short-term in nature as these are meant to be implemented on a temporary basis until normal market supply is re-established. In cases where measures could be considered for longer-term application, such as encouraging driving in more fuel-efficient ways (see eco-driving below), these can have heightened effectiveness in a crisis when the general public is more receptive to ideas for saving fuel. At the same time, it should be noted that where some measures become more commonly applied to take advantage of environmental or fuel efficiency benefits, these measures will likely become less effective for short-term emergency response.

Demand restraint measures are not restricted to one particular sector of consumption. However, due to the high proportion of oil used for transportation, the most effective demand restraint policies target this sector. This study has therefore focused on transport sector-related measures, grouped into the following eight categories:

1. Public transport systems: Public transport systems offer underutilised capacity everywhere they operate in the world, and the improved utilisation of this capacity could be very helpful when private vehicle mobility needs to be restrained.

2. Employer and institutional transport measures: Employers or institutions could offer more flexible work schedules (e.g. compressed workweek) and permit more frequent teleworking. Businesses can also help through voluntary, supportive efforts such as ride-matching systems for their employees to use in their commute to work.

[1] www.iea.org/publications/freepublications/publication/savingoil.pdf.

3. Car and ride sharing: All cities and countries have enormous unused capacity for moving people in the vehicles already in use on the streets, in the form of empty seats. Increased passenger occupancy rates along with fewer vehicle trips make ride sharing efficient to save oil, especially if passengers use pre-developed systems that enable and motivate ride sharing.

4. Vehicle efficiency measures: Many simple, voluntary measures including **eco-driving**, proper tyre inflation, and the removal of unnecessary (especially heavy) items in the car can save oil on short notice. Campaigns calling upon motorists to drive more efficiently are estimated to have a great potential for fuel savings in a crisis, with other benefits, including saving households money and making driving safer, adding to the incentive for drivers to adopt such driving techniques.

5. Pricing strategies: Dynamic pricing strategies, such as electronic road pricing or pricing schemes for parking, are a tool to manage vehicle use and help cut congestion that wastes fuel. In particular, systems that use real-time pricing and clearly advertise the price to drivers can provide a rapid response tool for reducing peak periods of congestion.

6. Driving restrictions: Schemes that limit vehicles on certain days or at certain times can save substantial amounts of fuel. Odd-even licence restrictions can be effective to mitigate panic buying at filling stations, for example; however, suitable enforcement is necessary to make such measures effective. Systems for implementing driving restrictions already exist in some countries for non-emergency purposes, typically to reduce traffic congestion and pollutant emissions, and these could be utilised for fuel saving purposes in an oil supply crisis.

7. Multi-fuel vehicles: In a situation where oil products are scarce, drivers could in principle turn to other available fuels: biofuels, natural gas, liquid petroleum gas (LPG), hydrogen or electricity. In order to be a viable short-term emergency response measure in an oil supply disruption, the ability to switch between oil products and alternative fuels would need to be maintained. For example, in cars enabled to use either LPG or petrol, where at the time of the crisis the driver could switch away from petrol to use only LPG. In the case of cars fitted with LPG-only engines, while the switch to these kind of cars already represents a saving of petrol use in general, there is no further potential savings to be obtained in a crisis.

8. Freight trucking: Encouraging trucking companies to combine trips and keep trucks full could be included in a general information campaign. Similarly, encouraging eco-driving, proper tyre inflation, reduction in truck speeds and fuel switching with increasing blends of biodiesel can also help. Truck energy savings can be the greatest in developing and emerging countries where trucking is a larger share of energy use relative to cars.

Some measures present a higher potential than others, and some are also implementable faster than others. For a quick overview of the most effective measures identified by this study, see Box 1.

Box 1 • Most effective measures for quick implementation in emergency situations

Driving restrictions (driving ban + speed limit reduction)

It comes as no surprise that the most impactful measures are also the most restrictive ones. A combination of an even-odd ban, cutting the number of vehicles allowed to drive on any given day by half, might result in global savings of 4.8 mb/d-6.8 mb/d. In addition, reducing speed limits could add another 0.9 mb/d-1.4 mb/d of global savings. These measures are best to be complemented by measures such as public transport service improvements and fare reductions, to ease the social and economic (and political) costs they might otherwise incur. They will only be effective with strict and consistent enforcement. See Section 2.6 for more details.

Reduction of public transit fares by 100% (free public transit)

This measure, when implemented in a package together with supporting measures such as increased service and designated priority lanes for buses to attract even more customers, might lead to global savings on the magnitude of 0.6 mb/d-1.4 mb/d. The study assesses that this measure would be particularly effective in the BRICS countries (Brazil, the Russian Federation (hereafter, "Russia"], India, the People's Republic of China [hereafter, "China"] and South Africa), Latin America, Asia and Africa. See Section 2.1 for more details.

Employer/institutional package

A package of measures calling on employers to allow employees to telework, shift eligible workers to a four-day work schedule and implement carpooling matching programmes might generate global savings on the equivalent of 0.5 mb/d-1 mb/d. See Section 2.2 for more details.

Public information campaigns

If led efficiently, eco-driving campaigns alone might be able to save 0.2 mb/d-1 mb/d from global demand. Supported by more "stringent" measures such as control points to check and/or fine drivers with empty roof racks or carrying excessive mass, savings could reach 1.6 mb/d-1.8 mb/d. See Section 2.4. for more details.

Real-world experiences of supply crisis and the impacts of efforts to reduce demand are vital to developing effective demand restraint policies. Therefore, in the event of a disruption, and where demand response measures like those mentioned in this report are implemented, governments should carefully monitor their impacts and assess their effectiveness. Governments should then share this information so that countries around the world can continue to improve their approaches and planning of demand restraint policies.

The concept of planning mobility in a way that enables cities and regional transport networks to be more flexible and resilient in the event of disruptions (e.g. weather, market and security-related incidents) is an emerging trend. This updated report provides initial aspects of these measures, which can also be implemented with a mid- to long-term time frame to encourage a low-carbon mobility strategy.

Table 1 • Summary table of oil measures in the transport sector

Measure	Description and key assumptions	Potential oil savings if implemented	Feasibility: Institutional	Feasibility: Technical	Feasibility: Political	Best suited regions	Other potential impacts
Ride- & car-sharing	Taking optimistic assumptions for business models (like 'Uber', 'Lyft', etc.) that integrate real-time IT to monetize empty car seats	**Very Large** (> 2 million BPD)	M-H	H	M-H	India, China, Other Asia, Africa	government must be supportive and address legal, safety, & market barriers
1 day in 2 driving ban	Even-odd license plate scheme prohibits cars from operating every other day		L-M	M	L	Russia, OECD & Non-OECD Europe	public resistance; strong enforcement necessary; potentially negative economic impacts
Ecodriving	Public information campaign to promote fuel efficient driving	**Large** (> 500 thousand BPD)	H	H	M-H	U.S. & Canada, Australia-NZ/Other OECD	safety benefits; substantial private benefits in reduced fuel costs; time costs
Speed limit reductions	Temporarily reduce freeway speed limits to 90 km/hr (55 mph in U.S.)		M	H	L	China, Other Asia, Africa, Other LAC	public resistance; strong enforcement necessary; safety benefits but time / efficiency costs
1 day in 10 driving ban	Passenger vehicles banned from operating 1 day in 10		M	M	L-M	Russia, OECD & Non-OECD Europe	economically inefficient ; likely public resistance; relatively easy to enforce
Dynamic parking pricing	Off-street urban parking meters set at prices to maintain ~85% occupancy at the block level throughout the day.		M	L-M	M	Australia-New Zealand & other OECD, Russia	requires adequate infrastructure (i.e. networked parking meters); potentially revenue generating; revenues can be used to fund public transit
Freight driver training	Includes education in ecodriving measures for trucks and financial incentives for efficient driving and/or intelligent vehicle systems		M-H	M-H	M-H	Middle East, Africa, Mexico & other LAC	must be tailored to the current level of expertise of drivers, functions best with financial incentives
Subsidize alternative fuels	Sustained subsidies through 2020 increase the potential to respond to an oil supply shock by switching fuels in multi-fuel vehicles (MFVs)		M-H	M	M-H	India, Other Asia, Brazil, Non-OECD Europe	multiple benefits of reduced oil dependence (e.g. lower GHG emissions, greater energy security)
Road pricing	Includes tolling, congestion and cordon pricing		M-H	L-M	L	Non-OECD Europe, Middle East	difficult to set up as economically efficient & effective; potentially revenue generating
Free public transit	Set fares of urban buses, metro, light-rail, and BRT to zero		M-H	M-H	H	Japan & Korea, Europe	potential long-term mode shift effects
Remove excess vehicle weight	Public information campaign to promote removal of excess mass in vehicles and to unmount roof racks when not in use	**Moderate** (> 100 thousand BPD)	H	H	M-H	U.S. & Canada, Australia-NZ/Other OECD	difficult to verify the actual effectiveness
Fuel switching	During supply disruption, ensure price advantage and adequate supplies of target alternative fuels		M-H	M-H	H	India, Other Asia, Brazil, US & Canada	multiple benefits of reduced oil dependence (e.g. lower GHG emissions, greater energy security)
Freight truck speed limits	Temporarily reduce freight speed limits to 95 km/hr (60 mph in U.S.)		M	H	M	Brazil, Africa, China	unpopular with freight firms; may raise costs
Employer TDM policies	Employer institutions offer incentives to carpools (e.g. public transit vouchers, preferential parking), and provide ride-matching services.		L-M	M-H	H	Japan & Korea, Brazil, U.S. & Canada	potentially costly for both private industry and public agencies
Ride- & car-sharing	Conservative assumptions for services like 'Uber', 'Lyft', etc.		M	H	M-H	BRICS, Asia, Middle East	potential that 'rebound' reduces effectiveness
Equip trucks with GPS	Subsidize the purchase of GPS units for freight trucks		H	H	H	India, Other Asia, Africa	likely feasible, popular, and effective
Freight idling reductions	Voluntary idling reductions - public campaign and/or subsidies		H	M-H	M-H	Brazil, Africa, China	difficult to verify, potentially unpopular
Transit fare reductions	Public transit fares reduced by 50%		M-H	M-H	H	Japan & Korea, Europe	potential long-term mode shift effects
Enhance transit service	Increase peak and off-peak transit service		M	M	H		
Freight areodynamics	Retrofit trucks and trailers with aerodynamic devices		M	L-M	M	Middle East, Europe	more effective where trucks travel at high speeds
Distance-based pricing	PAYD / PATP ; voluntary adoption	**Small** (> 50 thousand BPD)	L-M	L-M	H	Europe & Japan	multiple benefits: safety, private economic gains
Telecommuting	Active participation by employers / institutions with employees in jobs that would permit telecommuting from 1-3 days per week		L-M	M	H	OECD member states	may result in decreased efficiency in those sectors where implemented ; hence, potentially unpopular with business & industry
Compressed work week	Active participation by employers/institutions to permit a 9/80 (9 work days, 80 hours) or 4/40 (four work days, 40 hours) schedule		L	H	L-H	OECD member states	
Truck tyre inflation	Education campaign and/or subsidies for tire inflation devices in trucks		H	H	H	China, India, Asia, Africa	difficult to verify effectiveness
Car-free urban zones	2%-10% of urban roads shut off to car traffic on weekends		L-M	L-M	L-H	India, Asia, Europe	only advisable in areas w/ public transit service
Extend off-peak transit service	Increase off-peak & weekend service		M	M-H	H	Japan & Korea, Europe	potential long-term mode shift effects
HOV lanes	Repurpose the 5%-10% most highly congested lanes as HOV2 (or HOV3) lanes during peak traffic periods		M	M	H	U.S. & Canada, India, Africa, Latin America	requires adequate public information and enforcement
Dedicated truck lanes	Repurpose 5%-10% of non-urban roadways as dedicated truck lanes		M	M	M	Middle East, India	safety benefits; must be implemented w/ care
Add BRT service along bus lines	Express / priority BRT service added along 10% of urban bus routes		M	M	H	Europe, China, India	
Low-viscosity motor oils	Campaign to promote switching to lower viscosity motor oils whereever this is feasible	**Very Small** (< 50 thousand BPD)	H	H	H	Non-OECD Europe, Russia, China	Public subsidies can further promote purchase of low-viscosity motor oils
Tyre inflation campaign	Public information campaign promotes maintanence of correct tire pressure, mandatory pressure checks at automotive service stations		H	H	H	Middle East, Africa, Mexico & other LAC	Aggressive campaign can encourage (e.g. through subsidies) pressure checks at refueling stations

1. Introduction

The original study *SOIAH,* published in 2005, provided a quantitative assessment of a range of demand restraint measures on two aspects: how much oil might be saved if the measure is implemented during an oil supply disruption, and how much the measure appeared likely to cost. The scope covered IEA member countries and the results were estimated over four IEA regions (Japan/ Korea, IEA Europe, United States/Canada and Australia/New Zealand). Cost estimates were restricted to available data on implementation costs and did not consider co-benefits such as health, safety or environmental benefits of the proposed measures, nor the macroeconomic implications of responses that might affect productivity.

In 2015, the IEA Secretariat started on work to update the original study and extended its scope to reflect developments in the information technology and low-carbon mobility sectors. This report has three primary objectives:

- to provide recommendations on how to prepare for and manage oil supply disruptions via demand restraint measures
- to evaluate the effectiveness of measures in reducing oil demand; the cost levels of implementation; and the technical, institutional and political feasibility of the demand restraint measures targeting fuel consumption (primarily petroleum-derived gasoline and diesel fuels)
- to sketch out portfolios of demand management measures tailored to specific regions and countries that represent feasible strategies to save oil at minimal implementation costs.

Additionally, this updated report explores three types of measures not covered in depth in the original report:

- modal shifts (expanded public transit and pedestrian/bicycling alternatives to cars)
- multi-fuel vehicles: alternative fuels, including biofuels, hybrid electric drive and natural gas, which in the intervening decade have begun to provide viable substitutes to petroleum-based fuels
- freight/logistics, which, with ongoing revolutions in information technology and logistics, may provide some further opportunities for demand restraint savings.

This report also explores how some cities and countries have reshaped transport infrastructures to be more resilient to long-run oil supply challenges, by increasing modal choices, fuel efficiency and improved mobility. By expanding the provision and level of service of public transport, adopting high-capacity public transport networks, or measures to manage private motor vehicle use (e.g. cordon pricing[2] and time-of-day parking prices), certain regions have enhanced their capacity to respond to long-run oil supply challenges and at the same time improve the air quality in urban regions.

The 2005 *SOIAH* report focused on supply disruptions and oil demand management only for IEA member countries, with options selected that seemed most applicable to this set of countries. The present study expands coverage to a global assessment, using regional data sources to include emerging economies. The world has been broken down into 14 regions that share similar relevant characteristics (fuel costs, provision of public transit, mode shares, level of economic development and urban population density). The list of regions is presented in Annex 2.

[2] Cordon pricing, also called congestion pricing, is the practice of surcharging at peak times to reduce congestion.

This report intends to serve as a resource for IEA member countries, accession and association countries, or any other country interested in designing and implementing measures that can help reduce oil demand in the short term when confronted with sudden restrictions in oil supply. As the study has a global perspective, it is important for individual countries to conduct their own analyses, reflecting their priorities and their national circumstances. This study provides methodologies and data that can be useful in that context.

2. Demand restraint measures: Review and assessment

The general concepts listed below were applied in the original study and remain valid for this update.

Short-term supply disruptions usually require very different responses and measures than efforts to promote long-term energy savings or fuel shifts. This study focuses on both managing oil demand significantly in a matter of days or weeks, and policies and technology options that develop mobility and complementary long-term goals such as sustainable transport, energy independence, air pollution, improved traffic safety and greenhouse gas (GHG) targets.

One size does not fit all – every country is unique. One of the notable results of this analysis is that different measures save significantly different amounts of transport fuel in different countries and regions of the world, depending on a range of local factors.

A key principle in rapid response to an oil supply disruption is to increase options for individuals and companies to cope with the situation. Ways to avoid having to travel, options to share trips, options to shift fuels – anything that makes it possible to save oil can play an important role.

Allowing oil prices to respond to a disruption can be an important part of the solution. With price-responsive markets and a system that passes oil price dynamics through to consumers, market dynamics alone may provide a significant factor to change travel behaviours.

Most measures require advance planning. Governments must set up plans prior to actual disruptions and put in place systems that are implemented during emergencies. Co-ordination between administrations and key private or public stakeholders will contribute to build considerable resilience into the transport system to defend against supply disruptions. Training exercises involving all relevant parties are important for good implementation of the measures when they are needed.

"Pull" measures are generally preferable to "push" measures, though having both may create synergies. Push policies force consumer responsiveness and include driving bans, fuel pricing strategies, road pricing and parking charges, and speed limit reductions (with a price spike naturally occurring in a supply disruption providing an important push of its own). These types of policies are best implemented alongside pull policies, which encourage and enable consumer responsiveness and include expanded transit service and fare reductions, increased access to ride-sharing and telecommuting options, and provision of (hopefully inexpensive) alternative fuels. Well-developed combinations of push and pull may create synergies that are particularly effective.

In this report, the discussion of each category of measures opens with a brief and succinct literature review summarising the state of current knowledge for each of the measures and the assumptions for the estimates. The report then describes the assessment of the likely implementation costs, and concludes with the potential global oil savings for each measure in each world region.

These measures are compared in their regional and country-specific contexts, and measures that may work well in particular countries or regions are identified. The year 2014 is taken as the base year for these oil supply disruption scenarios, providing an important update to the previous study.

Measures are classified into the following categories:

- public transport systems
- employer and institutional transport measures
- car and ride sharing
- eco-driving and vehicle efficiency measures
- pricing and parking policies
- driving restrictions (e.g. speed limits, driving bans)
- multi-fuel vehicles
- freight trucking.

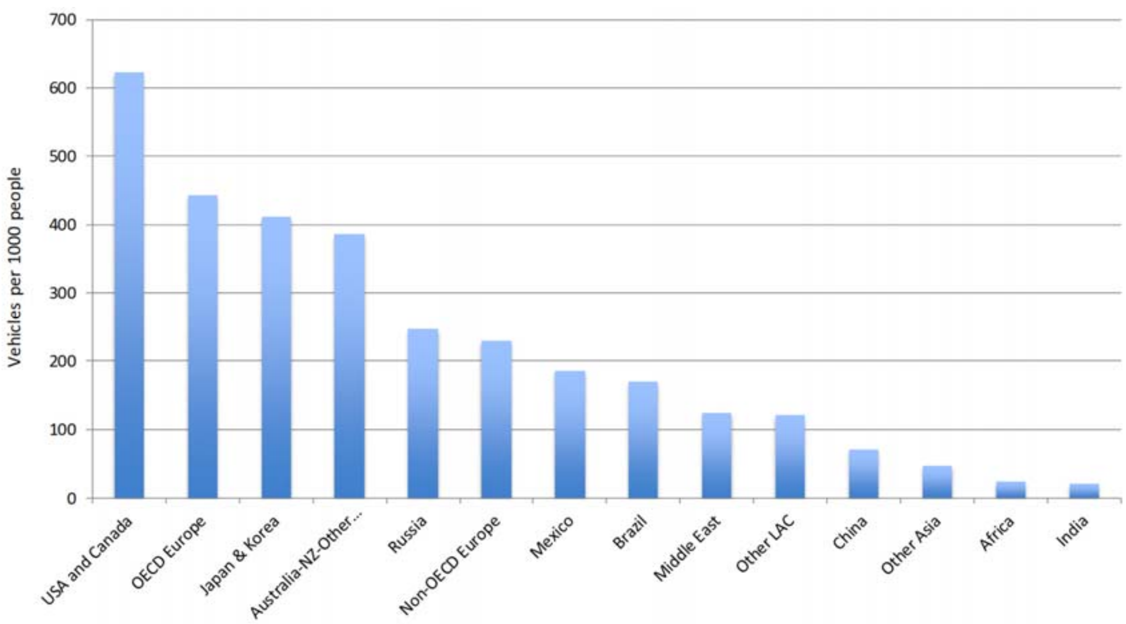
Each category regroups a set of measures, which are assessed in terms of potential oil savings and feasibility. The feasibility is assessed in a qualitative way (low [L], medium [M] and high [H] feasibility) for institutional, technical and political aspects. This qualitative assessment is based on expert judgement and done at a global level. Finally, the levels of cost for implementation of these measures are presented in terms of low/medium and high levels, based on the scheme of the original study presented in Annex 1.

The world has been broken into different regions that share similar relevant characteristics (fuel costs, provision of public transit, mode shares, level of economic development, and urban population density). The analysis has been conducted for 14 world regions, with Organisation of Economic Co-operation and Development (OECD) countries and other major economies broken out or placed in similar groupings (United States/Canada, OECD Europe, Japan/Korea, Australia/New Zealand, Russia, China, India, Brazil, Mexico) and other countries aggregated into regional blocs (Non-OECD Europe, Other Asia, Middle East, Africa, Latin America).

The list of regions is presented in Annex 2.

Figure 1 shows the number of personal light-duty vehicles (LDVs) per 1 000 people; as a measure of the dependence on personal cars, it is an important indicator of how passenger transport in the given region relies on oil.

Figure 1 • Vehicles per capita in each of the regions of analysis (2014)



2.1 Public transport systems

Modal alternatives to private car travel

Bus rapid transit (BRT) systems can provide high-efficiency, high-capacity transport, and can often run on electricity or other alternative fuel. These are therefore excellent alternatives to automobiles during supply disruptions, and provide important urban substitutes when automobile-focused demand restraint measures are in place.

One concern when relying on public transit to provide alternative capacity is the spare capacity on such systems. In some countries such as the United States, there appears to be a broad underutilisation of bus and rail travel, often even during peak travel periods. In Europe and many other parts of the world, peak travel capacity may be almost fully utilised, making a "shift to transit" more difficult during peak periods.

As a short-term, temporary response, reducing fares of public buses, metro and light rail seems the most easily implemented, universally implementable and politically popular among measures aiming to boost public transit ridership. Here two fare reduction regimes are considered: cutting fares in half (50% reduction), and making transit (temporarily) free (100% reduction).

In cities where they exist, metro and light rail systems provide cheap and convenient alternatives to commuting and travelling by car, but these modes do not easily lend themselves to ready expansion in response to an emergency. However, there is typically spare capacity in such systems in off-peak periods. This may be profitably exploited in two ways. First, existing spare capacity can serve to "spread" the peak, and is particularly valuable as a complement to employer/institutional transportation demand management (TDM) measures that shift working hours. This synergy is explored further in the discussion of flexible working hours. Second, it may be possible in some instances to expand the frequency and range of service that is available on workdays into the weekends and into the morning/evening hours (i.e. maintaining the full length of origins and destinations). Again, such a service expansion would effectively strengthen the incentives of employer/institutional measures, such as public transit vouchers, parking cash-outs and telecommuting.

Incentivising off-peak trips[3] by expanding service and/or reducing or eliminating fares may prove a particularly effective strategy for enticing new transit riders in crisis-type circumstances.

BRT systems are now being developed in countries all over the world. These systems can provide high-quality, high-capacity public transit at speeds much faster than conventional bus systems, and are cheaper and more easily modified (e.g. in terms of routing and frequency of service) than other infrastructure-intensive systems (e.g. metro, light rail) of comparable speed. BRT systems that are in place could be helpful during a supply disruption by offering an opportunity for expanding service in high-speed dedicated corridors. One way to do this (if the BRT buses are already fully utilised) would be to allow other types of buses to use the BRT corridors, since there is typically spare capacity within these corridors. Another is to add BRT service to pre-existing regular urban bus routes. There is evidence that adding express bus service such as BRT to the central business district of major cities may raise ridership substantially (Pratt et al. 2003).

[3] Pratt et al. (2003) cite numerous studies finding that new ridership is most often added in the off-peak periods, for discretionary trips (as well as the converse, that ridership is lost most often from discretionary, off-peak trips).

Table 2 • Fare reductions in public transport measures

Measure	Potential global oil savings (thousand barrels [kb] per day)	Feasibility		
		Institutional	Technical	Political
Reduce public transit fares by 50%	Moderate (100-500)	M-H	M-H	H
Reduce public transit fares by 100%, i.e. make public buses free	Large (500-2 000)	M-H	M-H	H

By cutting transit fares to encourage ridership and adding more buses at peak times where this is possible, transit services could save about 100 kb-500 kb per day of oil worldwide. The number rises when work schedules are shifted to take advantage of greater spare capacity during off-peak times.

Public buses show the greatest potential across all regions to accommodate a shift in ridership from cars because the share of passenger kilometres, currently accommodated by urban buses, is far greater than that of metro, light rail, and BRT systems combined. In Japan, Korea and OECD Europe, the shares of urban buses and minibuses are similar to those of high-capacity urban transit (metro, light rail and BRT).

In the case of fare reductions, oil savings are most sensitive to 1) the percentage of diversion of new transit ridership from cars; 2) the magnitude of consumer response (i.e. the price elasticity with respect to transit ridership); and 3) the severity of the price shock on transport fuels.

India and Africa, and to a lesser extent, Latin America, Brazil and Australia-New Zealand/Other OECD regions are likely to achieve larger cuts in proportion to their aggregate LDV fuel consumption from fare reductions than the United States and OECD Europe. Hence, by cutting fares, India might plausibly reduce fuel use for passenger transport by nearly 14%, whereas the United States cannot expect to reduce it by more than 1%.

Table 3 • Expansion of service (service frequency and hours improvements) measures

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Enhance transit service: increase peak and off-peak transit service	Moderate (100-500)	M	M	H
Extend off-peak transit service: increase off-peak and weekend transit service	Small (50-100)	M	M-H	H

Service frequency and hour improvements: Oil savings realised by improving the frequency and range of public transit service are significant. Between 60 kb and 325 kb per day of oil might be saved by increasing frequency of service, where the higher range could be achieved by making off-peak service as frequent as peak service and by offering more peak service trips. Repurposing urban roadways to prioritise buses over car traffic and adding BRT lanes could realise similar savings (50 kb-350 kb per day).

In particular, Africa, China and Other Asia might achieve substantial savings by prioritising bus service on urban roadways. A policy that designates lanes for buses may prove politically unpopular, but this effect might be limited by offering bus fare reductions. Particularly in highly congested metropolitan regions, repurposing roads to serve buses over cars would be technically simple to implement and highly effective. The emerging BRIC economies (Brazil, Russia, India and China), together with Africa, may find that improving service could be used to reduce fuel use for passenger transport by more than 2%. By cutting fares at the same time, it may be possible to realise double-digit savings in fuel used for passenger transport.

Car-free zones and bike-pedestrian promotion programmes

One measure that could be implemented in the event of an oil supply disruption is to follow the example of many cities (e.g. Paris, Vienna, Copenhagen, Berlin, Boston and others) in designating certain districts as car-free by making them inaccessible to all but local residential/commercial motor traffic. Many cities in developed countries have cordoned off sections of the downtown to pedestrian traffic only, including several cities in the United Kingdom (London, Nottingham, Liverpool, Leeds, Durham, Coventry), Germany (Mainz, Munich, Stoven, Essen, Stuttgart, Dusseldorf, Hanover, Frankfurt, Bremen), France (Paris, Besançon), the United States (US) (Boston, Minneapolis, Madison), and the Netherlands (the Hague, Groningen), to name just a few. Certain cities (including many of the above as well as Amsterdam, Edinburgh, Freiburg, Hamburg, and districts of London) have taken this policy further by designating car-free housing developments.

During a supply disruption or curtailment, adding car-free streets or zones can serve as an important reminder for people to drive less, much as “car-free Sundays” already sends this signal in many cities on a regular basis. If the streets or areas that will be designated car-free are well known to the public in advance, turning this system on or off under specific conditions should not be difficult to manage.

Support for the so-called “active” transport modes could be mobilised to some effect in an oil supply crisis. Although it may be unfeasible in the period of a supply disruption to carry out infrastructure improvements such as installing separated bike lanes, traffic-calming designs, tree-planting or off-street paths, some changes of urban space may be feasible, politically tractable and effective. Information and education programmes, as well as better signage, use of information technology (IT) and safety programmes, may prove more popular than under usual circumstances.

However, having a solid biking/walking infrastructure in place and a population used to utilising these modes may play an important role during a supply disruption. Though data are scarce, one can imagine that countries such as the Netherlands would be well positioned to carry out many daily activities on bikes (even those who do not already cycle every day) given the widespread cycling infrastructure there. The most important contribution that cycling and walking are likely to make relates to the basic daily commuting and household services. There are many reasons to undertake a programme to build infrastructure and promote these modes; resiliency during an oil supply disruption is just one of them.

It also is worth noting that many of the other policies analysed in this report would make cycling and walking more safe and attractive. Restricting the provision of parking, lowering speed limits and reducing public transit fares could all be expected to increase bike and pedestrian trips and connections (in the latter case due to the fact that transit trips are commonly linked to walking and cycling).

Another aspect of cycling that may be interesting for coping with oil supply disruptions is bike sharing. The number and size of bike-sharing systems have grown dramatically in the past ten years (Mason et al., 2015) and have provided an oil-free mode of transport even for those who do not own a bicycle. Many people may find the availability of shared cycles to be crucial in coping with fuel shortages, if the systems are in place and a sufficient supply of bikes is available when a crisis occurs.

Table 4 • Car-free zone measure

Measures	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Car-free urban zones: close 2-10% of urban road space to private vehicle traffic on weekends	Small (50-100)	L-M	L-M	L-H

Global savings from restricting cars from operating on weekends on 2% of urban roads range from 14 kb-28 kb per day, and those that might be achieved by closing 10% of urban roads to weekend car traffic range from 70 kb-140 kb per day.

The estimated potential to save oil by restricting urban road space to private vehicles is directly proportional to the volume of fuel consumed in urban areas within each region. The result is that the highest estimated savings are in the United States/Canada, which may save as much as 30 kb per day by closing 10% of road space on weekends, followed by OECD Europe (20 kb per day), and China (16 kb per day). Variations in the percentage of LDV[4] fuel consumption forgone are relatively minor, range from about 0.1-2.8%, and reflect the split of urban to rural driving.

This simple relationship – estimating fuel savings as a function of total urban car travel weighted by on-road fuel economy – likely drastically oversimplifies things. It cannot capture the competing determinants of both the feasibility and effectiveness of road restrictions. For instance, decades of car-centric development may mean that relatively few substitutes are viable in many districts of US cities, and that they are likely to be perceived both by the public and public officials as overly restrictive. While the atmosphere may well be more conducive to restricting cars on urban streets over weekends in OECD Europe or China, road closures are already in effect in certain areas in many European and Chinese cities, and so measures that add more of them may find that they are subject to diminishing returns.

Cost level for implementation of public transit measures

The costs of transit-related initiatives include increased costs of operating transit systems and/or losses in transit revenues from lower fares. It is important to distinguish between associated costs and changes in prices, which are transfers from one group to another (in this case from riders to taxpayers) and further between implementation costs and "resource" costs incurred by society as a whole (such as running more buses and paying for more driver time, fuel, etc.).

The cost analysis is based on a qualitative summary of costs. Table 5 points out that the revenue losses to transit agencies are offset by revenue gains to riders. For car-free zones, there are likely to be some administrative and investment costs to prepare streets for conversion, as well as to potentially provide additional parking outside the zones. There will no doubt be perceived losses in convenience to drivers, though this may be offset by gains to pedestrians. The net effect on business owners in these zones will depend on how people react to the change, and whether they frequent these stores more or less than before. European experience with pedestrian streets is generally very positive (Kenworthy, 2006; Pflieger et al., 2009; Buehler and Pucher, 2011).

Table 5 summarises these cost considerations for public transit measures.

[4] In the report, LDVs are referred to as cars.

Table 5 • Qualitative cost assessment of public transit measures

<table>
<tr><th rowspan="2">Measure</th><th colspan="4">Government (and transit agencies)</th><th colspan="2">Individuals and businesses</th></tr>
<tr><th>Government Administrative / enforcement</th><th>Government Capital investment/expenses</th><th>Government information / advertising programs</th><th>Impact on government (and transit) revenues</th><th>Compliance costs (for individuals/ companies)</th><th>Consumer surplus/ business profitability impacts</th></tr>
<tr><td>Fare reductions</td><td rowspan="2">Low</td><td rowspan="2">None</td><td rowspan="3">Low</td><td>Revenue loses to transit agencies</td><td rowspan="2">none</td><td>Reduced expenses to transit riders</td></tr>
<tr><td>Service frequency and hours improvements</td><td>Increased transit operating costs but also increased revenues</td><td>service gains to those taking transit</td></tr>
<tr><td>Car-free zones and bike-pedestrian promotion programs</td><td>moderate</td><td>Low-medium (possible repaving, amenities)</td><td>No change</td><td>unclear impacts on businesses in affected areas</td><td>gains to pedestrians; losses to drivers, truckers</td></tr>
</table>

Summary of the public transit/modal alternatives to private car travel

In the short term, ridership on existing urban transit systems can be increased by:

- Service expansions (e.g. by increasing the frequency of buses/light rail operation to reduce out-of-vehicle wait times, or by extending the hours of peak operation into morning and evening hours).
- System improvements (e.g. by adding amenities, prioritising traffic light operation for light rail and buses, or dedicating lanes to bus operation).
- Reducing fares.

In Annex 3, Figure 3 ("Oil saved by public transit policy packages") shows the potential fuel savings per region.

Individual measures from each of the three categories were combined to form three public transit demand restraint policy packages that vary in their level of stringency.

The "weak" package includes 50% fare reductions, moderate increases in off-peak transit service and closing 2% of urban roads to weekend car traffic. Estimated global savings of a weak transit policy package range from 290 kb-660 kb per day.

The "moderate" package makes all public transit free, increases off-peak service to peak levels and extends transit service to Sundays, and closes 2% of urban roads to cars on weekends. This moderate package might reduce oil use by 330 kb-740 kb per day.

Finally, a "strong" policy package incorporates all of the most ambitious measures: all public transit is made free, service in the off-peak increases to peak levels and peak service itself increases by 10%, bus priority lanes are designated and BRT service is expanded, and 10% of urban roads are closed to cars on weekends. The estimated global savings of such an aggressive policy package ranges from 580 kb-1 430 kb per day. Particularly the BRICS countries, as well as other countries in Africa, Latin America and Asia, might save a substantial percentage of their total car fuel consumption by implementing policies aggressively promoting public transit.

Regardless of which region might decide to impose road restrictions, these measures are a good example of a push measure that would be most wisely implemented together with pull measures such as service improvements and fare reductions. It is in this spirit that various policy packages in public transit were constructed, to estimate the total potential savings of reducing fares, improving service and restricting car usage in tandem.

2.2 Employer and institutional transport measures

Telecommuting

To assess the potential of measures encouraging telecommuting, the increase in the proportion of workers who telecommuted between 1997 and 2010 in the United States is used as a benchmark. According to the Survey of Income and Program Participation, conducted on the US workforce, the percentage of workers who worked at home at least once per week increased 2.5 percentage points (from 7.0% to 9.5%), and the percentage who worked the majority of the workweek or exclusively from home also increased, from 4.8% to 6.6%.

Next, these categories of employees were matched by category with available data on workers in Europe, China, India and other world regions. The share of commuting distance travelled (miles or kilometres) travelled as a percentage of all vehicle kilometres travelled (VKT) is taken from the summary statistics of the 2001 and 2009 National Household Travel Survey (NHTS), as reported in Davis, Diegel and Boundy (2014).

This percentage (27.0% in 2001, and 28.7% in 2009) is likely to be lower than in most other world regions, as US drivers make an exceptionally high share of discretionary trips, and hence this results in more conservative estimates. Moreover, the share of discretionary trips would likely decrease sharply as a consequence of high fuel prices. Finally, the proportion of kilometres travelled that is accounted for by commuting is weighted by the proportion of the population that is employed (relative to the US ratio of employment to overall population).

Estimates for telecommuting take three forms: a basic, a moderate and a strong policy.

In the basic policy, it is assumed that federal, regional and local policy makers would be able to work with employers to push through temporary measures enabling an additional 5-25% of workers at jobs that are most suitable and amenable to telecommuting (over the current telecommuting baseline penetration) to do so.

Under the moderate version of the measure, the case considered is that industries most suited to telecommuting (i.e. information and finance) shift to allowing a full 50% of the eligible workforce to telecommute once a week.

Estimates of the potential pool of telecommuters are the same in the strong policy as in the moderate one, but in this case all potential telecommuters are permitted to work from home three out of every five working days. In all instances, the actual implementation of the measures promoting telecommuting is flexible; certain employers might, for instance, find it more convenient to permit workers to telecommute once a month.

Under the moderate policy, it is assumed that the percentage of workers who might be able to shift to working at home in the event of an oil supply disruption would at minimum match the increase experienced in that industry in the US in the first decade of the 21st century. The maximum penetration of telecommuting under the moderate policy is then assumed to be three times this value (i.e. 9.6-10.8% of workers) for the construction, manufacturing and wholesale industries, and five times this value (i.e. roughly 25% of workers) for the information and finance industries.

In the policy that aggressively promotes telecommuting (the strong policy), the penetration of telecommuting is assumed to range from 25-50% of all workers in information and finance. Telecommuting is effective in reducing vehicle travel in direct proportion to pre-existing commute mode shares and load factors[5] – ultimately it reduces driving only for that subset of commuters who drove themselves to work previously.

To account for the likely rebound in vehicle trips, it is assumed that one-quarter of the resultant reduction in vehicle kilometres will be counteracted, even in the extraordinary conditions of an oil supply emergency, by other (i.e. non-commute) trips, as a result of commute vehicles being made available to the entire households. Based on differences in steady speed fuel economy ranging from 2-28% in on-road tests (Davis, Diegel and Boundy, 2014), it is assumed that reduced congestion will result in fuel consumption reductions on the order of 5%. These benefits are accrued to vehicles that travel on roads in proportion to the VKT forgone by telecommuting (and compressed work hours).

Table 6 • Telecommuting measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Active participation by employers/institutions with employees in jobs that would permit telecommuting from 1-3 days per week	Small (50-100)	L-M	M	H

Modest telecommuting measures that mandate that employees in relevant ("telecommutable") industries work from home one day per week are likely to save only a small fraction of total fuel consumption – the maximum estimated savings is 0.28% in the United States/Canada.

More aggressive policies, such as mandating that 25-50% of employees at viable industries telecommute on average three days per week, can expect to achieve up to 1.25% reductions in car fuel use. The effectiveness of this measure depends on the pre-existing commute mode share and on the occupancy factor of vehicles – countries where more employees drive to work alone or with few passengers benefit disproportionately from forgoing these car trips. Also, countries with a significant share of employees in information, finance and other industries where telecommuting may be most feasibly implemented stand to benefit more – Japan/Korea, the United States/Canada, Australia & New Zealand/Other OECD and OECD Europe see the greatest proportional savings from this measure.

Globally, **telecommuting may save 8 kb-32 kb per day for the basic measure** (one day per week for 2-10% of viable employees), **30 kb-47 kb per day for the moderate package** (one day per week for 25-50% of viable employees), or **90 kb-140 kb per day for the strong telecommuting policy** (three days per week for 25-50% of viable employees).

Absolute oil savings are proportional to commute mode share, the inverse of commute vehicle occupancy rates, the share of employees in the relevant occupations, total fuel consumption, the share of total oil consumption that comes from road transport and the share of road transport fuel consumption represented by passenger vehicles. As a result, the United States/Canada stands to save the greatest volume of oil – and would account for roughly two-thirds of the global oil savings – followed by OECD Europe (accounting for about 16% of global oil savings), and Japan/Korea (about 5% of global oil savings).

[5] Mode shares are derived from the Urban Mobility Model (Urban MoMo) (Replogle and Fulton, 2014), and apply a correction factor (1- passenger vehicle load factor) to estimate the fraction of car commuters who are drivers, as opposed to passengers.

Flexible working hours

Extending the time period over which the commute occurs can reduce peak congestion, thus not only saving fuel but also reducing the average time costs of the daily commute. In this respect, if implemented with due consideration of organisations' needs and priorities, flexible working hours may represent a politically popular opportunity to achieve fuel savings without incurring economic costs, and may potentially even present certain economic advantages (which are not estimated in this report).

Employers may find it possible to offer employees some flexibility in choosing when to arrive and depart from the workplace. Provided that employees are present during the main workday hours (typically 9:30 to noon and 13:30 to 15:30), it may be possible to give employees the preference of arriving and leaving either earlier or later than the common 9-17 (or 10-18) workday. Alternatively, work hours can be staggered over a 1-3 hour starting/finishing interval, with employees coming and leaving in 15- or 30-minute blocks, an arrangement that may make sense in manufacturing or similar industries (Kuzmyak, 2010). Finally, the workweek can be compressed into a 9/80 schedule (i.e. nine 9-hour days, with the 10^{th} day off) or a four-day, 40-hour "4/40" schedule (i.e. four 10-hour days, with the 5^{th} day off).

Flexible and staggered working hours could be implemented to greatest effect together with vouchers for public transit, increased frequency of public transit during (normally) off-peak hours, and any range of push policies designed to increase the real and perceived costs of driving.

The estimate of the fuel savings of flexible working hours is restricted, therefore, to the two examples of compressed workweeks. As with telecommuting, a 25% rebound in kilometres travelled for these policies is assumed.

Table 7 • Compressed work hour measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Active participation by employers/institutions to permit a 9/80 or 4/40 schedule	Small (50-100)	L-H	L	H

As with telecommuting, estimated oil savings resulting from compressed work schedules are greatest in the United State/Canada, OECD Europe and Japan/Korea. The fraction of global savings is disproportionately shared by these oil-consuming countries – the split of global oil saving is similar to that in telecommuting: about 66% of savings accrue to the United States/Canada, 17% to OECD Europe and 5% to Japan/Korea.

The estimated oil and fuel savings are globally in the following ranges:

- **20 kb-43 kb per day** could be saved by implementing a 9/80 schedule across 50% of viable employees (**basic plan**).
- **41 kb-86 kb per day** by adopting a 4/40 workweek across 50% of employees (**moderate plan**).
- **81 kb-172 kb per day** if the entire potential employee pool is mandated to work on a 4/40 schedule (**strong plan**).

Fuel savings as a proportion of total passenger vehicle fuel consumption range from 0.01-1.5%. Proportional savings are more even across regions than in the case of telecommuting measures, though they are greater in countries where a greater proportion of employees commute by car, and where jobs could feasibly switch to compressed work schedules. The results suggest that the compressed workweek measures would seem a more secure strategy than telecommuting, particularly in countries with a small share of workers in information, logistics and finance, and a greater share in construction, manufacturing and wholesale industries.

Carpooling/Vanpooling

To assess the potential of carpooling measures to reduce fuel consumption, estimates of passenger vehicle occupancy rates in each of the fourteen regions are taken as a starting point. As with the evaluation of telecommuting and compressed work schedules, only the percentage of kilometres that is attributable to commuting based on US data are taken (a very conservative assumption). For both measures, it is assumed that 25-50% of employees work for organisations that either volunteer or are mandated to adopt the carpooling promotion policies. Federal and regional governments will probably have to provide some kind of incentives to institutions and employers that adopt carpooling policies, such as tax reductions.

For the **moderate employer promotion measure**, the mean value (19%) of the range of reduction in kilometres travelled estimated in case studies cited by Kuzmyak (2010) is taken. For the **strong carpooling** measure, an above-average reduction in commuting distance of 24% is taken (this reduction is representative of the employer-based programmes that provided transit vouchers and/or parking cash-outs).

The differences in initial vehicle occupancy across regions could be construed either as an indication that carpooling in certain regions is more viable (e.g. culturally, technically, habitually), or as an indication of lower capacity for additional carpooling. In addition to the direct reduction in kilometres, the same 5% reduced fuel consumption (in proportion to distance reductions) is taken as in estimating telecommuting and compressed work hours.

Table 8 • Employer TDM measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Employer institutions offer incentives to carpools (e.g. public transit vouchers, preferential parking), and provide ride-matching services	Moderate (100-500)	L-M	M-H	H

Estimated savings from well-organised and comprehensive policies promoting carpooling outweigh those of the other employer-institutional measures. Opting to promote carpooling might prove attractive to employers and institutions that are hesitant or unable to allow employees to work from home or to alter working schedules.

Globally, even **moderate programmes may save on the order of 240 kb-520 kb per day**, and **strong carpooling programmes may save between 310 kb and 650 kb per day.** Savings are spread across regions – the United States/Canada (42%), OECD Europe (19%) and Japan/Korea (6%) still account for the largest savings; China in particular might benefit from this policy, and accounts for an estimated 6% of savings; and Other Asia countries might collectively contribute another 4% of global oil savings under this measure.

In terms of the percentage of car fuel saved, gains are spread across regions, and range from a low of 0.5-2% for about half of the regions to a high of 2-3.6% for the other half of the regions. The primary determinant of how much fuel is saved relative to the region's total car fuel use is the employment ratio relative to the United States – in regions where more of the population works, the assumed number of kilometres travelled is greater, and hence the estimated proportion of reductions is commensurately greater as well.

Cost level for implementation of employer-institutional packages

The costs of implementing telecommuting programmes depend heavily on the need for technology investments to support these programmes. If most workers who telecommute can rely on their own (or already existing company) computers and other equipment and few new investments are necessary, then the costs of these programmes should be low – apart from any productivity impacts, which could be either positive or negative. Compressed workweeks should not require any additional equipment, so the only potential costs are related to productivity. Carpooling programmes may incur organisation costs on the part of the government and/or businesses, along with a solid effort to "get the word out" that ride sharing is needed to help deal with the emergency.

To develop comprehensive TDM packages, which would be necessary to achieve the oil savings estimated here, businesses and institutions would need to invest non-trivial amounts of capital towards restructuring incentives (e.g. via parking cash-outs) and hiring the services of a TDM professional. These high upfront costs typically pay for themselves over a short time (between five and ten years), depending on the size of the employer or institution and its rate of growth.

Table 9 • Qualitative cost assessment of employer and institutional TDM measures

<table>
<tr><th rowspan="2">Measure</th><th colspan="4">Government (and transit agencies)</th><th colspan="2">Individuals and businesses</th></tr>
<tr><th>Government Administrative / enforcement</th><th>Government Capital investment/expenses</th><th>Government information / advertising programs</th><th>Impact on government (and transit) revenues</th><th>Compliance costs (for individuals/ companies)</th><th>Consumer surplus/ business profitability impacts</th></tr>
<tr><td>Telecommuting</td><td rowspan="2">Low</td><td rowspan="3">Low</td><td rowspan="3">low-medium</td><td rowspan="3">No change</td><td>Low-medium (possible equipment expenses)</td><td rowspan="2">Unclear impacts on business productivity</td></tr>
<tr><td>Compressed work week</td><td>none</td></tr>
<tr><td>Employer promotion of carpooling</td><td>Low (possibly assistance programs)</td><td>Low-medium administer programs, incentivize carpools</td><td>Low apart from administering programs</td></tr>
</table>

Summary of employer and institutional TDM packages

In Annex 3, Figure 4 ("Oil saved by employer-institutional packages") shows the different savings per region.

The basic/weak package, which consists of permitting 2-10% of eligible employees to telecommute once a week, switching to a 9/80 schedule for 50% of viable workers and setting up a basic carpooling matching programme with moderate financial incentives, might save **between 272 kb and 590 kb per day of oil, or 1.3-2.9% of global fuel consumed by cars.**

The moderate package, which mandates that 25-50% of eligible workers telecommute once a week, shifts 50% of workers to a 4/40 work schedule and also sets up the basic carpooling matching programme, **might save from 377 kb-780 kb per day, bringing the total car consumption levels down between 1.9-3.9%.**

Finally, the **aggressive/strong package**, which calls on employers to allow 25-50% to telecommuting on average three days per week, to shift all eligible workers to a 4/40 work schedule and to implement carpooling matching programmes with strong financial incentives, **might save 475 kb-950 kb per day globally, or as much as 4.7% of car fuel consumption.**

The benefits of employer-institutional packages are greatest in regions such as the United States/Canada, Japan/Korea, Brazil, and Australia-New Zealand & Other OECD countries. Russia, Mexico and Non-OECD Europe may also benefit from employer-based policies, due to a higher share of employees in occupations that might viably switch to telecommuting or compressed workweeks. On the contrary, India, Africa, the Middle East and Latin America would likely benefit less, as the mode share of car in the daily commute is relatively low.

2.3 Car and ride sharing

The original *SOIAH* report highlighted carpooling/ride sharing as having the greatest potential for saving fuel among all measures considered.

Three elements are crucial to ensuring the effectiveness of this policy in an international context:

- An informational campaign, conducted across many types of media (e.g. radio, television, billboards), explaining the functioning and purpose of dedicated high-occupancy vehicle (HOV) lanes. The campaign would ideally give estimates of resultant fuel savings to motivate the measure.
- The most highly congested corridors should be identified in advance of an emergency. HOV operations should last only during peak traffic hours, and care should be taken to ensure that the HOV lanes are implemented only if and when congestion levels are high. This would require periodic monitoring.
- Adequate enforcement and appropriate monetary penalty is advised for violators.

Measures to promote carpooling and ride-sharing schemes may be effective any time to cut oil use, though they may prove more effective under emergency and/or high fuel price circumstances, particularly if adequate support and incentives are provided by employers.

Public agencies considering implementing HOV lanes should ideally conduct attitudinal surveys to understand the likely effects of modifying incentives among travellers, to avoid or minimise mode shifts from public transit or induced demand that occur due to the increased speed and utility of HOV lanes. Transport agencies are also urged to directly monitor impacts and conduct surveys of HOV users after implementation.

HOV lanes – assumptions for the estimates

Even small increases in average vehicle occupancy may have a substantial aggregate impact. Jacobson and King (2009) estimate that adding a single passenger to every tenth vehicle in the United States would reduce fuel use by about 5%. This is not to say that achieving such a shift is easy, but under emergency conditions, many more riders might be drawn from single-occupant cars than normally.

Adding new HOV lanes is one mechanism for encouraging greater ridership. The designation of HOV lanes serves to constrict the utility of underutilised (low-occupancy or low-“load factor”) vehicles while encouraging carpooling. A typical approach is designating targeted stretches of single lanes in congested stretches of freeways to become HOV2 (vehicle occupancy is at least two per vehicle) or HOV3 lanes (for areas where the vehicle occupancy is already fairly close to two per vehicle).

In view of the literature on HOV lanes (Shewmake, 2012), conservative fuel reduction estimates for HOV lanes are adopted. Estimates of the potential effectiveness of HOV lanes in promoting carpooling and reducing the attractiveness of single-occupancy car trips over the designated stretches and time periods are taken from the validated model of Fontes et al. (2014). This model finds that HOV lanes could effectively increase average occupancy by 0.2 passengers per vehicle, on average, over designated stretches in and surrounding midsize cities.

Since congestion is typically and characteristically an urban phenomenon, estimates take as their starting point the fraction of urban passenger kilometres out of total passenger kilometres travelled. In the absence of good proxies for the prevalence of congestion across regions, it is assumed that HOV lanes are installed along the most highly congested roadways, and that these account for 5-10% of vehicle traffic.

Fuel savings that might be achieved by "upgrading" HOV2 lanes to require three occupants (HOV3) are applicable only to those regions where HOV2 lanes already operate (i.e. the United States, Canada, and to a far lesser extent Australia and New Zealand and some European countries).

Table 10 • HOV lane measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Repurpose the 5-10% most highly congested lanes as HOV2 (or HOV3) lanes during peak traffic periods, provide adequate public information and enforcement lanes	Small (50-100)	M	M	H

Globally, HOV lanes could save between about **40 kb and 90 kb per day of oil.** Regionally, the proportional reductions in fuel consumed are fairly even and range from 0.1-0.7% of total on-road car fuel consumption. The variation across regions in the percentage reduction reflects the proportion of distance that occurs in or around urban areas.

Publicise and promote ride-sharing business models – assumptions for the estimates

Two estimates for the potential of ride sharing are adopted: a "modest" and an "optimistic" scenario. In both scenarios, the average capacity of four occupants per vehicle is assumed. The difference between this and the regional average load factor represents the spare capacity available to ride-sharing businesses.

In the modest scenario, the assumption is that the number of occupants increases per vehicle by 5-15%; for example, in a city with an average of 1.5 riders per vehicle, this becomes 1.63 to 1.73.

In the optimistic scenario, the assumption is an increase in the occupancy of car travel by 20-30% over the baseline, because of the confluence of high fuel prices and the potential to travel affordably even under the oil shocks postulated by using dynamic ride-sharing business models.

Table 11 • Publicise and promote ride-sharing measures

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Taking optimistic assumptions for business models (i.e. Uber, Lyft) that integrate real-time IT to monetise empty car seats (optimistic scenario)	Very large (> 2 000)	M-H	H	M-H
Conservative assumptions for services such as Uber and Lyft (modest scenario)	Moderate (>100)	M	H	M-H

The absolute fuel savings (in kb per day) potential of promoting dynamic car- and ride-sharing business models, and of setting up HOV lanes, are shown in Annex 1.

Optimistic projections, that real-time ride sharing might lead to approximately a 25% increase in car occupancy rates, leads to an estimated **1.3 mb/d-3.1 mb/d savings,** which represents about 6.5-15.5% of pre-oil shock car fuel consumption.

Even modest assumptions concerning consumer response to the availability of ride and car sharing, enabling a 5-15% increase in average vehicle occupancy rates, lead to estimated global oil savings of **80 kb-790 kb per day in savings.**

The proportion of global oil savings is greatest in the United States/Canada (which accounts for 34% of global oil savings), OECD Europe (17%), the Middle East (9%) and China (9%) – combined these regions constitute more than two-thirds of the estimated oil savings potential of the ride-sharing measure. In contrast, the proportional gains relative to total road fuel consumption are equitably shared among world regions, and range from about 0.5-5% under conservative assumptions to possibly as much as 7-20% under optimistic projections.

Cost level for implementation of carpooling and car and ride sharing

With the exception of new HOV lanes, the suite of measures explored here appears to be implementable at generally low cost. HOV lanes may require direct investments in roadways – at a minimum, costs would be incurred to re-sign and potentially re-stripe lanes. During the supply period disruption, the signage can be "activated" (e.g. through changeable electronic signage); this may facilitate greater success. These costs can of course get much higher if new construction is involved.

Another cost concern is lost transit ridership in a very successful car ride-sharing programme. Table 12 shows the costs associated with carpooling and car- and ride-sharing measures.

Table 12 • Qualitative cost assessment of ride-sharing measures

<table>
<tr><th rowspan="2">Measure</th><th colspan="4">Government (and transit agencies)</th><th colspan="2">Individuals and businesses</th></tr>
<tr><th>Government Administrative / enforcement</th><th>Government Capital investment/expenses</th><th>Government information / advertising programs</th><th>Impact on government (and transit) revenues</th><th>Compliance costs (for individuals/ companies)</th><th>Consumer surplus/ business profitability impacts</th></tr>
<tr><td>HOV lanes</td><td rowspan="2">Low-medium</td><td>possibly high for signage, striping, etc.</td><td rowspan="2">low-medium</td><td>No change</td><td rowspan="2">none</td><td>gains to carpoolers</td></tr>
<tr><td>Promotion and publicity of ride- and carsharing businesses</td><td>Low</td><td>possible losses to transit ridership, revenues</td><td>gains to those choosing to rideshare</td></tr>
</table>

A second approach to encourage ride sharing is the provision of carpool/ride-share matching assistance, possibly combined with monetary incentives (e.g. subsidies, vouchers for reduced fuel or public parking prices) or preferential parking for carpools. This could be carried out by employers or governments, or through a combined campaign.

For example, companies and institutions in cities across the United States and Canada (including, for instance, many universities and Google) offer direct cash payments for commuters who cycle to work, as well as vouchers towards public transit fares. Employers in Paris are legally obligated to reimburse 50% of the costs of commuting by public transit or by bike share.

Although financial incentives may be expensive, they can also be very effective. Pricing efforts are likely to be more effective where there are supporting programmes, such as preferential parking and employer-based support for carpooling. Financial incentives may require co-ordination with outside entities such as vanpool providers, parking operators, etc., in order to be efficiently implemented.

The combination of a monetary incentive and exhortations to "share the ride" may have considerable impacts on driving patterns. The advent of ride-matching software and phone apps may also play an important role, and publicising such software should be part of the campaign.

2.4 Eco-driving and vehicle in-use efficiency

This section reviews estimates of the effectiveness and recommendations for implementing several measures designed to increase the real-world fuel economy of automobiles: eco-driving, tyre inflation and switching to low rolling resistance tyres, adopting lower-viscosity motor oil grades, and removing empty roof racks and excess mass from automobiles.

Eco-driving – assumptions for the estimates

"Eco-driving" refers to modifications in driving behaviour that lead to improved real-world fuel economy.

On surface streets, it may include moderate acceleration at green lights, early upshifting on manual transmission vehicles, anticipating traffic flow and signals to avoid sudden starts and stops, gradual and even deceleration, and turning off the vehicle at long stoplights to reduce idling.

On the highway, key eco-driving strategies are maintaining an even speed (and using cruise control) and driving at or below the speed limit.

The benefits of eco-driving extend to personal safety – resulting mostly from speed reductions and eliminating sudden changes in speed.

To estimate the effectiveness of eco-driving, half of the potential consensus fuel savings (i.e. 5% of the potential 10% reduction) are assumed to come as natural behavioural reaction to an oil supply disruption. Studies decomposing the short-run price elasticity of demand give ample empirical evidence of this reaction to increased fuel prices. The remaining range of potential fuel savings is 1% to 5%. This range of estimates is applied, noting that an aggressive promotion that includes a co-ordinated public information campaign and marketing of IT applications that measure and provide immediate feedback to drivers on their achieved fuel savings (expressed both in monetary and volumetric units) is likely to achieve something closer to the 5% fuel reduction. Currently, this range (1-5%) is applied separately to urban and non-urban (roughly, city and highway) vehicle kilometres.

Three package measures are used: basic, moderate and strong. The moderate package is based on a public information campaign, including distributing of booklets and estimates of fuel savings. The strong package includes an extensive public information campaign plus government subsidy of mobile IT apps to provide real-time, responsive feedback on actual fuel savings, rated against (e.g.) average and potential savings.

Table 13 • Eco-driving measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Public information campaign to promote fuel-efficient driving	Large (> 500)	H	H	M-H

Eco-driving is estimated to reduce fuel consumption in passenger vehicles by 1-5%. No further parameters were used to estimate the oil savings from this measure, so the range of oil saved is simply taken to be 1-5% of total fuel consumed by passenger vehicles. Hence, eco-driving campaigns alone might save **186 kb-990 kb per day globally**. Diverse cultural, economic, structural and legal factors will determine the actual impact of eco-driving campaigns. Variations in driving habits and in particular in the prevalence of fuel-economic driving, traffic conditions and road design, and the rules of the road will likely impact the effectiveness of this measure, both in terms of the potential savings and adoption rates.

Tyre inflation – assumptions for the estimates

This measure would involve educational and communication campaigns for drivers to maintain the maximum approved tyre pressure.

To estimate the impact of tyre inflation campaigns and making pressure checks mandatory at automotive service providers, it is estimated that the penetration of tyre pressure monitoring system (TMPS) technologies in each region based on the years over which TMPS requirements were phased in, as compared with the fleet penetration of TMPS experienced in the United States, reproduced from Sivinski (2012). It is then assumed that the global proportion of vehicles with underinflated tyres matches that documented by the 2009 and 2012 NHTSA (National Highway Traffic Safety Administration) surveys of the US car fleet, for both vehicles equipped with TMPS and those without. The average level of under-inflation reported in the 2011 NHTS (National Household Travel Survey) is then applied to vehicles with and without TMPS systems. These are summed to estimate the fleet-wide weighted average degree of tyre under-inflation, which serves as the baseline on which tyre inflation measures can improve.

Various estimates are used to relate tyre under-inflation to fuel economy. As stated above, according to NAS (2006), for every 10 kilopascals (kPa) (~1.45 pounds per square inch [psi]) that an under-inflated tyre is brought closer to efficient pressure, the fuel economy of the vehicle increases by an estimated 0.435%. Sivinski (2012) found that that average under-inflation per tyre between vehicles with and without TPMS is 7.24 kPa (1.05 psi), and further determined on the basis of previous studies that fuel economy increases by an estimated 0.308% for every 1 psi (or 6.9 kPa) increase in tyre pressure (for under-inflated tyres). The relationship between under-inflation and fuel economy is approximately linear.

Finally, it is assumed that a basic information campaign would effectively reduce the incidence of remaining under-inflation in the car fleet by about a third. A moderate policy requirement for car service providers to check tyre pressure would achieve a 50% reduction in under-inflation rates. And a stringent campaign to promote tyre pressure adjustments at gas stations might reduce under-inflation by about two-thirds, in addition to giving the drivers of vehicles queuing to refill their tanks a useful activity with which to occupy themselves.

Table 14 • Tyre inflation measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Public information campaign promotes maintenance of correct tire pressure, mandatory pressure checks at automotive service stations	Very small (< 50)	H	H	H

As the potential of this measure to save oil in the regions with the greatest aggregate on-road passenger vehicle consumption (e.g. United States/Canada, OECD Europe) is fairly restricted relative to e.g. eco-driving, the total global estimated oil savings are more limited. Tyre inflation campaigns may save anywhere from 18 kb-33 kb per day globally. Regionally, savings account for 0.8-1.6% of total road fuel consumption in regions with a high car fleet penetration of TPMS – like the United States and Canada – to 2.3-4.6% of passenger vehicle fuel consumption in developing countries with low proportions of vehicles equipped with TMPS. Hence, particularly in regions with limited options for responding to oil supply disruptions, tyre inflation may be an inexpensive and effective means of reducing car fuel use.

Removing excess mass and unmounting roof racks – assumptions for the estimates

Items left in the storage compartment or back seats of the car increase the weight of the vehicle and hence are detrimental to its fuel economy by increasing its inertia. In 2008, a study by Ricardo Inc. conducted on a representative range of vehicle classes (including small and midsize cars, sports utility vehicles (SUVs) and light trucks, and gasoline- and diesel-powered vehicles) in city and highway driving cycles concluded that on average, a 1% increase in weight carried in a passenger vehicle results in a 0.33% fuel economy penalty (Casadei and Broda, 2007).

Meier (2015) estimates that campaigns exhorting car owners to remove unused objects from their vehicles have the potential to reduce fuel consumption by around 0.5-1%. Applying the 0.33% fuel economy for a 1% weight increase, removing 30 kilogrammes (kg) of excess mass from a vehicle weighing 1 tonne (t) would result in a fuel economy improvement of 0.030 x 0.33 ≈ 1%.

Indeed, a full tank of fuel can be itself considered “excess mass.” Particularly in settings where queues at refuelling stations pose a challenge to maintaining a reliable supply, it may be worth incorporating an appeal not to top up when refuelling. Reducing the average amount of fuel in an LDV’s fuel tank by, say, 5 litres would reduce the weight by 5 kg, which represents 0.5% of a vehicle weighing 1000 kg. Applying the 0.33 multiplier (as discussed above) leads to an estimated 0.165% decrease in fuel consumption.

An estimate is used of a 1-2% fleet-wide reduction in fuel consumption for a public campaign calling on car owners to both remove non-essential objects from their vehicles, and to unmount empty and unused exterior racks. As with eco-driving, estimates are disaggregated for city versus highway driving so that assumptions of the percentage fuel savings can be changed for each of these driving profiles separately should better data become available.

Based on aerodynamics experiments in wind tunnels (Alam, Chowdhury and Watkins, 2009), proprietary rack and automobile manufacturer tests, and various readily publicly available online estimates, it is reasoned that unloaded roof racks (a classification that includes rear-mounted bicycle racks) increase car fuel consumption on average by at least 5-10%.

These find considerable variation in the drag and thus fuel economy impacts of roof rack models on the market – a result that suggests that regulatory action (e.g. efficiency labelling at minimum, or even minimum standards) might lead to fuel economy gains. Using Google Street View to conduct a survey of roof racks in California, Meier and Sathaye (2011) found that approximately 20% of vehicles had an empty roof rack. Assuming that the frequency of empty roof racks in California is representative globally, and that a public campaign might cut in half the incidence of driving with empty racks, estimated savings might range from 0.5-1%.

Table 15 • Remove excess vehicle weight measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Public information campaign to promote removal of excess mass in vehicles and to unmount roof racks when not in use	Moderate (> 100)	H	H	M-H

Together with eco-driving, the oil savings potential from removing excess mass, unmounting roof racks, and not topping up when refuelling is estimated to be large – globally between 186 kb and 396 kb per day might be saved.

Very little research has been conducted to date to determine the prevalence with which unnecessary objects are kept in the vehicle, exterior and unused add-ons are left attached, and owners fill their tanks at refuelling stations. The responsiveness of car owners to appeals to remove excess mass, unmount roof racks and fill their tanks for instance only half full is also uncertain. As with eco-driving, in the absence of better data, estimates of potential savings from this measure are simply 1-2% of total car fuel consumption.

Specification of motor oil grades – assumptions for the estimates

Different engine oil grades tend to result in different levels of fuel economy. Studies from a decade ago generally found a 1% to 2% increase in fuel efficiency when lower-viscosity oil is used in place of those grades most commonly used (ECMT/IEA, 2005). Efficiency improvements may be even larger during cold temperatures. This suggests one possible policy of requiring the use of low-viscosity oils in those cars where engine damage would not occur (probably nearly all cars, except for high-performance vehicles) or taxation policies to reduce the relative cost of low-viscosity oils.

To adequately estimate the improvements in fleet fuel efficiency, one would also need to know which oils are currently in use. Sales data in OECD countries in 2005 suggested that higher-viscosity 10W-30/40 oils were still the most frequently bought oils for oil changes while newer vehicles were normally filled with lower-viscosity oils at the factory (mainly 5W-30). Therefore, it might be possible to develop rough estimates of total fuel savings based on assumptions about current motor oil usage.

First, it is assumed that the vast majority of potential fuel savings have already been exploited in developed regions – 90% of vehicles in the highest income bracket are assumed to be running on the appropriate lower-viscosity motor oils, when permitted by climate. Half are assumed to have already switched to lower-viscosity oils in the middle gross domestic product (GDP) bracket, and only 25% are assumed to have switched to low-viscosity motor oils in the lowest GDP bracket.

In each region, the percentage of the fleet that typically operates in hot climates (i.e. much of India, Africa, China and the Middle East) is removed from the analysis, as it would be impractical and unadvisable to switch to low-viscosity motor oils in such climatic conditions. Estimates of the fuel efficiency improvements are taken from the lower range of values shown in Table 16 (1-2%).

Table 16 • Fuel efficiency improvements from low-viscosity oils

Lower viscosity oil	Previous oil type		
	10W-30	10W-40	5W-30
5W-30	1.2-2.0%	1.2-2.0%	-
5W-20	-	-	1.0-3.5%
0W-20	-	-	1.0-2.0%

Table 17 • Specification of motor oil grades measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Campaign to promote switching to lower viscosity motor oils where this is feasible	Very small (< 50)	H	H	H

Despite the fact that most economically developed countries have already switched whenever feasible to lower-viscosity motor oils, the potential for global oil savings from a concerted policy to switch in temperate regions is estimated to be on par with the savings from tyre inflation campaigns. **Worldwide, between 17 kb and 37 kb per day might be saved**. The regions that stand to benefit most from this measure have areas with large populations in temperate or sub-temperate climates where low-viscosity motor oils have not yet been universally adopted – Russia, non-OECD Europe and Northern China might still be able to reduce fuel consumption by 0.25-1.0%.

Cost level for implementation of eco-driving measures

Most eco-driving-related measures have few downside costs other than the government expenses involved in promoting these measures, and in some cases some efforts on the part of drivers to undertake the various measures (e.g. tire inflation, removing roof racks/weight from vehicles). Given the very low costs associated with these measures, the ratio to fuel savings is likely among the highest of all measures. The table below summarises the benefits and costs of eco-driving campaigns.

Table 18 • Qualitative cost assessment of eco-driving measures

<table>
<tr><th rowspan="2">Measure</th><th colspan="4">Government (and transit agencies)</th><th colspan="2">Individuals and businesses</th></tr>
<tr><th>Government Administrative / enforcement</th><th>Government Capital investment/expenses</th><th>Government information / advertising programs</th><th>Impact on government (and transit) revenues</th><th>Compliance costs (for individuals/ companies)</th><th>Consumer surplus/ business profitability impacts</th></tr>
<tr><td>Ecodriving</td><td rowspan="4">Low</td><td rowspan="4">Low</td><td rowspan="4">low-medium</td><td rowspan="4">No change</td><td rowspan="4">none</td><td>Gains to those who ecodrive</td></tr>
<tr><td>Tire inflation</td><td rowspan="3">Gains to those who participate</td></tr>
<tr><td>Roof racks excess mass</td></tr>
<tr><td>Specification of motor oil grades</td></tr>
</table>

Summary of eco-driving measures

The absolute fuel savings (in kb per day) potential of eco-driving policy measures are shown in Annex 3.

A basic eco-driving and efficiency campaign appeals to drivers to adopt strategies to reduce on-road fuel consumption, to monitor and inflate tyres, to remove excess mass and roof racks from vehicles and fill their vehicles' fuel tanks only half full, and to switch to lower-viscosity motor oils. This campaign might reduce global oil consumption by **700 kb-1 300 kb per day**.

A moderate package, which would include eco-driving training programmes and passage of laws to make tyre pressure checks and inflation mandatory at automotive service providers, might save **between 1 225 kb and 1 450 kb per day.**

A stringent package, which might include e.g. checkpoints at toll booths to record (and potentially fine) drivers of vehicles with empty mounted roof racks or clearly excessive mass, or mass mailings of informational brochures on eco-driving and other easily implementable vehicle efficiency measures, **might save 1 600 kb-1 830 kb per day globally**, or anywhere from 3.5-9% of global fuel consumption.

The potential for eco-driving and vehicle efficiency policy packages to reduce fuel consumption is quite even across regions and for most regions ranges from about 2.75-11%. The effectiveness of efficiency measures is reduced somewhat in regions where legislation has in the past decade advanced the development and diffusion of fuel-efficient technologies such as the United

States/Canada, OECD Europe and Japan/Korea – hence, these regions are already benefiting from the adoption of these technologies on a long-term and sustained basis.

2.5 Vehicle operation, fuel pricing and taxation-related policies

Increasing the marginal cost of personal car trips can serve as a powerful policy measure to reduce total vehicle travel. Drivers and passengers respond to high prices by taking fewer trips or shorter trips; by shifting the timing of their trips to avoid congestion; or by shifting to public transit, biking or walking.

This section examines multiple pricing measures, including distance-based pricing (i.e. fees implemented as either pay-as-you-drive [PAYD] or pay-at-the-pump [PATP]), facility-based tolls, congestion charges and parking policies.

Although in many cases, an oil supply disruption will trigger a price spike that provides sufficient (or more than sufficient) price signals to affect driving behaviours, in some countries various price controls or other systems may prevent such price signals from passing through to consumers.

The following set of price-oriented measures may provide substitutes in such situations, or may provide an alternative approach to sending price signals if the full price pass-through of an oil supply disruption is considered onerous.

Distance-based pricing – assumptions for the estimates

Using literature elasticity estimates, Cambridge Systematics and Eastern Research Group Inc. (2010) estimated that PATP tolls of 0.02 US dollars (USD) per mile (or equivalent gasoline or carbon taxes) would reduce aggregate vehicle miles travelled in the United States by about 2.5%. The most conservative estimate by Ferreira and Minikel (2010) for PAYD is similar: 3%. Following the methods applied in these two studies, estimates for the effectiveness of distance-based pricing are based on regional short-run price elasticity estimates.[6]

These elasticities are applied to the proportion of assuming the insurance costs range from about 3-6% of the estimated regional (post-oil shock) fuel cost per kilometre driven. The price increase corresponds to the prices considered in the above two studies: USD 0.01 per mile in Ferreira and Minikel (2010), and USD 0.02 per mile in Cambridge Systematics and Eastern Research Group Inc. (2010).

A consensus estimate of the potential impact of distance-based pricing (agnostic as to whether it is implemented as PAYD or PATP) is held to the following assumptions restricting its application:

- For multiple regions, only half of the countries in the region consider a distance-based scheme, given the variability in legal and regulatory frameworks and their varying conductivity to PAYD/PATP – this assumption is applied to Other Asia, Other LAC, the Middle East and Non-OECD Europe. While it may be the case that other countries currently lack the political climate and/or legal or institutional framework, it is assumed that PAYD/PATP models would be viable in all other regions as a basis for estimating oil savings if this were the case.
- Both schemes are rolled out on a strictly voluntary basis. Indeed, this form of implementation is likely preferable to a mandatory shift from conventional automotive insurance schemes. It

[6] Note that although the application of this elasticity is not strictly speaking appropriate considering the well-documented fact that PAYD and PATP reduce expenditures (in large part by reducing driving), it may nevertheless provide an acceptable proxy of the reduction in fuel use that occurs due to behavioural responses to the change in the pricing structures of distance-based pricing.

is likely that "first adopters" will consist of rational, well-informed, price-conscious consumers, and that the demonstrable savings that would likely be achieved by this demographic would then serve as valuable and convincing marketing for wider dissemination of the new insurance structures. One potential drawback of this voluntary opt-in roll-out might be that self-selection would reduce fuel savings, even for the (small) proportion of the population likely to take advantage. These first adopters are assumed to constitute only about 5-15% of the driving populace.

As a result of the (assumed) restricted voluntary adoption of distance-based pricing schemes, the estimated likely short-term fuel savings are quite limited. However, the longer-term potential fuel savings and other societal benefits are perhaps greater than any single other measure considered in this report. A 5% incremental increase in fuel economy is assumed to accrue to remaining passenger vehicle traffic, in proportion to the distance reduction achieved by distance-based pricing.

Table 19 • Distance-based pricing (PAYD/ PATP) measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
PAYD / PATP; voluntary adoption	Small (> 50)	L-M	L-M	H

Road pricing – assumptions for the estimates

The estimation method for tolls, congestion charges applies the short-run price elasticity of demand to the (already elevated) fuel price as calculated under the *SOIAH* scenarios. It is further assumed that road pricing increases (above existing levels, in regions where it was already used previously) the costs of driving on designated routes by 5% of the total fuel costs per kilometre driven (including taxes), and that it is applied on one-quarter (in the moderate policy case) to one-half (strong case) of the most congested roadways.

Estimates are agnostic regarding whether road pricing is implemented as tolls, cordon pricing or congestion charges. Of course, the effectiveness of the measure depends on careful planning in terms of getting the prices right such that e.g. tolls do not force traffic onto nearby arterials and alternative routes. In instances where road pricing is poorly executed, it may prove quite ineffective, even counterproductive. Tables 19 and 20 outline the fuel savings of distance-based and road pricing.

Table 20 • Road pricing measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Includes tolling, congestion and cordon pricing	Large (> 500)	M-H	L-M	L

The parameters that determine the estimated efficacy of both of these pricing measures in each of the world regions are quite similar, namely the sensitivity to fuel prices (i.e. the short-run price elasticity of demand) and the fuel prices – the latter of which are primarily determined by the levels of subsidies or taxes on automotive gasoline and diesel.

Hence, the patterns of regional estimated fuel savings are similar for both measures, but by construction, distance-based pricing is recommended only as a voluntary opt-in system, and is judged to be less efficacious than road pricing. While voluntary **distance-based pricing policies** might save **between 8 kb and 50 kb per day globally**, **road pricing** is estimated to have far greater potential and might save from **400 kb-1 100 kb per day worldwide**.

The estimated variation in the efficacy of pricing mechanisms across regions is determined in equal proportion by two parameters: the short-run price elasticity and the fuel price. The greater the price elasticity in absolute value, the more responsive travellers will be to the distance-based scheme. The cheaper the (post-oil shock) fuel costs of driving on a per kilometre basis, the greater the percentage of this variable cost of driving is constituted by the non-fuel (i.e. road pricing) costs.

The lower the initial fuel price and the greater the (magnitude of the) price elasticity of demand, the greater the potential for pricing policies to reduce fuel consumption. Many regions can exploit this combination of factors; among the best suited to do so are the Middle East, Non-OECD Europe and Russia. The policy is relatively less effective in the United States/Canada and Australia-New Zealand/Other OECD regions due to the highly inelastic demand elasticity in those regions for automotive fuels.

Dynamic pricing parking – assumptions for the estimations

Shoup (2005) enumerates the consequences of a US system that provides free parking as a requisite and right of car-oriented development. He estimates that 99% of parking is the United States is free, meaning that there are no direct costs incurred to occupy a space. However, beyond that, there are many substantial social, environmental and economic costs. Aside from the more obvious impacts such as emissions, increased oil consumption and traffic congestion, zoning requirements that mandate minimum off-street parking in commercial districts increase the costs of goods and services.

Shoup shows that “cruising for parking” results in a great amount of additional driving – according to his review of 16 studies conducted in 11 cities throughout many OECD (mainly US and European) metropolitan centres, cruising for parking constitutes 30% of urban traffic. In view of the relatively scant literature estimating the proportion of traffic made up of cruising for parking, a conservative estimate is adopted concerning the potential to reduce urban commuting as a consequence of rationalising off-street parking rates of 5-10%.

There are several options available to alter the costs of providing parking (from the employers’ perspective), and of deciding on how to commute (from the employees’ point of view). The most common is parking cash-outs. These are schemes whereby employers give their workers either cash or a transit subsidy, rather than simply provide free parking. They then charge for previously free parking. When designed properly, the change in cash flow is ideally revenue-neutral, but pilot studies confirm that simply providing the choice to employees changes their behaviour and results in increased carpooling and mode shift away from cars.

Kuzmyak (2010) points out that the switch to parking cash-outs is most attractive to employers/institutions facing parking shortages or expanding their workforce. Moreover, his study finds that of all the various measures using monetary incentives considered by an authoritative summary report on employer- and institution-based measures, parking pricing policies – including restricted parking, fees and HOV parking discounts – were the single most effective policy in reducing commuting.

A conservative estimate of the effect of raising parking prices on the reduction in urban travels is adopted. As cited by Litman (2011) and Shoup (2005), it is assumed that raising prices enough to result in a parking occupancy rate of 85% per block results in a reduction of 5-10% in distance travelled. Prices could be adjusted during a supply disruption, especially if other price signals are not sufficient to change consumer driving behaviour.

The effectiveness of employer-institutional adoption of parking cash-outs is estimated by adopting a narrow range of parking price elasticities of demand around the mean estimate: from -0.35 to -0.45. Given the wide variation in current prices within and across cities (even within a given country), it is difficult to assess the percentage increase in parking prices over the baseline that would be needed to achieve an 85% occupancy rate. Lacking better data, it is assumed that prices will increase 33-50% – but it should be stressed that in practice, prices typically increase in central business and commercial districts even while they decrease in other urban districts. Further, it is supposed that parking accounts for 30% of trip costs in urban trips that require parking.

Table 21 • Dynamic pricing parking measures

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Off-street urban parking meters set at prices to maintain ~85% occupancy at the block level throughout the day	Large (> 500)	M	L-M	M

Cost level of implementation of pricing measures

The costs associated with pricing measures can include administrative/information costs as well as substantial costs associated with new infrastructure. For electronic road pricing systems, a significant share of the revenues in current cordon pricing systems in cities such as Singapore, Stockholm and London go to pay for the infrastructure and administrative costs of these systems – an estimated 21% of toll revenues goes to collection costs in Singapore, 22% in Stockholm and 50-60% in London (Lindsey, 2006).

Compliance costs may be high for those who pay the fees, and time costs high for those who choose alternative routes. Significant benefits may accrue to all from lower congestion and to bus riders, cyclists and pedestrians from lower levels of traffic in urban areas. Table 22 summarises these costs.

Table 22 • Qualitative cost assessment of pricing measures

Measure	Government (and transit agencies)				Individuals and businesses	
	Government Administrative / enforcement	Government Capital investment/expenses	Government information / advertising programs	Impact on government (and transit) revenues	Compliance costs (for individuals/ companies)	Consumer surplus/ business profitability impacts
Distance-based pricing (PAYD / PATP)	medium-high	Low	low-medium	Increased	should break even	Gains to low mileage drivers
Road Pricing (tolls / cordon pricing / congestion pricing)	typically high	typically high			potentially high compliance expenses	potential gains from lower congestion

Summary of pricing measures

Pricing can be a powerful lever to restrain the use of cars and thus save oil in a hurry. Pricing policy packages alone might save from 4-13% of post-oil shock car fuel consumption, depending on the stringency of the policies and the region in which they are put into force.

Although it is unlikely to be a politically popular option for consumers who are already grappling with a sharp increase in the price of fuel and uncertain oil supplies, it has the benefits of economic efficiency – unlike driving bans, it is capable of accounting for the variation in the value travellers place on trips with different purposes and destinations. In addition, the revenues generated by changing or increasing prices can be recycled to fund public transit or even redirected to offset the economic impacts on certain vulnerable segments of the population.

The potential to save oil from rationalising parking pricing using dynamic pricing that results in block-level off-street parking occupancy rates around 85% is similar to the potential of road pricing (>500 kb per day).

Certain regions (including the United States/Canada and Australia/New Zealand and other OECD) may find changing the cost of parking to be not only cheaper and more politically palatable, but also more effective than conventional road pricing measures (e.g. tolls and cordon prices).

Targeting urban cores that have pre-existing alternatives to cars as the sites of price signals is likely to be more economically efficient and institutionally and politically feasible than many road-pricing measures.

There remain two open questions: the first is technical viability – i.e. whether metropolitan regions are equipped to switch to dynamic parking meters and enforcement – and the second, of adequate and consistent enforcement. The absolute fuel savings (in kb per day) potential of implementing driving and parking pricing measures are shown in Annex 3.

2.6 Driving restrictions and regulatory approaches

Two types of driving restrictions and regulatory approaches are considered: licence plate-based driving restrictions and vehicle speed reduction.

Odd-even licence plates – assumptions for estimates

Attempts to restrict driving by regulating how and when particular vehicles can be used have a long history, particularly licence plate-based restrictions. For example, Hoy No Circula in Mexico City has been applied in various forms as far back as 1989. These can take the form of "odd-even" plate days, where effectively half of all vehicles are not allowed to drive on a given day.

As a short-term measure in extreme circumstances, licence plate driving restrictions have the virtue of being simple and, in principle, easily enforceable. However, bans are likely to be politically unpopular, and could be inequitable and economically inefficient.

Overall it appears that driving restrictions can be somewhat effective at cutting driving levels in general conditions, and are more likely to be effective if they apply for shorter periods of time (weeks or a few months), where consumers may be less likely to take evasive action.

Two licence plate policies that might be implemented in emergency conditions are examined – a moderate one that restricts vehicles based on the final digit of the licence plate over a ten-day interval (i.e. restricting the operation of one-tenth of the vehicles per day), and the strong policy of an odd-even driving ban.

It might seem that the moderate driving restriction might reduce traffic and fuel use by 10%, and the strong ban by half. But when one considers the fact that some households have multiple vehicles, and that households might be induced to take more trips on days when they are permitted to drive (though they are more likely to chain trips under such an incentive structure), then the actual impact is less than this first consideration.

The effectiveness of a driving ban will depend on how many vehicles are available to an individual when making the choice of how and when to make a trip. In some countries, company vehicles are used widely, but the availability of a vehicle depends upon the number of vehicles owned by a household. Hence, the effectiveness of vehicle bans is estimated by considering first the distribution of vehicles available to automobile-owning households and then, for certain countries and regions – namely China, India, Other Asia countries, Other Latin American Countries and Africa – by estimating that vehicles provided by companies with fleets of ample size to circumvent the ban account for 10% of trips.

By estimating the distribution of the number of vehicles per household in each of the 14 analysis regions, it is possible to better gauge the likely real-world impact of driving bans. The derived country-level estimates of vehicles per household are used to estimate the probability of a vehicle being available to a household under the travel ban; the other parameters are the percentage of vehicles banned on a given day (0.1 under the moderate ban, and 0.5 under the strong ban), and the number of vehicles owned by a household.

Finally, a rebound of 25% is assumed, i.e. that one-quarter of kilometres travelled will be shifted to days on which cars are available to a household, or that households find other ways, aside from the intended mode shift (e.g. borrowing cars), to circumvent the ban. The resulting estimates of country-level driving reductions are aggregated to the regional level.

Table 23 • Driving restriction measures

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
One day in two driving ban: Odd-even licence plate scheme prohibits cars from operating every other day (strong ban)	Very large (> 2 000)	L-M	M	L
One day in ten driving ban Vehicles are prohibited from operating based on the final digit of their licence plate (i.e. 0-9), with the bans applying to a single number each day, at ten-day intervals (moderate ban)	Large (> 500)	M	M	L-M

A ban on vehicles with plate numbers ending in a given digit, effectively limiting one in ten vehicles from driving on any given day (but not resulting in a 10% reduction in VKT[7]) may reduce global oil consumption by **670 kb-950 kb per day**, or about 3-4% of global fuel consumption by passenger cars.

An odd-even ban, which cuts the number of vehicles allowed to drive on any given day in half, is estimated to result in **global oil savings of 4 800 kb-6 800 kb per day**, or about 20-30% of global fuel consumption by passenger cars.

Bans will be effective only with strict and consistent enforcement, and they are estimated to be more effective in regions where most households have access to only a single car and where company fleets make up a small proportion of passenger cars.

Temporarily reducing speed limits – assumptions for the estimates

In response to the 1973 Arab oil embargo, the United States enacted a national 55-mile-per-hour (mph) speed limit. Enforcement of the new federal law was arguably inadequate – the speed limits were widely flouted, and by 1995 when the law was repealed, its long-term effectiveness in reducing fuel consumption was disputed.

[7] Vehicle Kilometres Travelled – It might seem that the 'moderate' driving restriction might reduce traffic and fuel use by 10%, and the 'strong' ban by half. But when one considers the fact that some households have multiple vehicles, and that households might be induced to take more trips on days during which they are permitted to drive (though they are more likely to chain trips, under such an incentive structure), then the actual impact is less than this first consideration.

According to detailed study of driving speed on fuel economy conducted by researchers at Oak Ridge National Laboratory, maximum steady-speed fuel economy is generally achieved when a vehicle is operated at the lowest practical or recommended speed while in the highest gear, likely to be 40 mph-50 mph (about 64.4 kilometres per hour [km/h]-80.5 km/h) for common vehicles (Thomas et al., 2013).

Abstracting from raw dynamometer readings at various speeds, the study found that a "naïve" estimate of a constant increase in fuel consumption for each increase of 10 mph (i.e. from 50 mph to 60 mph, or from 60 to 70) yields about a 13.9% decrease in fuel economy. Although this simple linear relationship ignores the fact that drag forces increase at the square of the speed and hence had the lowest predictive accuracy of all five tests, it was nevertheless accurate to within an error of ±4% for 90% of the tests run.

Furthermore, in the United States, in expert testimony before the US Senate Committee on Energy and Natural Resources, Green (2008) estimates that a 5 mph reduction in speed limits, if strictly enforced, would reduce fuel consumption by up to 7% on the roads where it applied, and 2-3% nationwide.

In Europe, primarily for safety reasons, the European Community is considering adopting Intelligent Speed Adaptation technology to restrict freeway speeds by 2020. A recent simulation study cited by the European Environment Agency (EEA) found that reducing motorway speed limits from 120 km/h to 110 km/h could result in fuel savings given current technological characteristics of the European passenger vehicle fleet of 12-18%, assuming smooth driving and 100% compliance. A separate report by the EEA found that about two-thirds of European survey respondents claimed that they would "be willing to compromise a car's speed in order to reduce emissions," but that around 40-50% of drivers currently drive faster than legal speed limits.

The EEA rightly concludes from this contradiction between intentions and actions that strict enforcement would be needed to achieve compliance with reduced speed limits. In countries with older, less efficient fleets, the reductions in oil demand due to speed restrictions should be greater.

To estimate the fuel savings of reducing speed limits, the simple linear approximation derived by Thomas et al. (2013) is used, which translates into international units as an improvement of about 10% in fuel economy for each decrease in velocity of 10 km/h.

In this measure, a national or regional authority would temporarily lower the speed limits of motorways to a level deemed appropriate to save fuel without unduly restricting mobility. In light of the above data, a 50% compliance rate assumed by the original *SOIAH* report seems appropriate. For the United States/Canada and OECD Europe regions, fuel savings estimates are based on:

- A moderate measure that strictly enforces 60 mph speed limits across the United States and 100 km/hr in Europe on all major freeways.
- A strict speed limit reduction measure that limits speeds to 55 mph in the United States and 90 km/hr in OECD Europe on all major non-urban roadways.

Baseline speeds for the United States and OECD Europe are estimated as the approximate weighted average freeway speeds of the VKT by passenger cars across US states and European nations. Highway speed limits vary among US states and within certain states, mostly from 65 mph-80 mph. Speed limits on freeways in European OECD nations typically range from 100 km/h-130 km/h.

Table 24 • Speed limit reduction measure

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Temporarily reduce freeway speed limits to 90 km/h (55 mph in United States)	Large (> 500)	M	H	L

Reducing speed limits on freeways and other non-urban ways is estimated to result in **oil savings from 900 kb to about 1 400 kb per day.** On a regional basis, moderate to strong temporary reductions in speed limits may reduce fuel consumption anywhere from 2% to upwards of 10%, depending primarily on the split of highway driving.

Cost levels for implementation of speed limit reductions

The costs of driving bans include the need to administer the programme (developing regulations, compliance mechanisms, etc.) and then to enforce these restrictions once they are activated. Informational/awareness campaigns to alert drivers to the new regulations will also be an important, if not large, expense. These costs are likely to be dwarfed by the implicit costs of lost time to drivers (and hence to households and businesses) who would be restricted from driving on certain days, or would need to invest in solutions to be able to drive on those days (i.e. through accessing cars allowed to drive) or to seek alternative transport options.

In the case of speed limit reductions, the major costs would be investments in signage and information systems to let drivers know that the speed limits have changed during a crisis. Enforcement costs may also be significant, though this cost may be partially offset (or indeed result in a new public revenue source) by increased revenues from speeding tickets. Compliance costs may be low except for consumers and businesses due to longer, slower trips. Time costs may be significant – see, for instance, Wolff (2014) – but there are also likely to be valuable safety benefits during a period of lower speed limits (Holz-Rau and Scheiner, 2011). Table 25 provides a review of these costs for each measure.

Table 25 • Qualitative cost assessment of driving restrictions

Measure	Government (and transit agencies)				Individuals and businesses	
	Government Administrative / enforcement	Government Capital investment/expenses	Government information / advertising programs	Impact on government (and transit) revenues	Compliance costs (for individuals/ companies)	Consumer surplus/ business profitability impacts
1 in 10 ban	typically high	Low	low-medium	No change	potentially high from re-organizing activities	lost surplus to individuals and businesses
Odd-even ban	typically high					
Speed limit reduction	typically high	possibly high (variable speed limit signs)		Possible increases from enforcement	Direct costs may be low	Time costs likely to be high, though may be offset by safety improvements

Summary of driving restriction measures

Regulatory policy packages would require strong enforcement. Though they may incur substantial social and economic costs, and are unlikely to be politically popular, the potential to save oil via temporary speed limit reductions and licence plate-based driving bans is high (**900 kb to about 1 400 kb per day**). It is estimated to make up between 6-11% of regional fuel consumed by passenger vehicles for the moderate package and from about 30-44% for the strong regulatory package. This translates to a saving of anywhere from about 8-40% of fuel consumed by cars globally.

The absolute fuel savings (in kb per day) potential of temporarily regulating and restricting driving are shown in Annex 3.

2.7 Multi-fuel vehicles

Alternative-fuel vehicles – assumptions for the estimates

Since *SOIAH*, there has been a general increase in the use of alternative-fuel vehicles around the world, although numbers are still low in most countries. This includes electric vehicles (EVs) and plug-in hybrid cars (sales of which passed 1 million during 2015), with over 100 million electric two-wheelers, mainly in China.

Natural gas vehicles have reached over 16 million worldwide with high shares in countries such as Iran and Pakistan. Biofuels-capable vehicles (either flex-fuel or dedicated such as E-85 vehicles) have reached high market shares in Brazil and modest market shares in the United States and Sweden. These types of vehicles are potentially important for saving oil in a hurry in two ways: they can be driven on non-petroleum fuel, and in the case of vehicles capable of running on multiple fuels, often called flex-fuel vehicles (FFVs), non-petroleum-based fuels can be relied upon for operation during an oil supply disruption.

Two studies of the ethanol market and FFVs in Brazil have been conducted that shed some light on the use of gasoline versus ethanol in FFVs there (with one also including Sweden), and the propensity of people to switch between these fuels. Pacini and Silveira (2011) looked at consumer fuel choice in Brazil and Sweden, and found that consumers are price-sensitive between gasoline and ethanol and will switch between them when price changes make one more cost-effective than the other. They found this to occur even more often in Sweden, in part because of the relatively few instances in Brazil where gasoline was cheaper than cane ethanol.

De Freitas and Kaneko (2011) estimated elasticities of ethanol demand as a function of the ethanol/gasoline price ratio and found that the short-term elasticity is between -1 and -1.5. This appears to reflect the fact that not all vehicles in Brazil are flex fuel, suggesting that the elasticity for FFVs alone is higher, and will continue to rise as the penetration of FFVs within the total stock of cars in Brazil increases (which indeed continues to occur).

It is assumed that countries are stuck with the stock of alternative-fuel vehicles and fuel production infrastructure that they now have. The main effort is to make maximum use of this system during an oil supply disruption.

It is assumed that all multi-fuel vehicles are currently driven 50% of the time on gasoline and that this could be shifted to zero gasoline/100% alternative fuel. For biofuels, it is also assumed that a maximum 20% increase in production is possible on short notice (e.g. within a few days or weeks). It is also assumed that there are no restrictions in supply of natural gas or electricity.

For the mid-/long-term measures: in principle, countries could completely eliminate petroleum use in transport, but this would take many decades even with a very aggressive programme. Here it is assumed that EVs (including plug-in hybrids) could be increased to at least 1% of any country's vehicle stock – not as easy as it sounds in a world with 1 billion LDVs. Indeed, for any country this would take a very concerted effort, but it seems possible. For natural gas vehicles, it is similarly assumed that 1% would be possible, but in countries that already have a significant number of vehicles it is assumed that a 25% increase in stocks is achievable over today's levels. For biofuels, it is assumed that at least 1 billion litres a year of production capacity is possible (for each of ethanol and biodiesel), or a 25% increase if today's levels are significant. Sufficient sales of FFVs to use that much fuel is also assumed.

Incentives to encourage consumers to purchase alternative-fuel vehicles and producers to supply alternative fuels can build up the potential responsiveness of this system to oil supply disruptions. The nature of needed incentives depends heavily on the relative costs and consumer demand for such vehicles without incentives. Policies are already in place in many countries (e.g. a USD 5 000 tax rebate for EVs and USD 2 500 USD for plug-in hybrid vehicles in the United States) and Norway, France, China and other countries have developed similar schemes as part of a general oil conservation and/or GHG reduction strategy.

Table 26 • Alternative-fuel vehicle measures

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Sustained subsidies through 2020 increase the potential to respond to an oil supply shock by switching fuels in multi-fuel vehicles (mid-/long-term measure)	Large (> 500)	M-H	M	M-H
During supply disruption, ensure price advantage and adequate supplies of target alternative fuels (short-term measure)	Moderate (> 100)	M-H	M-H	H

The effectiveness of the above two policy measures was estimated separately for the 2014 base year and for 2020, assuming that the sales of multi-fuel vehicles are encouraged by subsidies. The potential oil savings for each region, in kb per day, are shown in Annex 3.

The graph shows that the current potential for oil savings by substitution is greatest in absolute terms in the United States/Canada and Brazil. The greatest potential in both regions comes from first-generation biofuels – ethanol primarily from corn, and biodiesel from soybeans and sugar cane. In contrast, the current potential for fuel switching in all other world regions, and most notably in Europe (OECD and Non-OECD), Russia, Japan, China and Other Asia economies, comes primarily from natural gas.

Even in a short time period, every world region has the potential to realise substantive gains in terms of eroding the current dominance of petroleum-based fuels in road transport. Many nations are aware of the energy independence and security benefits of promoting alternative fuels and multi-fuel vehicles, and this benefit is indeed among the reasons that many governments promote them.

Cost level of implementation for the alternative-fuel vehicle measures

The costs of using current alternative-fuel vehicle potential are mainly associated with ensuring the fuel supply of alternative fuels, along with the usual information campaign. The need for and cost of enhancing the supply of e.g. biofuels during an emergency is likely to be complex, variable by country, and worthy of its own study in most places. But there are not many investments that seem possible in the short term, apart from storage systems (which also are an important supply-side measure for petroleum fuels). Ultimately, the main effort here may be to exhort drivers to use electricity/natural gas/biofuels as much as possible – and to use their most efficient rather than least efficient vehicle as much as possible.

In the longer term, there is no limit to the investments that could be made to increase the availability of alternative fuels, vehicles that run on them, and infrastructure to supply these fuels to vehicles. Government subsidies for such programmes already run into the billions of dollars (e.g. vehicle price subsides in the United States, Europe and Japan). The benefits of such a programme would accrue more generally, in terms of lower reliance on petroleum and potentially lower GHG emissions.

The table below characterises the costs of supporting fuel switching both in the immediate advent of an oil supply disruption and as a mid-/long-term strategy of developing alternatives to petroleum-based road transport.

Table 27 • Qualitative cost assessment levels of supporting alternative-fuel vehicles

Measure	Government (and transit agencies)				Individuals and businesses	
	Government Administrative / enforcement	Government Capital investment/expenses	Government information / advertising programs	Impact on government (and transit) revenues	Compliance costs (for individuals/ companies)	Consumer surplus/ business profitability impacts
Short term- encourage alternative fuel use	medium	Possible minor investments to enhance potential	low-medium	possible losses in fuel taxes	Low	Gains to those with alternative fuel capability
Long-term increase in alt fuel vehicle system	typically high for major programs	possibly high (e.g. for infrastructure)			Possibly high if purchase requirements	Depends on costs and requirements

2.8 Freight trucking

Measures to rapidly reduce freight energy use during an oil supply disruption include some of the same approaches as for passenger transport, but there are some important differences, too. For example, freight mode shifts would be difficult to promote with policy measures in response to an oil supply disruption, given that supply chains have evolved to rely increasingly upon the speed and flexibility of road freight, relative to rail (Schipper and Fulton, 2003). However, there are varieties of other measures, most of which promote in-use vehicle efficiency, that would reduce fuel usage in freight trucking.

Many of these overlap with promising measures already discussed for the passenger LDV fleet – eco-driving, temporary speed limit reductions, tyre inflation, changing to low-friction lubricants and simple aerodynamic improvements are the freight truck analogues to measures assessed in previous sections for passenger vehicles.

In a review of potential oil demand restraint measures in the freight sector commissioned by the IEA, Noland and Wadud (2009) examined the feasibility, effectiveness and economic impacts of policies designed to save oil in the event of an oil supply disruption. Their literature review found that the majority of the measures that might rapidly reduce consumption come from simple operational measures, while most policies affecting supply chains and logistics, such as those intended to effect a major mode shift, would be difficult to operationalise quickly, as well as politically unpopular, and have substantial adverse economic impacts.

Two exceptions to this general finding are removing night-time driving restrictions (e.g. for food delivery in the United Kingdom) and relaxing or harmonising weight limits. The first measure would expand logistic flexibility, and thus enable truckers to avoid congestion and reduce idling – and thereby achieve better fuel mileage and reduce fuel consumption for idling operations. Relaxing or harmonising weight limits would enable greater service efficiency as measured in energy use per tonne kilometre, as greater efficiencies are typically possible as the weight of cargo increases.

One measure with the potential to save fuel by enabling freight companies to reduce backhaul (under-utilised cargo space on return trips) and increase load factor would be to temporarily prohibit same-day and next-day delivery services. Arvidsson, Woxenius and Lammgård (2013) show that time considerations act as the constraint to hauling companies' efforts to maximise backhaul and load factor efficiencies. This measure is unlikely to be politically popular with consumers, let alone the large freight companies.

For the estimates made for the following measures, data on middle- and heavy-duty truck on-road fleet fuel economy, total travelled distance, load factors (average tonnes carried), and fuel shares for gasoline and diesel in each region are taken from MoMo (IEA, 2014) and extrapolated for the year 2014.

Freight trucking – assumptions for the estimates

Simple aerodynamic improvements

Estimates of the potential fuel consumption reductions from aerodynamic retrofits range from 3-4% for single pieces of equipment (e.g. side, roof, and chassis fairings; cab extenders; vortex generators; air dams; and aerodynamic hoods, bumpers and side mirrors) (UCS, 2010), to 5.5-9.3% for a suite of retrofits on both tractor and trailer (NRC, 2010; UCS, 2010). Many of these aerodynamic retrofit devices are applicable only for heavy-duty trucks on long-haul routes (i.e. about two-thirds of class 8 vehicles and some lower class vehicles). This is taken into account by applying the reduction potential of this measure only to heavy-duty trucks. It is assumed that existing fleet penetration of aerodynamic devices is approximately correlated with economically feasible access to more sophisticated (and expensive) devices across world regions, hence in lieu of estimating baseline penetration of aerodynamic improvements, instead it is assumed that public subsidies and/or mandates could improve aerodynamics such that fuel use is reduced by 5.5-9%.

The power losses due to drag (air resistance) increase at greater than linear (but less than square) rates with increasing speed, in contrast to power losses from tyre friction, which are linear. Hence, the US Environmental Protection Agency (EPA) estimates that a typical combination truck spends at least 65% of its operating time driving at highway speeds (US EPA, 2016) is adapted to all world regions based on the relative fraction of the non-urban population relative to the United States in each region (with an assumed maximum of 85% of driving time at highway speeds). This estimate of relative time on highways versus other roadways is adapted for other assumptions (i.e. eco-driving, speed reductions, dedicated truck lanes) for which it is relevant.

The findings of Curry et al. (2012) note that aerodynamic improvements are relatively less effective in reducing fuel consumption as compared with rolling resistance and tyre inflation in trucks fleets that typically travel at lower speeds. In India or China, where trucks travel at highway speeds around 70 km/h, tyre improvements are likely to yield greater benefits. In the United States, where trucks travel 105 km/h on average, aerodynamic improvements are likely to result in greater fuel savings (though with the rapid construction of highways witnessed in China over the past decade, that country may well have already relegated slow trucking speeds in many regions to the past).

Moreover, Indian and Chinese trucks operate at a much higher gross weight (at least 49 t as compared with about 39 t in the United States), and hence the fuel economy gains of low rolling resistance tyres and air pressure monitoring are commensurately greater.

Tyre inflation campaign for freight trucks

The US EPA estimates that automatic tyre inflation systems can improve fuel economy in the freight trucking sector by 0.5-1% (US EPA, 2016). According to that agency, a survey found that less than half of tyres in the freight industry are inflated to within 5% of the recommended pressure, and that only 8% of truck drivers check tyre pressure at the outset of each trip. The EPA consequently recommends automatic tyre inflation (ATI) systems, which cost about USD 800,[8] as a potentially cost-effective alternative to manual monitoring of tyre pressure for long-haul fleets – it estimates a payback period of around two years for ATI systems from savings in tyre replacement, maintenance and fuel.

[8] https://nepis.epa.gov/Exe/ZyPDF.cgi/P100QJTW.PDF?Dockey=P100QJTW.PDF

To estimate the fuel savings of tyre inflation campaigns, the US EPA estimated range (0.5-1.0%) globally is applied to both middle- and heavy-duty truck fleets, across all driving cycles (i.e. for highway and city driving). The effectiveness of this measure is directly correlated with the public investment in the measure – subsidies or mandates to install ATI systems are likely to result in greater fuel reductions.

Speed limit reductions

Electronic control modules, also known as speed governors or speed regulators, are devices that limit vehicle speed. They have become standard manufacturer-installed components of heavy-duty truck engines and are routinely installed on many other types of freight trucks. Europe mandates the use of governors to limit truck speeds (for trucks of more than 3.5 t) to 90 km/h. Furthermore, on many freeways in the European Union, trucks are restricted to driving in the rightmost lane. In the United States, many large operators already limit the speed of trucks in their fleet to maximum cruising speeds of 60 mph-70 mph (~100 km/h-113 km/h). Some industry observers expect the US Department of Transportation to pass a mandate to require all freight trucks over 26 000 pounds (~11.8 t) to use governors to limit their speeds in the coming few years to somewhere in the range of 65 mph-70 mph (~105 km/h-113 km/h).[9] Japan and the Canadian provinces of Quebec and Ontario (which together account for a large share of Canada's population) have also mandated the use of speed governors to 90 km/h (Japan) and 105 km/hr (Quebec and Ontario).

Literature estimates of the fuel economy benefits that could be gleaned from reducing the speed of freight trucks range from about 7% (US EPA, 2016) up to 27% (Garthwaite, 2011) for a reduction of 10 mph.

Franzese and Davidson (2011) found that fuel economy of medium- to heavy-duty trucks carrying heavy loads (with a total vehicle weight of more than 65 000 lbs, or about 29.5 t) reaches its maximum from about 55 mph-65 mph, and that the optimal speed within this range is, in fact, 59 mph (~95 km/h). The US EPA further estimates that a typical combination truck spends at least 65% of its operating time driving at highway speeds (US EPA, 2016). Cooper et al. (2009) estimate that reducing speeds by 1 mph would result in an average 0.7% reduction in fuel consumption (or a 0.43% reduction per 1 km decrease in cruising speed).

To estimate the fuel savings of this measure, moderate and strict speed reductions are considered. The moderate case sets speed limits for trucks to 95 km/h (60 mph) and increases enforcement (e.g. higher fines, greater frequency of patrolling and higher probabilities of stopping speeding trucks) on trucks driving at steady speeds of more than 100 km/h.

A 50% effectiveness is assumed; trucks that were speeding reduce their speeds to half the previous gap between the original average speed and the mandated speed limit (note that this multiplier accounts for both the likelihood that some vehicles already travel at or below the optimal speed, and that other drivers will continue to drive above the designated speed limit).

The strict version of this measure utilises the fact that most engines manufactured presently already are or can be fitted with speed regulators. It is assumed that governments are able to mandate that the entire fleet (in the cases of the highest income regions), 75% of the truck fleet (in middle-income regions) or 25% of the truck fleet (in low-income regions) use speed regulators to limit steady state cruising speed to 95 km/h.

[9] A federal requirement for installing and using speed governors is supported by industry groups (including the American Trucking Association), consumer safety advocates and many truck fleet operators. On the other side, truckers and independent truck driver associations are generally against governors.

The fuel savings of the measure assume that in the United States, 50% of the truck fleet is already driving at speeds between 60 mph and 70 mph, that European and Japanese regulations have already captured the fuel economy gains of this measure, and that the average speed for the rest of the global truck fleet is about 105 km/h.

Eco-driving, driver training and intelligent vehicle systems

According to Michael Roeth, the executive director of the North American Council for Freight Efficiency, the difference in fuel economy based on driving habits ("between the best driver and the worst") is about 25% (Garthwaite, 2011). Vernon and Meier (2012) note that some freight firms award bonuses to their drivers based on fuel-efficient driving (though the incidence and size of these bonuses both seem to be smaller than bonuses for safety and on-time delivery records).

Estimates of the potential fuel savings from eco-driving training in freight range from 2-30%, where the average range of reduced fuel consumption from programmes combined with driver incentives (e.g. bonuses) is from 2-12% (Blinge and Svensson, 2006; Hedenus, 2008), cited in Arvidsson, Woxenius and Lammgård (2013).

To estimate the fuel savings potential of eco-driving training and intelligent vehicle systems, the conservative range of estimates cited above is adopted: 2-10%. It is assumed that this range of potential savings applies equally across medium- and heavy-duty trucks, and in both city and highway driving, in all world regions.

Dedicated truck lanes on motorways

As an "in-a-hurry" measure, dedicated truck lanes would need to be restricted to repurposed HOV lanes or other easily delineated lanes. This could also be achieved by simply restricting trucks to the slowest-moving traffic lane, which already occurs in some localities. NRC (2010) points to the multiple advantages of construction projects to repurpose lanes permanently for trucks, including the opportunity to upgrade road surfaces and highway designs, safety, and congestion benefits. These are clearly mid- to long-term projects and hence are not directly applicable to the *SOIAH* situation. However, an oil supply disruption may justify short-term reallocation of lanes.

To estimate the potential of creating dedicated truck lanes, the same potential coverage with truck lanes as for the HOV lanes measure considered under the "Employer and institutional policy" rubric are assumed: 5-10% of non-urban roadways. On these stretches, it is assumed that trucks are required to maintain a cruising speed of about 95 km/h (59 mph) plus or minus 5 km/h, as this is the speed of maximum fuel efficiency for trucks. Fuel consumption reductions are estimated using the same assumptions for regional baseline truck speeds as in the speed reduction measure, except that an effectiveness factor of 75%, rather than 50%, is applied, as dedicated lanes are likely to both encourage a steady flow of traffic and be easier to patrol and monitor than trucks mixed with passenger vehicle traffic. As Europe already mandates the use of speed governors and many European roads mandate that trucks drive in the rightmost lane, this measure is taken to be entirely ineffective in most of OECD Europe.

Voluntary idling reductions

Argonne National Laboratory has created an open-access online calculator to estimate the fuel consumption associated with vehicle idling.[10] Based on industry surveys conducted in the United States in 2008, Vernon and Meier (2012) estimate that engine idling to supply heating, electricity and other in-cab services during rest time consumed more than 3.8 billion litres, or at least 2.5% of fuel consumed by the road trucks. They note that the penetration of off-the-shelf products that supply electrical power and heating/cooling was somewhere between 26% and 36% in 2006. California has banned idling for more than five minutes per event, and there is a growing network of truck stop electrification sites across the United States (there were 116 in 2013). Plug-in ports on heavy-duty trucks allow drivers to use electricity for air conditioning, heating and electric power rather than idling their engine.

The fraction of energy consumption in trucking estimated in 2006 (about 2.5%) is adopted as a conservative baseline for all world regions except the United States, Europe and Japan/Korea, where it is assumed that fuel consumption has been cut in half from 2006 levels in the United States, and thus constitutes about 1.25% of freight fuel consumption. It is then assumed that fuel consumption attributable to idling could be cut in half by basic mandates and/or subsidies, or reduced by as much as 75% with stronger regulatory measures combined with market incentives.

Equipping trucks with GPS

Global positioning system (GPS) units can assist drivers in finding the shortest route and avoiding traffic congestion, and with generally tracking and dispatching vehicles, all of which can save considerable amounts of fuel. Clearly, the potential for this measure is likely greater in countries in the low- to mid-range of GDP, in inverse proportion to the fraction of trucks already equipped with and using GPS. In 2008, a major trucking company estimated that only 3-10% of a driver's total distance was travelled "out-of-route" (i.e. by routes that are likely suboptimal and could be made more direct using GPS and traffic monitoring devices together with fastest routing algorithms) (Vernon and Meier, 2012). GPS units have become inexpensive, particularly relative to the costs of fuel on a per kilometre basis, and thus have a very short payback period.

To assess the effectiveness of this measure, it is assumed that 90% of freight trucks in countries and regions in the highest income bracket already use GPS, that 50% of trucks are equipped with GPS in middle-income regions, and that only 25% of trucks are equipped with GPS in poor countries. The conservative range of the above cited estimate of out-of-route distance is 3-5%.

Table 28 • Freight/logistics improvement measures

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Freight driver training Includes education in eco-driving measures for trucks and financial incentives for efficient driving and/or intelligent vehicle systems	Large (> 500)	M-H	M-H	M-H
Freight truck speed limits Temporarily reduce freight speed limits to 95 km/h (60 mph in United States)	Moderate (> 100)	M	H	M

[10] A PDF of Argonne's idling fuel use calculator is available at www.transportation.anl.gov/pdfs/idling_worksheet.pdf. The PDF also provides a link to an Excel version of the calculator.

Measure	Potential global oil savings (kb per day)	Feasibility		
		Institutional	Technical	Political
Equip trucks with GPS Subsidise the purchase of GPS units for freight trucks	Moderate (> 100)	H	H	H
Freight idling reductions Voluntary idling reductions – public campaign and/or subsidies	Moderate (> 100)	H	M-H	M-H
Freight aerodynamics Retrofit trucks and trailers with aerodynamic devices	Moderate (> 100)	M	L-M	M
Truck tyre inflation Education campaign and/or subsidies for tire inflation devices in trucks	Small (> 50)	H	H	H
Dedicated truck lanes Repurpose 5-10% of non-urban roadways as dedicated truck lanes	Small (> 50)	M	M	M

Aerodynamic improvements: Simple aerodynamic devices may be mandated and/or subsidised by the government, and might save from **290 kb-490 kb per day** if applied worldwide. OECD and Non-OECD Europe, the Middle East, India, and China may benefit substantially from measures calling for the rapid retrofitting of the heaviest long-haul trucks.

Tyre inflation campaigns/ATI systems: Oil savings from this measure, while not as high as those of aerodynamic retrofits, are likely to be both cheaper and more easily realised. Moreover, the fuel economy benefits of tyre improvements (in alignment, pressure and low rolling resistance) are realised at all vehicle speeds, and hence are a wiser investment in regions where trucks travel at lower average speeds than aerodynamics. Global potential savings range from **54 kb-112 kb per day**.

Speed limit reductions: These are estimated to have the greatest potential in the Middle East, China, Non-OECD Europe, and Australia-New Zealand/Other OECD. The potential global oil savings from reducing speed limits for trucks to the range where they achieve maximum fuel efficiency are from **130 kb-220 kb per day**. Savings are small in Japan/Korea, and virtually no oil can be saved in OECD Europe via reducing truck speed limits, as governors are already used to constrain maximum cruising speeds in trucks.

Eco-driving, driver training and intelligent vehicle systems: This measure has the greatest potential of all measures in freight, if backed with financial incentives, to save oil in a hurry. The range of estimated global savings is from **215 kb-1 120 kb per day**. Drivers and trucks should at minimum be surveyed or even monitored (e.g. by truck hauling companies) in order to assess the effectiveness and costs of this measure.

Dedicated truck lanes: This measure might save from **65 kb-135 kb per day** globally. Russia, India and the Middle East are estimated to save the greatest percentage of truck fuel by designating dedicated truck lanes.

Voluntary idling reductions: Easing restrictions on driving hours may contribute to a willingness to volunteer to reduce idling for “hotel” electricity and heat services. Subsidies for the largest long-haul trucks to purchase idle reduction technology may also be a cost-effective means of reducing fuel consumption. Estimated savings are from **100 kb-165 kb per day**.

Equipping trucks with GPS devices: Government mandates for trucks to use GPS are likely to be popular with truckers in regions where GPS technology is not already widespread in trucking.

Subsidies to help companies owning large truck fleets as well as owner-operated trucks would strengthen support from freight firms. Savings from this measure are likely to be relatively easy to quantify and verify. Estimated global savings are from **115 kb-200 kb per day**. China and countries in Asia and Africa, as well as India and the Middle East are likely to benefit the most from this measure.

Cost levels of implementation of freight measures

The costs for the truck measures can be expected to be similar to the analogous car-related measures. Eco-driving measures are generally of low cost except in cases where equipment must be purchased. The capital costs of equipment quickly pay for themselves in reduced fuel costs even in times of relatively stable fuel prices – under conditions following an oil supply disruption, the payback period would be even shorter. Speed limit reduction would follow the same pattern as for cars (and can easily be implemented in a single measure) – signage, enforcement and time costs/safety benefits would all factor into the total societal costs. Special lanes for trucks would be similar to HOV lanes for cars: there would be expenses for signage and possibly new striping of roadways. Table 29 summarises the cost levels of fuel savings measures in road freight.

Table 29 • Qualitative cost assessment of freight measures

<table>
<tr><th rowspan="2">Measure</th><th colspan="4">Government (and transit agencies)</th><th colspan="2">Individuals and businesses</th></tr>
<tr><th>Government Administrative / enforcement</th><th>Government Capital investment/expenses</th><th>Government information / advertising programs</th><th>Impact on government (and transit) revenues</th><th>Compliance costs (for individuals/ companies)</th><th>Consumer surplus/ business profitability impacts</th></tr>
<tr><td>simple aerodynamic improvements</td><td rowspan="2">Low</td><td rowspan="2">Low</td><td rowspan="8">low-medium</td><td rowspan="2">No change</td><td>medium - equipment purchase</td><td rowspan="2">Gains to those who participate</td></tr>
<tr><td>tire inflation campaign</td><td>none</td></tr>
<tr><td>speed limit reduction</td><td>typically high</td><td>possibly high (variable speed limit signs)</td><td>Possible increases from enforcement</td><td>Direct costs may be low</td><td>Time costs likely to be high, though may be offset by safety improvements</td></tr>
<tr><td>Ecodriving, driver training, intelligent vehicle systems</td><td rowspan="2">Low</td><td rowspan="2">Low</td><td rowspan="5">No change</td><td>medium - investments in ecodriving</td><td rowspan="2">Gains to those who participate</td></tr>
<tr><td>Low rolling resistance and single-wide tires</td><td>medium - equipment purchase</td></tr>
<tr><td>dedicated truck lanes</td><td>Low-medium</td><td>possibly high for signage, striping, etc.</td><td rowspan="2">none</td><td>gains to passenger car drivers</td></tr>
<tr><td>Voluntary idling reductions</td><td rowspan="2">Low</td><td rowspan="2">Low</td><td rowspan="2">Gains to those who participate</td></tr>
<tr><td>Equipping trucks with GPS</td><td>medium - equipment purchase</td></tr>
</table>

Summary of the freight policy packages

Three freight policy packages were constructed for each region, at varying levels of stringency: basic, moderate and strong. The greatest potential for savings exists in middle- and low-income countries, and savings are greatest in the Middle East, India, Asia, Non-OECD Europe and China.

The basic package includes moderate government investment in aerodynamic retrofits, tyre inflation, eco-driving/driving training, voluntary idling reductions and equipping trucks with GPS. An estimated **760 kb-1 430 kb per day** may be saved globally by investing in basic measures to increase the fuel efficiency of trucking.

The moderate package entails investing more money in the same measures as the basic package (see above), plus a moderate investment in speed limit reduction and dedicated truck lanes. Worldwide savings of **1 540 kb-1 675 kb per day** could be realised with moderate measures to promote fuel savings in road freight.

The strong freight package incorporates all of the measures included in freight and implies aggressive public investment across the board in all measures. An estimated **2 100 kb-2 340 kb per day**, or between 5.4-6.0% of all road sector petroleum-based fuel consumption, could be saved in a hurry by dedicated global investments in freight trucking.

3. Policy interactions and packages

3.1 Combining oil-saving measures to create synergies

Many studies that have found that combining transport policies and measures can provide synergies in reaching goals such as dampening fuel demand or curtailing vehicle travel. While most of these are not developed as short-term measures associated with supply disruptions, their findings are nonetheless relevant when assessing individual measures and considering how these may be effectively combined in the context of a supply constraint. For example, the US EPA has developed the COMMUTER model[11] to calculate the impact of various transport demand measures (TDM), trips and emissions that can calculate interactive effects from combining measures.

Analysis with this model and many others (including Smith, 1991; Greening, Greene and Difiglio, 2000; Marshall and Banister, 2000)[12] have explored the use of policy portfolios to achieve a range of transportation objectives. General findings have included:

- Policy packages with multiple mutually reinforcing and complementary measures can be far more effective than any isolated policy. In particular, push policies (designed to increase the perceived cost of driving) should be complemented by pull policies (designed to lower costs and barriers of using modes other than private cars and improve their comfort, accessibility and attractiveness).
- Packages sometimes include elements implemented by different levels of government (local, regional, federal). Thus, co-ordination is critical to ensure a maximum of synergistic benefits and avoid policies working at cross purposes.
- A range of barriers to successful policy implementation has been identified (including institutional, legal, resource, social/cultural, side effects and others). Lack of sufficient resources has been found to be a common barrier to physical measures, including those intended to strengthen provision of alternative modes (public transit and bicycle/pedestrian infrastructure) and measures to alter the built environment to reduce car travel demand. Social/cultural barriers (i.e. issues of public acceptance) have been seen as a primary hurdle for push measures (pricing, TDM). Combinations of policies can help overcome these barriers by for example simultaneously offering travel alternatives as some alternatives are discouraged, or by raising revenues with some policies to help pay for other policy elements.

In sum, substantial reduction in fuel consumption will in most cases necessitate that a portfolio of policies is implemented in combination. May, Kelly and Shepherd (2006) argue that it is essential to take into account the likely interactions among policies in order to ensure that the estimated fuel savings are achieved. They categorise interactions among policies in the following schema:

Complementarity/synergy: Implementing two or more policies results in greater impacts than any single policy alone.

Additivity: Impacts of two or more policies are equal to the impacts of each policy implemented in isolation.

[11] Information on the model is available at: www.epa.gov/oms/stateresources/policy/transp/commuter/420b05017.pdf.

[12] A summary of the methods and key findings of the DANTE initiative is available online here.

Substitutability: Implementing an additional policy detracts from or wholly eliminates the fuel savings benefits achieved by another policy instrument.

Small and Verhoef (2007) point out the "virtuous cycle" that may be initiated by congestion charging in spurring mode shifts from cars to public transit. Simulations of push and pull policy packages implemented across European cities give further evidence of complementarity (Lautso et al., 2004).

3.2 Administration and devolution of policies among national, regional and municipal levels

The multilevel governance aspects of transport policy are both a significant challenge (the challenge of aligning resources) and an opportunity (when aligned, collective effort is very effective) in developing resilience during oil supply disruptions. More than for stationary energy-using sectors (buildings, industry), transport system accountabilities and resources are typically distributed across different jurisdictions in both the public and private sectors. A high degree of alignment across the various entities is required in order to implement the types of policy options discussed in this report.

A particular challenge is that many of the entities that need to be involved may not perceive a direct benefit (either in the short or long term) from efforts to improve the future resilience of transport systems to supply constraints until only reactive measures can be applied to the oil supply constraint.

Two IEA reports highlight the need for integrated policy actions in this area and highlight examples where policy makers have achieved successful innovations in transport policies by developing necessary collaborations.

- *Innovations in Multilevel Governance* (IEA, 2009)

State countries of the IEA are engaged in promoting innovative financial instruments, energy efficiency strategies and action plans. One strategy that many national governments and international organisations have used to address the implementation of national policies is to engage regional and local authorities. To that end, many programmes have been created that foster energy efficiency and other kinds of action and collaboration across levels of government. This report shared lessons focused on energy efficiency policy learned from daily practitioners in the field, to identify useful multilevel governance practices across geographical and political contexts. These lessons can help to:

- Design robust programmes.
- Modify existing programmes.
- Connect and share experiences with other policy makers in this field.

As described in the report, countries have shown remarkable creativity in their design of multilevel governance practices – as evidenced by the diversity of the group of case studies the report covers. However, some areas require more attention. In particular, all multilevel governance practices should have adequate accountability mechanisms and be subjected to regular external evaluations.

The direct co-operation among city, state and federal agencies and leaders was as crucial to enabling the urgent emergency responses during Hurricane Sandy as it was to putting in place the clean-up, short-term and longer-term redevelopments.

- *A Tale of Renewed Cities* (IEA, 2013)

This report outlines a practical policy pathway approach with case studies. Though not specific to supply disruptions or saving oil "in a hurry", the policy development steps are similar. They outline four key aspects to the process:

Identify transport needs and define objectives

The first steps towards improving implementation of energy efficiency in the urban transport system require asking several specific questions:

- Where are we now? Identify issues and needs.
- Where do we want to go? Define the objectives.
- How do we get there? Identify policy responses.

Identifying present transport issues and expected future needs helps to organise responses to improve transport system efficiency.

Identify and engage stakeholders early on

Stakeholders play an important role in the successful implementation of urban transport policies. They provide critical support and feedback and can have valuable experience with specific transport projects. Engaging stakeholders can increase awareness of policy objectives, help to ensure support and approval of policy goals, and bring in additional resources, including funding. Identifying and engaging stakeholders early in the planning process, therefore, can be extremely beneficial.

Address potential barriers and secure necessary resources

Many barriers to implementing transport efficiency policies can arise, including financial constraints, legal restrictions, regulatory frameworks and public opposition. Identifying potential barriers early in the planning process can help to formulate responses before barriers delay or inhibit policy initiatives.

Establish policy framework and action plan

Once transport system needs and policy responses have been identified, the next task is to establish the policy framework and action plan for policy implementation, monitoring and evaluation. Implementing and achieving policy objectives in the transport sector can take a long time, and policies can fail to meet objectives if strong frameworks outlining the necessary steps and actions to project achievement are not established in the early implementation stages.

The report describes these four steps in further detail, and is a recommended reference in developing plans for short-term demand restraint policies.

3.3 Regional results and potential packages

This section presents results of the foregoing analysis on a regional basis. It also considers policy packages, or combinations of measures that work well together. However, the most valuable presentation may be to show the most effective sets of packages on a regional basis, since these vary considerably. In most cases these represent a good starting point for considering policy packages.

Tables 30 and 31 show results on a 14-region basis in different ways. The tables show the top two or three measure categories or specific measures in terms of fuel savings for each region. The figures in Annex 3 show a summary of the total road sector consumption of petroleum-based fuel (gasoline and diesel).

Table 30 • Regional recommended policy categories in the transport sector

Region	Total on-road fuel use (thousand BPD)	Best Policy Package(s)	Potential Savings (% of passenger LDV fuel use)	Savings in Freight (% of truck fuel use)
All regions	**39,141**	**Eco-driving & vehicle efficiency campaign** **Temporary Speed Limit Reductions**	**2.5% - 10% (varies by region)** **2.5% - 8.5% (varies by region)**	**5% - 25% of truck fuel use (varies by region)**
USA & Canada	11,584	Employer-Institutional Packages	1.7% - 6.3%	6% - 20%
Mexico	1,150	Public Transit	0.3% - 4.0%	7% - 20%
OECD Europe	6,362	Employer-Institutional Packages Pricing Package	1.6% - 5.0% 6.6% - 12.6%	6.5% - 17%
Japan & Korea	1,915	Employer-Institutional Packages	1.7% - 5.3%	5% - 15.5%
Australia-New Zealand / Other OECD	791	Employer-Institutional Packages Pricing Package	1.6% - 5.2% 6.0% - 11.3%	5% - 18%
Non-OECD Europe	609	Public Transit	0.4% - 3.7%	5% - 23%
Russia	1,112	Employer-Institutional Packages	1.5% - 4.5%	7% - 21%
China	4,385	Public Transit	1.0% - 8.4%	8% - 23%
India	1,250	Public Transit	7%-12%	9% - 24%
Other Asia	2,692	Public Transit	1.0% - 8.4%	9% - 24%
Middle East	2,748	Pricing Package	6.6% - 12%	8% - 26%
Africa	1,824	Public Transit	3%-10%	8% - 22%
Brazil	1,189	Fuel-switching Employer-Institutional Packages	7.5% - 20% 1.2%-5.0%	7.5% - 21.5%
Other Latin American Countries	1,530	Public Transit	1%-12%	7% - 21%

Table 31 • Regional recommended measures in the transport sector

Region	Total on-road fuel use (thousand BPD)	Best Measure(s)	Savings (% of PDLVs road fuel use)
USA & Canada	11,584	Change Parking Pricing Employer-Institutional TDM Fuel switching	3.1% - 5.6% 1.4% - 2.9% 2.3% - 3.2%
Mexico	1,150	Fare Reductions - urban bus Ecodriving Speed limit reduction	1.1% - 2.1% 4.3% - 10.3% 4.7% - 7.3%
OECD Europe	6,362	Change Parking Pricing Fare Reductions - urban bus Employer-Institutional TDM	3.3% - 6.1% 0.7% - 1.5% 1.4% - 2.8%
Japan & Korea	1,915	Fare Reductions - high-capacity public transit Change Parking Pricing Employer-Institutional TDM	0.8% - 1.4% 2.9% - 5.3% 1.6% - 3.1%
Australia-New Zealand / Other OECD	791	Ecodriving Change Parking Pricing Fare Reductions - urban bus	4.2% - 10.1% 4.4% - 8.2% 2.4% - 6.6%
Non-OECD Europe	609	Change Parking Pricing Fuel switching Fare Reductions - urban bus	3.3% - 5.9% 2.9% - 6.3% 1.6% - 3.0%
Russia	1,112	Change Parking Pricing Employer-Institutional TDM Fare Reductions - urban bus	3.6% - 6.4% 1.5% - 4.5% 2.7% - 5.1%
China	4,385	Congestion Pricing Public transit improvements Fare Reductions - urban bus	2.5% - 5.0% 0.7% - 4.4% 2.5% - 4.7%
India	1,250	Change Parking Pricing Fuel switching Fare Reductions - urban bus	2.2% - 4.1% 4.7% - 6.9% 7.2% - 14.5%
Other Asia	2,692	Fuel switching Public transit improvements Fare Reductions - urban bus	3.4% - 4.9% 0.7% - 4.5% 2.5% - 4.8%
Middle East	2,748	Change Pricing Policies Ecodriving Campaign Fare Reductions - urban bus	6.1% - 12.2% 4.3% - 10.2% 1.2% - 2.2%
Africa	1,824	Fare Reductions - urban bus Speed limit reduction Public transit improvements	5.9% - 11.1% 5.8% - 9.0% 1.1% - 7.0%
Brazil	1,189	Fuel switching Fare Reductions - urban bus Employer-Institutional TDM	24.2% - 27% 3.3% - 6.2% 1.7% - 3.4%
Other Latin American Countries	1,530	Speed limit reduction Fare Reductions - urban bus Public transit improvements	6.1% - 9.4% 3.8% - 7.2% 0.7% - 4.4%

Overall these regional results reinforce the point that one size does not fit all – different regions may find that different types of measures are most effective at saving oil in a hurry. This may relate to the percentage of transport fuel used by passenger versus freight vehicles, or the share of car travel versus public transit. The potential for telecommuting or ride sharing also plays an important role. The rankings indicate this study's estimates of where the biggest potentials are, but this may not make these the most attractive options, taking into account costs, political feasibility, etc. Countries are encouraged to undertake their own analysis using techniques provided in this report to create a more robust ranking of options in their own context.

4. Conclusions

This report, updating the 2005 IEA publication *SOIAH*, provides a set of actionable recommendations for governments on how to effectively reduce oil demand in an emergency involving a sudden restriction in oil supplies.

Demand restraint measures are not restricted to one particular sector of consumption. However, due to the high proportion of oil used for transportation, most demand restraint policies target this sector. This study therefore has focused on transport sector-related measures, grouped into eight categories (public transit; employer and institutional transport measures; ride sharing; vehicle efficiency measures; pricing and parking policies; driving restrictions; multi-fuel vehicles; and freight trucking).

As in the original study, this report is meant as a toolbox for countries in determining the most appropriate short-term measures to save oil rapidly in a crisis. This study was done at a global level and it is important for countries to conduct their own analyses, reflecting their priorities and their national and local circumstances.

One of the notable results of this analysis is that different measures save significantly different amounts of transport fuel in different countries and regions of the world, depending on a range of local factors. This once again underlines that one size does not fit all, and that demand restraint policies must be adapted to the unique circumstances of the individual country.

Nevertheless, common principles can be identified in crafting policies that can have a maximum benefit in reducing oil use quickly in a crisis. Increasing options for individuals and companies to reduce fuel use, while also allowing oil prices to respond to a disruption, are important parts of any solution. Indeed, with price-responsive markets and a system that passes oil price dynamics through to consumers, market dynamics alone may provide a significant factor to change behaviours.

Demand restraint policy should be crafted in packages with multiple mutually reinforcing and complementary measures. For example, push policies (designed to increase the perceived cost of driving) should be complemented by pull policies (designed to lower costs and barriers of using other modes, instead of private cars, and improve their comfort, accessibility and attractiveness). Well-developed combinations of push and pull may create synergies that are particularly more effective than the individual measures implemented on their own.

Most measures require advanced planning. Governments must set up plans prior to actual disruptions and put in place systems that are implemented during emergencies. Co-ordination among administrations and key private or public stakeholders will contribute to build considerable resilience into the transport system to defend against supply disruptions. Training exercises involving all relevant parties are important for good implementation of the measures when they are needed.

This report should serve as a reference point in reviewing, improving, and/or establishing demand restraint policies and measures.

Table 32 • Qualitative summary assessment of oil-saving measures

		Government (and transit agencies)				Individuals and businesses		
Category	Measure	Government Administrative / enforcement	Government Capital investment/expenses	Government information / advertising programs	Impact on government (and transit) revenues	Compliance costs (for individuals/ companies)	Consumer surplus/ business profitability impacts	Global Fuel Savings
Public Transit	Fare reductions	Low	None	Low	Revenue loses to transit agencies	none	Reduced expenses to transit riders	Moderate - Large (~100-500 BPD)
	Service frequency and hours improvements				Increased transit operating costs but also increased revenues		service gains to those taking transit	Small - Moderate (~50-200 BPD)
	Car-free zones and bike-pedestrian promotion programs	moderate	Low-medium (possible repaving, amenities)		No change	unclear impacts on businesses in affected areas	gains to pedestrians; losses to drivers, truckers	Very Small - Small (~10-120 BPD)
Employer and Institutional	Telecommuting	Low	Low	low-medium	No change	Low-medium (possible equipment expenses)	Unclear impacts on business productivity	Small - Moderate (~20-150 BPD)
	Compressed work week					none		Small - Moderate (~20-175 BPD)
	Employer promotion of carpooling	Low (possibly assistance programs)				Low-medium administer programs, incentivize carpools	Low-medium apart from administering programs	Moderate - Large (~200-600 BPD)
Car- & Ride-Sharing / HOV lanes	HOV lanes	Low-medium	possibly high for signage, striping, etc.	low-medium	No change	none	gains to carpoolers	Small (~20-100 BPD)
	Promotion and publicity of ride- and carsharing businesses		Low		possible losses to transit ridership, revenues		gains to those choosing to rideshare	Moderate - Very Large (~100-2000 BPD)
Ecodriving	Ecodriving	Low	Low	low-medium	No change	none	Gains to those who ecodrive	Moderate - Large (~175-1000 BPD)
	Tire inflation						Gains to those who participate	Very Small (~20-35 BPD)
	Roof racks excess mass							Moderate (~175-400 BPD)
	Specification of motor oil grades							Very Small (~20-35 BPD)
Pricing & Parking	Distance-based pricing (PAYD / PATP)	medium-high	Low	low-medium	Increased	should break even	Gains to low mileage drivers	Small (~10-50 BPD)
	Road Pricing (tolls / cordon pricing / congestion pricing)	typically high	typically high			potentially high compliance expenses	potential gains from lower congestion	Large (~500-1000 BPD)
Restrictions & Reductions	1 in 10 ban	typically high	Low	low-medium	No change	potentially high from re-organizing activities	lost surplus to individuals and businesses if driving is restricted	Large (~675-1000 BPD)
	Odd-even ban	typically high						Very Large (~4750-6750 BPD)
	Speed limit reduction	typically high	possibly high (variable speed limit signs)		Possible increases from enforcement	Direct costs may be low	Time costs likely to be high, though may be offset by safety improvements	Large (~900-1400 BPD)
Multi-fuel Vehicles	Short term- encourage alternative fuel use	medium	Possible minor investments to enhance potential	low-medium	possible losses in fuel taxes	Low	Gains to those with alternative fuel capability	Moderate - Large (~400-500 BPD)
	Long-term increase in alt fuel vehicle system	typically high for major programs	possibly high (e.g. for infrastructure)			Possibly high if purchase requirements	Depends on costs and requirements	Large (~800-850 BPD)
Freight	simple aerodynamic improvements	Low	Low	low-medium	No change	medium - equipment purchase	Gains to those who participate	Moderate (~300-500 BPD)
	tire inflation campaign					none		Small (~50-100 BPD)
	speed limit reduction	typically high	possibly high (variable speed limit signs)		Possible increases from enforcement	Direct costs may be low	Time costs likely to be high, though may be offset by safety improvements	Small - Moderate (~175-275 BPD)
	Ecodriving, driver training, intelligent vehicle systems	Low	Low		No change	medium - investments in ecodriving medium - equipment purchase	Gains to those who participate	Moderate - Large (~200-1000 BPD)
	dedicated truck lanes	Low-medium	possibly high for signage, striping, etc.			none	gains to passenger car drivers	Small - Moderate (~60-135 BPD)
	Voluntary idling reductions	Low	Low				Gains to those who participate	Moderate (~100-150 BPD)
	Equipping trucks with GPS					medium - equipment purchase		Moderate (~115-200 BPD)

5. Annexes

Annex 1: Summary of implementation cost-effectiveness of various measures (original study of 2005)

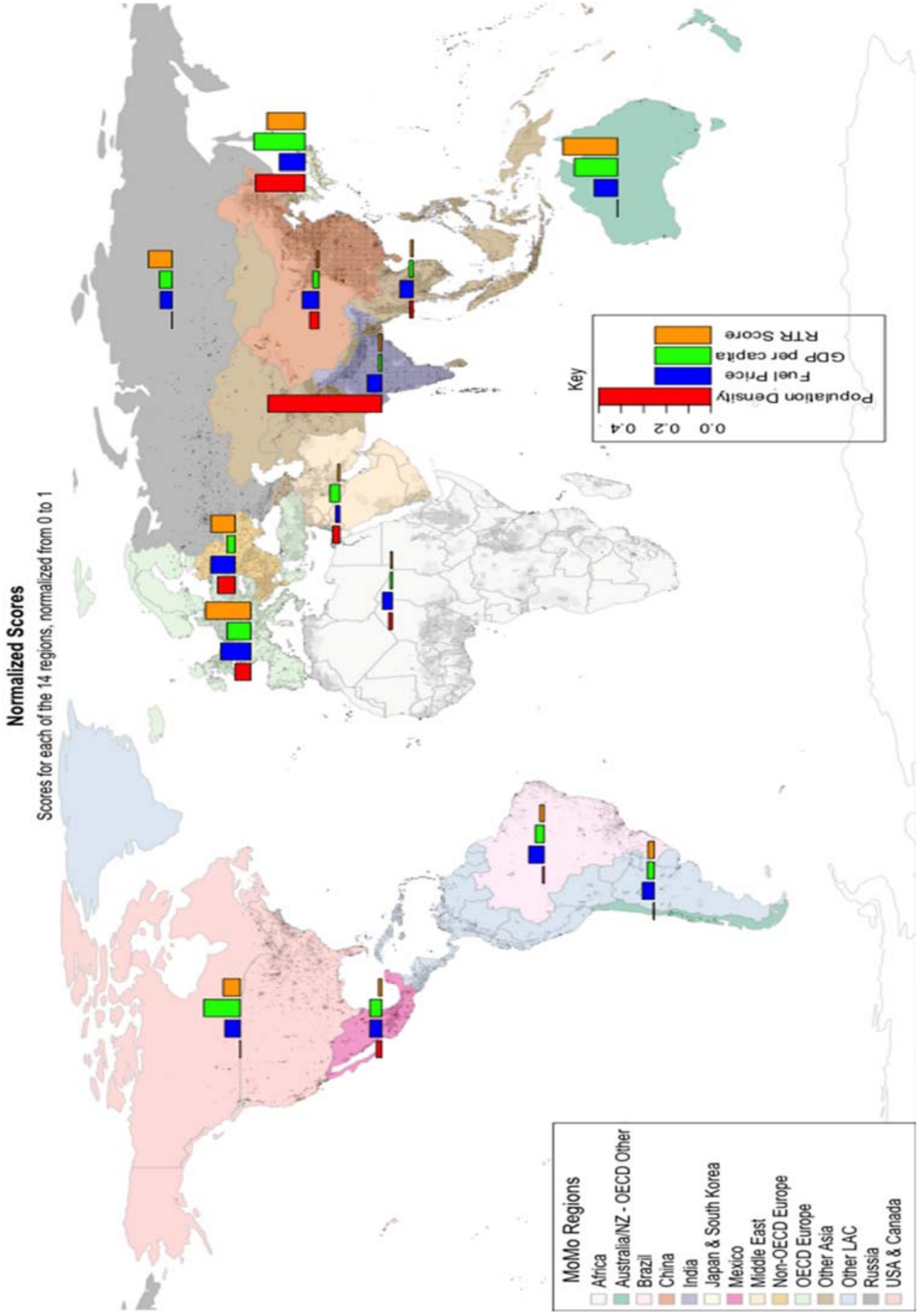
Table 33 • Summary of implementation cost-effectiveness of various measures

Implementation cost-effectiveness	Measure	Other potential impacts	Oil savings (from Table E-1)
VERY LOW COST Less than $1 per barrel saved	**Car-pooling:** large programme to designate emergency car-pool lanes along all motorways, designate park-and-ride lots, inform public and match riders		Very Large
	Driving ban: odd/even licence plate scheme. Provide police enforcement, appropriate information and signage	Possibly high societal costs from restricted travel	Very Large
	Telecommuting: large programme, including active participation of businesses, public information on benefits of telecommuting, minor investments in needed infrastructure to facilitate	Possible productivity impacts from changes in work patterns	Large
	Compressed work week (fewer but longer workdays): programme with employer participation and public information campaign		Large
	"Ecodriving" (efficient driving styles and vehicle maintenance steps): intensive public information programme	Likely safety benefits	Large
	Car-pooling: small programme to inform public, match riders		Moderate
LOW COST Less than $15 per barrel saved	**Speed limits:** reduce highway speed limits to 90 kph. Provide police enforcement or speed cameras, appropriate information and signage	Safety benefits but time costs	Large
	Driving ban: 1 in 10 days based on licence plate, with police enforcement and signage	Possibly high societal costs from restricted travel	Large
MODERATE COST Less than $50 per barrel saved	**Bus priority:** convert all existing car-pool and bus lanes to 24-hour bus priority usage and convert other lanes to bus-only lanes		Small
HIGH COST More than $100 per bbl saved*	**Telecommuting:** Large programme with purchase of computers for 50% of participants	Possible productivity impacts from changes in work patterns	Large
	Transit: free public transit (set fares to zero); 50% fare reduction, similar cost		Moderate
	Transit: increase weekend and off-peak transit service and increase peak service frequency by 10%		Moderate

* Note: no measures are estimated to cost between $50 and $100 per barrel saved.

Annex 2: 14 regions based on the Mobility Model (MoMo)

Figure 2 • Maps of indicators for the classification system (population density, fuel price, GDP per capita and rapid transit infrastructure per capita)



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Notes: RTR = rapid transit infrastructure per capita. The map shows a normalised bar chart for population density, fuel price, GDP per capita and RTR (a measure of transit availability). For each of these four indicators, the total height of each bar across all 14 world regions sums to one. The relative heights of these highlight the regional variation in conditions that underlie the study's analysis.

Annex 3: Potential global oil savings per demand restraint measure

Figure 3 • Potential global oil savings by public transit policy packages

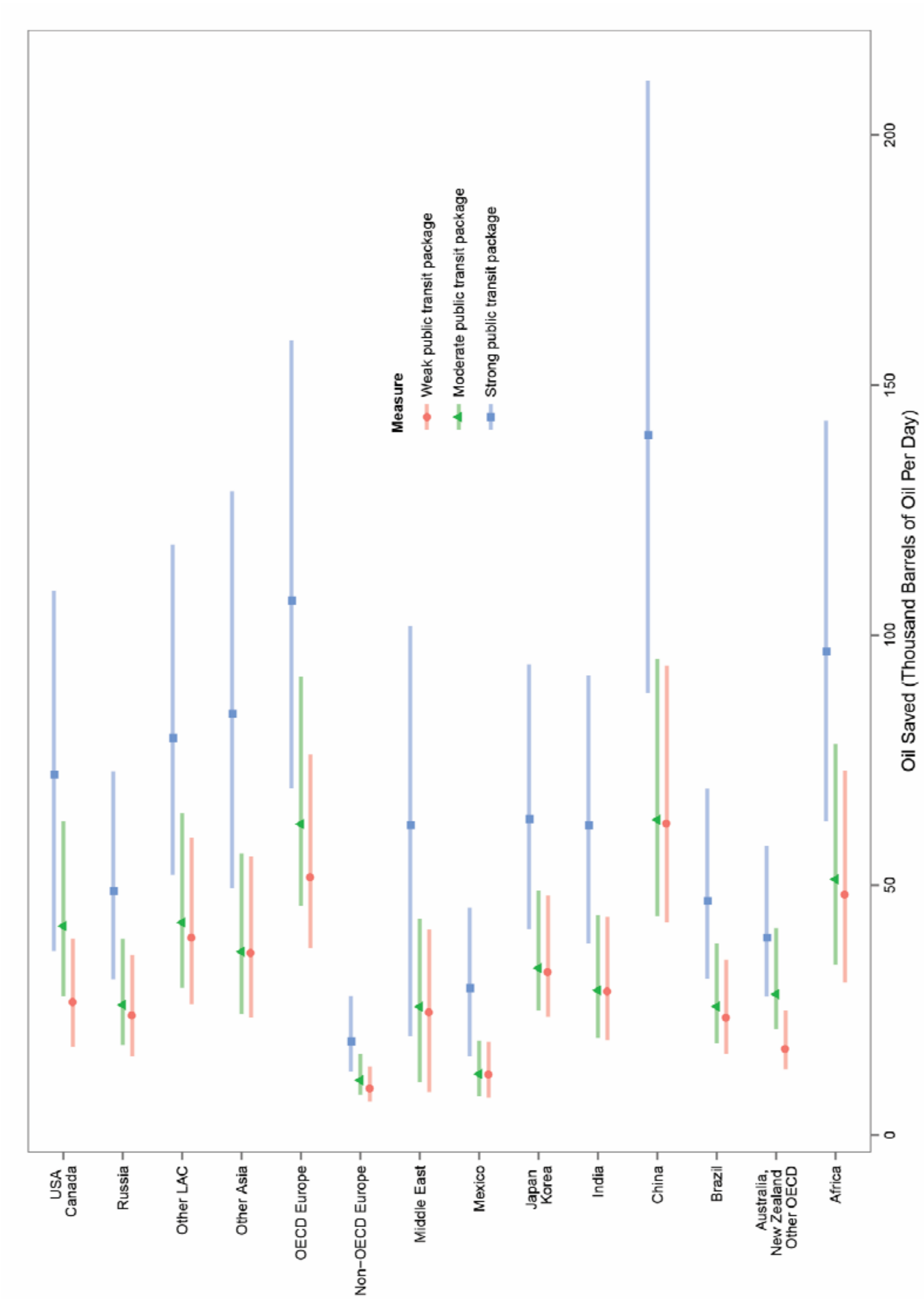


Figure 4 • Potential global oil savings by employer-institutional packages

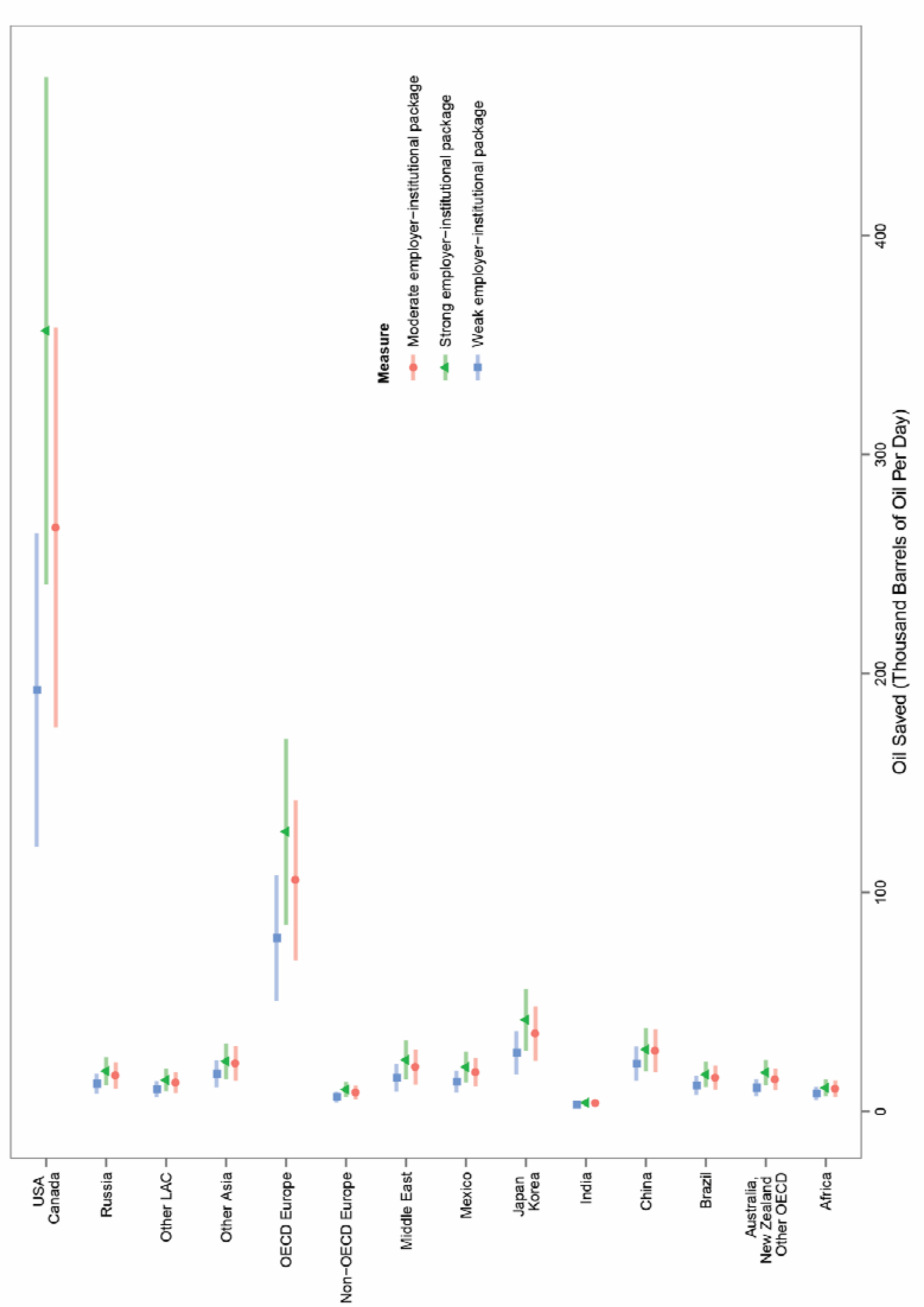


Figure 5 • Potential global oil savings by car and ride sharing and HOV lanes

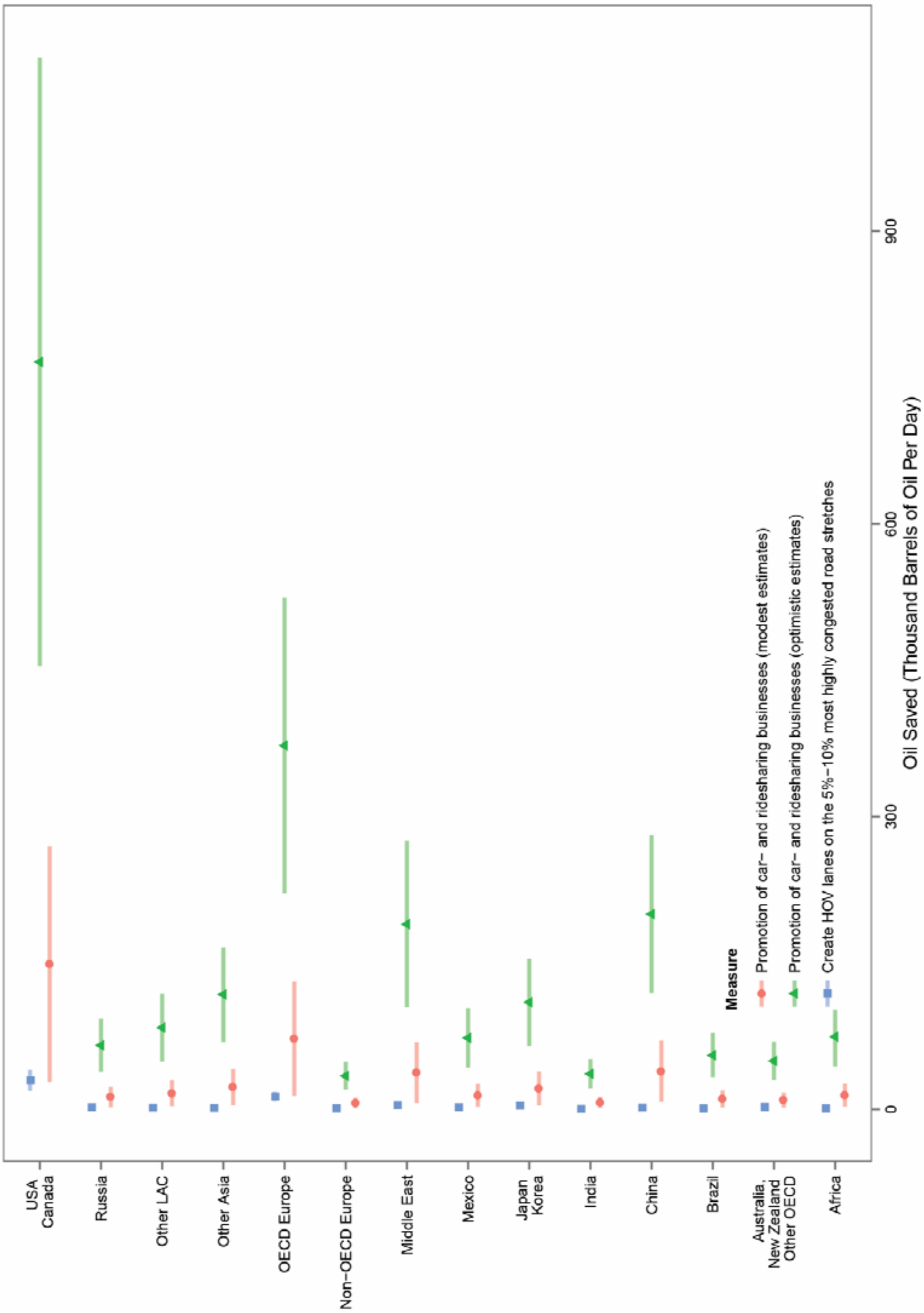


Figure 6 • Potential global oil savings by eco-driving policy packages

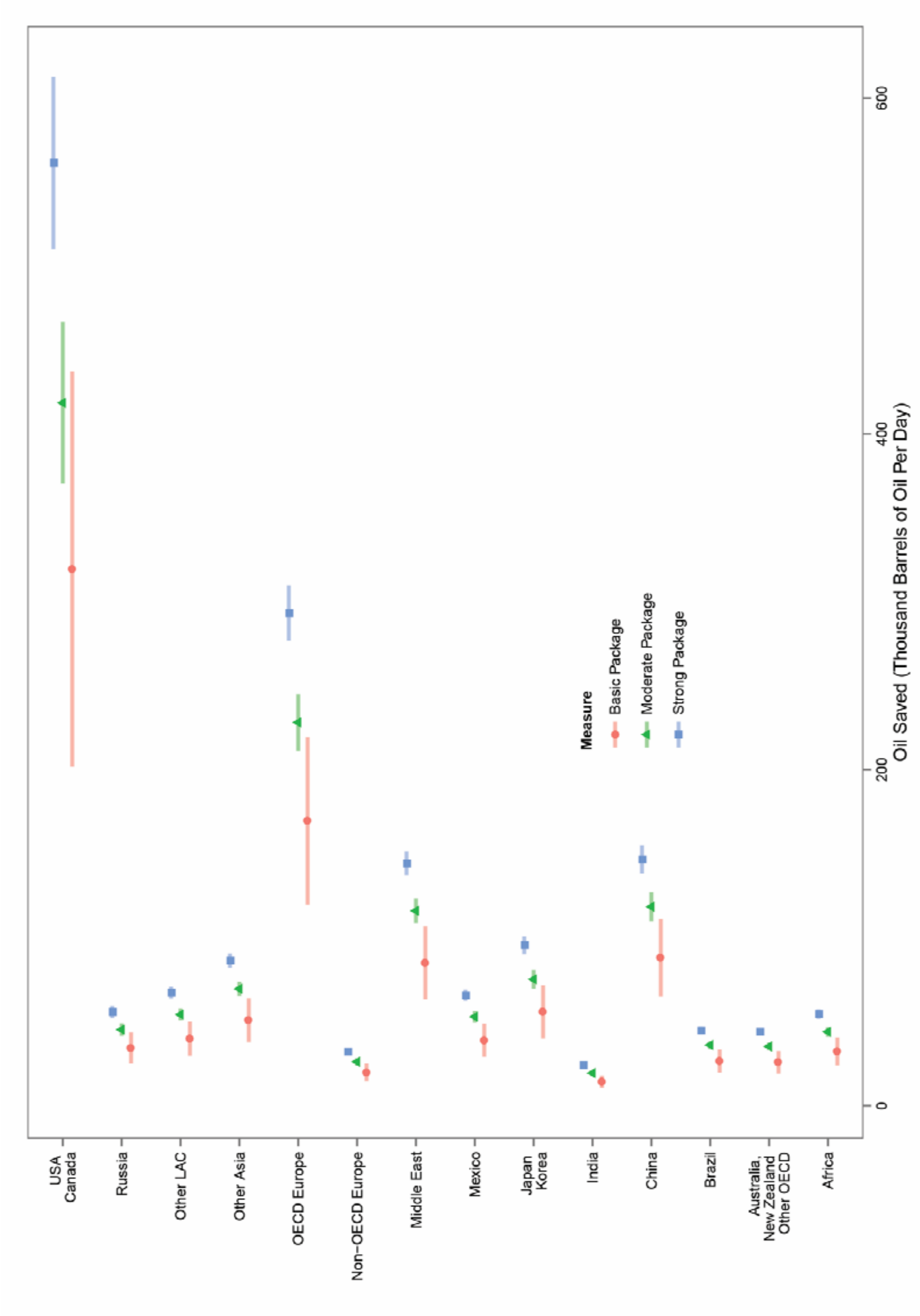


Figure 7 • Potential global oil savings by pricing measures

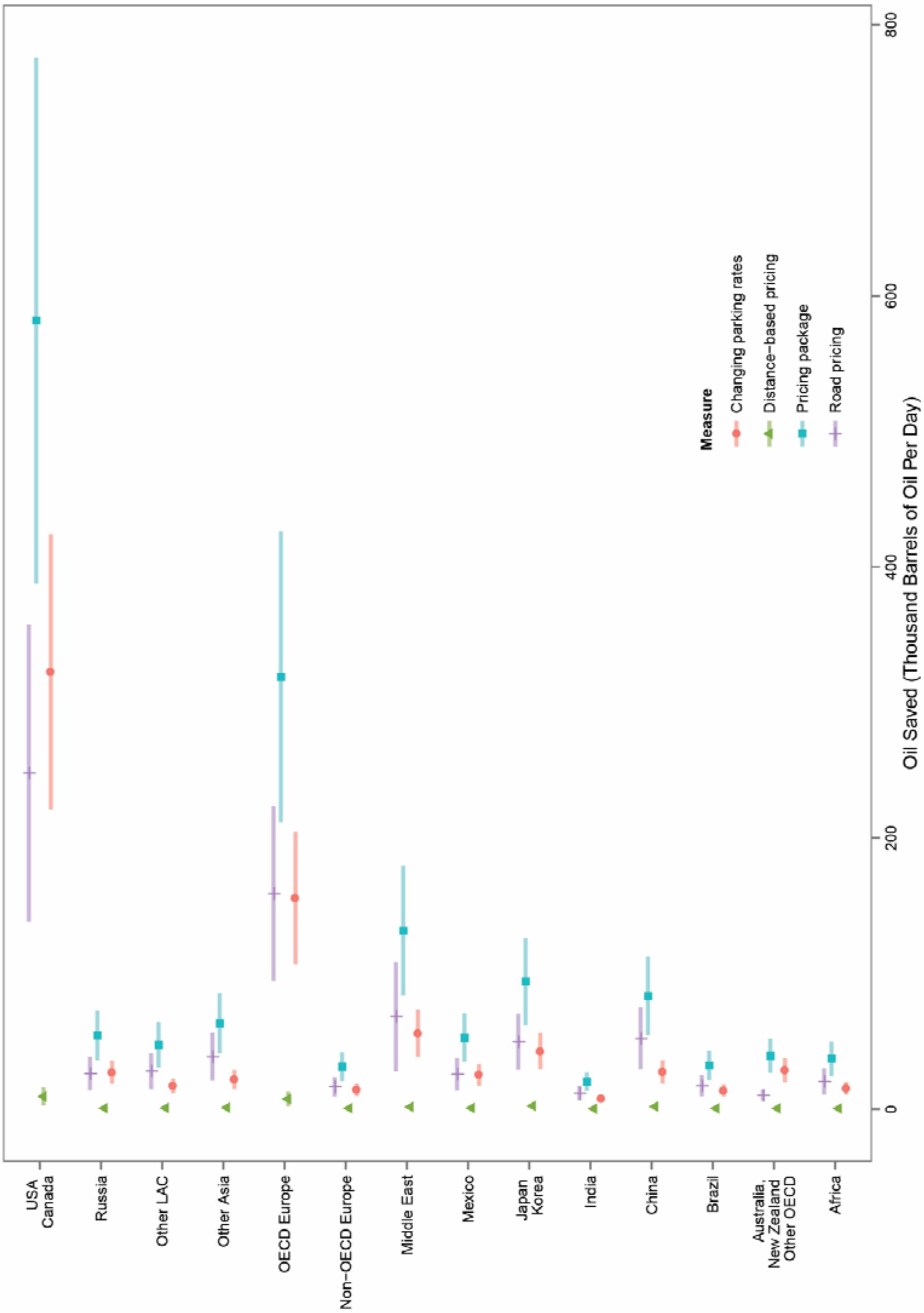


Figure 8 • Potential global oil savings by driving bans and speed limit restrictions

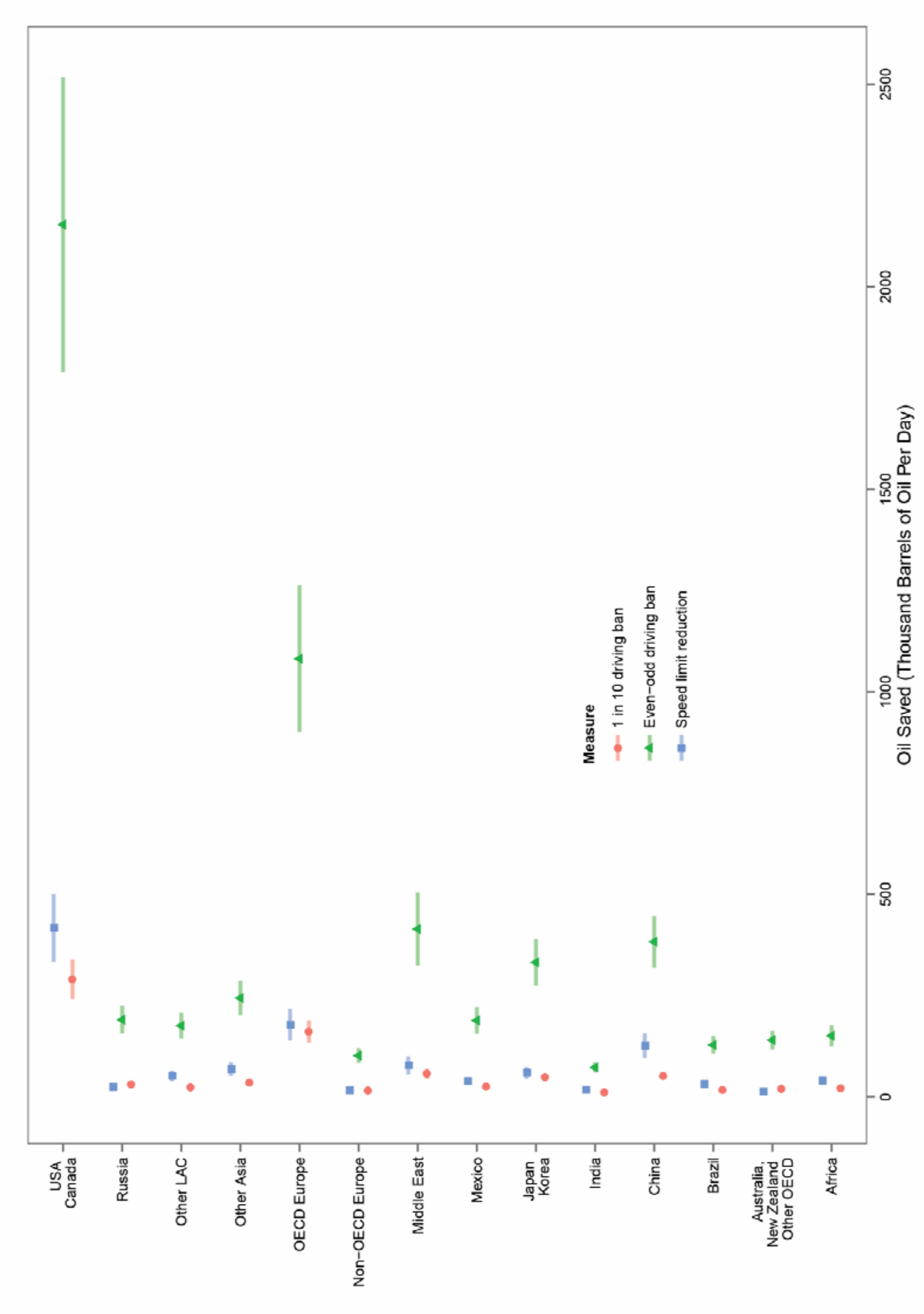


Figure 9 • Potential global oil savings by fuel switching in the 2014 base year and in 2020

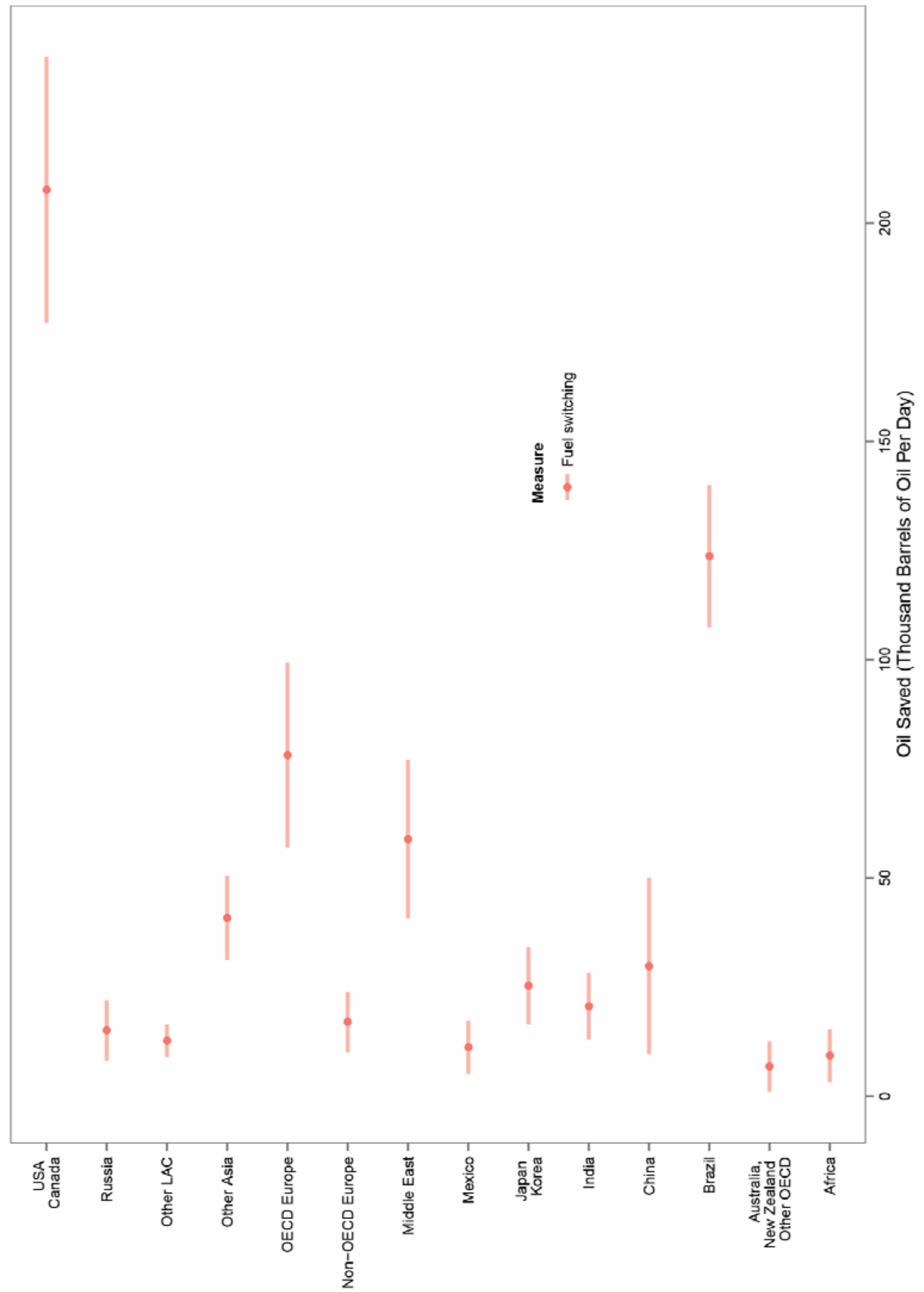


Figure 10 • Potential global oil savings by road freight measures

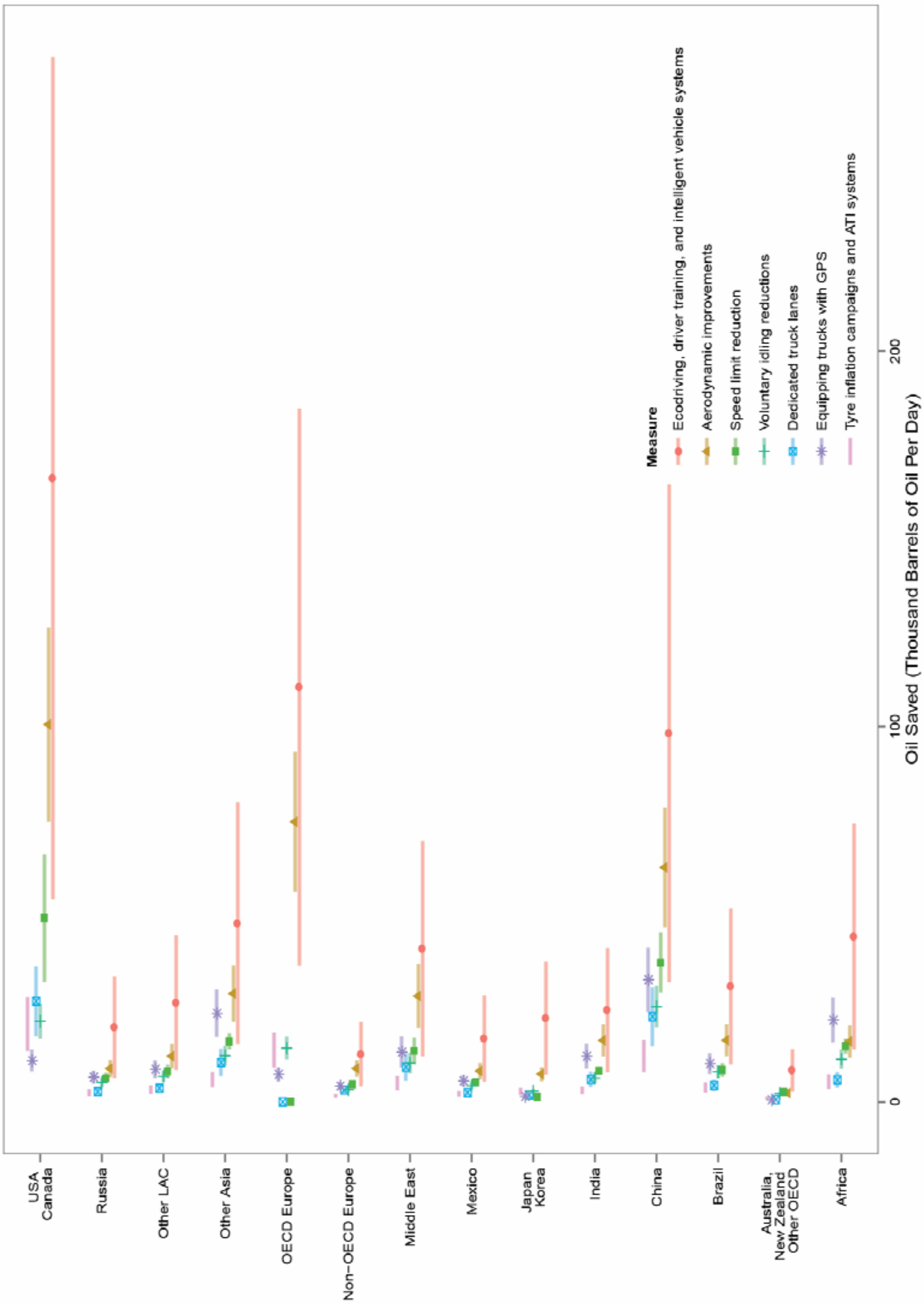
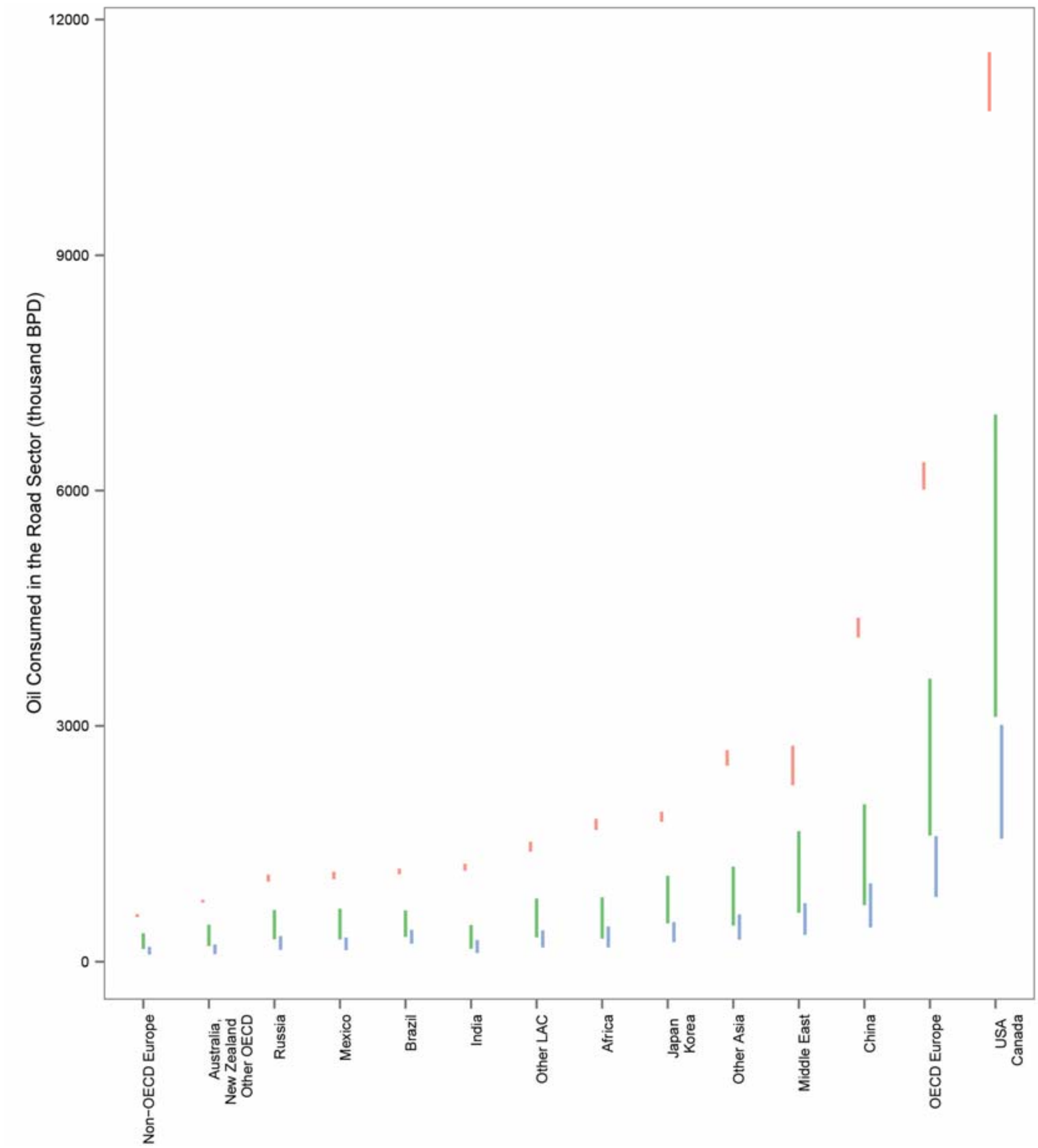


Figure 11 • Potential global oil savings per region based on oil consumption in the road sector

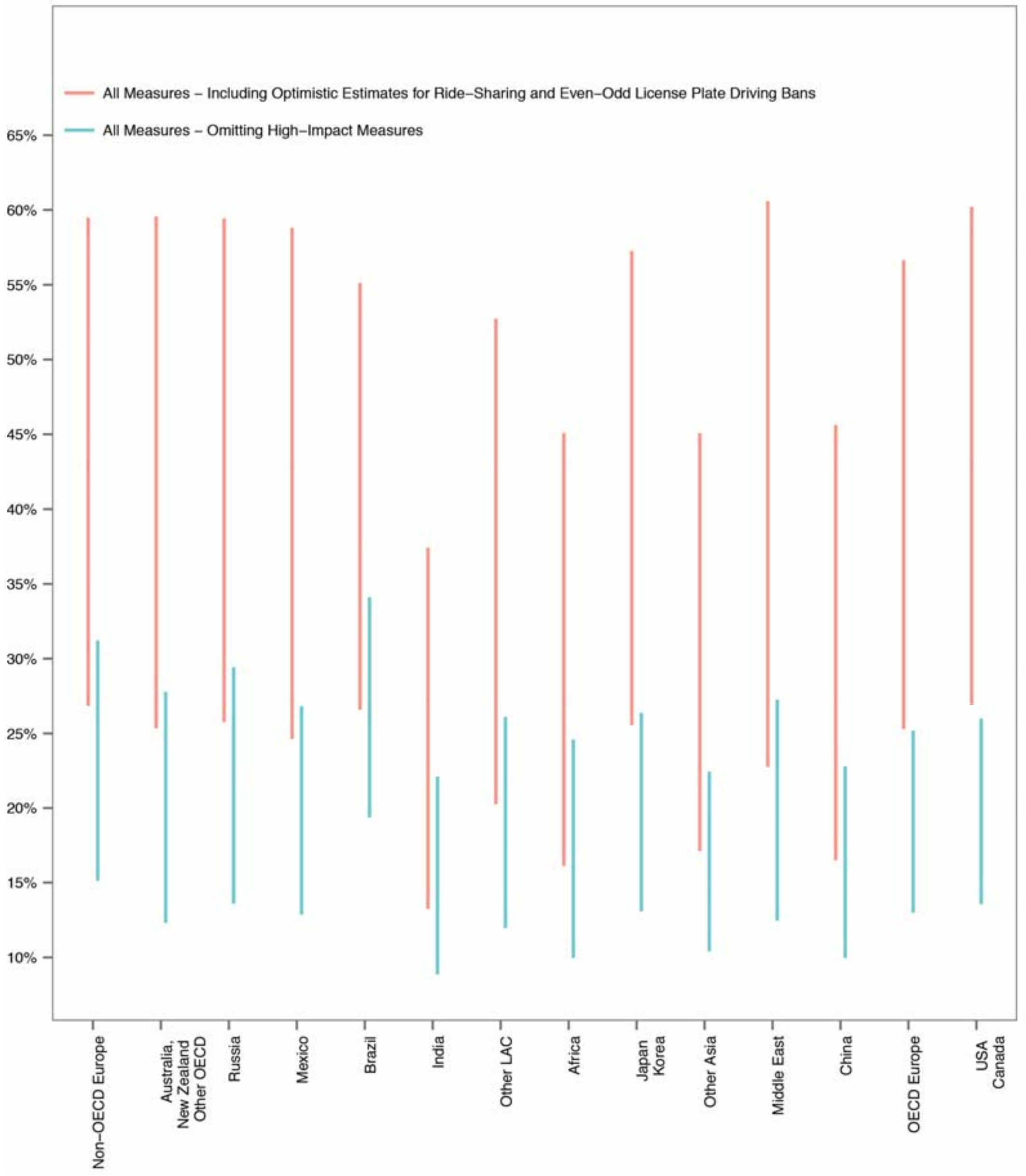


Note: Red lines show on-road petroleum-based fuel consumption (kb per day), with the high indicating 2014 actual consumption, and the lows indicating the projected demand response to oil supply disruption scenarios.

Green line ranges show the estimated oil savings from all of the transport demand restraint measures combined, including the two most extreme measures: 1) "optimistic" projections of the potential for car- and ride-sharing models to reduce fuel consumption; and 2) a strict odd-even licence driving ban.

Blue lines show the total potential of demand restraint measures to save fuel, not including the two "extreme" measures.

Figure 12 • Potential global oil savings per region as a percentage



Note: Red lines show the estimated percentage of oil savings (relative to baseline 2014 total on-road petroleum-based fuel consumption) that could be achieved from all of the transport demand restraint measures combined, including the two most extreme measures: 1) 'optimistic' projections of the potential for car- and ride-sharing models to reduce fuel consumption; and 2) a strict odd-even licence driving ban.
Blue lines show the estimated percentage of oil savings from demand restraint measures to save fuel, but not including the two "extreme" measures.

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Acronyms, abbreviations and units of measure

Acronyms and abbreviations

ATI	automatic tyre inflation
BRIC	Brazil, Russia, India, China
BRICS	Brazil, Russia, India, China, South Africa
BRT	bus rapid transit
EEA	European Environment Agency
EPA	Environmental Protection Agency (US)
EV	electric vehicle
FFV	flex-fuel vehicle
GDP	gross domestic product
GPS	global positioning system
HOV	high-occupancy vehicle
IEA	International Energy Agency
IT	information technology
LDV	light-duty vehicle
LPG	liquid petroleum gas
MoMo	IEA Mobility Model
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic Safety Administration (US)
OECD	Organisation for Economic Co-Operation and Development
PATP	pay at the pump
PAYD	pay as you drive
RTR	rapid transit infrastructure per capita
SOIAH	*Saving Oil in a Hurry*
SUV	sports utility vehicle
TDM	transportation demand management
TPMS	tyre pressure monitoring system
Urban MoMo	Urban Mobility Model
US	United States
USD	United States dollar
VKT	vehicle kilometres travelled

Units of measure

kb	thousand barrels
kg	kilogrammes
km/h	kilometres per hour
kPa	kilopascals
mph	miles per hour (US)
psi	pounds per square inch
t	tonne


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