REDUCING EMISSIONS FROM ROAD FREIGHT: EXPERIENCE IN CHINA

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ABSTRACT

China has been trying to find effective ways to energy conservation and emission reduction for the past ten years, particularly during the 11th Five-Year Plan period (2005-2010). However, the freight sector, particularly the road freight, remains a major concern. The fragmented structure of this sector along with its mobile nature makes the management of the sector very challenging. With the rapid growth of road freight vehicles and the corresponding increase in road freight tonnage, this sector has become a major contributor to air pollutants and greenhouse gas emissions. The road freight sector now accounts for 35 per cent of the world's transport energy use, and heavy-duty diesel vehicles are the major fuel consumer in Asia. They, in turn, account for a proportionate share of air pollution and carbon dioxide (CO_2) emissions.

To address the issues facing the road sector, China has undertaken various policy, legal, regulatory, and other measures including introducing pilot projects at different levels of the Government. The paper focuses on lessons learned from the Guangzhou Green Trucks Project, aiming to promote an alternative approach towards sustainable road freight transportation.

I. WHY FOCUSING ON ROAD FREIGHT?

A. Road freight as economic sector

The efficient movement of goods and services is important in achieving sustainable development. All modes of freight – road, water, air, and rail – have impacts on the economy, environment and society and, thus, need to be managed. Before the advent of the internal combustion engine, most of the world's freight relied on shipping and heavy rail. However, with the advancement of the road transport technology and the rapid expansion of the road network, the road sector has become the dominant mode of freight transport in most countries of the world.

The increase in economic activity in China is expected to be accompanied by an increase in the number of vehicles on the road, volume of goods transported by road vehicles, and the share of the road freight in the freight sector.

The total number of diesel motor vehicles is expected to grow from around 10 million in 2005 to almost 60 million in 2035 (figure 1). Diesel trucks, buses and vans, including light and heavy commercial vehicles will continue to constitute the dominant share of the road vehicle population.

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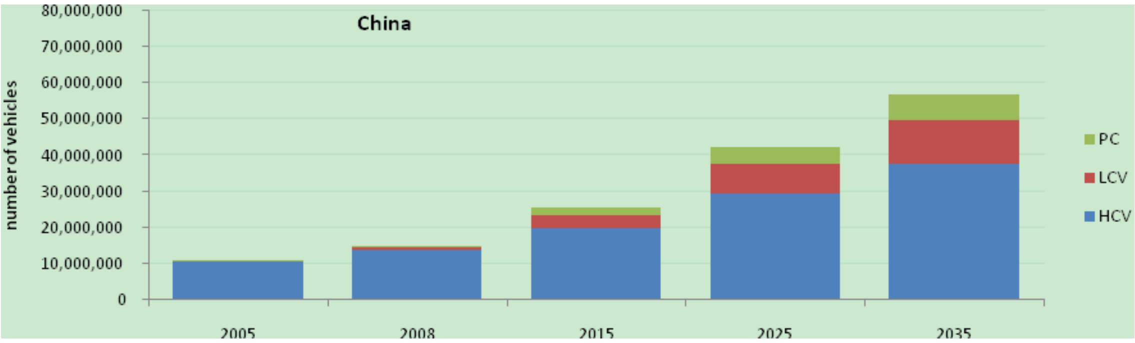
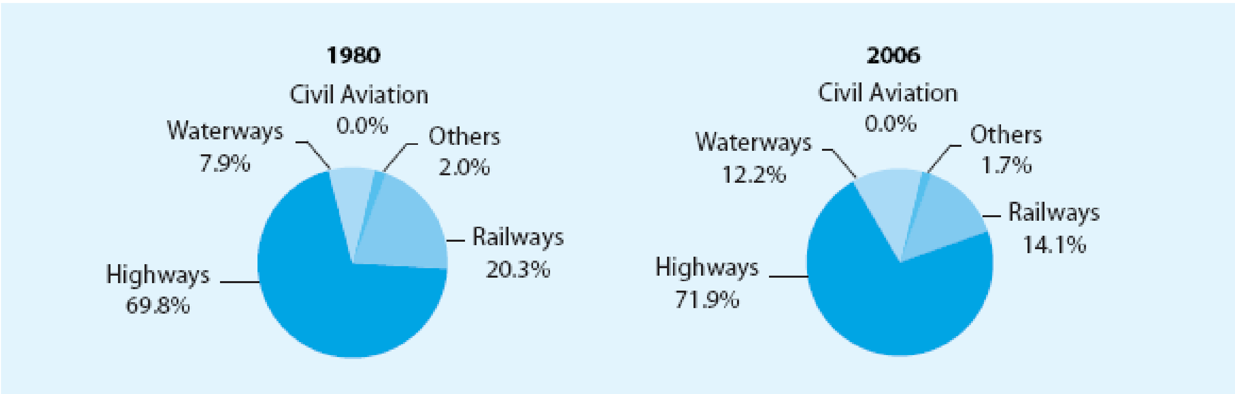
Figure 1. Expected growth in diesel motor vehicles in China 2005 – 2035



Source: Fabian and others (2011)
Notes: PC = personal cars; LCV = light commercial vehicles; HCV = heavy commercial vehicles

Similar to China, trucks also dominate the freight sector in many Asian countries even though the infrastructure for other freight modes is developed.

Figure 2. Freight transport mode per cent share in 1980 and 2006 in China

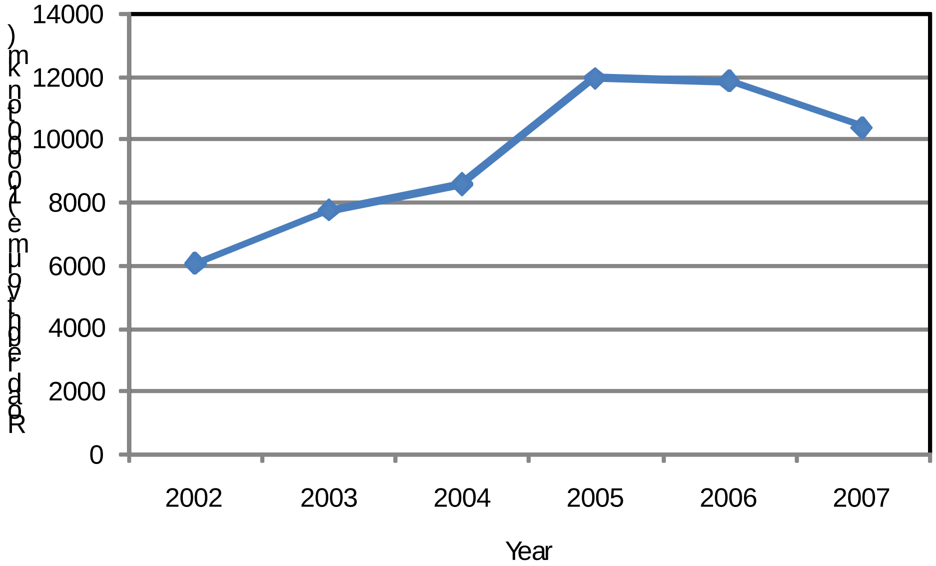


Source: ADB (2008).

Figure 2 shows that in 2006, the vast majority of freight in China, nearly 72 per cent, was transported by road; and the percentage has remained relatively stable since 1980. The share of railway has decreased from 20 per cent to 14 per cent over the same period. According to the Guangdong provincial transport plans, 220 billion yuan was budgeted for the construction of an expressway network in the province (Zhan, 2009). By 2012, the region will have 3,000 km of expressways. With further expansion of the road network, the road freight will continue to hold on to its dominant position in the freight sector.

Figure 3 shows that road freight volumes have increased from approximately 60 million ton-km in 2002 to over 100 million ton-km in 2007, representing a 67 per cent increase.

Figure 3. Road freight transport volume in Guangzhou



Source: Guangzhou Bureau of Statistics (2008) *Guangzhou Statistical Yearbook*.
Notes: Freight volume is expressed in ton-km which is the number of tons carried multiplied by the distance travelled.

Table 1 shows the distribution of commodities carried by road transport in Guangzhou from 2002 to 2007. Total freight tonnage by trucks registered in Guangzhou grew from 1.47 million tons in 2002 to 2.16 million tons in 2007, representing a 47 per cent increase. As truck numbers in Guangzhou increased by only 12 per cent, this may suggest that either trucks registered outside Guangzhou have largely contributed to the increase in truck numbers or it may also indicate higher volumes of freight transported. Currently available data does not show a further breakdown of “other” category of economic use, although this is the largest category.

The table also shows that at least one-third of the freight by weight, transported by trucks, represents non-perishable goods. Further analysis will determine the characteristics of the remaining two-thirds of the goods. When the freight is in a perishable category, it should be able to reach its destination fast, which limits the ability for redesigning routes and freight logistics.

Table 1. Freight transport by trucks in Guangzhou (in 10,000 tons)

Commodity/Year	2002	2003	2004	2005	2006	2007
Petroleum, natural gas and their products	3.33	6.84	6.93	6.80	4.00	5.90
Iron and steel	1.93	2.39	3.11	14.37	17.00	19.20
Mineral construction materials	0.14	0.30	0.55	0.30	0.28	0.28
Cement	0.58	1.40	1.42	3.98	7.00	7.23
Timber	0.08	0.33	0.39	0.52	0.32	0.28
Machinery	19.90	27.70	20.23	34.76	42.00	35.20
Chemical materials and products	1.11	1.43	2.27	6.99	1.00	1.58
Non-ferrous metals	--	0.75	0.28	0.35	0.21	0.17
Light industrial and medical	10.07	32.97	34.30	3.78	2.00	0.11

Commodity/Year	2002	2003	2004	2005	2006	2007
products						
Daily necessities	--	32.97	25.49	1.63	1.50	7.25
Others	109.55	161.93	228.57	154.20	144.05	139.25
TOTAL	146.69	269.01	323.54	227.68	219.36	216.45

Data on overloading of freight trucks, which is a major issue in China, and percentages of empty hauls on the road are not available, but may be obtained as part of a survey on truck drivers and companies.

B. Road freight transport as an increasing fuel user and a key emission source

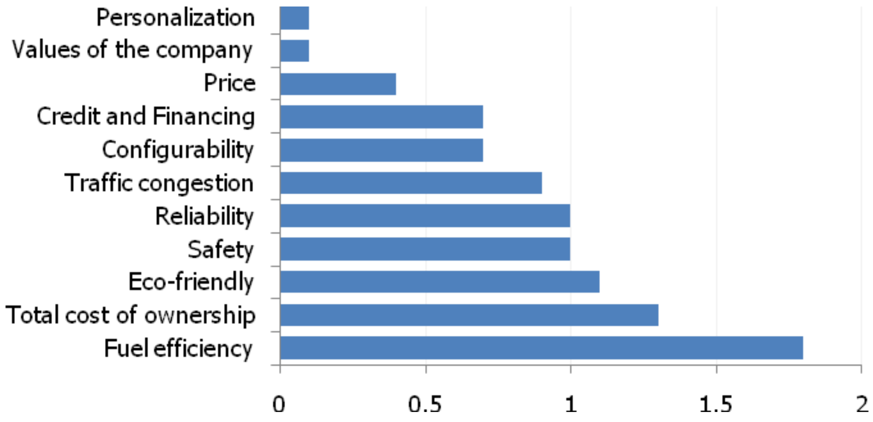
Fuel consumption

A more energy efficient road freight sector would favour not only the environment, but also road freight companies. Fuel costs represent a major component of the operating costs of trucking companies. For example, in Guangzhou, China, interviews with operators reveal that fuel costs represent 40-50 per cent of their operational costs (CAI-Asia Center, 2010a).

The risks brought about by imported fuel dependency can be seen in China. The 10 million trucks on Chinese roads, which represent more than a quarter of all vehicles in China, are the major consumer of oil. The total energy consumption by both passenger and freight transport in China accounted for 5.34 per cent of the total world production in 2005 and will account for 9.9 per cent in 2035 according to the estimates by the World Business Council on Sustainable Development (WBCSD) and the International Energy Agency (IEA) (2004). With international crude prices fluctuating from as low as US$ 40 to as high as US$ 140 a barrel in 2008, economists still expect that in the long term fuel prices will continue to increase (BAQ, 2008). The policy of subsidies on diesel for socio-economic reasons has resulted in a surge in diesel truck sales in China (in 2008 the sales were nearly twice as high as those in the United States of America) and, subsequently. diesel supplies could not keep up with the demand for diesel at service stations, causing rationing and shortages (Shen and Bai, 2008).

Fuel efficiency is becoming more and more important with the anticipated decrease in the global oil production in the future. As shown on figure 4, fuel efficiency was identified as the most important criteria in buying trucks in 2020 in a survey done by IBM with executives from organizations within the entire global truck value chain (Risbi and others, 2008).

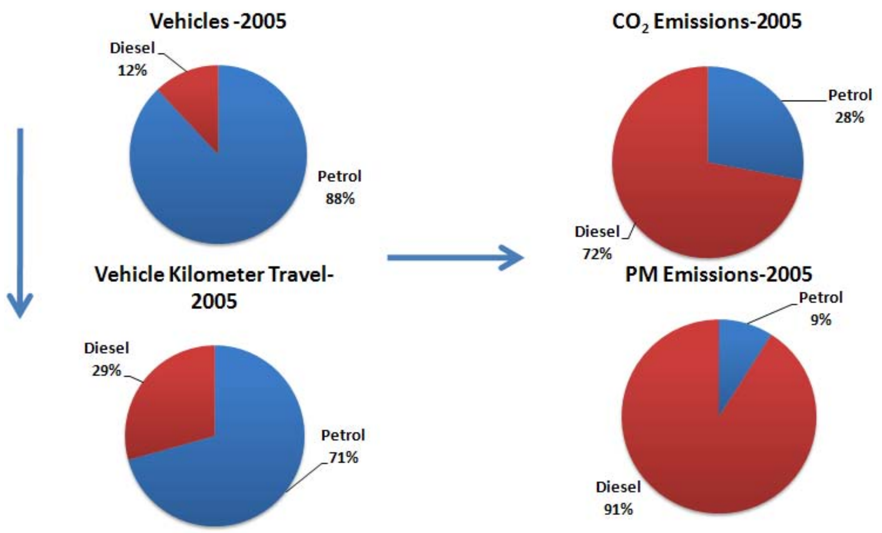
Figure 4. Change in vehicle buying criteria importance from 2008 to 2020



Source: IBM Institute for Business Value (2009)

Emissions

Figure 5. Trucks relatively high emissions impact in China



Source: Fabian (2010)

Air pollutants

A major problem caused by road freight is air pollution, which in many developing countries in Asia, including China, is usually considered a worse problem than greenhouse gas (GHG) emissions. The consumption of fossil fuels results in emission of air pollutants such as particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOCs), lead particles (Pb) and sulphur oxides (SOx).

The health impacts of diesel trucks have been identified through a number of studies and are summarized in box 1. The health effects from these pollutants vary in severity and symptoms. According to the World Health Organization, 800,000 people die prematurely each year because of air pollution, with more than half a million coming from Asia (Cohen, 2003). Air pollution has replaced cigarette smoking as the first cause of lung cancer in Guangzhou. In the recent decade the number of lung cancer cases has doubled.[1] In Hong

[1] http://www.lifeofguangzhou.com/node_10/node_37/node_85/2008/09/28/122258050352278.shtml

Kong, China, approximately 1,600 people died each year as a result of air pollution, mostly from heart attacks, stroke, pneumonia, and other lung diseases.[2]

Vehicle emissions also result in the formation of secondary pollutants, which are not directly emitted at the tailpipe but are developed through the reactions of different components in the air. One such example is ground level ozone or photochemical smog, which is formed from NOx and VOCs. Ground level ozone can result in acute health impacts on the elderly and people with weak lungs. NOx, SOx and VOCs emissions can lead to formation of $PM_{2.5}$ which are fine particles with diameters of 2.5 micrometres or smaller. They pose greater risks to human health as compared to larger particles because they can be lodged deeper into the lungs and can even penetrate the blood stream.

Box 1. Health impacts of diesel emissions

The results of studies, measuring exposure to diesel emissions coming from older and newer engines, indicate impacts on the respiratory, reproductive, and cardiovascular systems. Extrapolation of these findings to people exposed to much lower concentrations of diesel emission components than those used in experimental studies or in epidemiologic studies of occupationally exposed workers can be challenging.

Despite these challenges, many agencies have determined that diesel emissions are of sufficient concern to merit action to reduce emissions. New diesel engines with control systems meeting 2007 emission standards for heavy-duty highway vehicles are now on the market. A detailed report on emissions characteristics coming from four of such engines will be presented in the Advanced Collaborative Emissions Study (ACES), which is a joint effort of the Coordinating Research Council and the Health Effects Institute (HEI); chronic and acute health endpoints will be assessed for one of the engines. Although durable older engines with higher emissions level will continue to be used, these new engines, and those designed to meet the more stringent 2010 standards, will gradually become more common, with substantial replacement expected by 2030.

Source: HEI Air Toxics Review Panel (2007).

Greenhouse gases and black carbon pollution

Road freight is also contributing to the growing problem of climate change. GHG emissions are rapidly rising in Asia, particularly in major cities. The Kyoto Protocol covers six main greenhouse gases.[3] Air pollution and greenhouse gas emissions have similar causes, mostly energy-related, and there is an increased evidence that their effects are interacting.[4] The strongest evidence points to black carbon, the carbonaceous component of soot (particulate matter) that is produced mostly by burning of biomass, diesel and coal. In addition to its contribution to air pollution, black carbon is a dominant absorber of solar energy. Recent scientific studies suggest that black carbon is the second largest contributor to global warming following CO_2 (Ramanathan and others, 2007). The transport sector has been identified in a recent study of the United States Agency for International Development (2010) as the third largest source of energy-related black carbon emissions in Asia. On-road diesel consumption accounts for the majority in black carbon emissions within the transport sector in Asia where many countries have moved towards being more dependent on diesel.

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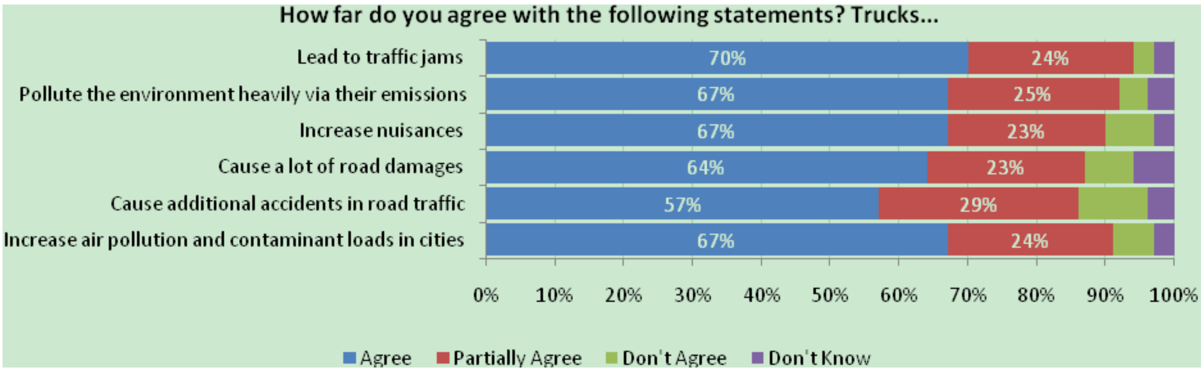
[2] http://www.redorbit.com/news/science/533045/pollution_costs_hong_kong_1600_lives_2bn_dollars_annually/index.html

[3] Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)

[4] Nitrogen oxides (NO_x), sulphur oxides (SO_x), carbon monoxide (CO), particulate matter (PM), volatile organic compounds (VOCs)

The IEA estimates that the transport sector accounted for 23 per cent of the world's carbon dioxide (CO_2) emissions and 13 per cent of global GHGs[5]. Although the share of the CO_2 emissions attributable to transport sector of developing countries is currently low, it is expected to increase by 45.6 per cent between 2005 and 2030. Unlike traditional air pollutants that can be monitored at the "tail-pipe," CO_2 emissions cannot be controlled that way and must be regulated by reducing fuel consumption.

Figure 6. Perception on the impacts of trucks on different issues



Source: Price Waterhouse Coopers (2008).

II. WAYS TO ADDRESSING THE PROBLEM

A. Existing measures

In China, key plans and laws are first developed at the national level and then employed at the provincial and local levels through provincial and local plans and policies. The most relevant ones are:

- Transport. 11th Five-year Plan for the Transport Sector (2006-2010) and various regulations on road transportation, including road freight transport;
- Energy. Energy Conservation Law. Fuel efficiency standards for commercial freight vehicles;
- Environment. Environmental Protection Law. Air Pollution Prevention and Control Law; Emission standards and policies relevant to diesel vehicles;
- Implementation Guidelines of the Law on Road Traffic Safety Law, effective 1 May 2004.

Table 2 below presents the key policies and laws relevant to road freight sector.

Table 2. Plans, policies and laws/regulations relevant to the Guangzhou Green Trucks Pilot Project

Policy/legislation	Level	Description	Relevance to the project
TRANSPORT			
The 11th Five Year Plan for the transport sector	National	• Aims to establish a highway transportation network. Trucks are projected to reach 7 million in	

[5] 2006 estimates

Policy/legislation	Level	Description	Relevance to the project
		2010 with the shares of heavy-duty trucks, special vehicles, and vans trucks reaching 30 per cent, 30 per cent and 20 per cent respectively. (www.moc.gov.cn/2006/06tongjisj/06jiaotonggh/shiyiwuguihuajd/guihuajd/200611/t20061107_115042.html)	
China Regulation on road transport	National	• Defines principles and management methodologies on road transport in China	Core regulation for Guangzhou freight transport
Management Regulation on Road Transportation of Guangzhou province (2002 amendment)	Provincial	• Defines road transport management in Guangzhou including freight transport, passenger transport, transfer, loading and unloading, service and maintenance of motor bikes	Local and direct management regulation on the freight transport for Guangzhou trucks
Regulations of road administrative control	National	• Defines the principle of road administrative control and the duties of road administrative control organizations	Main law for road management
State Council Circular: Decision on the Revision to Protocol of Road Management, 1 January 2009	National	• Road construction can be financed nationally and locally through designated investment companies, co-financing with international organizations, public funding, loans, and Vehicle Procurement Tax. • Charges can be introduced at main ports, bridges, Tunnels and toll gates on major roads with the purpose of repaying loans. Approval is required from the provincial government. • Charge rates should be approved by financial and pricing agencies. • Roads are classified as national, provincial or local roads. Provincial Department of Communications (DOC) is responsible for the construction, maintenance and management of the first two types of roads, while the local Bureau of Communications (BOC) takes care of the local roads.	Mandates of BOC/DOC on road transport; Linking the mandates on road construction and toll gate fees with incentives to reduce truck emission

Policy/legislation	Level	Description	Relevance to the project
Decision on the Revision of Management Regulation on Road Freight Transportation and Stations by Minster of Communications, July 2008	National	• Defines that DOC/BOC takes responsibilities for truck fleets and stations business permit and management • Regulates approval procedures • Defines the responsibilities of the business enterprises on transport or stations • Specifies the technical standards applied to trucks	Very important document as it identifies the full range of stakeholders: BOC/DOC, Business owners of truck stations, owners of truck fleet, management fees, set of of transportation rules, driving behavior, overloading, poor maintenance are also specified.
ENERGY			
Implementation Methods on Energy Conservation Law in Land and Water Transportation Sector, issued by the Ministry of Communications	National	• Defines the energy saving responsibilities of the Ministry of Communications (transport), the Provincial Department of Communications (transport), and the Municipal Bureau of Communications (transport). Define administrative management framework for energy saving in transport sector. Define responsibility to publish recommended technology for transport vehicles, etc.	Energy conservation is the key mandate of the Bureau of Communications. Shall have incentives to explore energy saving technologies and strategies
Fuel Efficiency Standards for Commercial Freight Vehicles issued by MOC in June 2008	National	• Stipulates standards for fuel efficiency	The standard impacts cost of truck freight transport, especially trucks using diesel fuel.
Trial Management Provisions on Qualifications of Freight Transportation Enterprises by Ministry of Communications, 2001	National	Classification of freight transportation enterprises, differentiated by the levels of approval and scope of work. MOC, DOC and BOC are the main approval and administration agencies. Annual review requirements for transportation enterprises	Fleet classification affecting the stability of economic output of the truck industry. Fleet selection for pilot projects.
ENVIRONMENT			
Law of China on environmental	National	• Main/general law on environmental protection in	One of the guild laws for vehicles

Policy/legislation	Level	Description	Relevance to the project
protection		China. Defines environmental protection and improvement and stimulates management methodology for environmental protection and monitoring, as well as legal responsibilities	management
Law of China on air pollution prevention and control	National	• Defines air quality standards and air pollution levels, including for the vehicle management	One of the guild laws for vehicles management
Limits and measurements for exhaust fumes from compression ignition and gas fuelled positive ignition engines of vehicles(III, IV, V) (GB 17691-2005)	National	• Light-duty gasoline vehicles and M-types light diesel vehicles need to accord with Grade III Emission standard as of 1 July 2008. • New gasoline vehicles with compression ignition engines should add OBD system as of 1 July 2008. • M-type light diesel vehicles need to accord with Grade III Standard in main cities. • Vehicle producers have to conform to environmental protection standards.	The regulation specifies the country's emission standard requirements for trucks
Management methods of vehicles emission monitoring	National	• Early policy and measures for vehicle emission control and management, show manage measures for the new cars, in-use cars and engines.	Early policy for vehicles in China, updated by the Air Pollution Prevention and Control Law
Technology and policy on pollution prevention and control for diesel vehicles	National	• Technology and policy to reduce pollution and control emissions in diesel vehicles, car-use diesel productions and diesel fuel	Technology and policy specific to diesel vehicles
Technology and policy on pollution prevention and control for vehicles	National	• Technology and policy for vehicles, including diesel vehicles, motorbikes and car-use engine production to reduce pollution and control emissions	Technology and policy for vehicles including diesel and gasoline vehicles
Method for an estimation of air pollution coming from vehicular transport in urban areas	National	• Stipulates the method for vehicular emission estimation as an industrial standard in urban areas	Relevant in measuring the pollution level coming from trucks and its health implications

An in-depth study, financed by the Asian Development Bank (ADB) and implemented by the Ministry of Transport (MOT) of China, discussed many aspects of 'green transport' Green or sustainable transport is a transport system that leaves a smaller physical footprint, uses less energy and produces less CO_2 and other harmful pollutants). The study provided a detailed analysis of the freight sector and offered some conclusions (ADB, 2008).

Table 3. Policies relevant to freight sector mentioned in the ADB study

Chinese legislation and regulations in relevance to GHG emissions	Effectivenes s level	Year of release*	Year of implemen-tation
China laws related to climate change			
Environmental Impact Assessment Law of China	Law	28-Oct-02	1-Sep-03
Environmental Protection Law of China	Law		
Energy Conservation Law of China	Law	28-Oct-07	1-Apr-08
China transport legislation related to emissions and energy consumption			
Road Transport Regulation of China	Regulation	30-Apr-04	1-Jul-04
Management of Toll Roads Regulation	Regulation	13-Sep-04	1-Nov-04
Provisions for the Administration on Training Motor Vehicle Drivers	Act	12-Jan-06	1-Apr-06
Policy on Automobile Manufacturing Industry	Policy	1994	1-Jun-94
Suggestion on Application of Smooth Traffic Project to China Urban Road and Transport Management (MoPS & MoCon)	N/A	N/A	N/A
Regulation Publication on Energy-Saving Products for auto and vessel fleets	Regulation	20-Mar-92	1-Jun-92
Popularization and Application of Energy-Saving Products (Technologies) for car and vessel fleets	Act	14-Aug-95	15-Oct-95
Transport Industry Directive on the Implementation of Energy Conservation Law	Act	16-Jun-00	16-Jun-00
China transport policy measures related to emissions and energy consumption			
"fee-to-tax" (fuel tax in China)	-	-	-
Congestion toll	-	-	-
Parking fee	-	-	-

Note: In China, "laws" are issued by The National People's Congress of China; "regulations" are issued by the Central People's Government of China; different "Acts" are issued by different ministries and departments of China.

The above acts are mainly issued by the Ministry of Transport (MOT) and other transport related authorities, while some are co-issued by MOT and State Environmental Protection Administration of China, National Bureau of Statistics of China, etc.
* "year of release" refers to the last revision.

Source: ADB (2008)

B. Barriers and policy gaps

The section provides an overview of issues, including policies and institutional arrangements, freight sector challenges and the availability of technologies and financing mechanisms that should be addressed to make the road freight industry more sustainable.

Policies and institutional arrangements

Most countries have adopted policies on trade facilitation and infrastructure development (e.g., improvement of ports and airports) to improve freight and cargo movement between countries and/or regions. However, policies dealing with the environmental performance of trucks and the trucking industry are often lacking or limited.

Many countries set heavy-duty vehicle emission standards but often have trouble enforcing them. Policies for light-duty vehicles usually are introduced first and the standards for heavy-duty vehicles often follow years later. This applies to vehicle emission standards, fuel economy standards and most other environmental-related policies. In China, the government introduced light-duty vehicle fuel economy standards in 2005, while the government fuel economy standards for heavy-duty vehicles were introduced only in 2010.

Furthermore, freight is seldom included in the design and planning of urban transport systems and policy development. As a result, ad hoc solutions are created to mitigate problems, associated with urban freight transport, as they arise. Some of the main issues are lack of dedicated trucking routes, limited parking facilities for loading/unloading of goods inside cities, and fragmented logistics centres.[6]

The number of government agencies that truck operators and drivers in China need to deal with adds more complexity to the sector.

Freight sector challenges

The road freight sector is highly fragmented with a majority owner-driver trucks. A survey carried out at logistics centres in Guangzhou, China, found that of the surveyed drivers, 48 per cent worked for truck companies and 52 per cent owned the truck they were driving. In Guangzhou, almost 80 per cent of the surveyed drivers, working for truck companies, were registered outside of Guangdong Province, which made it more difficult for governments to control or reach out to them. Multiple logistics centres, existing around many Asian cities, limit the coordination of trucking operations. Furthermore, shippers seem to have a less direct relationship with carriers than shippers in the United States, because they have contracts with the factories that they purchase goods from. These factories arrange for the transport of goods to ports or storage areas through logistics firms that hire small companies and individual drivers to carry the load. Environmentally and socially responsible companies will find it harder to reduce fuel consumption and emissions coming from the road transport in their supply chain.

The highly fragmented nature of trucking industry without strong government regulations makes it difficult to promote the use of newer vehicles and the adoption of better technologies (e.g., aerodynamic skirts, which can reduce fuel consumption).

The fragmented nature of the trucking industry is one of the main reasons for the high percentage of trucks on empty hauls. A Chinese study found that around 50 per cent of

[6] http://transport-solutions.blogspot.com/2010/08/urban-freight-victim-of-policy-neglect.html

truck trips were empty hauls (Guo and others, undated). These empty trips result to an annual estimated losses of US$ 8 billion.

For comparison, in the Philippines 89 per cent of delivery vehicles were found empty in their return trip.[7]

Another common problem in the Asian developing Asia countries is overloading of trucks. A study done in Anhui province of China found that vehicle overloading was widespread and a serious problem on the arterial highways of the province (Ying, 2008). The traffic load greatly exceeded the standard bearing capacity of the road pavement causing premature damage. The study also found that the mean gross vehicle weight of the load trucks went over the limits, which indicated that many of the trucks were overloaded.

Technologies and financing

The adoption of cleaner technologies is a key to addressing different impacts on the road freight sector, particularly in Asia, where many developing countries have poorly maintained and/or old truck fleets.

Table 4 presents the average reduction potential of different technologies. Long-range trucks have the greatest potential for fuel saving and GHG emissions reduction through technology applications.

Table 4. Fuel consumption reduction potential of different heavy-duty vehicle technologies[8]

Technology	Fuel reduction potential (per cent)
Aerodynamics	3 to 15
Auxiliary loads	1 to 2.5
Rolling resistance	4.5 to 9
Mass (weight) reduction	2 to 5
Idle reduction	5 to 9
Intelligent vehicle[9]	8 to 15

Table 5 presents the estimated potential for reduction of fuel consumption from tyre and aerodynamics technologies for the 1.23 million trucks registered in Guangdong Province of China in 2007.

Table 5. Fuel and emissions reduction potential from tyre and aerodynamics technologies for trucks registered in Guangdong Province[10]

Parameter	Total	Remarks
Total number of trucks registered in Guangdong Province	1,230,000	67.2 per cent heavy-duty (or 826,520), 19.8 per cent medium-duty (or 243,540) and 13.0 per cent light-duty (or 159,900) trucks, based on the ratios found in the truck industry survey.
Total investment	12,137,461,109	Tyre technologies, reducing rolling resistance,

[7] Garsuta, Rebecca (1995)

[8] Transportation Research Board (2010).

[9] Intelligent vehicles include information about the state of the vehicle, the environment around the vehicle, and Global Positioning System (technology with computers and mobile communications technologies in order to achieve fuel consumption reduction).

[10] CAI-Asia Center (2010b).

Parameter	Total	Remarks
costs (tyres and aerodynamics) (in US dollars)		included aluminum wheels (heavy duty trucks), low rolling resistance tyres and tyre pressure monitoring system. Aerodynamics equipment package, reducing air resistance and drag, and included a nosecone, cabin fairing, and trailer skirts.
Total fuel savings (litres/year)	3,962,456,995	Fuel savings for the tyre package are assumed at 5 per cent and for the aerodynamics package at 3-7 per cent compared to the United States' experience of 6-8 per cent and 10-13 per cent respectively.
Total fuel cost savings ($/year)	3,586,066,990	At diesel price $ of 0.9 per litre
Total CO_2 savings (tons/year)	10,233,591	CO_2 = 2.582 kg CO_2/litre
Total NOx savings (kg/year)	37,009,348	NOx = 9.34 g/litre
Total PM savings (kg/ year)	1,584,983	PM10 = 0.40 g/litre
Payback period (in years)	3.38	

Challenges to the wide-spread adoption of technologies by the road freight sector in China are the following:

- The availability of technologies in Asia is much lower than in the United States or Europe. A fragmented technology suppliers' network adds to the problem.
- High speeds requirement for the aerodynamic technologies to work properly could not always be achieved. This is partly caused by traffic congestion and poor conditions of highways. Another factor, contributing to low speed, is long-haul trucks delivering in urban areas rather than transferring their loads to smaller trucks when entering urban areas. All this lead to slow urban traffic.
- Limited case studies contain several examples that could help Asia build confidence in using technologies.

Financing green technologies will represent a challenge for China for the following reasons:[11]

- Limited tax policies exist for the road freight sector relevant to energy and emissions management and minimal experience of policymakers in applying economic instruments to the trucking sector.
- Initial investment costs are too high for many companies, even if potential savings are large and the payback period is short. High investment costs could be explained by small number of technologies suppliers and low technologies production and sales rates. Furthermore, the tariffs for imported truck equipment exceed 110 per cent.

[11] CAI-Asia Center (2010c)

- The trucking industry is not considered a reliable sector for lending, especially to small companies and individual truck driver owners.
- ESCOs (energy service companies), successfully operating in the industrial sector, have no experience working with trucking fleets.
- The local financial community lacks knowledge and tools required for new technologies financial appraisal. This has, so far, prevented the introduction of innovative financial mechanisms, such as revolving funds.

A specific challenge applies to using diesel particulate filters (DPF). Many Asian countries have high sulfur diesel fuel unacceptable for the use with DPFs. Though poor maintenance practices will impact most technologies to some degree, they are especially damaging for retrofitted DPFs, because without proper maintenance they risk getting blocked. On top of that, DPFs cost of several thousand dollars does not result in fuel savings enough to help recover such cost, unlike with many other technologies. For this reason, DPFs should either be mandated or included in a technology package that, as a whole, generates net savings.

III. GREEN FREIGHT STRATEGY

A. Description of the Guangzhou Green Trucks Pilot Project

The World Bank (WB) initiated a pilot project entitled “Guangzhou Green Trucks Pilot Project” in support of Guangzhou’s efforts to improve air quality in preparation for the 2010 Asian Games. The goal of the project was to develop a “proof of concept” for a truck programme in Guangdong Province, and possibly in China that aimed at:

- Enhancing the fuel economy of the truck fleet
- Reducing black carbon and other air pollution coming from trucks
- Consequently, ensuring GHG emission reduction

The project was implemented by the Clean Air Initiative for Asian Cities Center (CAI-Asia Center), in cooperation with Cascade Sierra Solutions, the United States Environment Protection Agency (EPA) and the World Bank and the support of Guangzhou Environmental Protection Bureau (GEPB), Guangzhou Transport Committee (GTC), and Guangzhou Project Management Office (PMO) for the World Bank.

The pilot project aimed at addressing three problems, related to truck fleet in Guangzhou and the wider Guangdong province: fuel costs and security; air pollution and associated health impacts; and greenhouse gas emissions and climate change.

The project covered Guangdong Province, focusing on diesel trucks accessing or passing through the city of Guangzhou and the surrounding cities, such as Shenzhen. Besides dealing with GHG emissions, the scope of project included black carbon and other air pollution from trucks because of their potential hazardous interacting effects and the contribution to climate change, and, also, because air pollution is an important local concern.

The pilot project consisted of the following components: background analysis; survey on Guangzhou truck sector; driver training course for fuel efficiency of trucks; and technology pilot.

The purpose of the technology pilot was to demonstrate that technologies used in the United States and other Western countries can also work in China, to identify factors of influence for China and to determine the potential for fuel and emissions reductions for Guangdong Province under a future programme. The pilot results are promising but a larger pilot is needed to confirm savings potential. For this reason the results from the technology pilot should be considered as indicative only and must be verified under a larger pilot.

The technology pilot component of the project tested:

- Tyre equipment package to reduce the weight and rolling resistance of the tyres consisting of aluminum wheels (heavy-duty trucks (HDTs) only), low rolling resistance tyres and a tyre pressure monitoring system
- Aerodynamics equipment package to reduce air resistance and drag consisting of a nosecone, cabin fairing, and trailer skirts

Summary of results

Three companies participated in the pilot: Star of the City Logistics (SOCL), Xinbang Logistics (XWBL), and Baiyun District Guangzhou. At SOCL, tyre and aerodynamics equipment were tested on two long-haul HDTs. Investment costs were US$ 16,333 and the estimated annual savings amounted to 3,557 litres of diesel (6.64 per cent), 9.18 tons of CO_2, 33.21 kg NOx, and 1.41 kg PM10. The project has a payback period of 5.1 years. The lower than expected fuel savings could be explained by the slower (50-60 km/h) average speed of pilot trucks, influenced by heavy loads, poor weather conditions, such as frequent fog, highway construction and traffic congestion,, while the highest benefits from aerodynamics equipment were achieved at a speed above 75 km/hr. If the equipment packages were installed on the entire long-haul fleet of SOCL, consisting of 30 HDTs, then, based on the pilot results, the initial investment of US$ 489,996 could have resulted in 106,704 litres of fuel savings, which is the equivalent to US$ 96,033. The payback period would have been five years. Emissions reductions would have comprised 276 tons CO_2, 996 kg NOx and 42 kg PM10 per year. It is important to note that SOCL is considering purchasing several equipment packages for its fleet, and is most confident about nosecones, cabin fairings, aluminum wheels and low rolling resistance tyres.

A shorter payback period could be achieved if:

- Equipment was factory-installed on trucks.
- Equipment was purchased wholesale (current costs are based on retail prices for equipment purchased for the Guangzhou pilot project).
- The longer life time of LRR tyres compared to existing tyres would be considered for the HDTs of SOCL as this would lower the LRR tyre investment costs over the time period.

B. Lessons learned from the Guangzhou project

Conclusions and recommendations are presented in three groups:

- Technology pilot and potential for the trucking sector
- Need for a nation-wide programme sector to improve fuel efficiency and reduce emissions from diesel trucks
- Considerations for the design of a Green Freight China programme

A Green Freight China programme may be designed with the lessons learned from the Guangzhou pilot project.

Lessons learned from the technologies tested

A general conclusion is that technologies used in the United States may not always be suitable for China. Based on the technologies tested, the following lessons can be drawn for future consideration in future pilots and a broader programme:

- Tyre quality is a key issue in fuel efficiency gains and emissions reductions. Low rolling resistance (LRR) tyres ease the rolling resistance on the road and thus reduce fuel use. Single wide LRR tyres would have provided the largest savings but could not be tested due to legislation in China barring all changes to the truck structure. Dual LRR tyres appear to generate enough savings to be economically feasible, especially due to the longer life span compared to normal tyres. The improved stability of tested garbage trucks with the LRR tyres contributed to the larger savings. Even improving the quality of conventional tyres used on trucks could result in significant savings. Aluminum wheels could be considered as part of the tyre package especially if they are factory installed, replacing existing steel wheels. The first Chinese SmartWay tyre, Double Coin Holding, is a very important step in for developing SmartWay technologies developed and distributed in China.[12]

- Tyre pressure monitoring systems have a good potential to reduce fuel and emissions, but depend on proper installation of the system and instruction of the drivers on how to operate them.

- Nosecones and cabin fairings were considered successful technologies because of reasonable savings, even at lower speeds, and relatively low investment costs. For this reason SOCL decided to install these equipments on the entire long-haul fleet.

- Trailer skirts, aimed to reduce drag, were less successful because the long-haul trucks did not reach average speeds of 75 km/hr when fuel savings became significant. At lower speeds, the added weight of trailer skirts offsets the fuel savings from reduced drag. High average speeds may be more difficult to reach in China than in the United States because of speed limits, traffic congestion, weather conditions and road quality. The weight of truck loads also plays an important role, as overloading of trucks is common and renders driving at high speeds unsafe. The pilot also found that a wide range of truck load is not always measurable because customers often pay per freight volume or units transported.

A future pilot project should have a stronger focus on domestic trucks, such as DongFeng, HOWO, STEYR. These trucks manufacturers could be involved in a pilot by installing selected technologies while trucks are being assembled, thus providing financial support for the pilot project in return for the use of the pilot results to promote their trucks. Global engine manufactures that have agreements with Chinese engine manufacturers could also be asked to financially support pilot projects to test new technologies, e.g. Jianghuai Automobile Co. Ltd. (JAC) and Navistar.[13] Available technologies and strategies for improved fuel efficiency and reduced emissions from trucks are shown in box 2.

[12] http://fleetowner.com/green/archive/china-made-first-smartway-0322/
http://www.tirereview.com/Article/72045/epa_smatway_adds_first_chinese_tire.aspx

[13] http://fleetowner.com/trucking_around_world/archive/navistar-chinese-engine-maker-1030/

Box 2. Technologies and strategies for improved fuel efficiency and reduced emissions from trucks[14]

- **Vehicle activity and driving pattern improvement** - Fuel consumption is strongly connected with vehicle driving pattern in real-world operation.
  - **Driver training**. Drivers can be trained to follow fuel-saving driving habits or keep their highway speed within efficient range.
  - **Reducing speed** on highways to a level where fuel consumption is most efficient
  - **Reducing overloading** can reduce fuel consumption.
  - **Improved freight logistics**. The total activity can also be reduced by better logistics management such as increasing returning load and reducing empty trip. Vehicle activity is linearly correlated with total fuel consumption.
- **Enhanced maintenance** - Truck condition can affect not only operation performance, but also fuel economy and emission. A routine inspection/maintenance (I/M) is barely enough to ensure good condition. Special training and improved fleet management can help contractors improve the condition of their trucks. Engine rebuilding is considered the strongest enhanced maintenance strategy.
- **Vehicle body improvement** - Several strategies based on vehicle body improvement can be applied to reduce diesel consumption by reducing the drag.
  - **Truck weight reduction** is a common strategy to improve the fuel economy of a truck.
  - **Improved aerodynamics** reduces drag and thus fuel consumption.
  - **Reducing rolling resistance** through tyre system modifications: single wide-based tyres, low rolling resistance tyres or automatic tyre inflation or tyre pressure monitoring systems can also reduce fuel consumption.
- **Reduced idling.** Several technological options, including auxiliary power units (APUs), automatic engine idle systems, and truck stop electrification can assist drivers in reducing truck idling,.
- **Fuel, oil and lubricant improvement**
  - **Low-sulfur diesel** can reduce emissions of in-use trucks immediately. It is also a precondition for a successful emission retrofit programme.
  - **Low viscosity lubricant** can also help improve fuel economy.
  - **Oil by-pass filtration system** improves oil life performance and indirectly contributes to fuel efficiency due to reduced engine wear.
- **Emission retrofit** - In-use diesel retrofit with emission control devices including EGR (Exhaust Gas Recirculation), DPF (Diesel Particulate Filter) and DOC (Diesel Oxidation Catalyst) systems have been widely applied in the United States and Europe. The selection for target trucks and technology verification is crucial for a successful retrofit.

Fleet and engine modernization - Fleet modernization can introduce much cleaner engines into the fleet to lower PM and NO_X emissions. Engine replacement is also a type of fleet modernization strategy

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[14] CAI-Asia Center (2010a)

Lessons learned from the training process

The training process is equally important in successful application of technologies. The main lessons brought for consideration in future pilots and a broader programme are as follows:

- Driver training, including eco-driving and equipment handling training can greatly add to fuel and emissions savings. For example, drivers mistakenly switched off pressure monitoring sensors while increasing tyre pressure, because instructions on handling the equipment had not covered the subject. Technology training of the drivers of pilot trucks directly by the technology supplier or OEM supplier would be preferable.
- Clear and detailed pilot protocols for data collection are essential. Their implementation can be difficult, and if not implemented correctly, the margin of error may exceed the savings percentage thus rendering unreliable results as was the case with XWBL. At SOCL, the protocols were initially not exactly followed, and it was due to strong personal interest and commitment from top management that the right incentives were provided to pilot drivers during an expanded pilot to ensure that data collected was reliable. Ideally, data collected for equipment tests should be integrated into a company's overall monitoring system.
- Conditions for pilot and control trucks need to be kept as close as possible. Of particular importance are the same load weight/daily load factor, same driver, same training, same cab – trailer combination and same routes.
- Participating companies are keen to be considered leaders in their sector. Identification of leading companies that would profile fleets that advance emissions reduction and fuel savings in the transportation sector would benefit a future pilot or programme.

In addition, other matters that may also be considered include:

- Focus on fuel, climate change and air pollution
- Focus on different type of trucks
- Bringing costs of equipment down
- Ensure broad stakeholder participation
- Build on existing successful programmes tailored to China

As part of the further design of a longer-term programme following the pilot implementation, existing taxes, subsidies and other economic instruments relevant to the trucking industry in China should be considered. The matter should be discussed with the Ministry of Transport, which, among others, is focused on improving the freight sector through promoting freight trucks types that are more environmentally friendly and energy efficient. Economic instruments could also play an important role.

C. Next steps

CAI-Asia noted that city level and regional level projects could be successful and sustainable only if an integrated policy package on freight carried across regional borders was introduced on the national level. For this reason it is proposed to establish a Green Freight China Programme, presented below in box 3 focuses on energy efficiency and reduced greenhouse gas emissions and air pollutants. The programme

- Fills policy and institutional gaps in the Guangdong project that was restricted just to Guangdong Province,

- Provides a basis for expanding experience gained in Guangdong Province and Guangzhou to the whole of China. To this extent it is important that the programme design makes use of the outcomes and results of the Green Trucks Pilot Project in Guangzhou as well as the lessons learned from the preparation phase and early implementation phase of the Guangdong Green Freight Project
- Can also be used as a model for other countries establishing such programmes, especially in developing countries

Box 3. Components of the Green Freight China Programme

- Green Freight Partnership of shippers, carriers and regulators relevant to Guangdong, China (mirroring the Smartway Partnership in the United States) and Green Freight Network, comprising broader stakeholder groups also including suppliers, NGOs, universities and other members. The globap membershiop network will be useful to access expertise and support for the programme as well as the Global Environment Facility (GEF) project.
- Technologies and Logistics, which also includes the policies that affects them
- Financing, which could include state loan programmes (revolving loan funds) or provision of limited grants for the purchase of technologies and/or new trucks
- Freight database, which would include data submitted by carriers on fuel use, technology application and other aspects of their fleet; results from technology applications and other measures taken by programme participants to reduce fuel use and emissions; data from surveys as part of the programme; and data from external sources, such as national statistics, and from studies carried out by others. It would also include a measurement model for energy use, CO_2 emissions and air pollutant emissions for the road freight sector.

In addition, there are a number of cross-cutting activities, including research, policy development, training, communication and marketing aimed at the freight sector, government agencies and other relevant stakeholders in China. Examples of cross-cutting activities are: research on methodologies for measuring fuel and emissions reductions from trucks; policy recommendations on how technologies can be promoted through national policies; capacity building and institutional strengthening activities; training materials, videos and tools; outreach centres to provide a face-to-face contact with drivers directly; marketing materials; a dedicated website on the Green Freight Programme.

CONCLUSION

The reduction of road freight activity is heavily influenced by the nature and amount of freight demand. This is valid not only for China but also for other Asian countries. There are several ways in which road freight activity reduction can be achieved:

- Promotion of local production and consumption, as well as compact land use planning can result in the avoidance of the road freight activity.
- If facilities within the same supply chain are located geographically closer to each other, the need for transportation would be lower. Similarly, industries producing goods that are to be shipped abroad should ideally be located as close to ports as possible. This can be achieved through better land use planning and industrial zoning.
- Logistics of the freight sector can be significantly improved. The measures include better communication linkages between shippers, carriers, logistics centres and manufacturers or end-users. Information and communications

technologies play an increasingly important role. Logistics centres help facilitate the efficient distribution of goods and thus the efficient use of trucks. However, in many cities, the number of logistics centres is high and their locations are selected on an ad hoc basis, often leaving the initiative with the private sector operators. Reducing the number of logistics centres and re-assessing their location, as well as improving the coordination between them are other options. Logistics centres can be improved to reduce the multiplicity of delivery points in urban areas by redistributing loads from large trucks to smaller ones. This would greatly contribute to reducing road freight vehicle trips, vehicles (as each vehicle's utility is maximized, fewer vehicles are needed) and vehicle kilometres travelled. [15] In turn, this would reduce supply chain cost.

- The reduction of road freight trips can also be achieved through policies and programmes directed at increasing the loads carried by freight vehicles. Over the past decades many developed countries have increased the legal axle limits to accommodate such higher axle loads. India's legal single axle load limit is now 10.2 tons, which used to be 8.16 tons a decade earlier. Thailand's maximum axle load limit is 8.2 tons while the truck-load limit is 25 tons, which was increased from 21 tons in 2006. Accompanying government subsidies and regulations for encouraging truck owners to shift to vehicles with more axles in order to minimize road infrastructure damage must accompany this trend of increasing loads limits (Sathaye and others, 2009).

DISCLAIMER

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[15] Brown, M. and M. Sweet, Urban Freight Consolidation Centres: Final Report.

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