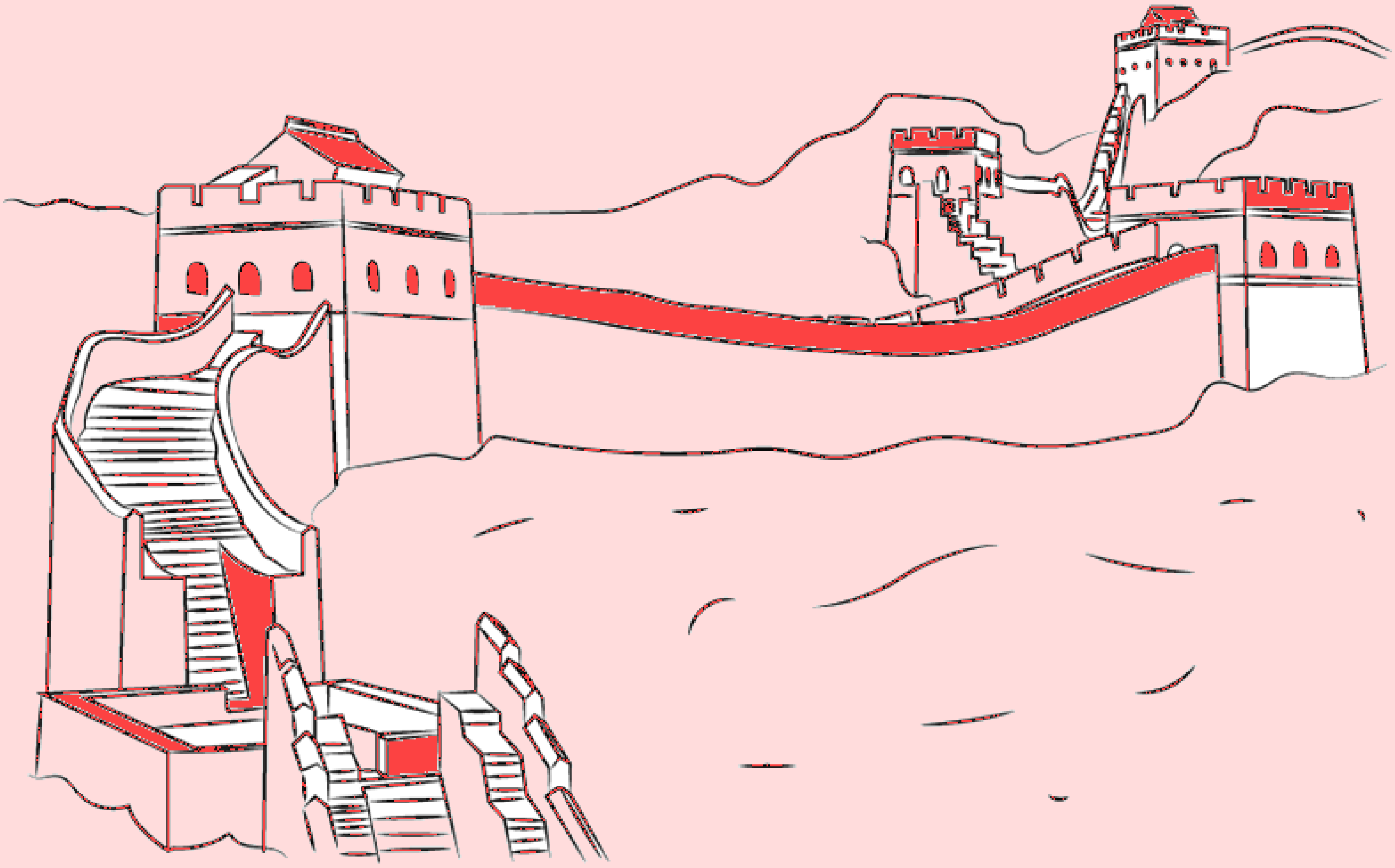

A Review of Air Pollution from Transport Sector in China

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(UEinfo) was founded in 2007 with the vision to be a repository of information, research, and analysis related to air pollution. There is a need to scale-up research applications to the secondary and the tertiary cities which are following in the footsteps of the expanding mega-cities. Advances in information technology, open-data resources, and networking, offers a tremendous opportunity to establish such tools, to help city managers, regulators, academia, and citizen groups to develop a coordinated approach for integrated air quality management for a city.

UEinfo has four objectives: (1) sharing knowledge on air pollution (2) science-based air quality analysis (3) advocacy and awareness raising on air quality management and (4) building partnerships among local, national, and international airheads.

This report was conceptualized, drafted, and designed by the members of UEinfo.

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A Review of Air Pollution from Transport Sector in China

Rapid industrialization, the reliance on coal and the burning of fossil fuels and a growing population have made China the world's largest producer of greenhouse gases, surpassing the United States in 2007[1]. Air pollution in the urban centers of China has received significant attention over the last year, primarily due the 2008 Olympic Games. A number of interventions were implemented over a wide range of sectors (domestic, industrial and transport), to achieve the target air pollution reductions and improve the number of clean air (blue sky) days in Beijing and the other participating cities in China[2].

The links between air pollution and health, the impacts of increasing exposure to higher ambient levels in the residential areas and along the transport corridors is well studied and documented[3]. In China, the cost of the impacts air pollution is estimated at 520 billion yuan, ~3.2 percent of the total GDP in 2003, using the willingness to pay methodology[4].

In China, the stationary sources are considered the main contributor to the air pollution; but the transport sector has been growing among all modes – personal, public, and freight[5]. In the urban centers, the share of personal transport has increased, resulting in not only an increase in air pollution, but also created serious traffic management nightmares with congestion along the major corridors[6]. In 2009, according to the Beijing Traffic Management Bureau, the city registered ~1,500 motor vehicles per day, compared to ~1,350 per day in 2008, leading to serious traffic pressures and safety risks[7].

During the two months (before and during the Olympic Games 2008), when traffic restrictions and shut down of local industries were implemented, the levels of nitrogen

[1] Climate Ark, June 2007, "China tops US in greenhouse gas emissions" @ http://www.climateark.org/shared/reader/welcome.aspx?linkid=78347

[2] UN news center, "Beijing Olympics raises bar on eco-friendly sporting events", on February 18th, 2009 @ http://www.un.org/apps/news/story.asp?NewsID=29935&Cr=sport&Cr1=environment

UNEP's independent environmental assessment of Beijing Olympics Games 2008 @ http://www.unep.org/sport_env/Activities/BeijingReport08/

A photo summary and statistically analysis of blue sky days in Beijing @ http://www.asiasociety.org/beijingair/#statistically-speaking

[3] Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review (2004) @ http://pubs.healtheffects.org/view.php?id=3; Mobile-Source Air Toxics: A Critical Review of the Literature on Exposure and Health Effects (2007) @ http://pubs.healtheffects.org/view.php?id=282

[4] Details of the methodology, underlying uncertainties, and the results are documents in the World Bank report, "Cost of Pollution in China". http://go.worldbank.org/FFCJVBTP40

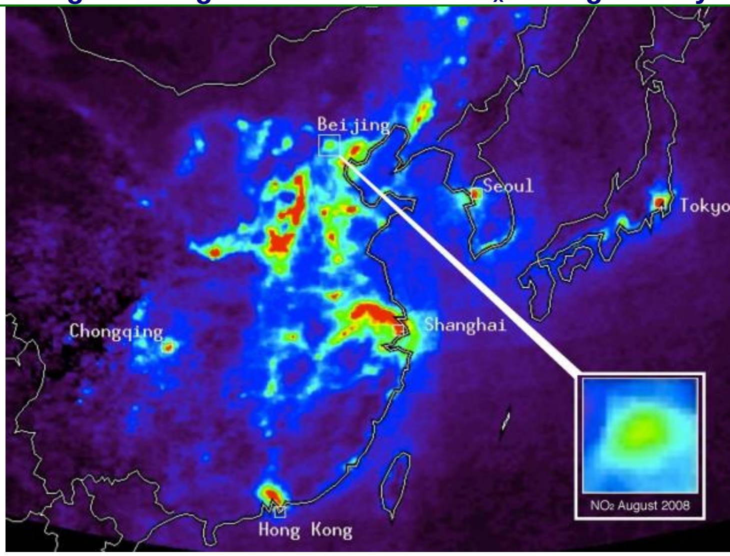
[5] Science Daily, June 30th, 2008, "China's export trade impacts environment" @ http://www.sciencedaily.com/releases/2008/07/080729142524.htm

[6] A study (October, 2008) from Tianjin, China, concluded that the passenger cars, taxis, buses, trucks, and motorcycles account for 61%, 17%, 7%, 9%, and 5% of total vehicles on the road respectively. And of the total 38 million kilometers per day passenger cars, taxis, buses, and trucks, account for 64%, 18%, 11% and 8% respectively, demonstrating the growing demand for personal transport and the increasing strain on the transport infrastructure. http://belfercenter.ksg.harvard.edu/publication/18645/inuse_vehicle_emissions_in_china_tianjin_study.html

[7] Grist, February 17th, 2009, "Imperial Traffic Jam" @ http://www.grist.org/news/2009/02/17/beijingcars/index.html

dioxide (NO_x) -- a gas resulting from fossil fuel combustion (primarily in cars, trucks, and power plants) -- plunged nearly 50 percent. Likewise, levels of carbon monoxide (CO) and the particulates (PM) fell about 20 percent. This was evident from the satellite images during this period (**Figure 1**).

Figure 1: Averaged change in the levels of NO_x during the Olympic Games



Source: Science Daily @ http://www.sciencedaily.com/releases/2008/12/081216131016.htm

The impact of the traffic restrictions during the games is yet to be quantified, as it was only one of the measures that lead to blue skies during the Games. However, it is important to note that, after the authorities lifted the traffic restrictions, the levels of these pollutants (NO_x and CO) jumped back to the levels measured before the Games[8]. Officials recently decided to reinstitute a less stringent version of the driving restrictions, requiring most cars to stay off the road at least one day each week.

This review note aims at understanding the role of transport in air pollution in China and the urban centers; and to better understand, quantitatively and qualitatively, the relative contribution of the transport sector in the urban centers.

[8] Science Daily, "Olympic Pollution Controls In Beijing, China, Had Big Impact On Air Pollution Levels", December 19th, 2008, @ http://www.sciencedaily.com/releases/2008/12/081216131016.htm

A Brief Note on Air Pollution

The Ministry of Environmental Protection of China, publishes the "**Air Quality Index**" (AQI) for all the major urban centers[9]. The AQI is an "index" determined by calculating the degree of pollution in the city or at the monitoring point and includes five main pollutants - PM, ground-level ozone, sulfur dioxide (SO_2), CO and NO_x. Each of these pollutants have an air quality standard which is used to calculate the overall AQI for the city[10].

Figure 2: Photo dairy of air pollution in Beijing, China

Clear Day in Beijing
September 23rd, 2008, AQI = 12

Polluted Day in Beijing
February9th 2009, AQI = 309

Source: http://www.asiasociety.org/beijingair/#room-with-a-view

Ozone, which is a large component of the smog found in the cities like Los Angeles, London, Delhi, and Beijing, results from the interaction of sunlight and chemicals (NO_x and hydrocarbons) found in motor vehicle exhaust. Though this is not routinely measured as a criteria pollutant, it is a known contributor to visibility problem in the morning, adversely affects breathing patterns and causes eye irritations.

Among the five main pollutants, the PM is considered the most critical and the fine particulates with aerodynamic diameter 2.5 microns or less is considered more harmful to health. The PM pollution is a mix of primary and secondary sources.

The primary PM has a wide range of sources from direct fossil fuel combustion (coal, gasoline, and diesel) to indirect fugitive sources (wind erosion, dust storms, and resuspension on roads). Traditionally, coal has been (and is a) major source of the PM pollution from industries and power plants, but the growing vehicular activity is contributing significantly, directly due to the exhaust emissions and the resuspension of the road dust.

[9] Air Quality Index for Urban Centers in China @ http://english.mep.gov.cn/

[10] In numbers, AQI is represented between 0 to 500 with 0 representing good air and 500 representing hazardous air. For better understanding and presentation, the AQI is broken down into six categories, each color coded with the number scale. **Good** (green) is for 0 to 50 meaning satisfactory air quality; **Moderate** (yellow) is 51 to 100 meaning acceptable air quality; **Unhealthy** for Sensitive Groups (tan) is 101 to 150 meaning sensitive individuals with sensitive skin may be affected; **Unhealthy** (red) is 151 to 200 meaning everyone may experience problems; **Very unhealthy** (pink) is 210 to 300 is a health alert, where everyone may have health problems; and **Hazardous** (purple) is over 300 and may contribute to emergency health problems and will affect most people.

The secondary pollution is due to chemical transformation of the primary emissions. The secondary PM includes sulfates from SO_2 emissions, nitrates from NO_x emissions, and organic aerosols from hydrocarbon emissions[11]. Most of the sulfates, nitrates, and secondary organic aerosols form part of the fine PM.

It is important to note that the health impacts, observed or estimated, are due to a combination of the mix of pollutants such as ozone, hydrocarbons, acidity in the air due to sulfur and nitrogen compounds, carbon monoxide, etc., and not due to the PM pollution alone. However, the PM forms the major contributor and hence the pressure to understand its sources better.

Quantifying the Contribution of Transport to Air Pollution in China

Along the major roads, the contribution of the transport sector is the main culprit. However, the city as a whole, it is important that a holistic picture and understanding of the sources (including the domestic and industrial) is established before a decision is made on the contribution (source apportionment).

For example, during the 2008 Olympics, the city of Beijing, did not achieve the reductions in the air pollution levels by halving the on road vehicular fleet alone. This was achieved only in conjunction with closing down a number of small and large industrial sites in and around the city.

Now, the long range transport plays a critical role. The transport emissions are ground based and tend to increase the local concentrations significantly. However, the industrial sources also contribute to farther distances. For pollutants like SO_2, the transport quotient is higher than the coarse PM and this was also evident in Beijing during the games. A series of measures, based on the modeling studies, resulted in shutting down industries in the neighboring cities, to achieve the necessary air pollution reductions.

On one side, the visibility of the growing transport sector creates an atmospheric cloud that multiples its contribution, while the industries contribute significantly in packets of puff and contribute to farther distances.

Since the people spend more time on the roads, because of traveling or due to sitting in a congestion zone, people tend to experience the most of the air pollution along the roads and thus conclude that the contribution of transport as the main culprit. However, quantifying the contribution of the transport sector is a challenge, not only for the researchers (studying the satellite evidence earlier), but also the policy makers to propose effective measures encompassing multiple sectors.

[11] The path and the quantity of chemical transformationation depend not only on the strength of the pollutant emissions, but also on their mix. In an atmospheric chemical mechanism, the number of interlinkages can run as long as 300 equations (among the known studies).

The methodologies utilized to quantify the contribution of the transport sector to air pollution in China are

<u>Methodology 01</u>: Emissions inventory Using Activity Data
Once an emissions inventory is established, through series of surveys, data collection, and emission factors, the contribution of all modes is established.

<u>Methodology 02</u>: Source Apportionment Using Ambient Data
This methodology applies to the PM pollution only. The ambient PM samples at various hot spots in the city are analyzed for the chemical composition, which are then regressed through series of source profiles, to arrive at the possible contribution of the known sources.

It is IMPORTANT to understand that the two methods are different and the numbers are indicative only.

1. The emissions are not same as ambient concentrations.
2. The contributions estimated from emissions NEED NOT be the same as the contributions estimated via the ambient measurements.
3. The emissions inventory is usually for the whole of the city or the area of interest, while the later method tend to represent the features around the measurement area.

None the less, both the top-down (ambient) and bottom-up (emissions) methods are very important (and essential) to understand the strength of the sources and their potential to control.

Transport Sector to Air Emissions

Significant efforts have been made during recent years to improve the quality of emission data for important air pollutants such as SO_2, NO_x, CO, VOC's, and particulates[12]. New emission inventories for Asia were developed in support of the TRACE-P, ACE-Asia, and INTEX-B field experiments in the Asia-Pacific region, using the energy consumption data (CGRER[13] and Dr. David Streets, personal communication).

For integrated support, emissions inventory includes gaseous and particulate pollutants, compiled by region, by fuels and by economic sectors; including natural emission sources such as volcanoes and forest fires. Different methodologies were applied in estimating emissions from anthropogenic and natural sources. **Table 1** presents country level emissions for each of the gaseous and particulate species for China for year 2006.

[12] Wang et al., 2005, "Emissions inventory for Eastern China in 2000", Atmospheric Environment @ http://dx.doi.org/10.1016/j.atmosenv.2005.06.051
Wang et al., 2006, "Impacts of air pollution in China on public health", Atmospheric Environment @ http://dx.doi.org/10.1016/j.atmosenv.2005.10.066
[13] Center for Global and Regional Environmental Research, USA

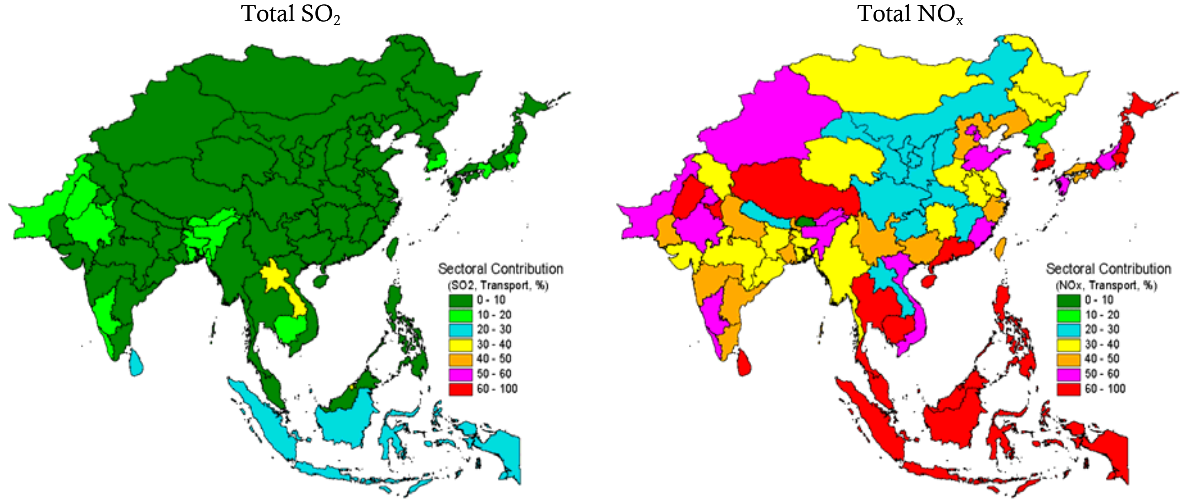
Table 1: Estimated emissions inventory for China for year 2006, ktons/year[14]

Pollutant	Power	Industry	Residential	Transport	Total
SO_2	18,333	9,725	2,837	123	**31,019**
NO_x	9,796	5,371	1,165	5,096	**21,428**
CO	2,361	74,935	55,883	33,708	**166,888**
VOC	960	8,055	7,600	6,629	**23,246**
PM_{10}	2,475	10,436	4,883	427	**18,223**
$PM_{2.5}$	1,473	6,923	4,461	398	**13,265**
BC	35	575	1,002	198	**1,811**
OC	5.6	505	2,605	101	**3,217**

Figure 3 presents contribution of transport sector to total anthropogenic emissions of SO_2 and NO_x annual emissions for year 2000. This is presented for year 2000 to provide an indicative analysis by province in China. **Table 2** presents percentage contributions by sector for year 2006.

Figure 3: Contribution of transport sector emissions by province in 2000

Total SO_2 Total NO_x



Source: Author

For SO_2, ~60% of total emissions originate from coal combustion, mainly from the power generation sector. In general, power and industry dominate the SO_2 emissions. The transportation sector contributes very little to SO_2 emissions in China.

Note that the contributions presented in **Figure 3** are average estimates based on provincial and national level activity data and when the same at a city level tend to differ, where the diesel consumption in the bus and truck industry accounts for a significant portion.

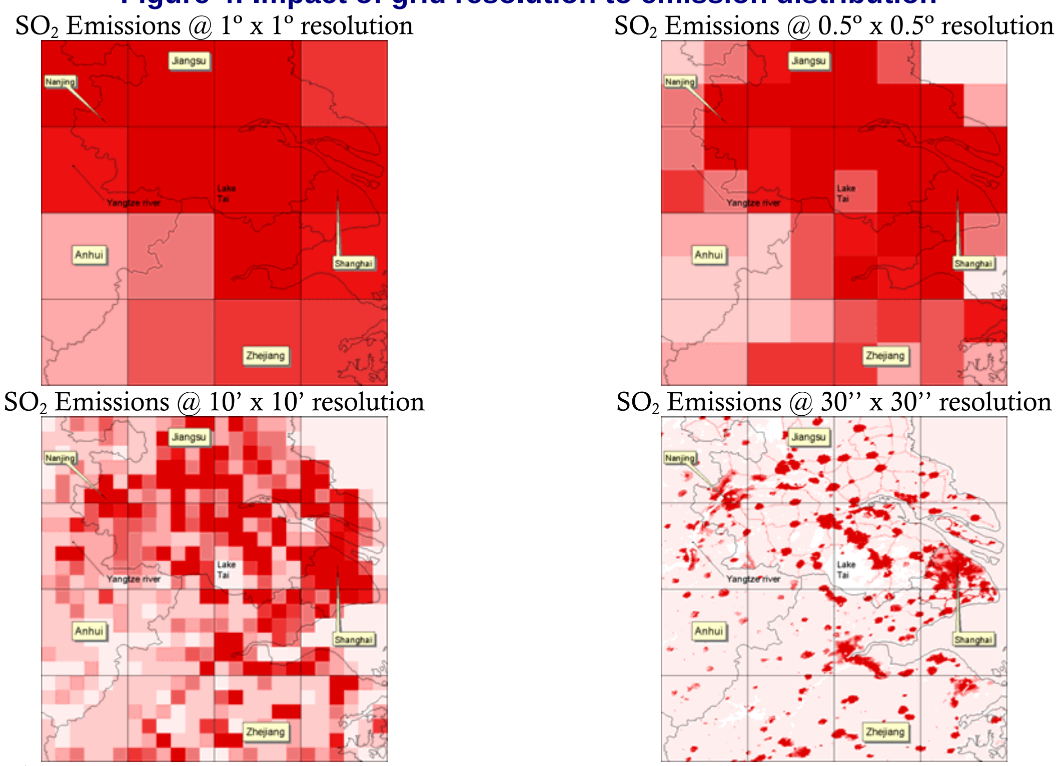
[14] This emission inventory was prepared by Qiang Zhang and David G. Streets, Decision and Information Sciences Division, Argonne National Laboratory, for the INTEX-B project of the National Aeronautics and Space Administration (NASA); in collaboration with He Kebin, Chen Dan, and Lei Yu of Tsinghua University in Beijing.

Table 2: Percentage contributions by sector (at national level)

Pollutant	Power	Industry	Residential	Transport	Total
SO_2	59%	31%	9%	0%	**100%**
NO_x	46%	25%	5%	24%	**100%**
CO	1%	45%	33%	20%	**100%**
VOC	4%	35%	33%	29%	**100%**
PM_{10}	14%	57%	27%	2%	**100%**
$PM_{2.5}$	11%	52%	34%	3%	**100%**
BC	2%	32%	55%	11%	**100%**
OC	0%	16%	81%	3%	**100%**

Unlike SO_2, the transport sector dominants the NO_x, CO, and VOC emissions, also responsible for the secondary pollutants such as ozone. In **Figure 3**, the percentage contribution of transport along the coastal provinces is high, mainly due to the concentration of the megacities, such as Beijing, Shanghai[15], and Hong Kong[16 17], which are experiencing increasing levels of air pollution, related to vehicular activity.

Figure 4: Impact of grid resolution to emission distribution



Source: Author

[15] BBC, "Can Shanghai turn green and grow?", May 27th, 2007, http://news.bbc.co.uk/2/hi/business/6683103.stm
[16] AFP, "Health concerns as Hong Kong pollution levels rise", January 22nd, 2009;
AFP, "Hong Kong air pollution worst since records began", January 2th, 2009
[17] Civic Exchange, "Hong Kong's Silent Epidemic - Public Opinion Survey on Air Pollution, Environment and Public Health 2008", January 2009, http://www.civic-exchange.org/eng/publication_ec.aspx

The black carbon (BC) emissions, a direct indicator of the diesel exhaust, are estimated at ~11% from the transport sector.

While discussing the percentage contribution of the sectors, it is important to note the geographical placement of these sectors. For example, the BC emissions are dominated by the domestic sector, mainly due to the use of biomass for cooking and heating, which is predominantly in the rural areas of China. Thus, while at the national level, the percentage contribution of transport sector may seem only ~11%, but at the city level, this will be higher due to diesel consumption, where the domestic sector (biomass burning) fares less. **Figure 4** illustrates the importance of the scale, while analyzing the emission inventories at coarser and finer scales around Shanghai (proxy to population).

According to Cai, et al., 2007, in 2005, the Beijing–Tianjin–Hebei region, the Yangtze River Delta, and the Pearl River Delta covering only 2.3%, 2.2%, and 1.9%, of national area respectively, generated about 10%, 19%, and 12%, respectively, of the national total transport emissions inventory.

Cai, et al., 2007, estimated the vehicular emissions inventory in China for the period of 1980 to 2005, using the statistics from the national bureaus and average national survey data for the activity levels. **Figure 5** presents a comparison of the gridded PM_{10} and NO_x emissions for years 1995 and 2005, highlighting the urban hotspots and the importance of the transport sector in the cities. Also presented in this study is the spatial analysis by regions, concluding that ~75% of the national total transport emissions are concentrated in developed regions of China's southeastern, northern and central areas covering only ~35% of China's territory, while the remaining emissions were distributed over the southwestern, northwestern and northeastern regions covering ~65% of the territory[18]. **Table 3** presents a summary of the transport emissions inventory estimated by Cai, et al., 2007, for years 1980 to 2005.

Table 3: Estimated transport emissions inventory for China, ktons/year

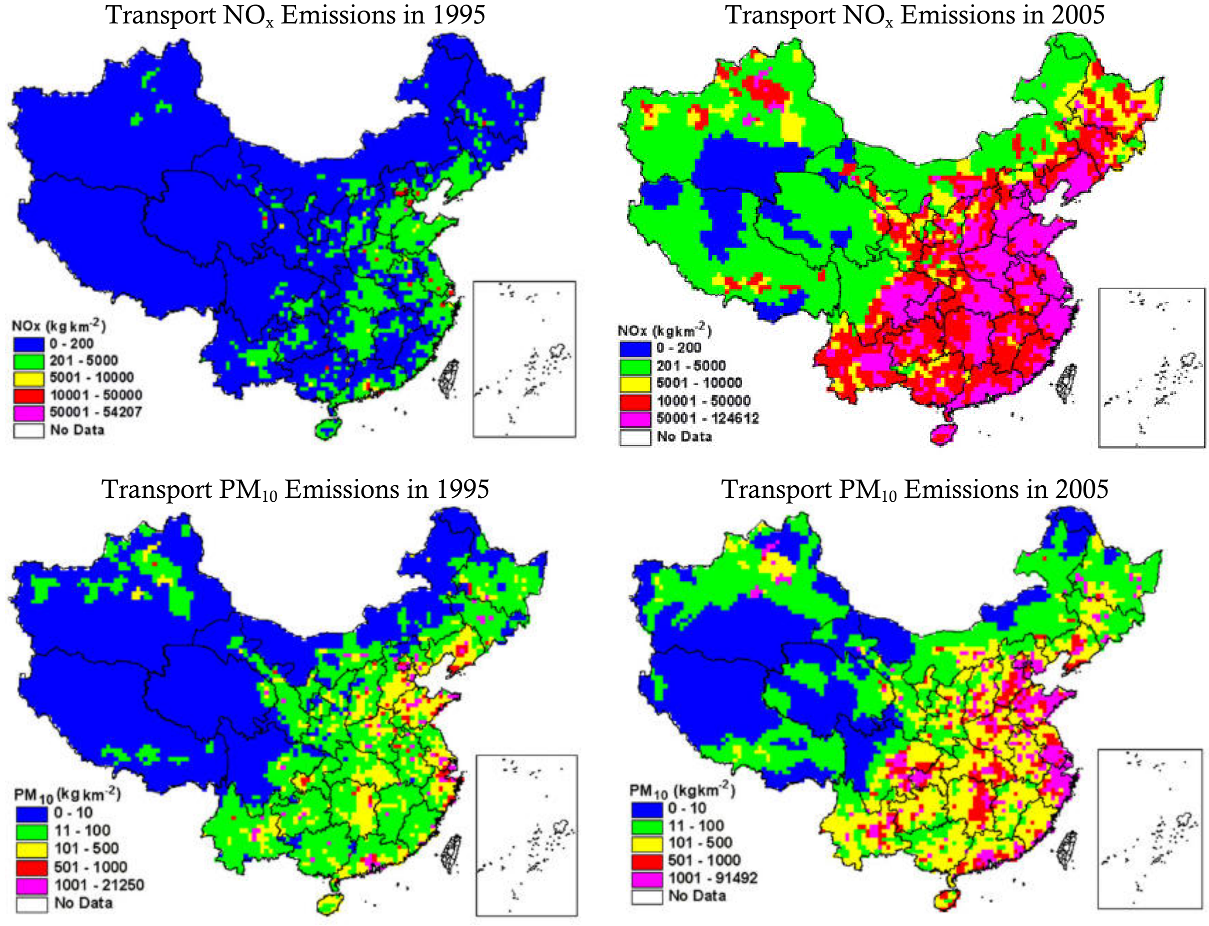
Year	CH_4	CO	CO_2	NMVOC	NO_x	PM_{10}	SO_2
1980	5	1,066	19,893	169	174	26	16
1995	128	15,122	234,663	2,326	2,091	361	198
2005	377	36,197	674,629	5,911	4,539	938	484

In 2005, the five provinces producing most vehicular emissions were Guangdong, Shandong, Jiangsu, Zhejiang, and Hebei, which cover ~7.4% of China's territory, and were responsible for ~40-45% of the national transport emissions for all the pollutants listed in **Table 2**.

The PM_{10} inventory by Cai, et al., amounts to ~938 ktons in 2005, which is comparable to the PM_{10} inventory by Streets, et al., (**Table 1**) at ~1,124 ktons in 2006, indicating an increase of ~20% in the vehicular activity. The methodology employed by the two groups may be different, but the analysis provides an indicator for comparing the growth and the importance of the transport sector in the country, by the provinces, and in the cities.

[18] For details on the GIS based spatial distribution methodology refer the article @ http://dx.doi.org/10.1016/j.atmosenv.2007.08.019

Figure 5: Comparison of gridded annual transport emissions



Source: Cai, et al., « Estimation of vehicular emission inventories in China from 1980 to 2005 »Atmospheric Environment, 2007 @ http://dx.doi.org/10.1016/j.atmosenv.2007.08.019

The emissions inventory is based on the anthropogenic activity in the transport sector. In the urban centers, an important source which is not a direct product of fuel combustion is the road dust. The fugitive dust from the paved and unpaved roads gets resuspended due to the constant vehicular movement. The cities like Shanghai and Beijing, with their increasing traffic, are experiencing a higher quotient of fugitive dust in the ambient air. This problem is severe in the spring time (dry season), due to storms settling more dust along the roads and on the buildings[19].

Estimating the fugitive dust is a challenging exercise, compared to the anthropogenic emissions inventory. This is mainly due to its dependence on the level of vehicular activity which varies from corridor to corridor and day to day, types of vehicles on the road since the weight and speed dictate the possible resuspension, the level of silt loading which varies among roads and seasons, and the meteorological conditions which control the resuspension levels. Given the uncertainty in the estimation methodology of this source, this

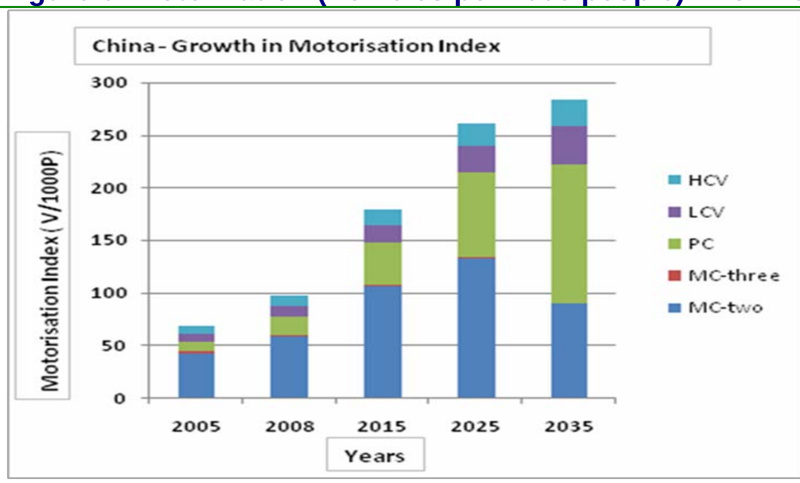
[19] BBC, dust storms hit Northern China, February 20th, 2009, http://news.bbc.co.uk/2/hi/7901227.stm

cannot be listed in the emission inventory. However, during the air pollution modeling and analysis procedures, this source cannot be (and is not) neglected, and calculated as an online source based on the local meteorological and terrain conditions.

Urban Air Pollution Sourced to the Transport Sector

The motorization in the urban centers, where the impacts are felt the most, is rising and is expected to at least quadruple in the next 30 years (**Figure 6**). Since health impacts are key to an effective urban planning, more than the emissions, their contribution to the ambient levels plays a vital role. For the transport sector, because the source is ground based, their impacts are felt more at the local level and via the secondary pollutants like smog and haze, at the regional level.

Figure 6: Motorization (Vehicles per 1000 people) in China



Source: Draft ADB, CAI-Asia, 2008 ;
HCV = heavy commercial vehicles ; LCV = light commercial vehicles ; PC = passenger cars ; MC = motorcycles

Once emitted, the pollutants are well mixed in the atmosphere and advected to long distances, depending on the local meteorology, making it harder to differentiate between the sources. The methodology, briefly discussed earlier, estimates the contribution based on the ambient measurements and provides a science based source apportionment [20]. A comprehensive bottom-up approach (via emissions) and a better mapping of the pollution sources can compensate for some of the differences.

This methodology has its disadvantages, such as not being able to differentiate between the diesel consumption in the generators vs. the vehicles, soil dust vs. road dust, and coal combustion in the domestic vs. industries. However, in the regulatory world, the **top-down approach is more acceptable**, primarily due to the involvement of direct pollution measurements at hot spots, analysis of the samples in the lab, and determining (statistically) the contribution of various sources to the pollution at that particular spot.

[20] For details, SIM-16-2009, “Urban Particulate Pollution Source Apportionment” @ http://urbanemissions.info/simair/simseries.html

Table 4: Summary of recent source apportionment studies in the Chinese Cities

Source & Details	*Percentage Transport Contribution*
Liu, et al., 2008, analyzed the ambient VOC concentrations in Guangzhou, for samples measured in October 2004. *Atmospheric Environment, 42 (2008) 6261–6274*	Gasoline and Diesel exhaust accounted for ~50% of the measured sample.
An, et al., 2007, conducted a modeling analysis for Beijing and the neighboring provinces, using local and national inventories. *Atmospheric Chemistry and Physics, 7 (2007) 3103–3114*	The study accounts ~25% and ~35% of the PM_{10} and $PM_{2.5}$ to non-Beijing sources, and the rest to have a strong local transport signature.
Feng et al., 2007, conducted a PM source apportionment study for the city of Jiaozuo (Henan), for sample measured in the summer months. *Journal of AWMA, 57(2007) 561-575*	A spatial average of ~12% is associated with the vehicle exhaust and ~46% to the re-entrained road dust in PM_{10}.
Song et al., 2006, conducted PM2.5 source apportionment study in Beijing, using a series of receptor models. *Science of the Total Environment, 372 (2006) 278–286*	The vehicle exhaust and road dust combined for ~20% of the sample. Secondary sulfate and nitrate were not included in the above estimate, which are also a product of the vehicle exhaust.
Huang, et al., 2009, conducted source analysis of samples from high pollution days in Hong Kong, for the period of 1998-2005. *Atmospheric Environment, 43 (2009) 1196–1203*	Due to proximity to the urban centers in the Pearl River Delta, the coal combustion, vehicular exhaust, and residue oil combustion, showed the highest contributions associated with northwesterly wind (~50%). With the transboundary pollution included, the vehicle exhaust accounted for ~12%.
Tao, et al., 2009, studied the impact of $PM_{2.5}$ composition on visibility in Guangzhou, in Spring 2007. *Particuology, 7 (2009) 68–75*	Study concludes that the sulfates in $PM_{2.5}$ (~40%) from diesel and coal, are the limiting factor affecting the visibility levels in Guangzhou.
Shi, et al., 2008, investigated the impact of urbanization on the frequency of fog formation in the Anhui Province. *Atmospheric Environment, 42 (2008) 8484–8492*	The aerosol concentrations are negatively correlated with visibility related to fog, a direct indicator of industrial and vehicular activity. No specifics are provided on vehicular contribution.
Bi, et al., 2007, conducted source apportionment analysis for six cities in Northern China Urumqi, Yinchuan, Taiyuan, Anyang, Tianjin and Jinan. *Atmospheric Environment, 41 (2007) 903–912*	In all the cities, the road dust is estimated to be the largest contributor (> 40%), a direct result of increased vehicular activity (>15%). **Table 5** summaries the results for the six cities and three seasons.

The **Table 4** presents a summary of the transport sector contributions based on recent source apportionment studies across the Chinese cities and **Table 5** presents a summary from a similar study conducted in six cities in Northern China for three seasons (with a mean PM_{10} concentrations of >100 μg/m^3).

Table 5: Estimated vehicle exhaust (VE) and road dust (RD) contributions from six cities in Northern China

Year	Winter		Spring		Summer & Fall	
	VE	**RD**	**VE**	**RD**	**VE**	**RD**
Urumqi	10	11	7	48	15	38
Yinchuan	8	49	5	67	7	52
Taiyuan	12	30	12	35	18	23
Anyang	7	36	5	41	16	33
Tianjin	11	33	12	39	18	28
Jinan	4	30	7	54	17	40
Average	**9**	**32**	**8**	**47**	**15**	**36**

In China, besides the vehicle exhaust (**average 10-20 percent** of the measured samples), the road dust also dominates. While the dust is caused by sporadic or widespread activities due to wind or vehicle travel, it can often be difficult to quantify such emissions. However, the source apportionment provides an approximate estimate because it is difficult to track the number and types of vehicles on roads, conditions of the roads, and entrainment factors which are partly dependant on the local meteorological conditions. In China, the sporadic dust storms, especially during the spring time and the dry summer seasons, are known contributors of the resuspension of dust, also observed in the six cities in **Table 5**.

Given the mix of air pollution sources in the Chinese cities, the role of transportation, though crucial for policy makers, is difficult to quantify. Among the anthropogenic sources, transport sector comes second only to the coal consumption in the industrial sector. At the same time, the long range transport of the industrial emissions tend to diminish their role in the ambient air quality (in the vicinity of the source), while **the transport sector, along with its indirect effect on the dust generation, plays a bigger role in exposure analysis**.

In Conclusion

PM_{10} AMBIENT CONCENTRATION
PM_{10} is the criteria air quality indicator for most of the urban centers and their concentration is a result of both primary (direct emissions) and secondary pollution (chemical transformation.

The industrial coal combustion still dominates the measured PM_{10} concentrations with a direct transport share of 10~15 percent. The fugitive road dust accounts for ~30 percent (see Annex)

$PM_{2.5}$ IS NOT MEASURED
According to the health studies, the $PM_{2.5}$ is the most harmful. However, the routine $PM_{2.5}$ measurements are limited in the urban centers. The significant portion of the $PM_{2.5}$ is secondary, which is dependant of the SO_2, NO_x, and VOC emissions and meteorology.

The share in $PM_{2.5}$ is uncertain, depending on the mix of emissions and sources. The transport shares vary disproportionately between cities, with a share ~30 percent from direct emissions.

NO ROADSIDE MONITORS
The PM concentrations along the road side will be high due to ground level source of the vehicles and road dust. The monitors placed on buildings (common practice) understate the impact of average PM levels in the city and related human health exposure levels.

A lack of roadside monitoring not only underestimate the city averages linked to exposure levels, but also underestimate the share of the transport sector to measured PM concentrations.

HUMAN EXPOSURE IMPACT
The diesel soot and carcinogenic hydrocarbons are more concentrated along the roadside, increasing the acute exposure times due to higher driving and congestion times, and hence increasing the chronic respiratory illnesses and other health risks.

The transport sector, though contributing ~10-15% of the measured PM_{10} (average), their share to human health risks is higher, accounting for ~7 percent of Beijing's GDP in 2005.

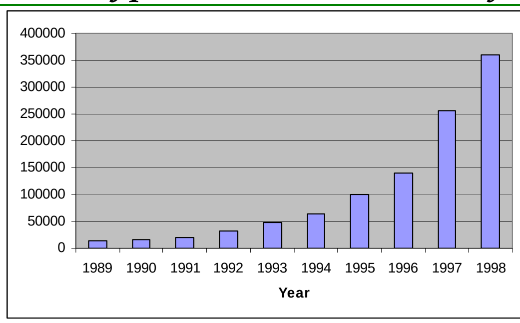
CONCLUSION: In the cities, the transport sector is a growing contributor to the ground level air pollution, resulting in higher acute exposures. While the coal based interventions might be effective in reducing the air pollution on a large scale, the measures in the transport sector would be helpful in reducing the exposure times more significantly.

China is showing a shift in its policy towards more environmentally friendly management with a number of regulations already in place, some of which were successfully piloted in Beijing during the 2008 Olympic Games. The existing policies in the transport (and industrial) sector suggest that they are capable of reducing the emissions linked to PM pollution. The challenge is in the scale-up of these strategies and to improve the quality of the monitoring network to include $PM_{2.5}$ at the hotspots.

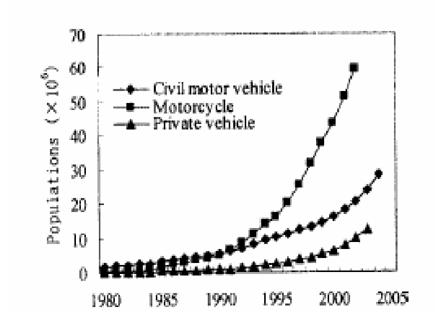
Annex: Vehicle Mix in China – Diesel Contribution is Increasing

In 2006, the number of total vehicles was 1.26 million in Beijing. In 2009, according to the Beijing Traffic Management Bureau, the city registered nearly 1,500 motor vehicles per day, compared to 1,350 per day in 2008, leading to serious traffic pressures and safety risks[21]. Compared to 0.82 million in 2000, the 3.5 million currently registered in 2009 is a four fold increase.

Number of private buses and cars in Beijing



Vehicle volume in China



Source: China Statistical Yearbook and Tian et al., 2007 [22]

The increase over the last 15 years is most visible in the number of private cars and buses and in the number of state-wide vehicle volume.

However, the data on in-use vehicle population is not widely available and the uncertainty of these numbers is high. It is estimated that the total vehicle population in China is ~90 million[23] in 2005 and is predicted to increase at double-digit rate for the coming decades. The largest increase is expected among the personal vehicles (cars and motorcycles). Among the fuels, the share of diesel based passenger cars and heavy duty vehicles is increasing[24].

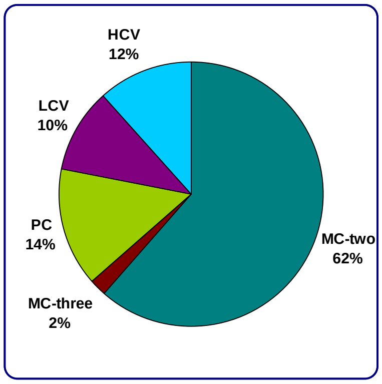
[21] Grist, "Imperial Traffic Jam", February 17th, 2009, http://www.grist.org/news/2009/02/17/beijingcars/index.html

[22] Tian, H. et al. (2007). Recent Trends of Energy Consumption and Air Pollution in China. Journal of Energy Engineering 133(1), 4-12.

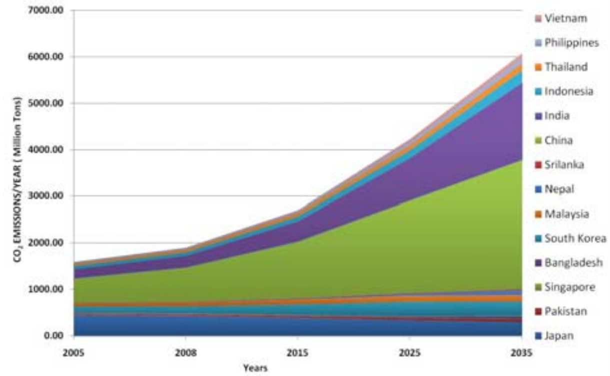
[23] National Bureau of Statistics cited in http://www.autoproject.org.cn/APECC%20NEWS%202-2007.html#_Toc160601691

[24] International Herald Tribune, December 8th, 2007, "Trucks at Heart of China's Diesel Problems", @ http://www.iht.com/articles/2007/12/07/asia/china.php;
Science Daily, February 24th, 2009, "Invisible Emissions from China's Exports", @ http://www.sciencedaily.com/releases/2009/02/090224133507.htm

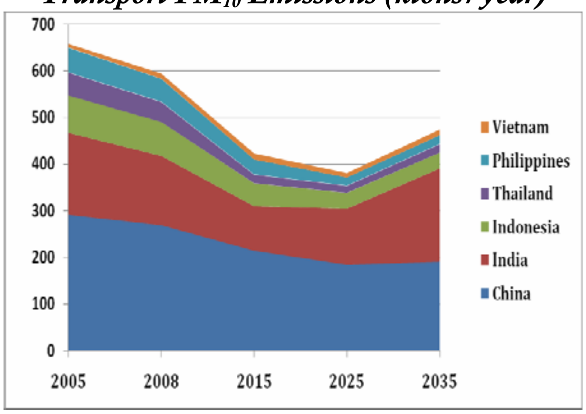
Vehicular Mix in 2005 (Total = 90 million)



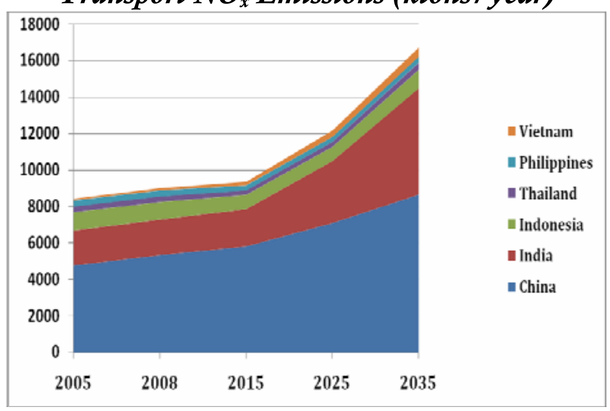
Transport CO_2 Emissions (million tons/year)



Transport PM_{10} Emissions (ktons/year)



Transport NO_x Emissions (ktons/year)



Source: Draft ADB, CAI-Asia, 2008

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