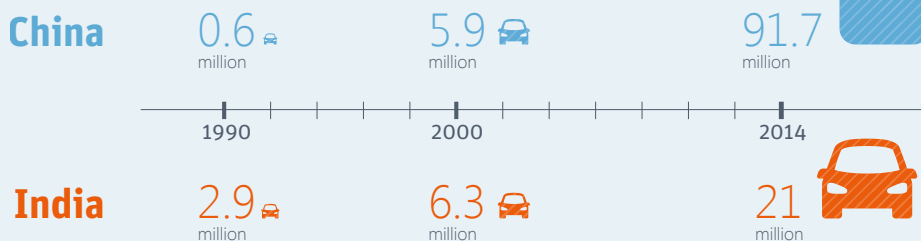


Low-Carbon Mobility for Mega Cities

What Different Policies Mean for Urban
Transport Emissions in China and India

The rise of the motor vehicle

Registered light-duty vehicles
in India and China (millions)



Source: IEA, 2015

The issue

Urban motorisation in China and India

China and India, the world's two most populous countries, have experienced rapid population growth, exponential economic development and accelerating urbanisation over the past few decades. These trends have gone hand in hand with significant increases in the number of motor vehicles on the streets.

Motor vehicle growth in both countries is heavily concentrated in urban areas, where 54% of China's population and 32% of India's currently live. The flexible and comfortable personal mobility which private motor vehicles provide can help to ensure the daily functioning of urban life. Yet the growth of individual, car-based transport also creates negative side effects on an increasing scale - from congestion and traffic fatalities via local air pollution to greenhouse gas emissions that have consequences far beyond the cities themselves by contributing to global climate change.

The level of carbon dioxide (CO₂) emissions from the transport sector in China is currently about 7% of its total CO₂ emissions. Of this share, 86% comes from road transport. CO₂ emissions from the transport sector increased by 160% from 1994 to 2007 in China and are expected to continue to increase due to the growing number of vehicles. In 2010, China surpassed the United States as the largest automobile market in the world. More than 20 million vehicles were sold in China in 2014, taking

the total number of light-duty vehicles on Chinese streets to 92 million.

Despite its low ownership rate of 39 light-duty vehicles per 1 000 persons (compared to the United States' 680 vehicles per 1 000 persons) in 2010, China is already the world's largest CO₂ emitter and has recently become the top global importer of crude oil. With the transport sector over 90% dependent on oil due to the dominance of internal combustion engines, China's demand for oil will only increase as its transport sector grows, which it inevitably will. Increased CO₂ emissions will follow, unless a comprehensive range of policies and measures is implemented to alter the course of development.

In India, increasing household incomes, a growing urban population and surging vehicle sales are also leading to a more motorised society. India's urban population increased from 62 million in 1951 to 285 million in 2001, and as cities grow and new urban agglomerations develop, the demand for transport and total distance travelled by Indians will grow as well, with cars and motorised two-wheelers increasingly becoming the preferred mode choice. The number of passenger vehicles on India's roads grew from 16 million in 1990 to almost 40 million in 2000 and reached 131 million in 2014.

Most of these are motorised two-wheelers, with only 21 million (16%) light-duty vehicles in 2014.



India
71.4
persons/vehicle



China
25.6
persons/vehicle



USA
1.47
persons/vehicle

Potential to grow

Motorisation rates in India,
China and the United States

Registered light-duty vehicles in 2010

drives CO₂ emissions growth

Compared to China, India has a much smaller light-duty vehicle market, yet the transport sector is still a leading contributor to Indian cities' CO₂ emissions, mainly because motorised two-wheelers dominate the passenger vehicle market and are still the fastest-growing type of vehicle in India and with mostly two-stroke engines, they are heavy polluters. India's light-duty vehicle ownership is currently still at a relatively low rate of about 16 per 1 000 persons and about 100 per 1 000 persons when two and three-wheelers are included.

The motorisation of China and India is clearly just at the beginning. China's urban transport activity in passenger-kilometres is projected to grow by 159% in 2050, according to the *ITF Transport Outlook 2015*. This would lead to a 196% increase in CO₂ emissions. Transport activity will see an even higher growth rate in India, which will experience a 623% increase in personal mobility resulting in a 630% increase in CO₂ emissions.

Addressing the urban transport challenges in China and India is vital in the broader context of reducing global CO₂ emissions. For this, a thorough understanding of motorisation trends in China and India and of the policies and measures that can reduce energy use in transport, change mobility behaviour and, ultimately, limit CO₂ emissions from urban transport is necessary.

Major urban centres in China and India have vehicle ownership rates that are significantly higher than the national average. They will continue to drive their countries' energy use and CO₂ emissions. Reductions in CO₂ emissions will occur when transport demand is met through less carbon-intensive mobility options and when the total travel distance declines. Advanced vehicle technology and alternative fuels will also reduce CO₂ emissions. However, increases in vehicle numbers may cancel out the mitigating effect of better technology. Integrated land-use planning, strategic development of public transport, the targeted use of economic incentives and government regulations must therefore be considered in an urban mobility context. Such policies and measures directly influence transport demand and behaviour and will complement efforts to improve vehicle efficiency and fuel intensity.

To provide a better basis for developing appropriate policy tools, this paper presents results from a series of policy scenarios that examine how different urban transport policies will affect motorisation rates in ten major Chinese and Indian cities through 2030 and 2050. The outcomes were derived using data from specific cities, but the insights gained can also benefit other urban areas within and beyond China and India that face similar challenges in developing efficient and sustainable urban transport.

The approach

Modelling urban transport policy options for China and India

For five Chinese and five Indian cities, the International Transport Forum explored how urban mobility would develop under different policy scenarios, notably how effective different types of policies and measures are in reducing transport CO₂ emissions.

The cities studied are Beijing, Shanghai, Guangzhou, Tianjin, and Xi'an in China and Mumbai, Delhi, Bangalore, Ahmedabad, and Jaipur in India. All of the selected cities are characterised by rapid population growth, increasing urban density, rapid economic development, and massive motorisation. On the other hand, they also represent a range of different characteristics in terms of demographics, per-capita GDP, land-use characteristics, existing policies, and available transport services. Transport modes included in this study are light-duty vehicles, two-wheelers, three-wheelers (for Indian cities only), bus, Bus Rapid Transit (BRT) and passenger rail.

A set of three scenarios was developed for each city to 2030 and 2050. Each scenario reflects a set of policies and measures that include land-use planning, quality of public transport development, economic instruments such as tax incentives and government regulations. The impact of such policies and measures on travel demand is evaluated using demand elasticity. Elasticity is often used as a standard measurement to compare demand responses to changes in price, public transport service, or other variables. Estimates for transport CO₂ emissions associated with the different policy scenarios are also calculated, using key components that include passenger distance travelled, fuel efficiency, fuel type and the carbon intensity of fuel.

The first case examined is a **Status Quo** (STO) scenario. In this scenario, no new public transport developments, economic instruments or government regulations are implemented in the selected cities beyond those that have already been introduced. For example, any existing restrictions on vehicle registration in Chinese cities will continue but will not be tightened or expanded to other cities that currently do not have such policies.

Based on an analysis of historical motorisation and per-capita GDP rates, motor vehicle ownership and use in China and India are assumed to follow trends seen in other developed Asian countries, such as

Korea. It is also assumed that they continue to increase in those cities with no current restrictions on vehicle ownership, namely all five Indian cities and Xi'an in China. Due to an overall decline in motorised two-wheeler ownership in China in recent years and bans or restrictions on motorcycle use in many cities - including Beijing, Shanghai and Guangzhou - it is unlikely that two-wheelers will grow significantly over the next few decades in the five Chinese cities studied.

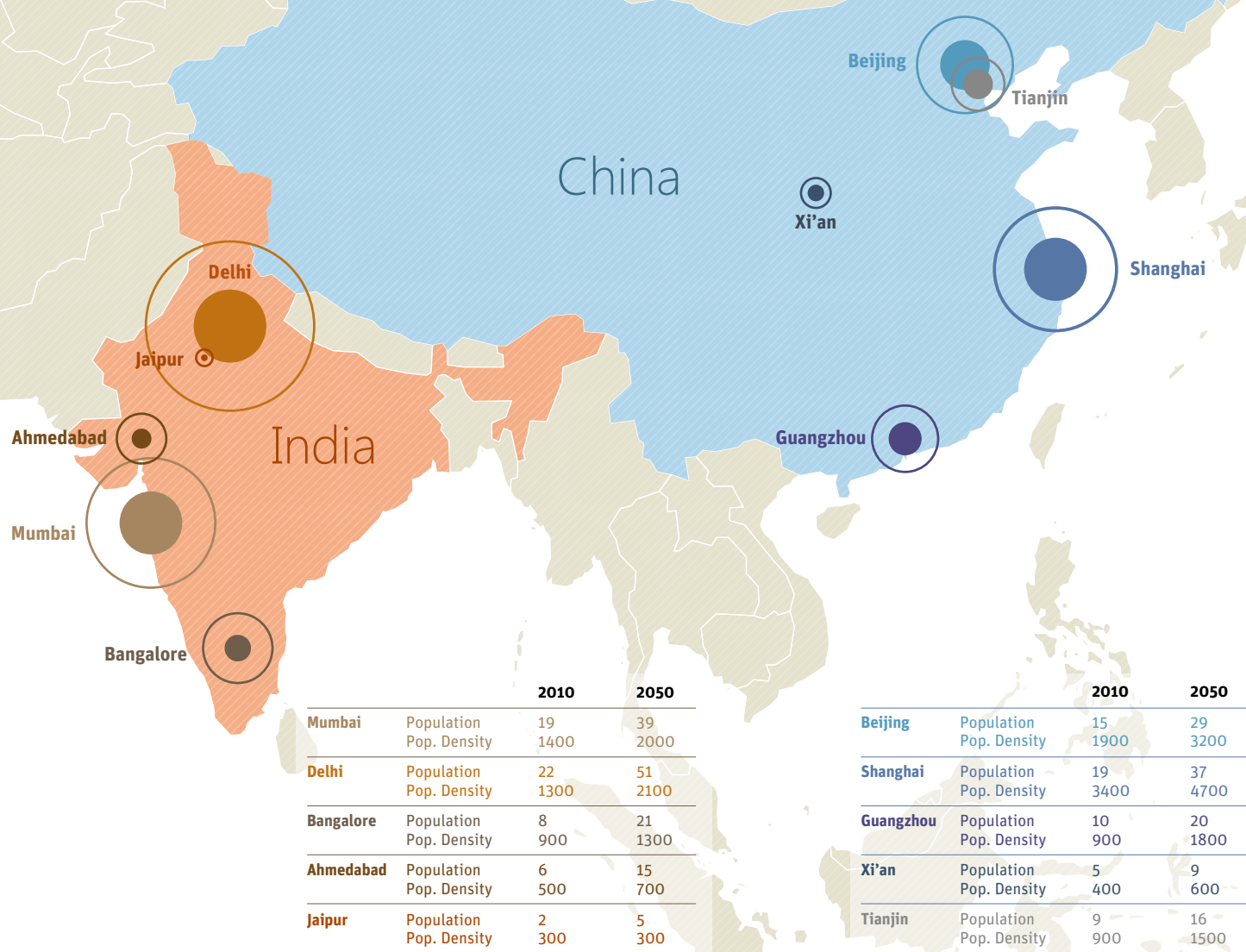
In India, however, the use and ownership of two-wheelers in urban centres will continue to grow until the cities reach a certain average per-capita GDP. In most other Asian cities with high two-wheeler ownership rates of 300 to 600 two-wheelers per 1 000 persons, this threshold has been around USD 10 000. The average per-capita GDP in 2010 was less than USD 3 000 for the Indian cities included in this study and their average two-wheeler ownership rate was 140 per 1 000 persons, which shows a great potential for future growth.

Population density in all cities is expected to increase, but due to urban sprawl, this increase will not be substantial, so the total distance travelled by private vehicles is still assumed to increase over time. In the STO scenario, there is also no additional effort to improve public transport services. Advanced vehicle technology and alternative vehicle fuel use are assumed to penetrate the market at a relatively low rate and there will be no significant improvement in fuel efficiency standards.

In the second scenario, labelled **Robust Governance** (ROG), city governments play a more active role in regulating vehicle use and ownership. The scenario assumes that all Chinese cities will adopt vehicle registration restrictions starting from 2016. Pricing policies such as fuel taxes, road tolls and parking pricing will also be widely implemented in all Chinese and Indian cities, leading to a general increase of 64% in the cost of driving in 2030 and 99% in 2050. In addition, there will be an increase in bus and rail subsidies, which will lower the cost of public transport to users by 30% in 2030 and 50% in 2050.

Fuel efficiency standards and the market penetration of advanced vehicles and alternative fuels in this scenario for all Chinese and Indian cities reflect

Population and population densities



UN World Population Prospects 2014. Population in millions, density in persons per square kilometre.

the assumptions made in the latest 2°C Scenario (2DS) developed by the International Energy Agency (IEA). In Chinese cities, it is assumed that gasoline vehicles will make up 20% of the market in 2050, while gasoline hybrid will have a 50% share, electric vehicles 20% and fuel cell vehicles 10%. Indian cities follow a similar trend, but with 10% compressed natural gas (CNG) and liquefied petroleum gas (LPG) vehicles, 10% less electric and 5% more fuel cell vehicles than Chinese cities. Gasoline vehicles will therefore only hold a 15% market share in Indian cities in 2050. Population density remains the same as in the STO scenario.

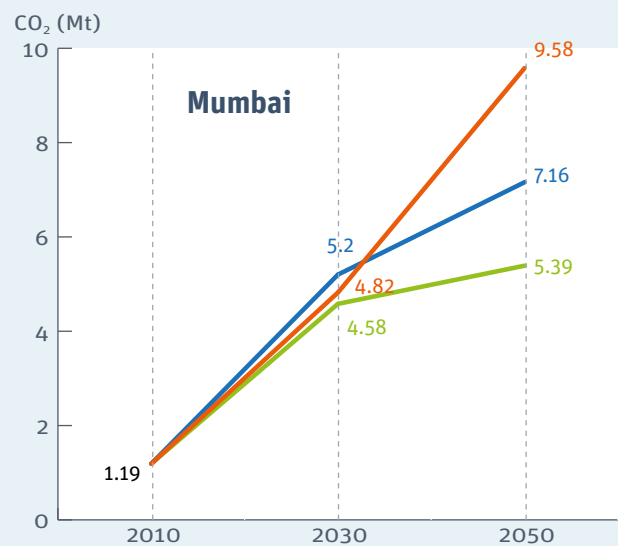
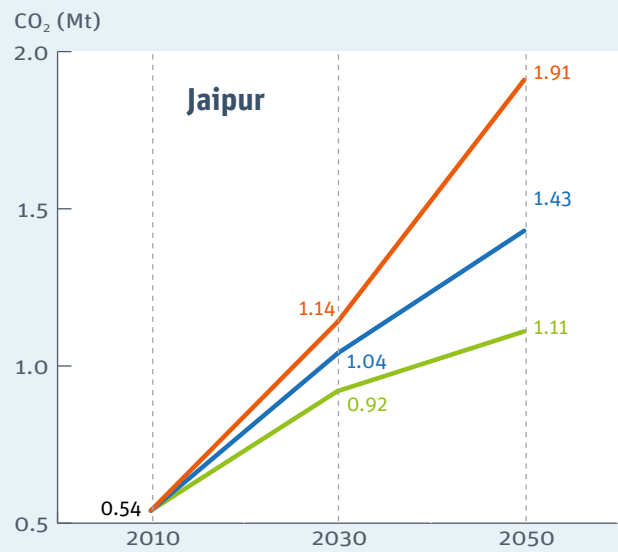
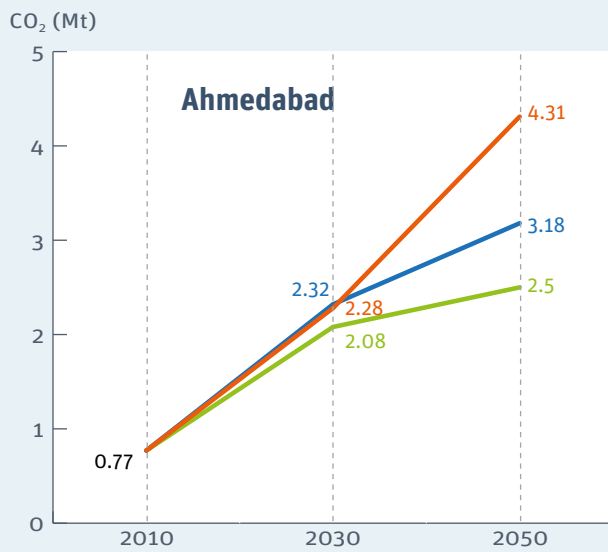
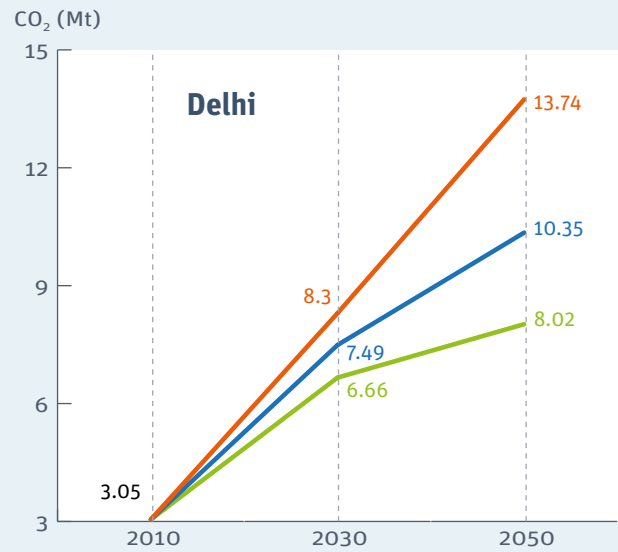
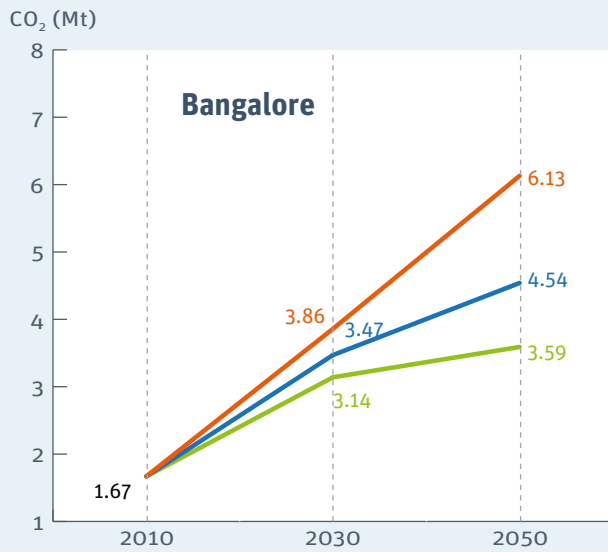
The **Integrated Land Use and Transport Planning (LUT)** scenario, the third case examined, assumes a strong prioritisation for sustainable urban transport development in Chinese and Indian cities. Economic instruments are thus implemented

jointly with urban transport planning measures that stimulate a reduction in total travel distance. Population density is assumed to be higher in this scenario, due to more mixed-use transit corridors that reduce distances and encourage the use of public transport. Public transport is assumed to be improved through the reduction of bus and rail travel time by 30% in 2030 and 60% by 2050 and BRT services are now available in all ten cities. Economic instruments and government regulations that favour public transport are applied, as are the stringent fuel efficiency standards. Market penetration rates of different vehicle and fuel types are the same as the ROG scenario.

The key difference between the LUT and ROG scenarios is improved public transport in the former (which leads to relatively shorter bus and rail travel times) and the availability of BRT systems in all cities.

Possible emissions pathways

Development of transport CO₂ emissions to 2050 under different scenarios in Indian cities



- Status Quo scenario
- Robust Governance scenario
- Integrated Planning scenario

The insights

Think long term, identify key constraints, act early

A number of insights for policy makers grappling with gridlock, air pollution and greenhouse gas emissions can be drawn based on the outcomes derived from each of the three scenarios.

In the Status Quo scenario, where authorities continue to follow current policies and transport development patterns, total passenger travel will increase by an average of 710% for the five Indian cities and 111% for the cities in China between 2010 and 2050. At 1 207%, Ahmedabad has the highest growth rate among Indian cities in this scenario. Of the Chinese cities, Xi'an would face the highest mobility growth rate with an increase of total passenger travel by 224%. Beijing, by contrast, would only see mobility grow by 30% in 2050. This is less than a tenth of Mumbai's growth rate of 334%, which is the lowest of all the Indian cities in the STO scenario.

One of the main reasons for the difference in passenger travel growth rates is the implementation of government regulations on vehicle ownership. In Xi'an, the only Chinese city studied that has no car ownership restriction in place today, the 2010 light-duty vehicle stock would increase by 784% in 2050. For Beijing and Shanghai, the increase would be 148% and 300% respectively, as vehicle restriction policies already exist. Among the Indian cities, where no restriction on vehicle use is currently in place, the number of light-duty vehicles could increase by more than 3 000% in Mumbai and by 1 383% in Jaipur over the next three-and-a-half decades.

Consequently, increases in CO₂ emissions from motor vehicles in Indian cities range from 112% in the best case (Jaipur) to 305% in the worst case (Mumbai) in 2030 and from 255% to 706% in 2050. From 2010 to 2030, CO₂ emissions in Chinese cities' will range from 7% (Beijing) to 85% (Xi'an). In 2050, the change will be between a 9% decrease and a 120% increase. Beijing is the only city where the emission estimate for 2050 is lower than its 2010 level.

These projections underline the importance of targeted regulations, for instance through auctions

or lotteries, to allocate a quota of annual vehicle registrations as a highly effective way to control vehicle numbers and emissions in urban areas.

Where cities complement vehicle ownership restrictions with specific economic incentives to reduce vehicle use itself (i.e. in the Robust Governance scenario), the impact on distance travelled and CO₂ emissions is even greater. The increases in fuel tax and road and parking pricing are policies in place under the ROG scenario and reduce light-duty vehicle travel by an average of 8% (2030) and 15% (2050) for both Chinese and Indian cities compared to the STO projections. CO₂ emissions will decrease in all Chinese cities, between 33% and 50% less in 2050 compared to the STO case, with Xi'an displaying the lowest percentage of reduction. Benchmarked against the 2010 baseline, Xi'an is the sole Chinese city of the five that will still see an overall increase of emissions compared to the 2010 baseline in the ROG scenario.

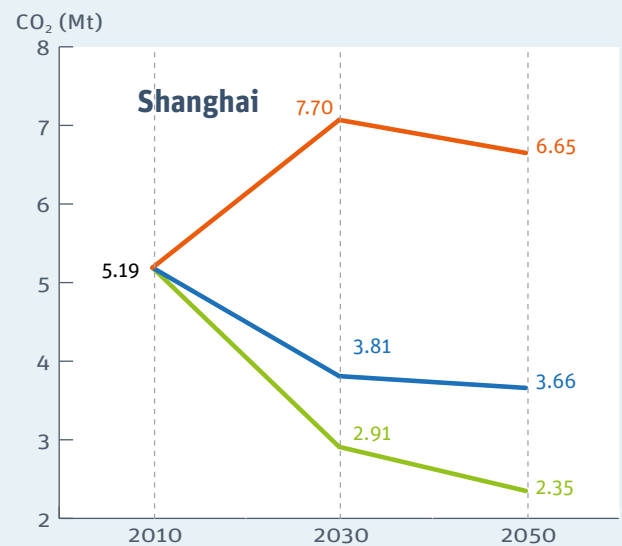
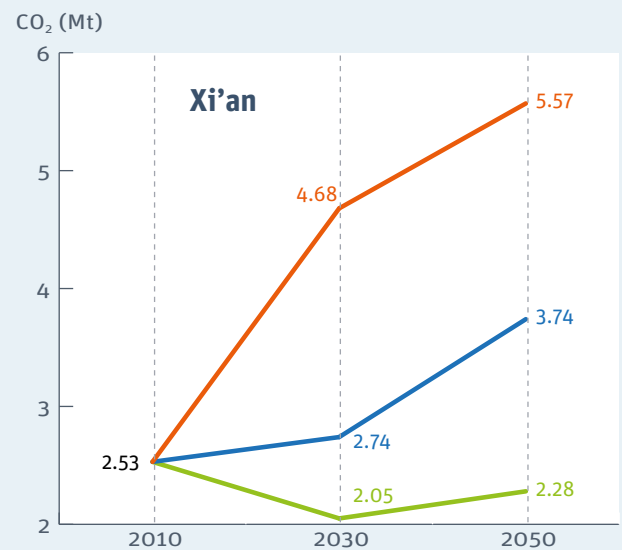
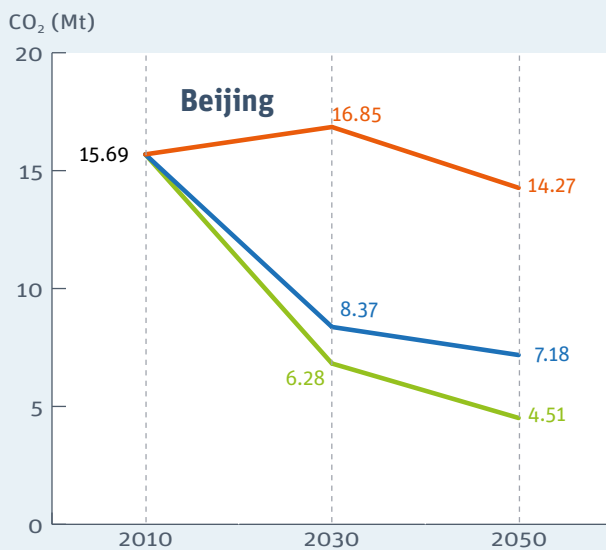
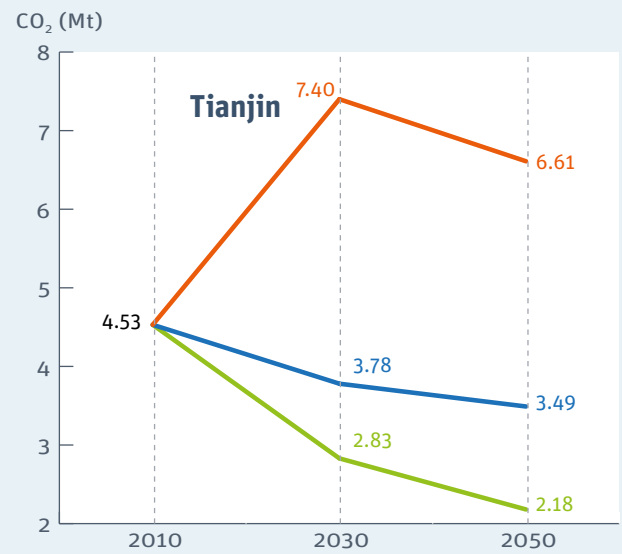
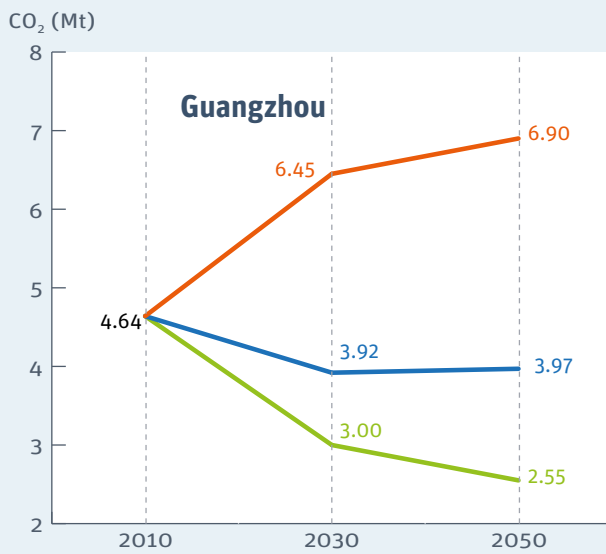
The five Indian cities did not behave uniformly under the ROG scenario. CO₂ emissions only decreased in Delhi, Bangalore and Jaipur by 2030, with the effect ranging from an 8% increase for Mumbai to a 10% reduction in Bangalore. A more consistent pattern emerges by 2050, when all five cities in India see emissions reduced by roughly a quarter compared to the STO scenario.

A reason for this alignment post 2030 is the application of higher price demand elasticities for fuel tax, parking and road pricing policies in the long term. Consumers have more time to adjust to changes in price than in the short run. Travel behaviour may take a longer time to change in some cities compared to others due to the existing mobility options available in different cities, which will influence travel preferences, constraints and alternatives. City authorities need to identify and address specific reasons that will delay behavioural changes that could be attained through economic policies targeted on transport.

The most powerful additional lever to make urban mobility less private-vehicle dependant and more sustainable are integrated policies for land use and

Possible emissions pathways

Development of transport CO₂ emissions to 2050 under different scenarios in Chinese cities



- Status Quo scenario
- Robust Governance scenario
- Integrated Planning scenario

transport planning. Under such policies, as included in the LUT scenario, the decrease in light-duty vehicle travel is significantly higher than under either the STO or ROG scenario. In 2050, light-duty vehicle travel is basically half of STO's estimate, or a 35% decrease compared to the ROG scenario. The additional impact on vehicle use is mainly due to the increased population density assumed in the LUT scenario.

Reduced private vehicle use translates directly into urban CO₂ emissions. The LUT scenario yields emission reductions that outstrip those achieved under ROG for all ten cities in both 2030 and 2050. Compared to the STO scenario, Chinese cities would see vehicle emissions drop between 59% and 68% by 2050, with Beijing achieving the highest CO₂ emission reduction. Among the Indian cities, Delhi would see the longest percentage reduction over the medium term (20% in 2030), while the impact on Ahmedabad (9%) and Mumbai (5%) would be small. Emissions are also lower than 2010 levels for all Chinese cities in this scenario, while Indian cities will experience the lowest growth in CO₂ emissions compared to the other two scenarios.

Over the longer term, the gap among Indian cities would narrow, with emissions reductions ranging between 41% and 44% compared to the STO. The gap of emission reduction levels between Chinese and Indian cities will also narrow over time. While in 2030, Beijing will achieve an emission reduction rate at three times that of Delhi's, their average difference in 2050 is only 30%.

The main factor in realising these significant reductions in CO₂ emissions across all cities is improved public transport services. The average public transport occupancy rate in the Chinese and Indian cities included in this study is currently at about 40%. This percentage should be further increased in order to develop a more sustainable transport system. Since the cost of public transport is relatively low in Chinese and Indian cities, the provision of further subsidies may not be most effective in encouraging higher bus or rail ridership. Other ways to increase the appeal of public transport include the improvement of its services by cutting average travel time and by providing a better overall user experience. This implies the development of faster travel modes with greater convenience through improved scheduling, better (real-time) user information and other forms of service improvement.

As a result of improved services, bus travel will increase by an average of 179% and rail travel by 73% in the LUT scenario compared to STO. In the ROG scenario, bus and rail travel reach a much lower level, being only 22% and 8% higher than

STO. A conclusion from this is that decreasing travel time and generally improving public transport services will be more effective in increasing modal shift from private vehicle travel than increasing subsidies in an attempt to encourage bus and rail travel through low ticket prices.

The scenario results show how important it is for cities facing rapid motorisation to choose and implement the right set of policies to create a more sustainable set of mobility alternatives. Yet timing can be just as important as the choice of a policy itself. For example, in 2010, Beijing had the highest light-duty vehicle travel in China, while Delhi had the highest vehicle travel in India. This remains the case by the end of 2050 in all three scenarios. Even though Beijing has actively controlled its vehicle ownership rate since 2011, its total passenger vehicle travel remains high and will continue to be so. Shanghai, on the other hand, implemented vehicle ownership restrictions 25 years earlier, in 1986.

By the time Beijing started regulating the number of passenger vehicles, the total number of light-duty vehicles on its streets was already more than three times greater than Shanghai's. At the time of the introduction of a vehicle ownership restriction policy, Beijing's rate had reached 321 light-duty vehicles per 1 000 persons, or four times that of Shanghai's. The late start (at least relative to Shanghai) will shape future vehicle demand in the Chinese capital for the next 35 years, considerable efforts to reduce vehicle use and to encourage the use of less carbon-intensive alternatives notwithstanding.

Although Beijing in China, and Delhi in India, can achieve substantial CO₂ emission reductions if they pursue active mitigation policies (i.e. follow the ROG or LUT scenario), the absolute amount of CO₂ emissions remains high. Despite having a larger population and higher GDP level, Shanghai has managed to keep its vehicle ownership rate low. As a result, its CO₂ emissions from light-duty vehicles are about a third of Beijing (5.19 Mt compared to 15.69 Mt in 2010). Shanghai has achieved this not only by choosing the right policy but also by putting it into force when its motorisation rate was still low. A lesson from this is that rapidly growing and motorising cities have to act now if they want to avoid an acceleration of the challenges arising from traffic congestion, local air pollution or CO₂ emissions. The sooner policies and measures are designed and implemented, the more effective and less costly they will be.

Further reading

"China Motorization Trends: New Directions for Crowded Cities". *Journal of Transport and Land Use. Special Issue: Transport and Land Use in China, 2010*

OECD/IEA, *Energy Technology Perspectives 2015: Mobilising Innovation to Accelerate Climate Action*, Paris 2015

OECD/ITF, *ITF Transport Outlook 2015*, Paris, 2015.

"CO₂ Emissions from Land Transport in India: Scenarios of the Uncertain". *Transportation Research Record: Journal of the Transportation Research Board*, 2009

About the International Transport Forum

Who we are

The International Transport Forum at the OECD is an intergovernmental organisation with 57 member countries. It acts as a think tank for transport policy and organises the Annual Summit of transport ministers. ITF is the only global body that covers all transport modes. The ITF is administratively integrated with the OECD, yet politically autonomous.

What we do

The ITF works for transport policies that improve peoples' lives. Our mission is to foster a deeper understanding of the role of transport in economic growth, environmental sustainability and social inclusion and to raise the public profile of transport policy.

How we do it

The ITF organises global dialogue for better transport. We act as a platform for discussion and pre-negotiation of policy issues across all transport modes. We analyse trends, share knowledge and promote exchange among transport decision-makers and civil society. The ITF's Annual Summit is the world's largest gathering of transport ministers and the leading global platform for dialogue on transport policy.



This brochure presents a concise synthesis of ITF research into policy issues. Its purpose is to stimulate policy discussion, not to state policy positions. The views contained in this brochure do not necessarily reflect the opinion, collective or individual, of ITF member countries.



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