

# **Urban Transport and the Environment, Hangzhou, China**

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# Urban Transport and the Environment, Hangzhou, China

*David Banister and Jian Liu*

## Introduction

As the second largest city in the Yangzi River Delta and one of the largest tourist cities in China, Hangzhou has been in the forefront of the sustainable transport development in Chinese cities over recent years. Facing the challenges of growing transport energy consumption and CO<sub>2</sub> emissions, air pollution, traffic congestion and noise, the local transport authorities' objective is to build a highly integrated and low carbon intensive transport network consisting of metro, bus rapid transit (BRT), cycle, walk and water transport infrastructure under a coordinated development framework. Hangzhou's 'Non-Motorized Transport' project yields the world's largest public bicycle programme, and the city also has been developing electric bicycles since 2000, with a large market being established. Hangzhou has also been chosen as one of 13 pilot cities to develop new energy vehicles, and it currently has the highest level of new energy vehicle subsidy for private customers with one of largest charging infrastructure networks in China.

This case study firstly provides the background for Hangzhou covering the city's population, economy and the current transport situation. The main body discusses the local low carbon transport policies which include non-motorized transport (NMT), public transport, interchange and new energy vehicles. The conclusion summarizes the features of implemented policies and the implications generated from the case study.

## Background

Hangzhou is one of 15 sub-provincial cities in China, with a resident population of 8.1 million (2009). The total GDP of Hangzhou is RMB 509.866 billion (US\$76.156 billion) and the GDP per capita is RMB 63,475 (US\$9,292), which ranked 8<sup>th</sup> and 9<sup>th</sup> respectively for all Chinese cities (NBS, 2009a). As the capital city of Zhejiang province, Hangzhou also serves as an economic, political and cultural centre in the region. Hangzhou has the direct jurisdiction over 8 districts, with the metropolitan area covering Shangcheng, Xiacheng, Xihu, Gongshu, Binjiang and Jianggan districts. The suburban area includes Yuhang and Xiaoshan districts, plus 3 county level cities (Linan, Fuyang and Jiande) and 2 counties (Chunan and Tonglu) which are also governed by Hangzhou municipal government (see Figure 1).

**Figure 1. Geography of Hangzhou**



Source: <http://en.wikipedia.org/wiki/Hangzhou>, last accessed 25 May 2011.

**Table 1. CO<sub>2</sub> emissions from passenger transport in Hangzhou (2009 and 2020)**

Year	Travel mode	Mode share (%)	Number of trips	Average distance (km/trip)	CO <sub>2</sub> emissions per km (g/km)	Total CO <sub>2</sub> emissions (tonnes/day)	CO <sub>2</sub> emissions shares (%)
2009	Automobile	13.7	1,972,800	7	200	2762	77
	Public transport (by road)	19.7	2,836,800	8	30	681	19
	Metro	0.0	0	0	15	0	0
	Non-motorized transport and electric bicycles <sup>a</sup>	66.6	9,590,400	3	5	144	4
	Total	100.0	14,400,000			3587	100
2020	Automobile	15	2,610,000	10	150	3915	68
	Public transport (by road)	24	4,176,000	9	25	940	16
	Metro	16	2,784,000	18	15	752	13
	Non-motorized transport and electric bicycles	45	7,830,000	3	5	117	2
	Total	100	17,400,000			5724	100

\* Non-motorized transport: walking and cycling. Electric bicycles are classified as motorized transport in this paper.

Source: Adapted from Chen et al, 2010.

Hangzhou's main transport modes include car, bicycle, bus, taxi, bus rapid transit (BRT) and waterway transport. The transport sector accounted for about 8 per cent of Hangzhou's overall carbon emissions (2008), and given the high and increasing rates for travel demand and private car ownership, this share is likely to further increase (Shi, 2010). In 2009, the total transport CO<sub>2</sub> emissions in Hangzhou were estimated at 3586.61 tonnes per day, with automobiles and public transport vehicles together accounting for the majority of total road transport carbon emissions (96 per cent – see Table 1). In 2020, the total transport CO<sub>2</sub> emissions are estimated to increase by 59.6 per cent (on 2009 levels) to reach 5723.73 tonnes a day (Chen et al, 2010). With the introduction of the metro system in Hangzhou, all other travel mode shares are expected to reduce by 2020. However, the overall emission volume will still be driven by the surging travel demand and the motorization trend. For example, the private car stock in Hangzhou was 566,200 (2008) and it has been increasing at a rate of 400 vehicles every day since then (Ma et al, 2010). With this growth in car ownership, automobiles alone are expected to generate more carbon emissions in 2020 than the total amount attributed to the transport sector in 2009. In addition, according to 'Hangzhou Statistics Yearbook' (Hangzhou Statistics Bureau, 2008), the freight transport volume was 7154 million tonnes-km, generating about 3207 tonnes of carbon emissions per day. The figure is estimated to increase by 21.6 per cent and to reach 3901 tonnes in 2020.

The Hangzhou local government aims to reduce carbon intensity per GDP by 50 per cent in 2020 compared with the level in 2005, and this target is 5–10 per cent tougher than the national average target. To achieve that target, the Hangzhou's authorities have proposed a series of strategies to reduce the transport carbon emissions, such as introducing a non-motorized transport (NMT) programme, the Hangzhou metro system and electric vehicles. For instance, there is 278km of metro under construction and the public transport modal share

is expected to increase to 50 per cent by 2020. A free public bicycle service will cover all 8 districts, with the provision of 175,000 public bicycles (Wang, 2010). Hangzhou is the first Chinese city to introduce a ‘public bicycle’ programme. The bikes are provided by local public transport companies and people can use public bikes for free via their citizen cards. By May 2009, there were over 800 free bicycle service points and 20,000 bicycles under this programme. The first three metro lines with a total length of 68.79km will be operational by the end of 2011 (Yu et al, 2009). The local government has introduced a ‘zero transfer network’ strategy under the NMT programme to construct a green transport system with seamless connections between metros, buses, taxis and public bicycles. There are 9 BRT routes operating in Hangzhou (2010) and another 10 BRT routes are planned for 2020 (Chen et al, 2010).

Hangzhou is one of the 13 pilot cities selected for the promotion of new energy vehicles in China, and it is one of 25 cities that have already built electric vehicle charging stations. In June 2010, Hangzhou became one of the 5 cities to be granted subsidies by central government for new energy vehicles in the private automobile market. In August 2010, Hangzhou local government further introduced a supplementary subsidy, which extends the maximum subsidy for every new energy vehicle purchased in the private market to RMB 123,000 (US\$18,000) – this is the highest new energy vehicle subsidy level currently available in China (Xinhua News, 2010). For the latest plug-in hybrid electric BYD F3DM that is priced at RMB 168,000 (US\$ 26,000) in China’s market, the total subsidy reaches RMB 89,000 (US\$ 13,700) (53 per cent).

**Low Carbon Transport Polices**

Hangzhou’s low carbon transport polices consist of a range of strategies, such as cycling/walking, public transport, interchange network and new energy vehicles, and each of these is now discussed in more detail.

**Non-motorized transport (NMT)**

The non-motorized transport (NMT) programme (cycling and walking) is the core policy in Hangzhou’s sustainable transport development framework. It covers transport and urban planning, infrastructure provision and regulation preparation and it aims to establish a comprehensive low-speed NMT system across the city with a high accessibility for the

**Figure 2. Mobile public bicycle service point**



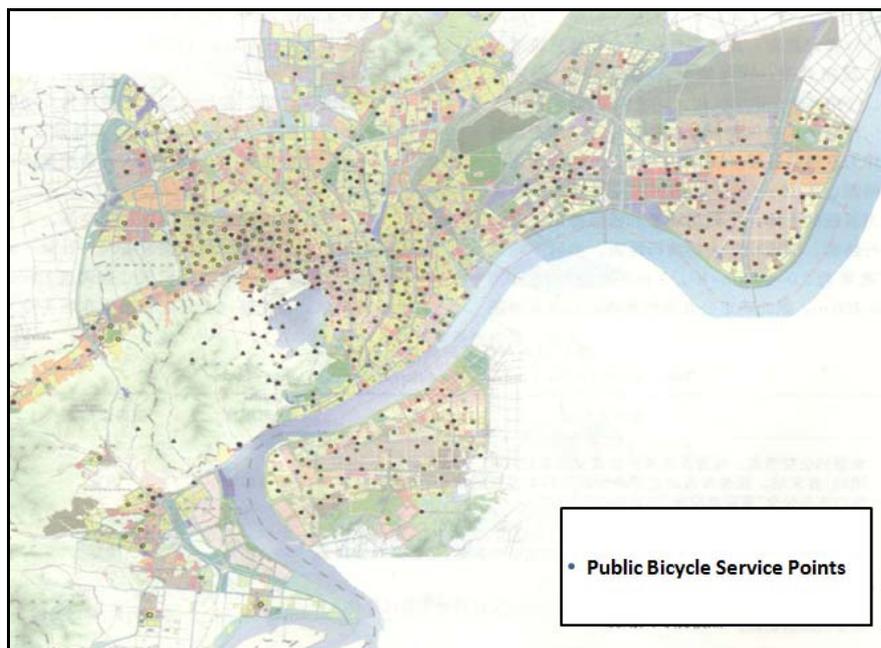
- 1 hour: for free  
(1.5 hour for bus passengers)
- 1–2 hours: RMB 1 (US\$0.15)
- 2–3 hours: RMB 2 (US\$0.30)
- 3+ hours: RMB 3 (US\$0.45)

*Photo: Xinhua News, 2009.*

general public. As a key element in the NMT system, Hangzhou launched (2008) the first ‘public bicycle’ programme in the country (Figure 2). With the rapidly growing urban sprawl and the private car ownership increase, cycling trips has seen substantial reduction in Hangzhou from 60 per cent modal share in 1997 to 33.5 per cent in 2007 (Yao and Zhou, 2009, p30), even though cycling is still one of the major travel modes for many citizens. In order to attract people back to cycling, Hangzhou launched its ‘public bicycle programme’ on 1 May 2008, providing 2500 public bicycles and 61 service points (31 fixed and 30 mobile) across the city. People can rent a public bicycle from a service point for free for the first hour. Fees of RMB 1/hour and RMB 2/hour are charged for the second and the third hours, and RMB 3/hour for the longer time. In order to enhance the B+R programme (‘bike and ride’) and close integration with local public transport, the authority has further extended the free use period for public bicycles from one hour to 1.5 hour for any riders who take a public transport before renting a public bicycle. All borrowed public bicycles can be returned to any of the other hire points in the city.

By June, 2009, a total of 17,342 public bicycles were under operation from over 800 service points spread across the city (Yao and Zhou, 2009, p37). These service points were mainly located in four areas: public transport stations/stops, residential districts, tourist destinations and college/university campus (Figure 3). From these fixed service points, there are several mobile service points that create a sub-network. The capacities of each fixed point normally range from 30 to 140 bicycles and 8–12 bicycles for a mobile point.

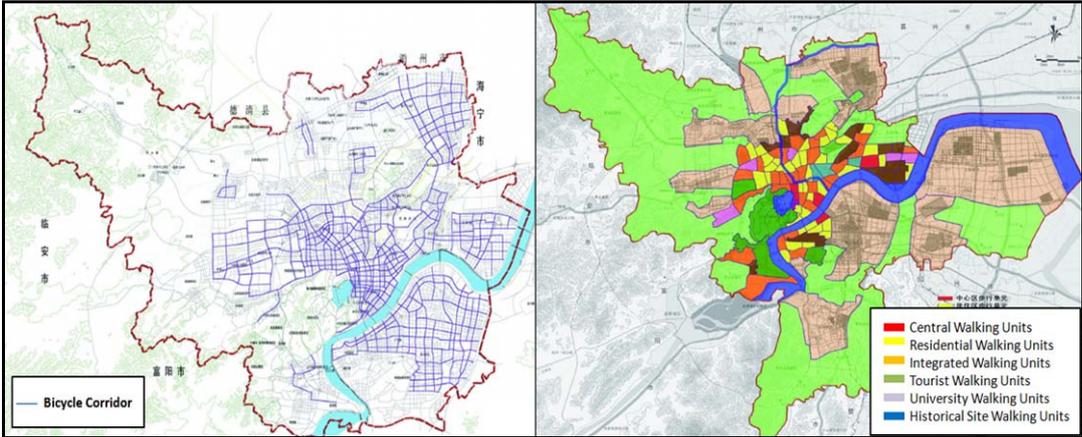
**Figure 3. Public bicycle points (fixed) in 2009**



*Source: Yao and Zhou, 2009.*

Along with the ‘public bicycle’ programme, the local authorities also introduced a ‘design guide for non-motorized transport system’ (see Figure 5) and a network containing 59 horizontal and 66 vertical bicycle corridors has been proposed by the local transport planning authority to encourage cycling (Figure 4 left). The network consists of a four-class road system with total length of 1130km and construction is planned to be completed in 2020 (Yu et al, 2009, p47).

**Figure 4. Bicycle corridor network (left) and walking areas (right)**

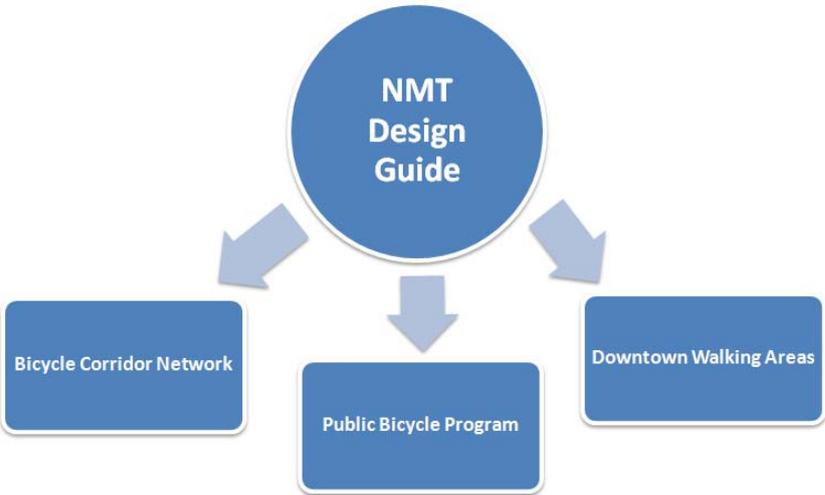


Source: Yu et al, 2009.

In addition to cycling, the NMT design guide also contains a medium term development plan for pedestrian infrastructure under which the city’s downtown area is divided into 8-class walking areas (Figure 4 right). With the combination of bicycle corridor network and pedestrian infrastructure, the NMT transport system will be mainly allocated to the West Lake scenery spots and the riversides across the city.

With the high inter-mode accessibility, Hangzhou’s public bicycle programme within the bicycle corridor network has appealed to a great number of car drivers. Each bike is used for an average of 6-times every day, and public bicycles have begun to serve an increasingly important role in local people’s daily commuting life. It accounts for a substantial amount of their short-range shopping and leisure travel. In addition, the service quality of public bicycles has been upgraded as its service range has expanded, and as the operating experience has increased. The authority has opened a public bicycle service website for online enquiries, and a more personalized service is being offered through different types of bicycles for elderly and young people. Although the public bicycle programme has developing rapidly, some side-effects and criticisms have emerged during the implementation, such as the lack of on-site

**Figure 5. Non-motorized transport (NMT) design guide**



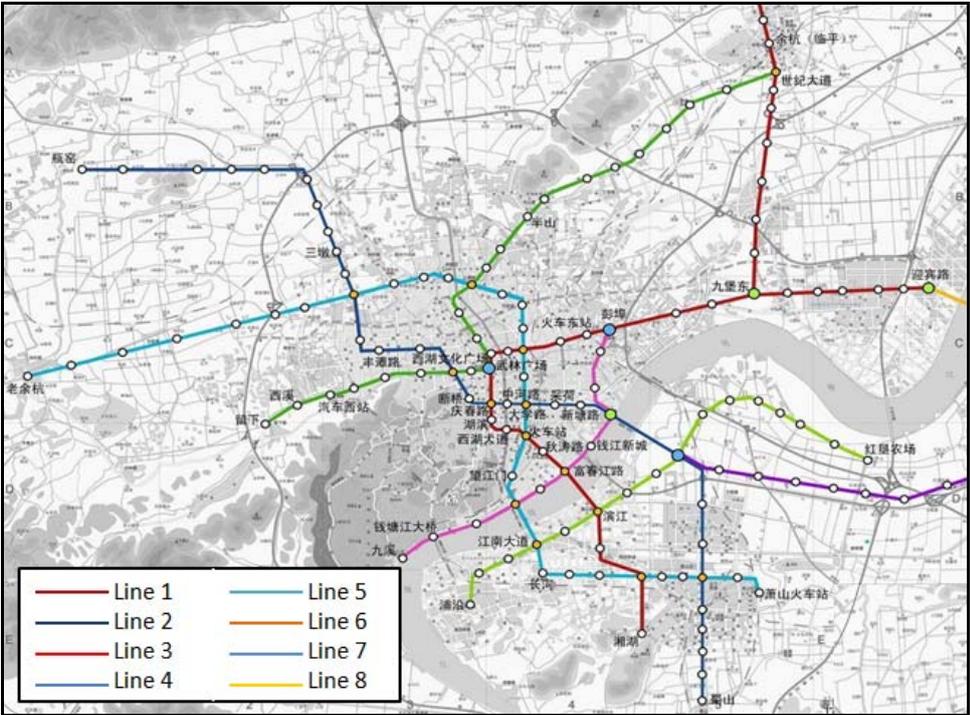
Source: Authors.

telecommunication services for customers, the absence of an information hotline and the LAN access to neighbouring service points. Others criticisms have proposed the need for more direction signs to the public bicycle service points. There is also a financial concern for the continued investment in the public bicycle programme. Currently, ‘free users’ account for more than 90 per cent of all public bicycle customers. From 2008 to 2010, the total investment had reached RMB 369 million (US\$57 million). Through commercial advertisement authorization and co-operation with newsstands organizations, the aggregated revenue in 2010 was RMB 10.5 million (US\$1.6 million) and expected amount in 2011 will be RMB 25 million (US\$3.8 million). Moreover, a series of bicycle operating equipment and infrastructure in Hangzhou have been patented and there have been a number of Chinese cities that tend to purchase the whole operating system (Jiang, 2010). Nevertheless, the subsidies may not be sustainable in the longer term, and so more consistent investment and a robust business operation are both needed.

**Public transport**

The promotion for public transport including metro, BRT (bus rapid transit) and waterway transport has long been an important low carbon transport strategy in Hangzhou. Urban rail transport (the Hangzhou metro) has been under construction since March 2007. Figure 6 shows the Hangzhou metro development plan, where lines 1, 2 and 4 will be completed and start operations from late 2011. By 2050, there will be 8 metro lines running over 278km of track. The Hangzhou metro system is characterized by dual-direction accessible platforms and an integrated platform design for universal transferability between intersecting metro lines. This contrasts with the Beijing and Shanghai metro systems where inter-lines transfers take a large share of metro travel time due to long walking distances between transfer stations.

**Figure 6. Hangzhou metro lines to 2050**



Source: [www.ZZHZ.com.cn](http://www.ZZHZ.com.cn).

**Figure 7. Borrowing public bicycle via a ‘Citizen Card’**



*Photo: Tencent News, 2010.*

‘Intelligent transport systems’ (ITS) have been widely introduced to improve the quality of the bus service in Hangzhou. In 2003, the Hangzhou Public Transport Corporation announced the ‘T’ card which integrates bus and taxi payment functions. More recently, the ‘Citizen Card’ was introduced with integrated utilities of public transport services (including borrowing public bicycles), united payments for some convenience stores and public services (Figure 7). Both the ‘T’ card and the ‘Citizen Card’ are compatible with the new metro system, so that a universal payment for all public transport can be realised. In addition to smart cards, onboard GPS and TV, and a bus stop electronic broadcast system were introduced in 2001 (Zhao, 2010). The consistent improvement in service levels has undoubtedly helped increase the passengers’ satisfaction and ensured a greater public transport mode share.

The high delivery capacity and the lower cost have made BRT a popular strategy in handling the surging travel demands in many Chinese cities. BRT with dedicated bus stops has been operating in Hangzhou since April 2006 (Figure 8). The number of daily BRT passengers is now over 53,000, with operating speeds of 60km/hour. This can save 40 minutes for each BRT passenger per day on average, as the BRT travels at three times the speed of conventional bus (Guo et al, 2008). Although BRT is regarded as a cost-efficient strategy to alleviate urban congestion and with additional positive effects on car travel and emissions reduction, the practical enforcement of BRT lanes, which significantly influence the BRT reliability, has been a controversial issue in Hangzhou. The provision of dedicated separate traffic lanes can provide a high service capacity and punctuality for BRT. But inappropriate deployment of exclusive BRT lanes that occupy valuable road space can reduce the space for other traffic on the road, and this has triggered many disputes. There have also been some concerns about the traffic capacity reduction resulted from the increase in BRT routes, since they were first introduced (2006). BRT needs to ensure coordination between all transport modes, rather than encourage competition for road space. The Hangzhou transport authorities have now classified the BRT infrastructure as a part of an integrated public transport system, and the BRT passengers can take subsequent bus trips for free. Further research is also being carried out for a better geographical allocation of space to BRT (Xu et al, 2006).

**Figure 8. Hangzhou BRT**



*Photo: Baidu Photo, 2010.*

Hangzhou is also characterized by an extensive waterway system comprising Jing-Hang Canal, Qiantang River and West Lake. This is another low carbon transport mode that the local authorities aim to further develop. The Jing-Hang Canal passes through four administrative districts with a total of 39km in Hangzhou. In 2002, the ‘Protection and Development Plan for Jing-Hang River’ was proposed by the Hangzhou Urban Planning Bureau (Xu, 2003), aiming to improve the residential environment as well as waterway transport along the drainage area. Given that water transport only uses about 1/8 energy consumption with significant higher cost-benefit than road transport, the Hangzhou Transport Bureau has introduced the first water bus service line in China (2004) (Du, 2009) (Figure 9). There are now three water bus lines in operation conveying more than 300,000 passengers every year. The water buses are mainly serving tourist demand and the operating body has recently opened two lines with increased service frequency to attract more local commuting travel. As Hangzhou’s future urban development has been largely allocated along the river system, waterway transport is expected to play a more important role in the city’s future transport system.

The success of Hangzhou’s sustainable transport not only relies on the well-known NMT and public transport systems, but it also depends on a well established interchange network. This has presented a major challenge to many Chinese cities, as it involves close cooperation between many official, management and construction bodies. The proposed Hangzhou integrated transport interchange system is currently being developed in a framework for ‘seamless connection’ and ‘zero interchange’ between the different transport modes, and passengers will be able to make their mode transfers within interchange hubs. For instance, the Hangzhou Eastern Railway station (currently under construction) will operate as an integrated interchange hub connecting metro, bus, taxi and maglev<sup>1</sup> lines within the station. The Jiubao Long-Distance Passenger Transport Terminal, which will be responsible for the

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1. Maglev is a mass transit that uses magnetic elevation for lift and propulsion.

**Figure 9. Hangzhou waterway bus**



Photo: [Hudong Wikipedia, 2008](#).

whole city's long distance coach and bus transport services, will be linked to Hangzhou Metro line No.1 and local expressways (Chen et al, 2009).

The Shanghai-Hangzhou high speed railway (under construction) and the Hangzhou metro lines are planned to achieve a 'zero transfer' between each other. The Hangzhou Metro-Yuhang line is 10.978km with 6 stations in Yuhang district, while the Yuhang section of Shanghai-Hangzhou high speed railway is 10.1km with a fully elevated design. In order to offer a better interchange accessibility between the railway and metro stations, a new metro station has been added so that the transfer distance to the railway station was reduced to 56m (Chen et al, 2009).

### **New Energy Vehicles**

The new energy vehicles have been regarded as one of the most effective tools in directly cutting transport energy consumption and emissions. Recently, China has maintained an annual increase of about 20 per cent in the rate of car ownership, and given the current low level of 50 cars per thousand population<sup>2</sup> the successful introduction of new energy vehicles for China's huge emerging automobile market will be vital, both for the overall car market in China and for reducing global carbon emissions and energy consumption. Over the past decade, China has developed a massive electric bicycle market with a well established battery and motor manufacturing industry, which provides the basis for electric vehicle introduction. In June 2010, China's central government announced the first group of five cities, including Hangzhou, to introduce new energy vehicle subsidies for private customers. According to the announcement, the electric vehicles and fuel cell vehicles buyers are eligible for a maximum of RMB 60,000 subsidy per vehicle (US\$9,000). In addition, a RMB 3000 (US\$450) per

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2. This is about half of the world average (NBS, 2009b).

vehicle subsidy is also offered for those fuel efficient vehicles with lower carbon emissions than the traditional internal combustion engine vehicles.

However, the previous experiences from new energy vehicle projects show that an isolated financial subsidy could not effectively promote the public acceptance of new energy vehicles in China. Within the 13 pilot cities that have adopted new energy vehicles for official and public service sectors, there have been substantial concerns about the low actual energy efficiency of some hybrid electric vehicles and high vehicle prices (Auto Times, 2010). Some public transport companies also complained about the limited battery range and life cycle that have further increased their operating costs. For example in Guangzhou, some hybrid electric buses substituted 8 batteries within 3 years causing RMB 100,000 extra operating cost for each vehicle (US\$15,000). The battery capacity and reliability are particularly important for buses due to the intensity of their daily operating duty. Since 2005, new energy vehicles, including electric buses, hybrid electric buses and natural gas buses have been under operation in the Hangzhou public transport fleet (Lu, 2009). The new vehicles have significantly reduced fuel consumption by 11 per cent to 20 per cent compared to the older petrol and diesel buses. The accumulated volume of petrol saving from the new energy vehicles is more than 6.1 million litres and the estimated CO<sub>2</sub> reduction is more than 16,000 tonnes (Shi, 2010). At present, there are 300 hybrid electric, 53 electric and 48 liquid natural gas buses operating in Hangzhou, and the local public transport company has further purchased 195 new hybrid electric buses (2010).

Many customers have more concerns about the inadequate charging infrastructure for private electric vehicles. With the latest progress in battery technologies and ranges for automobiles, together with the significantly low level of daily travel distance for urban drivers in China, the customers have begun to concentrate more on the benefits of other elements for using electric vehicles rather than the vehicle performance (Liu and Santos, 2010). According to an electric vehicle survey conducted by Ernst and Young (2010), except for 'battery driving range', 69 per cent and 64 per cent Chinese respondents reckon 'access to charging stations and reliability' and 'safety' as their 'most concerns' on electric vehicles, and these factors are ranked even higher than the 'price' factor of 57 per cent. Therefore, in order to address the various customers' concerns of new energy vehicles, the Hangzhou authorities' plan to provide a policy package for the local new energy vehicle development. In addition to the RMB 60,000 subsidy from central government, the Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, and the National Development and Reform Commission have all approved the 'Subsidy Plan for Private New energy Vehicle Customers in Hangzhou'. This plan further facilitates the growth of new energy vehicles for Hangzhou. Rather than only providing discounts for buyers, this subsidy plan provides support for both electric vehicles and charging infrastructure (Figure 10), and different purchase and lease methods for customers (Hangzhou Government, 2010):

- In addition to the national subsidy, customers can receive a maximum of RMB 60,000 (US\$9200) local government subsidy for purchasing an electric vehicle, while they are exempted from charging fees<sup>3</sup> for the first 3 years or 60,000km travel.
- Instead of purchasing a whole vehicle, customers can rent a battery for electric vehicles at a discounted rate and again they are also exempted from charging fees for the first 3 years or 60,000km travel.

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3. Electric vehicle charging fees are paid by EV drivers to charge their vehicles. This fee is based on the electricity consumption and local electricity price. In Hangzhou, the current charging fee is RMB 0.6/kWh (\$0.09/kWh).

**Figure 10. Electric vehicle charging posts in Hangzhou residential communities**



Standard charging:  
AC 220V/3830V, 20A,  
5kW,  
8-hour charging;

Fast charging:  
DC 380V, 400A, 200kW,  
20–30 minutes charging;

Battery swap:  
3–5 minutes.

*Photo: Science and Technology Daily, 2010.*

- Electric vehicle hirers can receive a subsidy of 50 per cent rentals and are also exempted from charging fees for the first 3 years or 60,000km travel.
- For group purchase of more than 10 new energy vehicles, a further RMB 3000 (US\$460) is subsidized for each vehicle.
- Customers, who purchase a new energy vehicle with trading back a used internal combustion engine vehicle, can receive a further RMB 3000 (US\$460) subsidy.
- The electric vehicle charging stations and battery swap stations projects can receive a subsidy of 20 per cent for capital construction costs.
- Battery manufacturers are responsible for recycling the used batteries and eligible for a RMB 15/kWh subsidy.

In aggregate, customers in Hangzhou can get a maximum of RMB 123,000 (US\$18,000) subsidy for purchasing an electric vehicle with free charging services in the early stage of use. The strategy of the local authority is to provide an integrated policy package for electric vehicles covering sectors of price reduction, purchase/rent alternatives, recovering old automobiles, charging service provision and battery recycling. Such a comprehensive consideration is essential for early electric vehicles market promotion and penetration. A number of experts have already recognized that the barrier for new energy vehicle development is far more than just the price related factors (Auto Times, 2010). It has been suggested that the development of new energy vehicles also requires a set of measures to raise the customers' confidence rather than just an isolated financial stimulus.

Under the new energy vehicle development framework, the Hangzhou government aims to build 4 electric vehicle charging stations, 38 sub-charging and battery swap stations and 3,500 charging posts by 2012. Meanwhile, some innovative supporting policies have been introduced. For example, in order to improve charging efficiency for electric vehicles, the local authority introduced 'battery swap stations'. The depleted batteries can be replaced in a few minutes at the swap stations that are distributed in high demand areas. The government has also cooperated with local electric vehicle manufacturers and it plans to use 1,100 electric vehicles in the public service sector, including official vehicles and mail delivery vehicles

(2011). The new energy vehicles have already been confirmed as one of the pillar industries of Hangzhou, and a 'three dimensional' platform consisting of car manufacturers, battery manufacturers and public charging service providers has been established. A new public transport company for electric bus and taxi services is also being discussed. With the comprehensive development strategies, Hangzhou is on the way to becoming China's first city to achieve the commercialization of electric vehicles.

In China, electric bicycles have already become a popular transport mode in many cities including Hangzhou. Since electric bicycles were formally admitted as legitimate non-motorized vehicles 1999, the electric bicycles market has developed at a phenomenal rate. China's electric bicycles stock has reached 60 million with an annual increase of 124 per cent (since 1998) and in Hangzhou this figure were 600 thousands in 2007 (Zheng, 2007). China has now become the worlds' largest electric bicycle producer and consumer. Compared with bicycles, electric bicycles largely improve the travel range and comfort, and maintain the bicycles' advantages of high flexibility and accessibility. Although public transport provides an alternative for longer distance travel, the electric bicycles avoids traffic congestion with door to door convenience. Compared with automobiles, electric bicycles are apparently less expensive both in terms of purchase and operating cost. In China, electric bicycles' price generally ranges from RMB 1,000 to RMB 2,000 (US\$150–US\$300), which is only about 1 per cent or 2 per cent of a normal car. The energy cost of a typical electric vehicle is about RMB 15 per 100km which is even lower than public transport (Chen, 2009). Therefore, with an improved travel quality with an affordable cost, electric bicycles have grown into a large market in China over the last 10 years. In addition to the cost benefit, electric bicycles require less road and parking spaces as compared to cars, and this has substantial benefits for large cities like Hangzhou. Electric bicycles have a strong role in reducing carbon emissions and traffic noise, at least in the city.

Although electric bicycles are thought to make an important contribution to sustainable transport and have lower financial and environmental costs, there is still controversy about their road safety record. According to the 2007 local statistics in Hangzhou, there were 45 more electric bicycle related accidents in 2007 – a 71 per cent increase from the level in 2006 (Liu, 2008). This increase can be partially attributed to the increased travel share of electric bicycles, but the relatively high speed and limited protection to riders are also important factors. Another concern is that of battery disposal and recycling. Most electric bicycles use lead-acid batteries with a short life cycle, and as the battery disposal and recycling system are not well-established in China, a large electric bicycle fleet is bringing substantial battery pollution. With further concerns about the continued increases in traffic congestion and traffic management difficulties compared to automobiles, some Chinese cities have even banned electric bicycles on urban roads, including Beijing. In Hangzhou, rather than simply prohibiting electric bicycles, the authorities issued a series of regulations and standards on electric bicycle production, sales and management stages to control electric bicycle growth to a reasonable rate.

## Conclusions

In common with many other cities in China, Hangzhou has been facing a severe challenge in mitigating carbon and energy consumption from surging travel demand. Sustainable transport in Hangzhou is largely attributed to a comprehensive and integrated planning and implementation framework, which covers public transport, walking and cycling, urban planning and new energy vehicles. In particular, the large-scale 'NMT' and electric vehicle programmes have made Hangzhou one of leading cities in developing low carbon transport in

China. The transport authorities have also attempted to fully extract the potential for building a sustainable transport system based on the local characteristics, such as providing public bicycle services in scenic spot areas, developing the waterway transport system, and in cooperating with the local automobile industry to promote new energy vehicles and public charging services. It can be seen that the policies are usually packaged within a set of relevant supporting guidelines or regulations which are designed to guarantee the effectiveness of implementation.

However, the development of sustainable transport is never an easy task, and there are still a number of difficult issues that need to be addressed. The huge variety of sustainable transport modes makes the coordination and integration between them more problematical, and this may be a particular issue when several of them are new systems. For example, the roles of public and waterway transport should be reviewed both in terms of quantity and space, when the metro system begins to operate. For new energy vehicles, the unified vehicle and charging infrastructure standards should be confirmed as early as possible to save the potential large environmental and financial cost of redundancy. While the electric vehicle charging infrastructure is phased in, a new profitable operating model should be developed for electric vehicle charging and battery leasing. All these are important issues to consider in helping Hangzhou move from a city that is 'experimenting' with several different and innovative forms of transport to a city where the transport system really 'works'.

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