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ORIGINAL ARTICLE

Sustainable urban development in China: challenges and achievements

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Abstract China is undergoing rapid urbanization, along with economic growth and transport automation. Because it is densely populated, China is constrained by natural resource limitations and potential impacts of global climate change. Significant challenges for sustainable urban development include urban sprawl, traffic congestion, air pollution, city layouts not oriented to twenty-first century lifestyles, declining traditional urban culture, selective over-development, and social inequities. Increasing awareness of these pressing problems has led national and provisional governments and cities to seek sustainable urban development solutions. Central ministries and non-government organizations have implemented pilot projects demonstrating best practices in the Chinese context. These are being scaled up to develop local and national guidelines and policies. This paper describes China's urbanization issues and national and local efforts toward the realization of sustainable urbanization. It is hoped that China's urbanization trends and challenges will stimulate sustainable and low-carbon concepts and approaches that can enrich sustainable urbanization theory and practices in and beyond China.

Keywords China · Eco-city · Environment · Climate change · Planning · Sustainable · Urbanization

1 Introduction

China is undergoing a process of accelerated urbanization as a result of rapid economic growth. Because of its large population base, the speed and scale of population migration from rural to urban areas are unparalleled in comparison to other countries (see Table 1). This transformation began in the mid-1990s, and the urban population has subsequently increased at an annual rate of 1.1 to 1.5 %, with more than 20 million people moving to the cities each

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Table 1 China's urban population, along with annual population increases, growth rates, and urbanization percentages from 1990 to 2012 (China National Statistics Bureau 2013)

Year	Total urban population (in 1000s)	Annual increase of urban population (in 1000s)	Urbanization rate (% of total population living in urban areas)	Annual increase in urbanization rate (%)
1990	301,950	6550	26.4	0.2
1991	312,030	10,080	26.9	0.5
1992	321,750	9720	27.5	0.6
1993	331,730	9980	28.0	0.5
1994	341,690	9960	28.5	0.5
1995	351,740	10,050	29.0	0.5
1996	373,040	21,300	30.5	1.5
1997	394,490	21,450	31.9	1.4
1998	416,080	21,590	33.4	1.5
1999	437,480	21,400	34.8	1.4
2000	459,060	21,580	36.2	1.4
2001	480,640	21,580	37.7	1.5
2002	502,120	21,480	39.1	1.4
2003	523,760	21,640	40.5	1.4
2004	542,830	19,070	41.8	1.3
2005	562,120	19,290	43.0	1.2
2006	582,880	20,760	44.3	1.3
2007	606,330	23,450	45.9	1.6
2008	624,030	17,700	47.0	1.1
2009	645,120	21,090	48.3	1.3
2010	669,780	24,660	50.0	1.7
2011	690,790	21,010	51.3	1.3
2012	711,820	21,030	52.6	1.3

year. By 2012, the total urban population had reached 0.71 billion and the national population urbanization rate had risen to 52.6 % (China National Statistics Bureau 2013).

In addition, because of the country's rapid economic growth and the government's policies with respect to the automobile industry, viewed as a pillar of China's economy, private cars have become affordable for middle-income Chinese families. The total number of privately owned vehicles increased from 6.26 million in 2000 to 88.39 million in 2012 (see Fig. 1). This equates to a 14-fold growth expansion from the level in 2000 and an average annual growth rate of 24.7 % (China National Statistics Bureau 2013). However, the average number of vehicles owned per 1000 people is only 89, implying that significant further growth is required to reach the global average vehicle ownership rate of 170 vehicles per 1000 people (OICA 2012). It is noteworthy that current average vehicle ownership rates in Japan and the United States (US), respectively, are 599 and 791 vehicles per 1000 people (OICA 2012). In 2013, China produced more than 20 million vehicles and sold 21.98 million, demonstrating a growth rate of 13.9 % compared with 2012 sales.

Figure 1 shows that the total number of private vehicles in China increased from about 800,000 in 1990 to almost 88.4 million in 2012. The expansion of vehicle numbers has predictably been highest in the most influential first-tier cities. Automobile ownership in

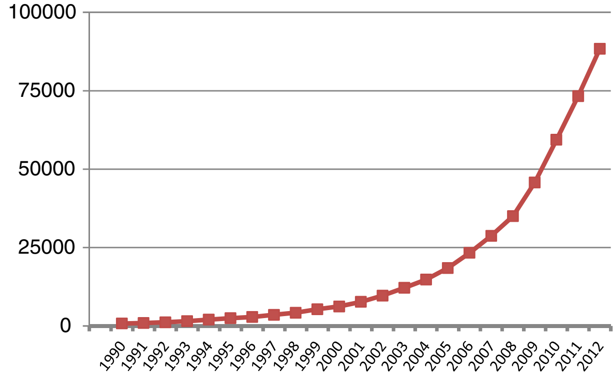

Fig. 1 Increase in the total number of private vehicles in China (in 1000s) between 1990 and 2012 (China National Statistics Bureau 2013)

Beijing had reached more than 5.2 million vehicles by the end of 2012, of which 4.07 million were privately owned, as shown in Fig. 2 (BTRC 2013). From 2003 to 2012, the average annual growth rate for private vehicles was 18.1 %, notwithstanding the new purchase restriction policy implemented in 2011.

Even in cities where population and economic development levels are lower than in metropolitan areas such as Beijing and Shanghai, private car ownership has increased dramatically. For example, in Kunming, the capital of Yunnan Province in southwestern China, vehicle ownership increased by 72.5 % between 2008 and 2012 (see Fig. 3), also evidencing an annual average growth rate of 18.1 % (KITR 2012). A nationwide survey in 2012 found that the level of desire for car ownership among citizens was quite high, with only 2.6 % of non-car owners claiming that they would never purchase a car (Wang 2013).

However, rapid urbanization and the associated expansion of automobile ownership have had many negative effects on cities. These include traffic congestion, air pollution, deterioration of the pedestrian and cyclist environments, and social disparity, leading to stratification and inequality. Other significant impacts include the loss of farmland (Calthorpe et al. 2013), discrimination experienced by rural people in gaining access to urban residences because of

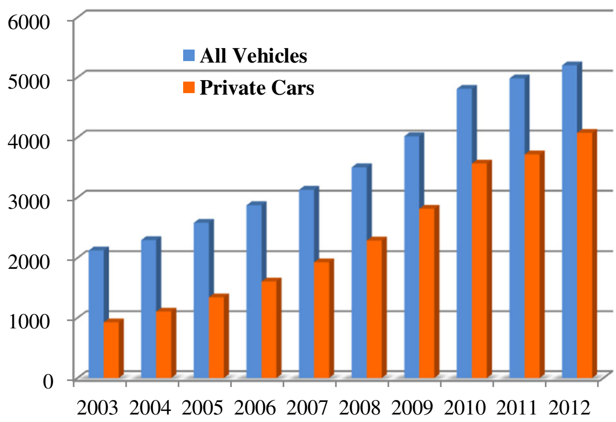

Fig. 2 The total number of vehicles and private cars in Beijing from 2003 to 2012 (BTRC 2013)

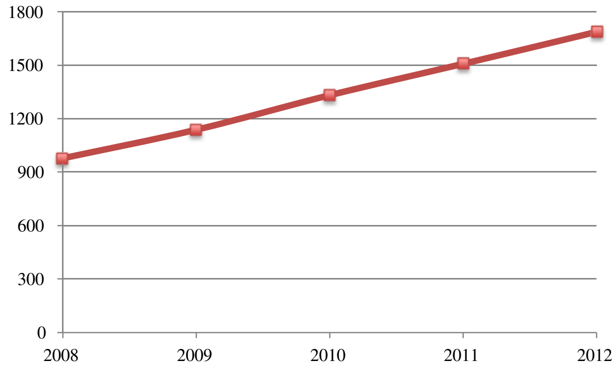

Fig. 3 The number of vehicles (in 1000s) in Kunming from 2008 to 2012 (KITR 2012)

the requirement of Hukou (urban citizenship certificates) to reside in a particular city (Chen 2014; Song 2006; Jiang 2009), and the over-concentration of populations in leading metropolitan areas (Qiu 2006; Yang 2004). All of these impacts have resulted in severe problems associated with maintaining China's social, economic, and environmental sustainability and stability.

Urbanization clearly contributes a high percentage of carbon emission, with the US being the greatest contributor (62 %), compared with the rest of the world (37 %), because of its advanced development and extensive urban sprawl (see Fig. 4). Moreover, automobile-oriented development is a greater multiplier of the carbon contribution compared with public transit-oriented development (TOD) and the use of bicycles (He et al. 2013) (see Table 2).

Decision-makers and urban planners have increasingly recognized urbanization problems and their environmental implications. Although efforts are being made to promote sustainable city development, formidable challenges remain. This paper summarizes challenges as well as

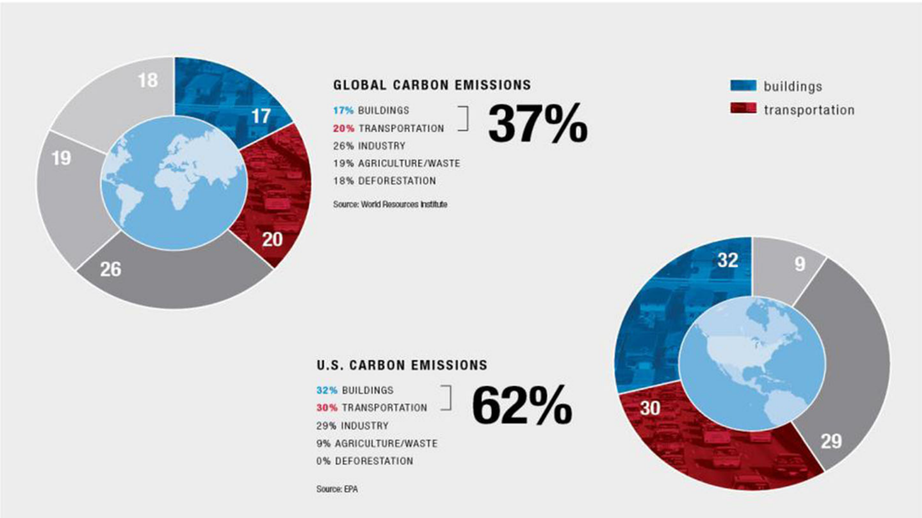

Fig. 4 A comparison of urbanization's contribution to carbon emission globally and in the USA (Calthorpe 2010)

Table 2 Emission rates of different urban transportation modes (He et al. 2013)

Emissions	Pedestrian/bicycle	Urban rail	Bus	Taxi	Car
CO_2 (ton)	0.0	7.5	19.8	116.9	140.2
NOX (kg)	0.0	17.5	168.4	662.0	746.0
Fuel (ton)	0.0	2.6	6.9	41.0	49.2

Unit: emission/km/million population

achievements resulting from these efforts and recommends actions to be taken. It is hoped that ongoing discussions of China's urbanization challenges and trends will lead to more sustainable and low-carbon concepts and approaches relating to China's urban development that will enrich sustainable urbanization theory and practice in and beyond China.

2 China's urbanization issues and challenges

Among the main factors influencing rapid urbanization and the growth in vehicle ownership, some are significantly related to urban planning decisions. The following section describes some of the primary reasons for this relation.

2.1 Separation of urban functions and urban sprawl

Beginning in the 1990s, in the names of decentralization and urban renovation, many traditional residential communities within urban centers were uprooted and families were relocated to city suburbs (Wu 2012). Suburban clusters were planned with the intention of relocating both jobs and housing from city centers. However, the population density within urban centers was not actually decreased. Instead, to compensate for relocation costs, higher density buildings with offices and retail centers, as well as residential subdivisions, were developed. In suburban clusters and new towns, large tracts of lower cost residential buildings were developed. To support these suburban developments, expressways were constructed, radiating out from the city centers. Ring roads were also built with the intention of diverting commercial trucks and through-traffic away from city centers, in addition to serving suburban areas. However, most of the proximal suburban clusters eventually connected to urban centers, thereby expanding city centers. Development of lower density new towns resulted in further urban sprawl (Qiu 2006; Calthorpe et al. 2013). This phenomenon is illustrated for the city of Changsha in Fig. 5, which shows that during Changsha's expansion process from 1978 to

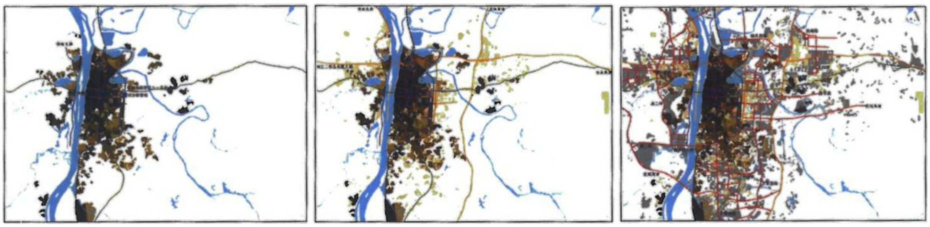

Fig. 5 Changsha's expansion from 1978 to 2009 (Calthorpe et al. 2013)

2009, the development of suburban centers did not alleviate population density in the city center. Moreover, the introduction of ring roads has further accelerated development. This is evident in Beijing's master plan of 2004 (Fig. 6a) and the map of its roadway plan, depicting proposed multi-center and a ring-road structure of radiating roads (Fig. 6b).

Most of the new towns in China have been constructed with large, single-use tracts and wide roads and have insufficient transit services and local roads. As a result, traffic is becoming concentrated on arterial roads and expressways radiating from city centers. The accommodation of pedestrians and cyclists, which was a feature of traditional Chinese cities, has been significantly reduced in these new towns and remodeled city centers. Lengthy commuting and insufficient transit services have resulted in a higher dependence on cars and a corresponding reduction in the proportion of bicycle and transit users (Calthorpe et al. 2013). Tidal traffic (that is, concentrated traffic to and from city centers during peak morning and evening hours) and high congestion levels in these urban areas are approaching nightmare proportions (see Fig. 7) (BTRC 2013).

2.2 The detrimental effects of single-function superblocks and wide streets on pedestrians and cyclists

"Single-function superblock" refers to a typical Chinese urban development pattern over the last three decades, which is characterized by single-use urban blocks (for example, only for residential use) of very large size (generally over 400 m on a side). Single-function superblocks were the preferred option when initial urban plans were being developed, as they are faster and easier to develop. The superblock is normally walled, as fencing a property has been considered a safety measure and has been regarded as more likely to result in a good design. These superblocks, associated with wide roads, have engendered a very challenging walking environment, while sparse road networks have resulted in concentration of traffic on wide roads. Transit lines are also aligned with major arterial roads. Thus, the task of enabling pedestrians to cross roads and to walk to transit stops has become a difficult one. This problem is illustrated in Fig. 8a, b, which shows, respectively, a large tract of single-use blocks in Beijing's Huilongguan residential area and a typical arterial pedestrian crossing in Beijing that is difficult to negotiate. Road spaces previously frequented by bicycles have been occupied by cars. Coupled with longer commuting times, this change has sharply decreased the proportion

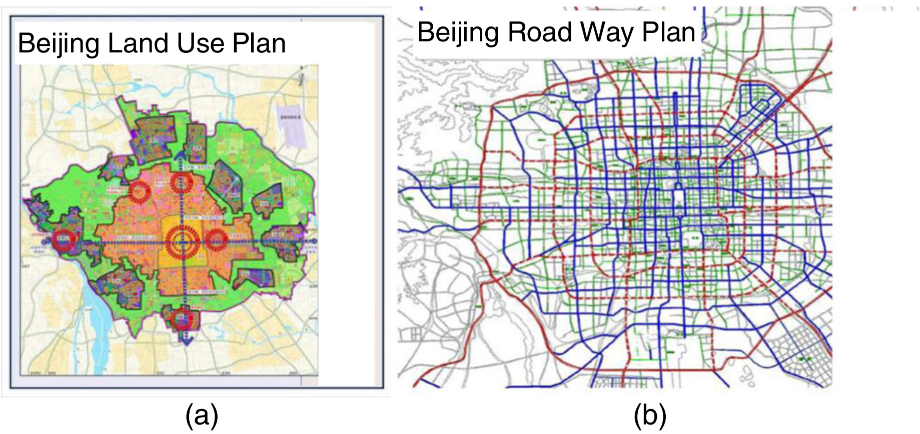

Fig. 6 Beijing 2004 master plan: **a** land use plan, **b** roadway plan (Beijing Municipal Commission of Transport 2006)

Fig. 7 A view of the congested Jingtong expressway extending from Beijing's city center to its suburbs during the peak evening hour (BTRC 2013)

of bicycles in the urban transportation mix. Figure 9 shows the dramatic reduction in the number of cyclists on Beijing's Changan Avenue in 2012 (b) compared with 1986 (a).

In association with wide roads, regulations often specify large setbacks. Therefore, retail environments situated along these roads have been adversely affected because of inaccessibility by pedestrians. Moreover, the sparse road networks do not guarantee smooth traffic. Instead, the opposite is true: Because of the availability of fewer choices in travel routes, traffic congestion tends to become increasingly severe, especially during peak hours.

2.3 Erosion of the urban cultural fabric associated with the loss of the traditional Chinese urban structure

During the process of urban renewal and the development of new towns from the mid-1990s to about now, many historical buildings and streets were demolished. In their place, uniform

(a) (b)

Fig. 8 **a** An aerial shot of Beijing's Huilongguan residential area (source: Google Earth); **b** a typical arterial pedestrian crossing in Beijing

(a) (b)

Fig. 9 Cyclists on Beijing's Changan Avenue **a** in 1986 (source: Baidu Photo Gallery) and **b** in 2012

buildings, lacking character, and wide streets were built. Figure 10 aptly illustrates this contrast in its depiction of: (a) a traditional Beijing alley (Hutong) and (b) a contemporary street with superblocks in a Chinese town. Cities have thus begun to lose their unique and distinctive identities in the production of what have been described as "a thousand cities, the same face" (Wu 2012).

At that time, the government considered this type of uniform development with tall glass buildings to be reflective of a modern, high-end society. Demolition was also viewed as an easy option for urban renewal, as it clears out the entire blocks to achieve higher density and opens up opportunities for land-lease revenue. Concurrently, the traditional low-density urban fabric was viewed as being of lower value. Thus, realization of the value of traditional Chinese architecture has come too late. However, the renovation of Beijing's Ju'er Hutong neighborhood as part of the revitalization of the traditional style in a Beijing subdivision showed that with careful design, high quality and high density could be achieved at the same time (Wu 1999).

2.4 Insufficient transportation planning measures resulting from unanticipated urban growth

Not only has the pace of urbanization been underestimated in various urban master plans, but the scale of expansion of cities has also been significantly underestimated. For example, the Beijing Urban Master Plan (2004–2020) projected that Beijing's population would reach 18 million by 2020 (BMPB 2005). However, the city's population had already reached 20.2

(a) (b)

Fig. 10 **a** A revitalized traditional Beijing alley (Hutong); **b** a contemporary street, with superblocks, in a new Chinese town million by 2011—almost a full decade ahead of the projection. A similar phenomenon is evidenced by a comparison of city populations in 2010, revealed by the sixth National Survey, and projected 2020 population goals. As Table 3 shows, actual populations in many cities had already eclipsed the 2020 planning goals by 2010.

The underlying reason for underestimation of urban populations has been the desire to control the match between urban populations and supplies of available resources such as water, energy, and services. However, once the master plans were executed, gross domestic product (GDP)-oriented development resulted in the loss of control of city scale and, further, in inadequate development of urban infrastructure, especially transportation. The infrastructure of cities is being overburdened, and there is an urgent need for the construction of public transportation infrastructure such as subways and other facilities.

During the period of the 1990s and the early 2000s, most city planners attributed traffic congestion to insufficient roadways. As a result, roadways were expanded. The purchase of private cars was encouraged as a result of a policy that considered the automobile industry to be one of the supporting pillars of the national economy. The dangers of future traffic congestion and related problems were not anticipated, and very few travel demand management (TDM) measures were planned. In most cities, the importance of subways was not recognized until car dependency was established, and the construction of subways became highly costly. Only a few cities, for example Shanghai, took precautionary measures and executed license plate auctions starting in 1994 (Mao 2011).

Transit development has mostly followed, rather than led, urban development because the concept of transit-oriented urban planning has remained foreign for too long. As a result, transit capacities and land use density have not been well matched.

2.5 Pollution and resource depletion

The depletion of energy and water resources as a result of urban development and dependency on automobiles constitutes a major threat to the sustainability of China's cities. A vast engineering project that draws water from southern China to supply Beijing and surrounding northern Chinese cities is currently being implemented. Consequently, drawing water from underground sources has become a daily operation instead of an emergency measure.

China is currently the largest consumer of energy in the world, and air pollution related to automobile use has become a top concern for both citizens and governments (see Fig. 11). Leaving aside the issue of carbon emissions, which citizens cannot see, emission of fine particulate matter (PM) such as $PM_{2.5}$ (with a size of 2.5 μm or less) is now the issue of

Table 3 A comparison of population forecasts for 2020 for major Chinese cities and actual population statistics for 2010 derived from the sixth National Survey (Calthorpe et al. 2013)

	2020 Population goal (000)	2010 "6th National Survey" population (000)
Beijing	18,000	19,610
Changsha	6880	7040
Hangzhou	8500	8700
Xiamen	3300	3530
Wenzhou	8900	9120
Changzhou	4300	4590
Yiwu	950	1230

Fig. 11 Pollution masks worn by residents in response to Beijing's smog (Jiang, China Sustainable Transportation Center)

greatest concern to citizens. In 2011, automobile $PM_{2.5}$ emissions in China totaled 46 million tons, which signified a 3.5 % increase compared with 2010 (Tao 2012). Most Chinese cities accept the estimation that 20–30 % of $PM_{2.5}$ is derived from automobiles, and further evidence is still being assessed.

3 China's new urbanization movement and its achievements

Awareness of the effects of urbanization is on the rise within the central government and among urban planning practitioners, academics, and ordinary citizens. In particular, traffic congestion and air pollution have emerged as the top concerns of citizens.

3.1 The central government's proposed new urbanization concept

In 2011, the Central Economic Work Conference hosted by the central government, which makes the most significant decisions regarding China's economic development, proposed a new urbanization concept. This concept emphasizes the establishment of rational and scientific urban patterns. Subsequently, from December 12 to 13, 2013, the central government held the National Urbanization Working Conference. All of the top national leaders participated in the conference, and both President Xi and Prime Minister Li delivered key speeches.

The conference advocated people-centered urbanization that was characteristically Chinese, and emphasized efficient land use, improved management at the city level and the quality of urban development, as well as conservation of Chinese cultural and natural assets. In the wake of the conference, a series of specific policies and regulations are being formulated (Xinhua News 2013).

The importance of this conference lies in the national leadership's redirection of China's urbanization from a focus on GDP to one on people and from urban sprawl to efficient land use. This has set the tone for China's urbanization process at a critical juncture.

3.2 Efforts relating to eco-cities at different levels of government

Since 1995, several policy documents have been issued by the State Environmental Protection Administration, the Ministry of Finance, the Ministry of Housing and Urban–Rural Development (MoHURD), and the National Development and Reform Commission (NDRC). These documents relate to the framework and evaluation criteria for eco-regions, eco-counties, eco-cities, and low-carbon city development, renewable energy demonstration cities, and low-carbon pilot cities. These documents have been highly influential in promoting the development of low-carbon eco-cities. In particular, NDRC issued a "Notice to Carry Out Low-Carbon Regions and Low-Carbon City Pilot Provinces" in 2010, with the main objective of building low-carbon cities. This document explicitly designated Guangdong, Liaoning, Hubei, Shaanxi, and Yunnan provinces and the cities of Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang, and Baoding, as pilot locations (Wang et al. 2013). In parallel, MoHURD issued a document entitled "Low-carbon eco-city pilot (town) application and management methods" (MoHURD 2011). Subsequently, MoHURD created the first pilot program that nominated eight eco-green districts from across the country.

Many more cities have spontaneously joined these efforts by implementing low-carbon eco-city development. For example, in 2010, during the planning of the Chenggong (Kunming New Town) city core area, the TOD approach was applied in place of automobile-oriented development. Compact and mixed land use, small road grids, and reduced building setbacks were accepted by the city and legalized within its regulatory plan in 2013 (Fig. 12) (Calthorpe Associate et al. 2012b). The new design was friendlier to pedestrians and cyclists, offered enhanced economic benefits to the developer, and was more economical since it was much less auto-dependent compared with the current single-function superblock model. The new plan is currently being implemented, and part of the area is under construction as per the plan. The first nine block areas have been developed in complete accordance with the design. However, some cities have misused the term eco-city by implementing limited undertakings such as planting trees and building green buildings without considering options for urban forms and people-focused development.

Among the pilot cities, a few have partially implemented sustainability measures and achieved good results. Examples include the Tianjin China–Singapore eco-city, Shenzhen-Guangming New Town in Guangdong Province, and the Kunming-Chenggong core area in Yunnan Province. Their main features are summarized in Table 4. As depicted in the table, eco-recovery, the realization of savings in energy and water use, clean energy use, and implementation of green building measures are widely regarded as the goals in pilot cities. Several projects have considered compact development and green transportation, while a few projects have considered small grids for road networks (Wang et al. 2013; Calthorpe Associates et al. 2012a and 2012b).

In addition to official efforts to develop sustainable cities, a number of international organizations and non-government organizations, including the World Bank, the Energy Foundation (EF), and the World Resource Institute, have focused on sustainable urbanization approached from different angles. These efforts commenced with EF's introduction of the Bus Rapid Transit system in Beijing in 2005. This initiative was followed by TOD and non-motorized transportation (NMT) pilot projects. On the basis of these projects, empirical studies, and local contributions, EF collaboratively developed eight principles for developing low-carbon sustainable cities. It has especially contributed to the last two pilot projects, the Chengong core area and Yuelai eco-city projects, listed in Table 4, by introducing international experts in the new urbanism and by working closely with local governments and design teams to plan and implement these projects. Apart from components common to other eco-cities, the

Fig. 12 Application of the TOD approach in the Chenggong (Kunming New Town) Core Area Master Plan (Calthorpe Associate et al. 2012b)

Chenggong and Yuelai projects incorporate additional features, including small street grids, TOD, a job–housing balance, and NMT development.

As previously discussed, the construction of superblocks has contributed significantly to the creation of pedestrian-unfriendly environments and more concentrated traffic and congestion. Of note, however, are several eco-cities that are making a special effort to develop small grid road networks, including, for example, the Chenggong core area in Kunming, the Yuelai eco-city in Chongqing, the Tianjin China–Singapore eco-city (Fig. 13a), and Caofeidian in Hebei (Fig. 13c). Figure 13 also provides a comparison, using the same scale, between the two Chinese eco-cities (Fig. 13a, c) and the renowned city centers of San Francisco in the USA (Fig. 13b) and Barcelona, Spain (Fig. 13d). This comparison demonstrates that the two Chinese eco-cities are moving toward developing smaller and more people-friendly street grids. While these grids are still large compared with those in other world cities, they, nevertheless, indicate that China has begun to explore the issue of ideal size in relation to its cities. However, as a result of habits, regulations, and resistance encountered from various

Table 4 Details of pilot eco-city development initiatives in China, including their goals and main features (Wang 2013; Calthorpe Associates et al. 2012a and 2012b)

Name	Area (SQ km)	Population (in 1000s)	Starting year	Proposed completion year	Primary goals	Main features
Tianjin China–Singapore eco-city	31.2	350	2007	2023	Economic prosperity, harmonious social life, environment friendly, energy efficiency	Transit-oriented development, mixed land use, eco-recovery, large eco land use and zero wetland lose, renewable energy, intelligent grid, untraditional water treatment and reuse, cleaning and utilization of garbage, green transportation and fuel, green building and eco-industry park
Caofeidian Eco-city in Hebei	74.3	1000	2007	2020	Green, eco-friendly, livable	No farm land taken, small street grid, mixed land use, eco-recovery, renewable energy, untraditional water treatment and reuse, recycled garbage, green transportation, 100 % green building, eco-industry park and R&D
Shenzhen Guangming New Town, Guangdong	156.1	800	2007	2020	Green, entrepreneurship, and harmonious new town	Compact land use and proper allocation of functions, wet land recovery, emission treatment, greening roads, reuse of flood water, enclosed garbage treatment, pedestrian and car grade separation, transit priority, green building by national standard, high value and green industry
Chenggong Core Area	9.8	150	2010	2020	Pedestrian and bicycle-friendly, small grid, mixed land use and job–housing balance, transit priority, land use compatible with transit network, green building.	Breaking up of superblocks, non-motorized roads, small grid system, small setbacks and turning radius, high-density mixed land use focused on transit knobs and corridors, green buildings
Yuelai Eco-city in Chongqing	3.4	50	2010	2020	Natural eco-resources protection, pedestrian-friendly, small grid, mixed land use and job–housing balance, transit priority, land use compatible with transit network, green building	Small grid following natural resources protection, high-density mixed land use focused on transit knobs and corridors, escalators accessing river, green buildings

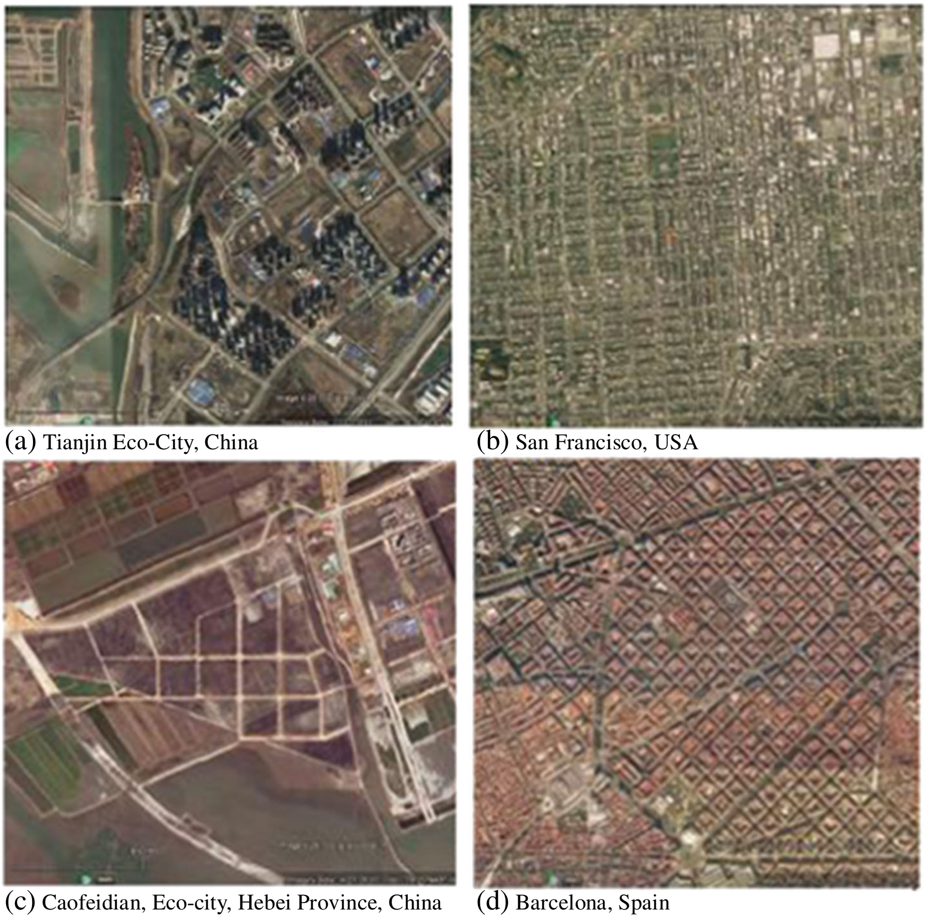

Fig. 13 A comparison of China's proposed human-scale street networks for its eco-cities in **a** Tianjin and **c** Caofeidian with those of **b** San Francisco and **d** Barcelona (source: Google Earth)

sources, there are demanding challenges ahead in making this idea a reality in terms of planning and implementation processes.

3.3 Green transportation and TDM efforts at different levels of government

Over the last decade, transit issues have emerged as a priority within China's national urbanization policy, and several important policy documents on sustainable transportation have been issued within the last few years. In 2012, the Ministry of Transportation (MOT) proposed developing a "Transit Metropolis" in China. So far, 37 pilot cities have been designated for this initiative. Each of these cities, in turn, has developed detailed strategies and public transit development goals (mainly mode sharing for public transit) and is being closely monitored in accordance with MOT's evaluation criteria.

In addition, the central government has made enormous efforts in developing the NMT system. MoHURD has been conducting a National Walking and Cycling Transport System demonstration program since 2010. In 2012, MoHURD, the NDRC, and the Ministry of

Finance jointly issued a document entitled "Guidelines to Enhance the Urban Pedestrian and Bicycle Transportation System." Further, in 2013, the States Council issued a "Guideline to Enhance the Urban Infrastructure System," which re-emphasized people-focused transit as a priority, as well as high-density street networks and enhanced facilities for pedestrians and cyclists. On the last day of 2013, MoHURD issued the policy document "China's Urban Pedestrian and Bicycle Transportation System Planning and Design Technical Guidelines," which sets up a landmark for Chinese NMT system development (MoHURD 2013). The first national guideline of its kind, this document clearly stipulates that each city should develop a NMT plan by 2015 and provides all the recommended technical standards. In 2014, MoHURD proposed to designate 100 NMT pilot cities to create momentum for these initiatives.

Following the examples of Shanghai and Beijing, several cities have started to adopt travel demand measures to help alleviate severe traffic congestion and air pollution. Beijing has developed a combined package composed of 28 measures, including a quota for car purchasing, increased parking fees, and restrictions on car use according to license plate numbers. Other cities, including Guangzhou, Guiyang, Chengdu, and Tianjin, have all started to restrict new car purchases. Together with the enhancement of subway development and the prioritization of transit, the total transit share has begun to rise, and the increase in the proportion of private vehicles has begun to slow down. Congestion levels have shown some improvement, but there is a significant way to go before they show meaningful decreases. The results illustrate that these measures have had certain positive effects, although NMT shares continue to drop in most cities. As Fig. 14 indicates, in Shenzhen, the use of public transport (bus and metro) as a proportion of total transportation use increased from 44.2 to 46.9 % between 2005 and 2012. Notably, metro use increased from 1.7 to 9 % between 2005 and 2012 (SUTPC 2013). While these data indicate that TDM has had some effect, more efforts are required to achieve a meaningful shift toward congestion reduction and carbon reduction. Beijing experienced a reduction in congestion between 2011 and 2012, but congestion bounced back to a slightly higher level in 2013, as shown in Fig. 15 (BTRC 2013).

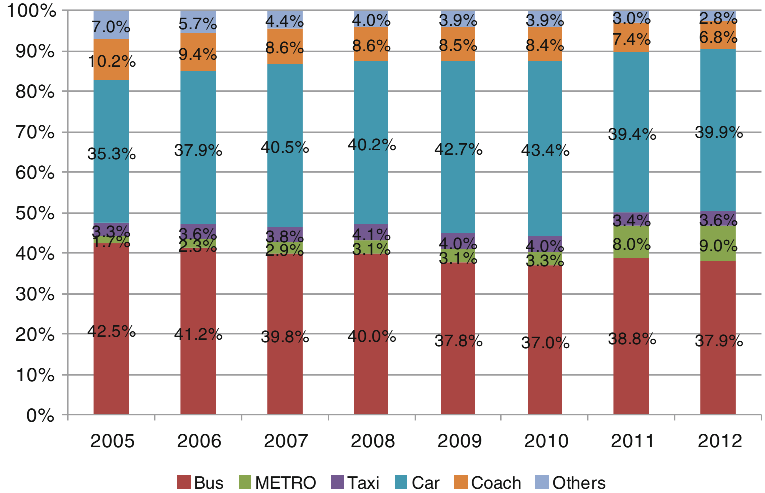

Fig. 14 Proportions of different modes of transport used in Shenzhen from 2005 to 2012 (SUTPC 2013)

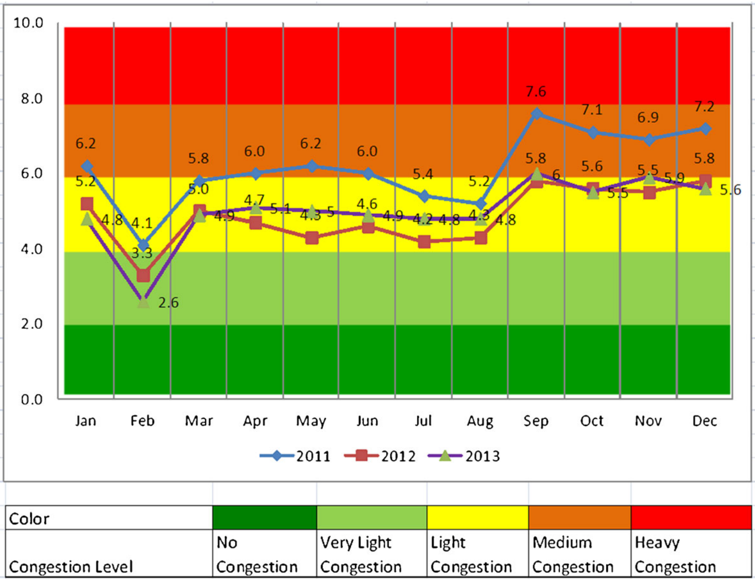

Fig. 15 Beijing's Congestion Index before and after the implementation of Travel Demand Management measures from 2011 to 2013 (BTRC 2013)

4 Conclusions

Urbanization in China is a large-scale, rapid, and multi-issue process with some characteristics that are common to urbanization processes in other world cities, but with others that are uniquely Chinese. Sustainable urbanization is critical for ensuring the livability of China's cities and contributes to energy savings and reduced carbon emissions. Transportation systems determine the urban fabric, and urban layouts create the foundation for the livability and travel demand characteristics of cities. Although China's new urbanization concept is a valuable one, many details, policies, and regulations still need to be developed and localized. Achievements within each of the Chinese pilot projects have offered valuable lessons. The main challenge that is currently being faced is the speed of the urbanization process (approximately amounting to one additional city per year). Once the urban layout of a city has been fixed, it is very difficult to correct. The coming 15 years will thus be critical. All stakeholders, including government agencies and urban planners, must work together to avoid the creation of future development issues originating from past mistakes.

Throughout the last decade, EF has been working with international experts, Chinese pilot cities, and ministries. In collaboration with other organizations, the Energy Foundation in China has developed the following eight principles in support of the goal of sustainable, people-friendly cities:

- Develop neighborhoods that are conducive to walking,
- Prioritize bicycle networks,
- Create dense networks of streets and paths,
- Create mixed-use neighborhood zones,
- Support high-quality public transit,
- Match density to transit capacity,

- Create compact regions with short commutes, and
- Increase mobility through parking and road regulations.

Urban planners should consider implementing the following measures to support sustainable urbanization in China:

- Introduce international best practices and identify the characteristics and unique qualities of individual cities;
- Identify best practices in the Chinese context and scale these up by working with related government agencies to develop regulations and standards;
- Develop appropriate evaluation criteria and tools to measure the success of sustainable cities, identify deficiencies, and select proper plans; and
- Conduct education and training programs for all levels of decision-makers, planners, and students.

As discussed above, the efforts made in controlling carbon emissions by means of the urbanization process in China illustrate another perspective of carbon emission mitigation. Compared with supply-side mitigations such as energy supply efficiency improvements, the efforts described in this paper aim to change people's activities and behavior through adjusting urban development patterns to reduce energy demand. Given the fact that urbanization will be one of the key economic driving forces in China (and in the developing world) for the next few decades, the measures presented in this paper regarding urbanization practices can contribute greatly to carbon emission reduction in the developing world. Even for the developed world, some of these measures, such as promotion of public transit and non-motorized trips such as biking and walking, can play an important role in shifting people from cars to green transportation to reduce carbon emissions from the urban transportation sector.

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