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Comprehensive evaluation of environmental and economic benefits of China's urban underground transportation construction projects

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Abstract

Urban underground transportation projects are introduced to address problems of scarce green land and traffic pollution. As construction of urban underground transportation is still in its infancy, there is no definite quantitative measurement on whether the construction is beneficial and what influences it will place on the region in China. This study intends to construct a comprehensive evaluation method for evaluating social, economic and environmental benefits of urban underground transportation projects and proposes the concept, role and principle for evaluation of environmental and economic benefits. It figures out relationship between the environment and factors of city development. It also summarizes three relevant factors, including transportation, biophysics and social economy, and works out indicators to evaluate the influence of urban underground transportation construction. Based on Contingent Valuation Method (CVM), Cost of Illness Approach (CIA), Human Capital Approach (HCA), this paper constructs 13 monetization calculation models for social, economic and environmental benefits in response to seven aspects, namely, reducing noise pollution and air pollution, using land efficiently, improving traffic safety, reducing traffic congestion, saving shipping time and minimizing transportation costs.

Key words

Economic benefits, Environmental benefits, Monetization model, Underground transport

Introduction

The 21st century has witnessed an increasingly severe problem of China's urban environment, such as air pollution (Chan and Yao, 2008; He *et al.,* 2002), noise pollution (Dong *et al.,* 2011; Li *et al.,* 2002), extreme lack of green space (Li *et al.,* 2005; Wang, 2009), nerve-wracking traffic congestion (Gu *et al.,* 2012; Long *et al.,* 2008), long-term coexistence of pedestrians and vehicles (Tang *et al.,* 2010) and undesirable community split (Yaping and Min, 2009), which makes it an imminent task to develop underground space (Sterling *et al.,* 2012). However, most of the underground space in China has been developed as commercial centers and parking lots, which can achieve significant economic benefits in short time. Driven by these huge economic benefits, the developers are actively engaged in such kind of construction (Bobylev, 2009). Meantime China's urban underground transportation construction is still in a relatively lagging stage (Chen *et al.,* 2009). The reason is that in China, it is generally believed that the investment on underground space construction projects is significantly higher than that of same facilities on the ground (Anas and Lindsey, 2011). Furthermore, people have not collected enough information about the social and environmental benefits generated by underground space. Environmental and economic benefits of project proposals and technology methods have not been integrated into economic estimates. All these factors mentioned above lead to the fact that projects with environmental protection are not fully supported and projects with environmental damage are not strictly restrained in China. The development of urban transportation can not only solve the problems of urban transportation and reduce urban pollution, but also save the ground land for composite development of urban greening and further achieve the goal of improving urban ecological and living environment. Relationship among underground transportation, greening and road space is shown in Fig.1.

Fig. 2 shows dynamic causal relationship among underground transportation, urban environment, urban traffic and urban development. There are 3 major dynamic feedback loops: I. Sustainable urban development→large traffic demand→ serious urban traffic congestion→increase in ground transportation→large urban traffic pollution’!serious urban air pollution→limiting the sustainable urban development. II. Large amount of urban ground transportation→less urban greening area→large urban traffic pollution→severe urban air pollution’!limiting sustainable urban development→hindering economic development→hindering the development of urban transportation. III. Development of underground transportation→ increase in available urban ground area→increase in urban greening area→reduction of urban traffic pollution→ corresponding reduction of urban air pollution→sustainable urban development→economic development→underground transportation development.

It can be seen that feedback loops I and II are vicious cycles, while the development of underground transportation construction projects presents a virtuous cycle as shown in feedback loop III.

In terms of evaluating of Environmental and Economic Benefits of Underground Transportation, the possible factors that affect engineering construction shall be analyzed in a comprehensive way, which is mainly divided into traffic and transportation, biophysical environment and social and economic environment, respectively.

For example, the United States has carried out the most complex, the most grand and the most technically challenging construction project in Boston in the 20^{th} century since 1994. The project includes demolishing the original six-lane elevated Central Artery, and building an eight or ten-lane underground expressway and an eight-lane underwater tunnel throughout Boston Harbor that leads to airport (Central Artery/Tunnel Projectÿ CA/T). Fig. 3 shows City Environmental comparison before and after completion of CA/T. After CA/T project was completed, the average congestion time on expressway shortened from 10 hrs to 2 hrs and urban CO emissions was reduced by 12% (Marquez and Smith, 1999).

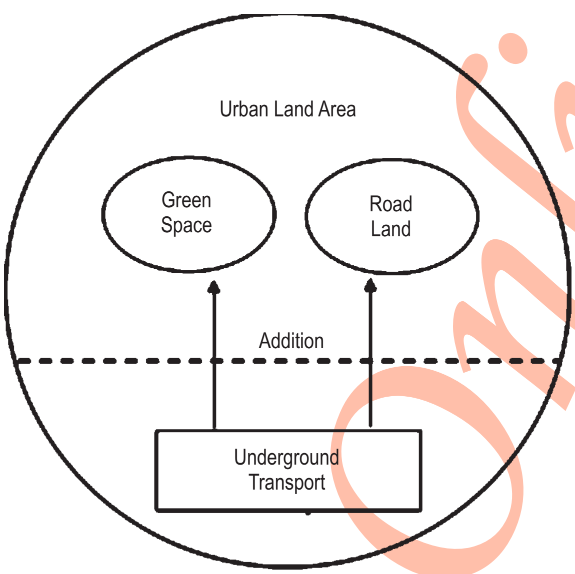


Fig. 1 : Relationships between underground transportation and ground space

At the end of last century, some advanced countries such as Netherland, which attached importance to environmental protection, proposed that the focus of indicator system of comparing diverse engineering project proposals should be transferred from “Technology and Economy” to “Technology, Economy and Environment”. Only by doing so the ecological awareness of society can be truly integrated into the projects that will bring about ecological environmental compensation and inhibit short-term benefit pursuits.

Tokyo underground logistic system is located in District 11 with a network of 201 km. Suppose that only the direct economic benefits are considered and the constructors bear all construction costs, the total investment cost cannot be returned even with toll charges. However, given the benefits brought by the system such as reducing traffic jam and improving environmental protection (see Table 1), the cost-benefit ratio in first stage is 4.6. In addition, the proportion of cost-benefit is increasing with the expansion of network. It is expected that the cost-benefit will reduce to approximately 3.5 when the entire network is completed.

In order to realize the optimization of project and proposal decision, not only construction cost but also the social and environmental benefits are required to be fully considered for their economic benefits. Therefore, a comprehensive evaluation of environmental and economic benefits of Underground Transportation Construction Projects is of great importance.

Apparently, due to relatively high cost, the scientific economic argument is necessary before conducting a large-scale underground transportation construction project. Given the social and environmental benefits of the project, underground transportation indicates an irreplaceable advantage. Since China’s Urban Underground Transportation Construction Projects are still at initial stage, no explicit evaluation methods are available for both citizens and government in determining whether it is suitable to be applied for the construction of underground transportation in some given areas and what will be the potential influence of underground transportation development on the comprehensive environment. Thus, it is of great significance to regulate and raise the idea for evaluation of environmental and economic benefits of China’s Urban Underground Transportation Construction Projects. The economic benefit assessment of underground transportation construction requires a monetary calculation of construction's environmental benefit and social benefits. Therefore, an in-depth understanding of current status and a comprehensive method of accurately evaluating environmental and economic benefits of urban underground transportation construction project are in urgent need. It aims at proposing a comprehensive evaluation index system for social, economic and environmental benefits of underground transportation projects and working out a comprehensive evaluation model after analyzing how the projects react to environment and development.

Ridker adopted Human Capital Approach (HCA) to calculate the United States' economic loss from disease mortality caused by air pollution in 1958 and concluded that the total health benefits from air pollution control was $ 80.2 billion (Ridker and Ronald, 1967). This study led to beginning of calculating and evaluating economic benefits of environmental governance. From then on, National and International Organization (such as the World Bank, World Health Organization etc.) have carried out a series of studies on the environmental and economic benefits to support the evaluation of environmental policy (Burton, 1987; WHO, 2000, 2006).

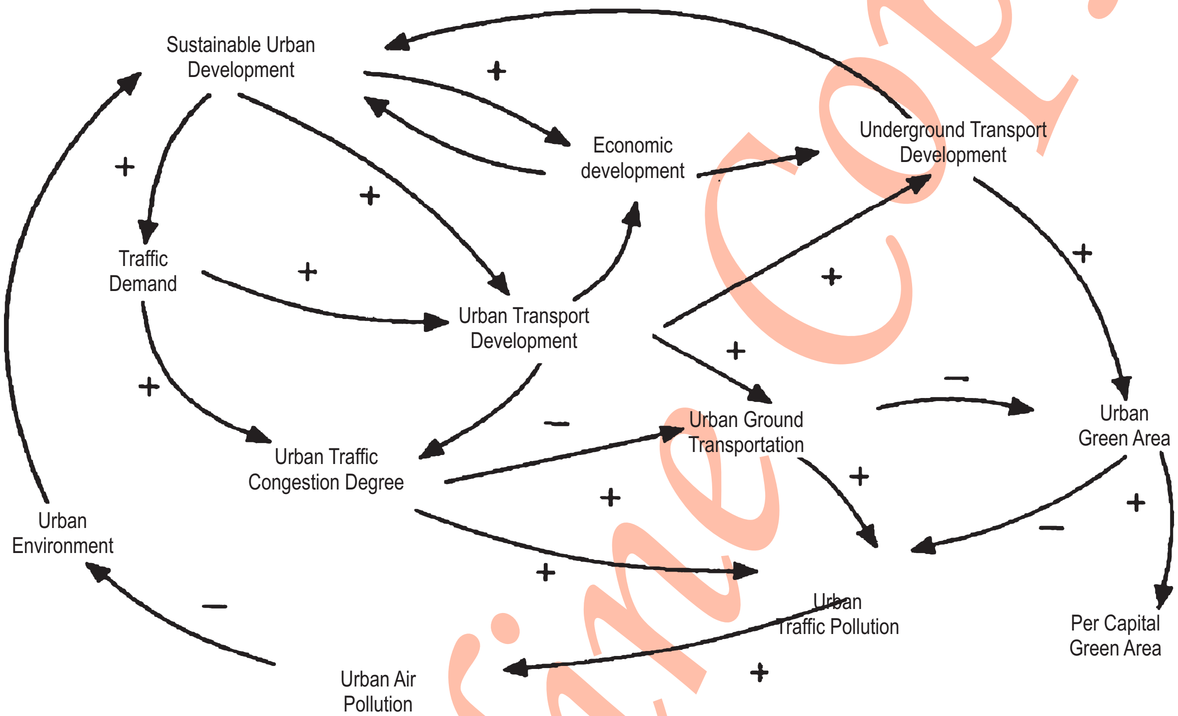
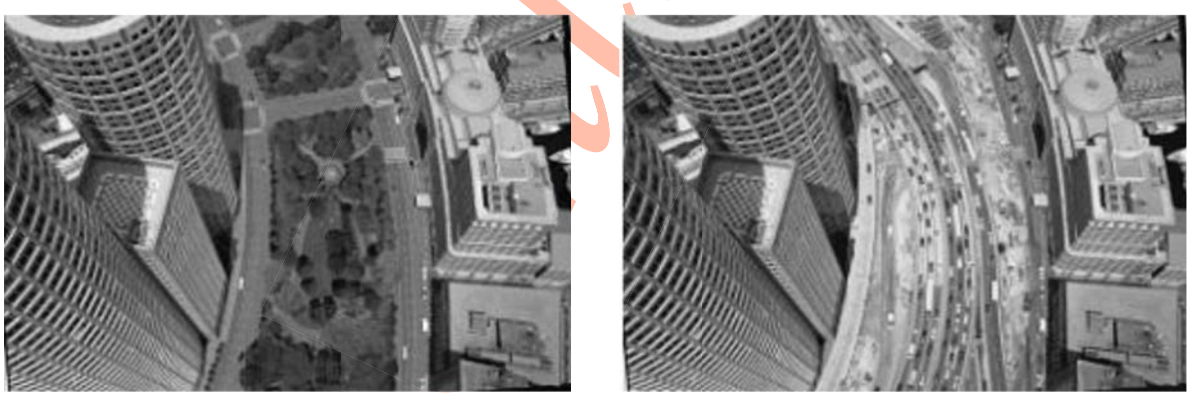


Fig. 2 : Casual relationship between urban development, urban traffic, underground transportation and urban environment



After completion Before completion

Fig. 3 : Environmental comparison of the city before and after completion of CA/T

As American Lung Association (Cannon, 2002) calculated, the direct medical costs from 1985 to 1989 caused by air pollution totaled $ 16 billion and economic loss of lower productivity due to illness stood $ 24 billion. These two combined were as much as $ 40 billion. World Bank Technical Report in 1995 (Wijetilleke and Karunaratne, 1995) showed that if lead, particulate matter, ozone and sulfur dioxide in Bangkok in 1994 were 20% less, $ 96 to $ 402 per capita health benefits could be generated. In 2000, it was predicted that in Ontario (Ted *et al.,* 2000), the annual impact of urban air pollution on health was about $ 10 billion, of which loss of life, life quality losses, medical expenses and productivity losses were $ 4.1 billion, $ 4.8 billion, $ 600 million and $ 560 million respectively.

Chinese researches on environmental and economic benefits mainly focused on economic loss caused by environmental pollution. In 1984, "Year 2000 China Environmental Prediction and Countermeasures" in which thousands of experts were engaged in estimated nationwide economic loss caused by environmental pollution for the first time (Guo and Zhang, 1990) and concluded that the loss from 1981 to 1985 averaged 38 billion yuan annually. Among them, air pollution cost 124 million, accounting for 32.5% of environmental pollution loss. Guo and Zhang (1993) led the study of "Guo-Zhang Model". Due to high academic value and practical value, the study was frequently cited by other people. The results of these studies showed that environmental pollution loss accounted for a large proportion of total loss, revealing severe consequence of air pollution. The study also found that air pollution was the biggest culprit of health. However, the researches relied on different kinds of assessment techniques with various categories, which made it hard to unify parameter selection, so that the estimation results varied from one another.

In terms of methodology, most of the researches have followed the "Guo-Zhang Model" since 1980s. This model included the evaluation content, health impact, and value assessment. For example, Zhou Anguo et al estimated roughly the economic loss from air pollution in Zhejiang Pronvince in 1996 and found that the loss of human health reached up to 1.27 billion yuan, taking up one third of the total economic loss (Zhou and Feifei, 1998). Wang *et al.* (2005) to calculate the economic loss of human health and agriculture and the clean-up costs caused by air pollution in Shandong Province from 2000 to 2002. Their results showed that the loss was more than 15 billion yuan every year, accounting for 1.85% -1.92% of GDP (Wang *et al.*, 2005).

After 2000, Jin and Dong (2004) conducted the monetization research on health loss from air pollution in Wushun based on Xu Zhaoxiang's research (Jin and Dong, 2004) the loss of 157.34 million Yuan in Dalian in 1996 through Human Capital Approach (HCA) (Xu and Hongguang, 2001).

In addition, few studies are available that have taken dose-response method. The dose-response coefficient is selected in line with World Bank's standards or global epidemiological studies. Han Guifeng, Ma Naixi estimated the wage loss due to premature death, loss from medical expenses and lost income in Xi'an, and concluded that in 1995 TSP brought about 201 million Yuan of economic loss (Han and Ma, 2001).

Table1 : Benefits of underground logistic construction in Tokyo at different stages (Taniguchi, Ooishi and Kono, 2000)

Benefits	Phase 1	Phase 2	Phase 3
Traffic-related benefits(One hundred million yen / year)	145	142	116
Time-related benefits(One hundred million yen / year)	8,490	9,084	11,360
CO_2 reduction benefits(One hundred million yen / year)	44	48	68
NO_x reduction benefits(One hundred million yen / year)	345	392	617
Reduce traffic benefits(One hundred million yen / year)	83	94	149
Total(One hundred million yen / year)	9,107	9,761	12,309

Table 2 : Benefits of ground and underground railway in Delft, Holland (Reid, 2012)

Monetization	Viaduct program	Tunnel (dug-style)	Tunnel (TBM method)
Construction cost	308	494	536
Land/ migration / destruction	122	146	37
Direct cost	430	640	573
	100%	148%	133%
Operations and maintenance cycle	31	64	47
Life Cycle Cost	461	704	620
	100%	152%	134%
Damage (In terms of money)	133	168	5
Overall cost and damage	594	872	625
	100%	147%	102%

Wang Li referred to Han Guifeng and estimated that health loss from atmospheric particulate matter was up to 251.6 million Yuan (Song *et al.,* 2006).

Foreign scholars also conducted a series of studies in China. In 1997, the World Bank estimated that the economic loss from air and water pollution was $ 54 billion per year, or 8% of GDP. The results were described in Blue Sky Blue Water: China's Environment in the 21st Century (Johnson *et al.,* 1997). In 2007, World Bank once again estimated China's environmental pollution loss with PM_{10} as an indicator of air pollution. It reached a conclusion that in 2003, Chinese urban air pollution-related health cost averaged 1570-52900 Yuan, about 1.2-3.8% of GDP (Ho and Nielsen, 2007). Harvard University simulated pollutant emissions and space distribution of various industry sectors, assessed their impact on health and calculated the profits of pollutant emissions control (Cao *et al.,* 2009).

The literature review indicates that domestic researches mostly paid attention to the damage of air pollution and bad influences on health. They rarely considered measures to improve environment and took environmental benefits into account. Human Capital Approach (HCA) has been the one of the dominant methods. Cost of Illness Approach (CIA) is a complementary approach taken by most of the studies. Some even use foreign willingness to pay (WTP) to value damage (Zhang, 2010). This method aims at addressing development issues in underground transportation construction for the purpose of efficient use of land, increasing the green area and the ground open space, reducing environmental pollution, improving urban ecology and bringing many other benefits (Carmody *et al.,* 1993). But now researches on underground transportation development are very limited. Environmental benefits for Japan and Netherland described in the first chapter were only a source of data rather than an analysis model.

Several scholars have studied the relevant issues of underground transportation system from diverse perspectives inducing the stability (Chuanhua and Qingwen, 2004), risks (Fouladgar *et al.,* 2012), the safety (Canós and De Zulueta, 2004), and the profitability. Other studies proposed that the cost analyses of underground transportation in different countries and regions such as Barcelona (Riera and Pasqual, 1992) and New York City (Berechman and Paaswell, 2005) should be taken as case studies.

However, little has done in the detailed discussion about the important role and the general evaluation methods of urban underground transportation projects. Therefore in this study, the role of urban underground traffic construction project will be discussed at length. In addition, the purpose, significance and comprehensive economic evaluation methods of underground traffic construction projects will also be proposed.

Materials and Methods

In terms of evaluation of Environmental and Economic Benefits of Underground Transportation, the possible factors that affect the engineering construction shall be analyzed in a comprehensive way, which is mainly divided into urban biophysical environment and social environment.

Measurement of biophysical environment impact is the core of urban underground transportation environment assessment. (1) Terrain, geology and soil. Before engineering construction, the terrain, geology and soil of engineering construction area shall be described in detail. The analysis of terrain should be carefully conducted, including the minerals with important economic value, energy and slope stability in order to ascertain the possible impact of the construction on surface, underground materials and geologic structure (Loew *et al.,* 2007). The corrosive substance in the soil should be examined within some certain scope. (2) Underground water quality. The depth, quality, quantity, distribution and utilization of underground water in the area should be determined. (3) Surface water quality. The impact of engineering construction on neighboring waters, rivers, and water resource in reservoir needs to be clarified. The change in water quality due to construction should be considered from physical, chemical and biological perspectives. The seasonal water flow changes should be compared to that under normal conditions. (4) Air quality. The impact of engineering construction on air quality can be divided into two parts including during construction and after completion. The assessment of air quality during construction shall associate engineering construction with the change of air quality of neighboring area to estimate the potential impact, thereby proposing the management and supervision of air quality during construction (Yuan *et al.,* 2014). After completion, the air quality around construction areas shall be connected with the air discharge of underground transportation (Chang *et al.,* 1981) where the main factors consist of the position of outlet in underground transportation, traffic flow, and local terrain characteristic and meteorological data. (5) Noise and vibration. Noise monitoring equipment should be set in the entrance, important road section, and ventilation facilities of urban underground transportation. Proper models should be established to calculate the noise produced by some essential areas and data of vibration as well as to analyze the vibration produced by the vehicles passing through the urban underground transportation and the impact of noise on surface. (6) Flora and fauna formation. Both land and aquatic animals and plants adjacent to engineering construction will be explored in order to determine their species, bio-coenosis, growing environment, health status and potential threat they face due to noise, dust and light during the engineering construction (Holmberg *et al.,* 1991). All possible damages to plants and animals caused by construction directly or indirectly should be demonstrated. The content will contain the impact on ecological environment caused by the change of surface and underground water due to construction.

The keys to the evaluation of urban city underground transportation is to evaluate the social, economic and environmental benefits. Land use should be investigated the local land use and the land planning in the adjacent areas to know about the land tenure of various lands The land changes resulting from the construction projects should be evaluated. (2) Historical and cultural heritage. Prior to the construction project, the lists of local historical and cultural heritages should be systematically examined with field trips and site visits. The large quantity of information of heritage in the project location shall be gathered based on which the final environmental evaluation can be conducted. (3) Social environment. It is inevitable to investigate and evaluate the social environment of the project, including the research on people's health status, housing conditions, social foundation, people quality, and social security (Thomas, 1986). The potential impact of the construction project on people's life quality, population growth, values and social assets should be evaluated (Zhang *et al.,* 2009). The public, the government and the investors should hold discussions together to quantify the effects and benefits of the projects and thereby identifying the social benefits in detail according to the technical evaluation. (4) Economic environment. The economic assessment is mainly conducted through evaluating the economic benefits before and after the construction (Thampapillai and Sinden, 2013). In this work, the relationship between the construction project and local labor force, labor market and job opportunity changes is considered. The project's potential and prospect can be deduced from the commercial and real estate developments caused by the project, and also from the time and cost changes by driving private cars, taking buses, riding bikes and walking past this region.

On the basis of the above analysis, the ecological indicators commonly used in the city underground tunnel construction can be sorted. By analyzing the role and function of each indicator in the environmental evaluation of the city underground tunnel project, this study determined the evaluation indicator system as shown in Table 3. Based on existing social benefits and environmental benefits calculation theories, this paper proposes an improved method to calculate social (Social environment) benefits and environmental (Urban biological environment) benefits, as shown in Fig.4.

In this paper, "with-without method" is adopted to do the evaluation in which real situation is compared to that of the absence of actual occurrence for the purpose of weighing real benefits and influences. The key is to distinguish the influence of the project and that of external factors (Shadish *et al.,* 1991). It is worth noticing that the economic benefits should be attributed to the project rather than external factors.

For a project as huge as underground transportation, there is a necessity to pay attention to the real effects and influences after construction and take external factors into account (Pimentel, David, *et al.,* 1995). The willingness to pay for extra fees of individuals in the society is categorized as direct benefits of the project. Environmental and social benefits are indirect benefits. Social benefits here refer to the effects reached but cannot be measured by money, such as saving the cost of transport, saving shipping time and other economic benefits generated from better transportation. Environmental benefits include reducing the number of vehicles on the ground, less consumption of fuel, less air pollution, etc.

Table 3 : Indicator system of the environmental impacts evaluation of urban tunnel

Factors	Sub-system	Details
Urban biological environment	Terrain, geology, soil	Unbalanced strata movement, uneven subsidence, soil erosion, desertification rate
	Groundwater	The affected scope, distance between the project and the susceptible area
	Surface water	Quantity of the affected water resources, pollutants gathering, distance between the project and the susceptible area
	Air	Pollutants emission and gathering, population subjected to the polluted area
	Noise and vibration	Noise and vibration level, the affected population
	Plants, animals	Diversity index changes, Species evenness changes, Species dominance
Social environment	land	Project areas and length of time
	Historical and cultural heritage	Historical relics loss, distance between the project and these regions
	Social environment	People's health status, housing conditions, social foundation, people quality, social security
	Economic environment	The relationship between the construction project and local labor force, labor market and job opportunity changes, commercial and real estate developments arising from the project
	City design and visual environment	Visual effect's scope and features
	Engineering risks	Hazardous materials of the project, accidents and various natural disasters

Social benefits refer to external effects reached but cannot be measured by money. It is presented in the way of reducing transportation costs, saving shipping costs, reducing congestion, improving traffic safety and efficiency and using land efficiently of underground transportation.

Monetization of social benefits is computed by equation (1).

$$B = \sum B_i \qquad (1)$$

Where B is the total social benefits of underground expressway. Various social benefits of underground expressway are reflected in transportation cost saving benefits B_1, transportation time saving benefits B_2, congestion reduction benefits B_3, high traffic safety benefits B_4 and land conservation revenue benefits B_5. In accordance with the method of "with and without comparison", the above social benefits can be monetized.

The economic losses caused by pollution depend on the degree of environmental pollution. The quantitative relation between them can be expressed by "hazard and loss cost curve". As shown in Fig.5, the pollution degree is expressed reduction amount of pollutants. The hazard degree is measured by economic losses resulting from pollution, or to say, expressed by the pollution losses of the pollutants discharged. The hazard degree increases with the increase in the quantity of pollutants discharged and with

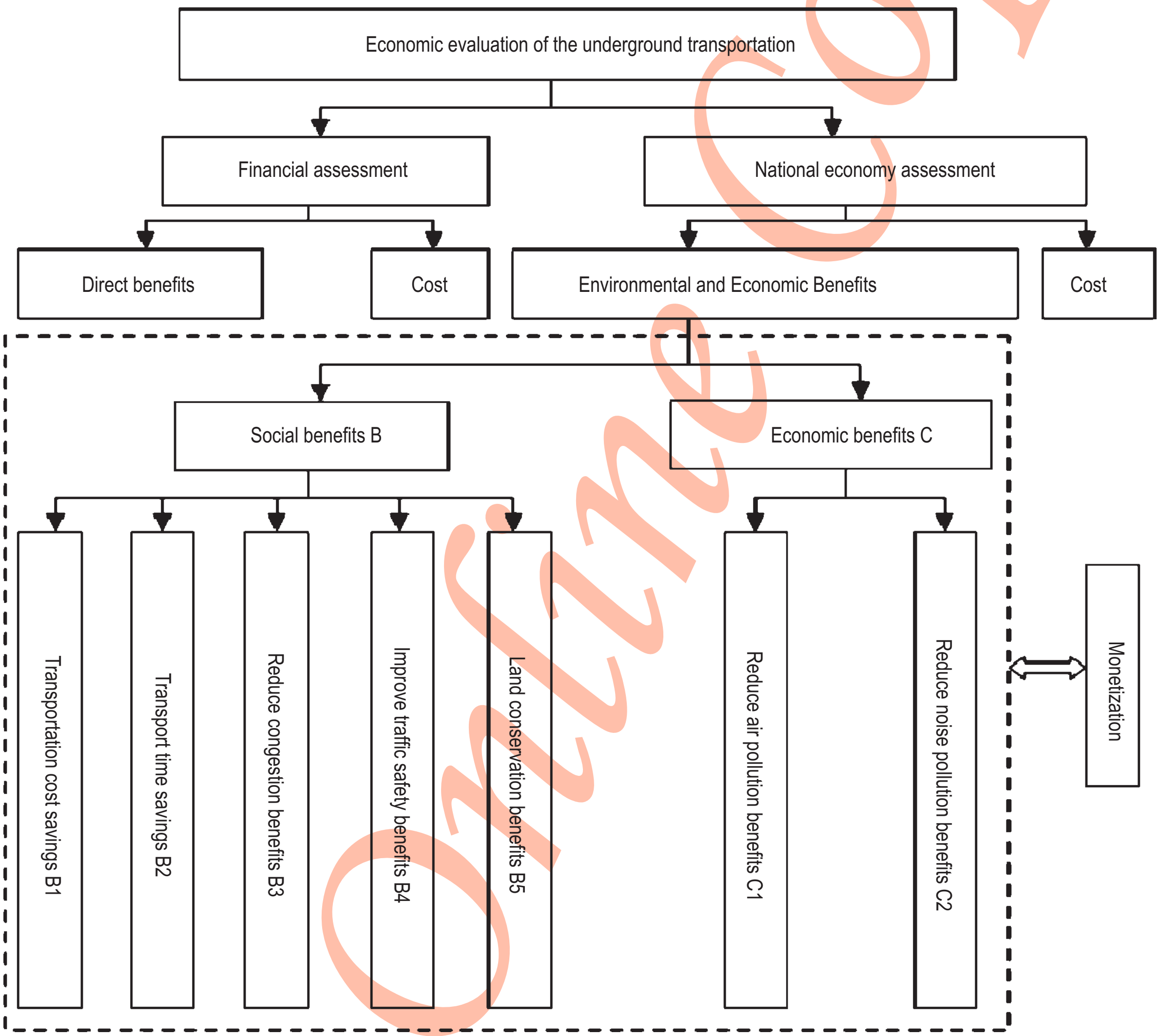


Fig. 4 : Flow chart of benefit assessment on underground transport project

the decrease of the reduction amount of pollutants. The hazard curve shows an upward trend from right to left and the growth rate gradually increases, forming a quadratic curve.

Pollutant reduction cost depends on the reduction amount of the pollutants, and their quantitative relation can be expressed by the cost curve. The cost of pollution reduction increases with the increase of the reduction amount of pollutants. Its growth rate is a bit slow at the beginning and then quickens gradually.

Before the underground transportation construction projects are implemented, the value of the pollutants is in a state *a*; after their implementation, the value of the pollutants is in a state *b*. Then, the pollutants are reduced by Δa. Thus, pollution losses cost is reduced by Δh_1, which is shown in the curve from state 1 to state 2. In the meantime, the treatment cost saved is Δh_2, which is shown in the curve from state 3 to state 4. So, the formula is as follows:

$$EN = \Delta h_1 + \Delta h_2 \quad (2)$$

In the formula, *EN* represents the environmental benefits of underground transportation construction projects; Δh_1 is the pollution reduction benefits; Δh_2 is the treatment cost saved. Among the underground transportation construction projects, environmental benefits are mainly comprised of air pollution reduction benefits and noise pollution reduction benefits.

This paper relies on Contingent Valuation Method (CVM) to see how the interviewees perceive the value of reduced noise pollution because of underground transportation construction. Contingent Valuation Method, (CVM) is typical to assess the risk of illness or death due to environment pollution. Usually, interviewees are asked what are their WTP (willingness to pay for this change) or WTA (willingness to be compensated) under different situations. By confirming people's pricing on resources, it can be understudied the WTP and evaluate the value of environment (Mitchell, Robert Cameron, and Richard T. Carson, 2013). There are two types of questions for underground transportation projects: WTP: How much are you willing to pay to free from the environment noise; WTA: How much do you ask to give for bearing the environment noise; WTP is restricted to individual income. But WTA is not. There is no cap limits for WTA and thus it is hard to be measured accurately. Therefore, this paper adopts WTP rather than WTA to evaluate the loss from noise pollution.

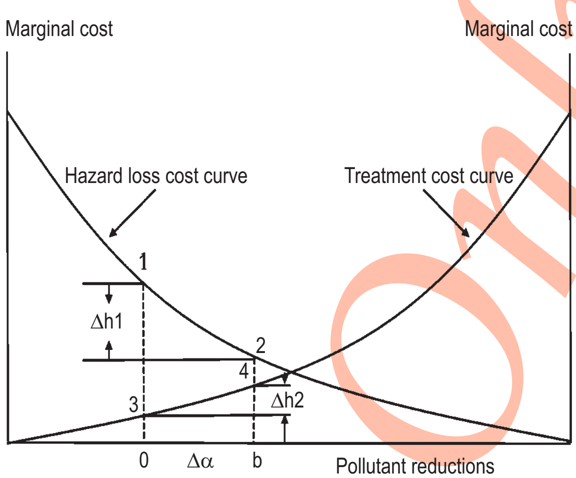


Fig. 5 : Hazard loss curve and cost curve model of governance

Results and Discussion

Transportation cost saving benefits refer to lowered transportation costs owing to implementation of underground transportation projects. Calculation of transportation costs benefits is in accordance with freight savings of normal traffic, transfer traffic and induced traffic. The gap between transportation costs under the underground transportation system and without the system is the exact reduced amount of transportation costs.

According to the normal transportation amount, the calculation formula is shown in equation (3).

$$B_{11} = (C_w L_w - C_y L_y)\, Q_m \quad (3)$$

In the formula, B_{11} is the transportation cost saving benefits (10,000 Yuan a^{-1}) under normal transportation amount; C_w and C_y are the unit transportation costs (Yuan t^{-1} km or Yuan person^{-1} km) with the project and without the project respectively; L_w and L_y are the transportation distances (km) with the project and without the project respectively; Q_m is the normal transportation amount (10,000 t a^{-1} or 10,000 people a^{-1}).

According to the transfer transportation amount, the calculation formula is presented in equation (4).

$$B_{12} = (C_z L_z - C_y L_y) Q_z \quad (4)$$

Where B_{12} is the transportation cost saving benefits (10,000 Yuan a^{-1}) under transfer transportation amount; C_z is the unit transportation cost (Yuan t^{-1} km or Yuan person^{-1} km) of the original transportation line; L_z is the transportation distance (km) of the original transportation line; Q_z is the transfer transportation amount (10,000 t a^{-1} or 10,000 people a^{-1}).

Passengers' time saving benefits are calculated by the numbers of production personnel of normal passenger volume and transfer passenger volume respectively. When calculated, only half of the time saved is used for production.

According to normal passenger volume, the calculation formula is shown in equation (5).

In the formula, B_{21} represents passengers' time saving benefits (10,000 Yuan a^{-1}) under normal passenger volume; b is passengers' unit time value (Yuan h^{-1}) calculated by national income per capita; T_n is the time saved (h $person^{-1}$); $T_n = T_w - T_y$ (T_w and T_y are the travel times with the project and without the project respectively); Q_{np} is the number of the production personnel (10,000 people/a) under the normal passenger volume.

According to the transfer passenger volume, the calculation formula is shown in equation (6)

$$B_{22} = \frac{1}{2} bT_z Q_{zp} \qquad (6)$$

In the formula, B_{22} represents passengers' time saving benefits (10,000 Yuan a^{-1}) under transfer passenger volume; T_z is the time saved (h $person^{-1}$); $T_z = T_o - T_y$ (T_o is the travel time on other transportation lines); Q_{zp} is the number of production personnel (10,000 people a^{-1}) under transfer passenger volume.

The benefits of congestion reduction are produced by the alleviation of congestion of related transportation lines and facilities, whose calculation formula is presented in equation (7).

$$B_3 = (C_z - C_{zy}) L_z (Q_{zp} - Q_z) \qquad (7)$$

In the formula, B_3 represents benefits (10,000 Yuan a^{-1}) brought by congestion reduction; C_{zy} is the unit transportation cost (Yuan t^{-1} km) of the original related transportation lines and facilities under the situation with project. The calculation formula of the benefits brought by improvement of traffic safety is shown in (8).

$$B_4 = P_{ah} (J_w - J_y) M \qquad (8)$$

In the formula, B_4 represents the benefits (10,000 Yuan a^{-1}) brought by improvement of traffic safety; P_{ah} is the average losses fees (Yuan $times^{-1}$) of traffic accidents; J_w and J_y are the accidents rates (times ten^{-1} thousand vehicles km) with the project and without the project respectively; M is the transportation amount (10,000 vehicles km a^{-1}).

Traffic accidents damage costs can be referred to as previous accident compensation and treatment. Statistical prediction or data are a good source for accident evaluation. Without the project, accident statistics should not be applied to the situation. Rather, future traffic condition should be taken into account as a factor of accident.

The land revenue saved can be calculated by net benefits of "best alternative use", namely the possible benefits produced by the land conserved during the use of underground transportation in accordance with the land's current functions. The land conservation benefits can be given by:

$$B_5 = \sum_{i=1}^{n} M_{ii} Q \qquad (9)$$

Where, B_5 is the land conservation revenue (10,000 Yuan a^{-1}); M_i is the area of the *ith* land (m^2) among the lands saved; Q_i is the net benefits per unit area of the ith land with best alternative use (10,000 Yuan m^{-2} a) (Annual net income per unit area can be replaced by net benefits per unit area of the city).

Many cities will invest a great deal of money in air pollution control and the implementation of underground transportation projects, which can reduce part of air pollution. The benefits come from two major parts including the prevention fees for air pollution reduction and the profit and loss fees of human health resulting from air pollution reduction.

In order to prevent the damage caused by deterioration of environmental quality to economic development, people can take appropriate measures to prevent or control pollution. For example, they may increase further investment or expenditure to reduce or offset the consequences of the deteriorating quality of the environment. In this case, it is believed that the investment or expenditure for the same amount of air pollution reduction reflects the benefits or expenses of underground transportation projects, which is given in equation (10).

$$C_{11} = \sum R\lambda \qquad (10)$$

In the formula, C_{11} represents the prevention fees (10,000 Yuan/a) for air pollution reduction; **"***R* is the amount of various funds (10,000 Yuan) invested for reducing 1% of air pollution; λ is the percentage of the reduced air pollution in the total air pollution.

Human Capital Approach (HCA) (Tietenberg, Thomas H., and Lynne Lewis, 2004) is designed to evaluate human health as an indicator of environment evaluation. Human capital refers to the capital embodied in labors, including cultural knowledge, skills and health. In Human Capital Approach (HCA), production wealth is a kind of capital and used to define human values. As the marginal product of labor equals to one's income, the total income (discounted) is used to define human values. Traditional Human Capital Approach (HCA) holds that the economic costs due to premature death refers to the loss of human capital return on investment within life expectancy. So the loss of the present value of expected income is the cost of premature death. If a person dies at age t because of environmental pollution, according to the description, the present value of his income to receive if he lives as expected is expressed as:

$$E_c = \sum_{i=1}^{T-t} \frac{\pi_{t+i} E_{t+i}}{(1+i)^r} \qquad (11)$$

In the expression, E_c refers to loss of income from premature deaths due to the change of environment quality. π_{t+i} is the possibility of a *t*-year-old man to live *t*+*i* years. E_{t+i} is the expected revenue (million) when the person is *t*+*i* years old. *r* is the discount rate and *T* is a normal life expectancy.

Briefly speaking, the health benefits resulting from air pollution reduction mainly consist of two aspects, including the reduced economic losses caused by prevention of premature death as well as reduced work-delaying and medical losses caused by reduced diseases frequency. The former amounts to the product of influence of changes in environment quality on workers' life expectancy and working years and the present value of her/his expected income. The latter amounts to the product of the number of patients increased resulting from changes in environment quality and the average treatment cost (weighted calculation in accordance with different conditions) of each patient, which is given by:

$$C_{12} = \sum T_1 \alpha_1 \mu + \sum T_2 d\,(\omega + \beta) \qquad (12)$$

In the formula, C_{12} is the profit and loss fees (10,000 Yuan a^{-1}) of human health resulting from air pollution reduction; "T_1 is the reduced death toll (person a^{-}) due to air pollution reduction; 1 is the number of average years of potential life (a) loss due to various death causes; μ is the annual income per capita (10,000 Yuan person^{-1} a); "T_2 is the reduced number of patients (person a^{-1}); d is the number of work-delaying days (d person^{-1}) of each disease; ω is the average daily wages (10,000 Yuan d^{-1}); β is the average daily medical expenses (10,000 Yuan d^{-1}).

The underground traffic can reduce noise pollution from the roads. If the observed and measured results resulting from changes in the environment is not evaluated, the assumed environmental changes can be present to the respondents. After that, their WTP for the changes can be given by:

$$C_2 = 12 \sum_{i=1}^{n} F_i WTP \qquad (13)$$

In the formula, C_2 is the benefits (10,000 Yuan a^{-1}) of noise reduction; F_i is the family number (household) within the Scope *i*; *WTP* is the willingness to pay (Yuan month^{-1} household).

In order to ask the respondents about their willingness to pay or to receive payment, Researchers choose different scopes (such as land price) according to the situations of different locations and gave out questionnaires to the nearby residents. For *WTP* question, the respondents usually felt embarrassed, confused and were unable to provide useful estimations due to a lack of reference points. For most residents, the most suitable reference points may be their payment for the public utilities such as monthly fees for water, electricity, gas, and sanitation, as well as their monthly income. Towards *WTP* question, most respondents apted for relatively fixed payment for public utilities as *WTP* reference point, so that a reliable *WTP* value could be achived.

In the present study, firstly the roles of underground transportation construction projects in improving urban traffic and environment were introduced in solving the shortage of urban land, improving urban traffic and improving urban ecological environment. Second, necessity for evaluation of environmental and economic benefits of China's urban underground transportation construction projects was revealed. Thirdly, indicator system for the evaluation of environmental and economic benefits of underground transportation construction projects was built, based on analysis of traffic and transportation impact, biophysical environment impact, together with social, economic and environmental benefits. Finally, comprehensive economic evaluation methods of underground traffic construction projects were proposed.

Through monetary calculation of social and environmental benefits of the underground transportation projects, it can be seen that the cost of underground traffic projects is not higher than that of ground projects, with comprehensive benefits considered from environmental and economic perspectives. This evaluation method is extremely useful in urban road planning and construction associated decision-making problems. This method can be applied in determining whether to remove these viaducts and the build underground tunnel. In application case of these monetary calculation models, when per 100 km underground roads will be constructed in Beijing, 65,795,000 Yuan can be saved in the cost of environmental governance.

Therefore, transportation investment should be guided by "appropriate advanced" awareness. A correct understanding of the environmental and economic benefits of the underground transportation projects will promote the development and utilization of underground space.

References

Anas, A. and R. Lindsey: Reducing urban road transportation externalities: Road pricing in theory and in practice. *Rev. Environ. Econ. Pol.*, **5**, 66-88 (2011).

Berechman, J. and R.E. Paaswell: Evaluation, prioritization and selection of transportation investment projects in New York City. *Transportation*, **32**, 223-249 (2005).

Bobylev, N.: Mainstreaming sustainable development into a city's Master plan: A case of Urban Underground Space use. *Land Use Policy*, **26**, 1128-1137 (2009).

Burton, Ian: Report on Reports: Our common future: The world commission on environment and development. Environment: Science and Policy for Sustainable Development (1987).

Carmody, John, and Raymond L. Sterling: Underground space design: Part 1: Overview of subsurface space utilization Part 2: Design for people in underground facilities. University of Texas Press (1993).

Canós, J. H., and F.De Zulueta: Using hypermedia to improve safety in underground metropolitan transportation. *Multimed. Tools Appl.*, **22**, 75-87 (2004).

Chan, C. K. and X. Yao: Air pollution in mega cities in China. *Atmosp. Environ.*, **42**, 1-42 (2008).

Cannon J.S.: The health costs of air pollution: a survey of studies published 1984-1989, American Lung Association, Washington DC (2002).

Cao, J., M.S. Ho and D.W. Jorgenson: The local and global benefits of green tax policies in China. *Rev. Environ. Econ. Pol.*, rep005 (2009).

Chang, T., S. Modzelewski, J. Norbeck and W. Pierson:Tunnel air quality and vehicle emissions. *Atmos. Environ.,* **15**, 1011-1016 (1981).

Chen, Z.l., P. Zhang, D.J. Guo and C.Y. Wang: Study on Construction of Underground Roads for City Center in China. *Chin. J. Undergr. Spa. Engin.,* **1**, 000 (2009).

Chuanhua, X. and R. Qingwen: Fuzzy-synthetical evaluation on stability of surrounding rockmasses of underground engineering. *Chin. J. Rock Mecha. Engin.,* **11**, 015 (2004).

Dong, Y., M. Ishikawa, X. Liu and S. Hamori: The determinants of citizen complaints on environmental pollution: An empirical study from China. *J. Clean Prod.,* **19**, 1306-1314 (2011).

Fouladgar, M., A. Yazdani-Chamzini and E. Zavadskas: Risk evaluation of tunneling projects. *Arch. Civ. Mech. Eng.,* **12**, 1-12 (2012).

Gu, J., S. Zhou, X. Yan and L. Deng: Formation mechanism of traffic congestion in view of spatio-temporal agglomeration of residents' daily activities: A case study of Guangzhou. *Sci. Geogr. Sini.,* **32**, 921-927 (2012).

Guo, X. and H. Zhang: China Environmental Prediction and Countermeasures AD 2000. Tsinghua University Press, Beijing (1990).

Guo, X. and H. Zhang: Environmental and Economic Systems Analysis. Tsinghua University Press, Beijing (1993).

Guifeng, H. and M. Naixi: Health loss the TSP pollution preliminary analysis of Northwest University: *Nat. Sci. Edit.,* **31**, 359-362 (2001).

He, K., H. Huo and Q. Zhang: Urban air pollution in China: current status, characteristics, and progress. *Annu. Rev. Energ. Env.,* **27**, 397-431 (2002).

Holmberg, J., S. Bass and L. Timberlake: Defending the future: A guide to sustainable development. Earthscan Pubns Ltd., London (1991).

Ho, M.S. and C.P. Nielsen: Clearing the Air: The health and economic damages of air pollution in China. MIT Press (2007).

Jin, F. and J. Dong: Loss monetization of fushun city air pollution health research of heilongjiang. *Environ. Bull.*, **27**, 8-9 (2004).

Johnson, T., F. Liu and R.S. Newfarmer: Clear water, blue skies: China's environment in the new century. Vol. 2. World Bank Publications, (1997).

Li, B., S. Tao and R. Dawson: Evaluation and analysis of traffic noise from the main urban roads in Beijing. *Appl. Acoust.,* **63**, 1137-1142 (2002).

Li, F., R. Wang, J. Paulussen and X. Liu: Comprehensive concept planning of urban greening based on ecological principles: A case study in Beijing, China. *Landsc. Urban Plan.,* **72**, 325-336 (2005).

Loew, S., V. Lützenkirchen, U. Ofterdinger, C. Zangerl, E. Eberhardt and K. Evans: Environmental impacts of tunnels in fractured crystalline rocks of the Central Alps. *Groundwater in Fractured Rocks, IAH,* **9**, 55-68 (2007).

Long, J., Z. Gao, H. Ren and A. Lian: Urban traffic congestion propagation and bottleneck identification. *Sci. China Series F: Infor. Sci.,* **51**, 948-964 (2008).

Marquez, L.O. and N.C. Smith: A framework for linking urban form and air quality. *Environ. Modell. Softw.,* **14**, 541-548 (1999).

Mitchell, R.C. and R.T. Carson: Using surveys to value public goods: the contingent valuation method. Routledge (2013).

Pimentel, D., D. Harvey, P. Resosudarmo, K. Sinclair, D. Kurz, M. McNair, S. Crist, L. Shpritz, I. Fitton, R. Blair: Environmental and economic costs of soil erosion and conservation benefits. *Science,* **267**, 1117-1127(1995).

Reid, R. L.: Digging Delft. *Civil Eng.,* **82**, 66-71 (2012).

Riera, P. and J. Pasqual: The importance of urban underground land value in project evaluation: A case study of Barcelona's utility tunnel. *Tunn. Undergr. Space Technol.,* **7**, 243-250 (1992).

Ridker and G. Ronald: Economic costs of air pollution, studies in measurement (1967).

Shadish, R. William, T.D. Cook and L.C. Leviton: Foundations of program evaluation: Theories of practice. Sage (1991).

Song, T., W. Li and D. Xiaolin: Xi'an estimate economic losses and environmental contamination analysis. Chang'an University (Social Science Edition). **Vol. 8** (2006).

Sterling, R., H. Admiraal, N. Bobylev, H. Parker, J.P. Godard, I. Vähäaho and T. Hanamura: Sustainability issues for underground space in urban areas. *Proceedings of the ICE-Urban Design and Planning,* **165**, 241-254 (2012).

Tang, T.Q., H.J. Huang and H.Y. Shang: A dynamic model for the heterogeneous traffic flow consisting of car, bicycle and pedestrian. *Int. J. Mod. Phys. C.C.,* **21**, 159-176 (2010).

Taniguchi, E., R. Ooishi and T. Kono: Development and future perspectives for underground freight transport systems in Japan. In the Proceedings of 2nd International Symposium on Underground Freight Transportation by Capsule Pipelines and Other Tube/Tunnel Systems (2000).

Ted, B., M. Perley, P. Graham, C. Lee, D. Bates, S. Hamalainen, E. Hanna, R. Havelt, K. Khatter, D. Kopansky, D. McKeown, D. Schneider, S. Spencer and P. Victor: Illness Cost of Air pollution Technical Report (2000).

Thampapillai, J.D. and J.A. Sinden: Environmental economics: Concepts, methods and policies. *OUP Catalogue* (2013).

Thomas, L. M.: Risk communication: Why we must talk about risk. *Environment: Science and Policy for Sustainable Development,* **28**, 4-40 (1986).

Tietenberg, T.H. and L. Lewis. Environmental economics and policy. Boston: Pearson Addison Wesley (2004).

Wang, X.J.: Analysis of problems in urban green space system planning in China. *J. Fore. Rese.,* **20**, 79-82 (2009).

Wang, Y., X. Zhao and Y. Xu: Estimates of Shandong Province atmospheric pollution economic loss. *Urban Environ. Urban Ecol.,* **18**, 30-33 (2005).

Wijetilleke, L. and A.R. Karunaratne: Air quality management: Considerations for developing counties, World Bank Technical Paper 278. Washington DC: World Bank. 77-79 (1995),

World Health Organization. Air quality guidelines for Europe (2000).

World Health Organization. Regional Office for Europe, and World Health Organization. Air quality guidelines: Global update 2005: particulate matter, ozone, nitrogen dioxide, and sulfur dioxide. World Health Organization (2006).

Xu, Y. and S. Hongguang: Loss estimates of Dalian municipal environmental pollution economic. Liaoning. *Urban and Rural Environ. Sci. Technol.,* **21**, 38-41 (2001).

Yaping, W. and Z. Min: Urban spill over vs. local urban sprawl: Entangling land-use regulations in the urban growth of China's megacities. *Land Use Policy,* **26**, 1031-1045 (2009).

Yuan, C., E. Ng and L.K. Norford: Improving air quality in high-density cities by understanding the relationship between air pollutant dispersion

and urban morphologies. *Build. Environ.,* **71**, 245-258 (2014).
Zhang, P., Z. Chen, H. Yang and H. Wang: On utilization of underground space to protect historical relics model. *Tunn. Undergr. Space Technol.,* **24**, 245-249 (2009).
Zhang Yifei. CVM urban river ecosystem services assessment. Diss. (2010).
Zhou, A. and L. Feifei: Economic losses caused by air pollution, Zhejiang, preliminary estimates .*Environ. Poll. Con.*, **20**, 36-38 (1998).