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# Environmental and social challenges for urban subway construction: An empirical study in China

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**Abstract**

With rapid urban development in China, investments on subway projects are increasing. Although the type of projects can relieve transportation pressure in cities and make citizen's life easier, it raises many environmental and social problems during the construction process, in particular, problems about residents' daily life. Therefore, it is necessary to identify key environmental and social impacts of urban subway constructions and adjust construction programs and urban transportation programs to reduce negative impacts on citizen's daily life during construction. This paper analyzes the key factors for measuring environmental and social influences of subway construction and their interrelationships by using structural equation modeling (SEM) method. Four major impact factors are identified, namely, the impact on residents' travel, transportation, environment and daily life. Then some suggestions are made accordingly. These findings can be used as references for governments, contractors and other parties to develop more rational construction programs to minimize negative impacts of subway construction in urban development.


*Keywords:* Subway construction; Environmental and social impacts; Structural equation modeling; Factor analysis

## 1. Introduction

Urban subway project is considered as a safe and environmental friendly transportation mode. It has evolved considerably since its inception in the late 19th century when the first underground opened in London in 1863 (Jain et al., 2008). With the development of metropolitan economics, the conflicts caused by traffic congestions have become more significant than ever. The choice of traveling by private car invites more traffic jams, thus reducing the efficiency of public transport and the quality of life in urban districts. Hence, to alleviate the pressure of urban transportation, large cities in China have been actively constructing urban subway systems. By December 2009, ten cities including Beijing, Shanghai, Guangzhou, Shenzhen and many others have constructed 31 urban railway transportation lines, which add up to 835.5 km (People's Daily, 2009). The highly developed economic and demographic progress of China have caused a heightened demand for subway systems, which helped it spread across cities in China faster than a high-speed train. The subway lines in China are expected to grow from 48 in 2010, to 96 in 2015 and 289 in 2050 (Guangming Daily, 2011).

The subway projects play an important role in urban cities nowadays. There are many benefits to own subway projects for a modern city. In many cities, subway systems appear as the optimal solution to achieve a sustainable mobility for the growing urban population. Subway has a reputation of "green transport" for its rapid, efficient, low pollution, convenient and

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comfortable services and becomes one of the effective methods to alleviate problems in urban development (Ieda, 2010). They can provide many benefits including 'fast', 'regular', 'safe' and 'comfortable' services (La Vigne, 1997). Some other benefits include 'reduced traffic congestion', 'increased property values', and 'stimulated urban development' (Frisken, 1991; Mackett and Edwards, 1998). However, the subway projects also lead to many negative impacts on environment and society. For example, it may bring about disturbance to neighborhoods' daily life and challenges the existing urban transportation system as the construction is usually located in the central areas of a city. Sustainable construction has therefore become a global issue. Subway as an important infrastructure is a kind of public good in which government policy plays an important role to influence the effects of the project on economic development and social needs. The promotion of subway projects has been making significant contributions to the economic, social and environmental development in the developing country. In line with the promotion of the principle of sustainable development, subway projects should be developed to bring along benefits across all aspects, including economic, social, and environmental issues.

While there are many literatures that have conducted studies on the impacts of construction projects from economic, social and environment perspectives (Shen et al., 2005; Zhang et al., 2014), a few of them have investigated the dark side or challenges from those impacts in the developing countries, such as China. In China, subway construction site usually lies in the most prosperous business district. Construction caused part of the traffic jams, brought about negative influence on the benefit of the shops around, and inconvenience to urban residents. Life sewage and rubbish of the construction workers also had negative effect on city appearance. Mechanical activities in the construction process produced a lot of noise and vibration, which also disturbed the residents nearby. However, those countries with railways being constructed regarded the sustainable construction as the key issue for railways to avoid those negative impacts. For example, during the period of construction and operation, Hong Kong adopted technology innovation in terms of greenhouse gas emission, preserving non-renewable resources, vibration control and noise reduction to preserve the environment (Paul and Sun, 2008). It offered better service and security to the public and established a series of supervision system of transportation security that maintained the subway in a high level in terms of transportation intension, security, reliability, efficiency and benefit (Arthur, 2004). Comparing with the developed countries, the sustainable development of subway construction in China has fallen behind. To a larger extent, the subway projects are classified into infrastructure projects. It is therefore interesting to investigate the environment and social impacts of infrastructure projects in the context of China.

The aim of this paper is to investigate the environmental and social challenges for the construction of urban subway projects in China. This is followed by a brief review of the literatures that have studied the environment and social impacts of the construction projects. A quantitative structural equation model (SEM) is introduced to identify the key indicators that bring about negative impacts from environmental and social aspects. Results from the case study in the Harbin Subway project are presented to better understand the quantitative impacts of discovering environmental and social contamination on a project site. Finally, recommendations are given to guide the government, operating companies, designers, and contractors on how to deal with this issue.

## 2. Literature review on environmental and social impacts of construction projects

According to the Brundtland Report on the definition of sustainable development, where sustainable development is seen as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987), it has been commonly accepted that sustainable urban infrastructure projects emphasized on the prevention of unnecessary consumption of natural resources (especially non-renewable ones) and mitigation of harmful emissions. The social, economic and environmental indicators of sustainable development are drawing attention on the sustainable infrastructure projects. Many publications provide a generic classification on the types of environment and social impact. Environment impact includes high-energy consumption, solid waste generation, global greenhouse gas emissions, external air pollution, environmental damage and resource depletion and so on (Melchert, 2005; Zimmermann et al., 2005). Social impacts refer to both quantifiable variables such as numbers of immigrants (newcomers), and qualitative indicators such as cultural impacts involving changes to people's norms, values, beliefs, and perceptions about the society in which they live (Vanclay, 2002).

### *2.1. Environmental impact*

Construction projects have been considered to cause environmental problems ranging from excessive consumption of global resources both in terms of construction and building operation and the pollution to the urban environment. For example, Guggemos and Horvath (2006) indicated that the construction of commercial buildings consumed significant amounts of energy and produced lots of emissions and waste and the major contributors were the inappropriate equipment used in the construction phase. Jaselskis and Anderson (1994) identified the need to use automated construction remediation techniques for site exploration, cleanup, and long-term monitoring of hazardous-waste sites. Siow et al. (2003) identified the modeling framework to assess the construction impacts during the major construction phases in the construction of George Bush Intercontinental Airport/Houston project. Guggemos (2003) conducted a research on environmental impacts of on-site construction processes with emphasis on structural frames. A construction environmental decision support tool was proposed to calculate the quantities of energy use and air emissions during the construction process of a building. Until now, there are many environmental assessment tools that have been developed to help evaluate the environmental loadings among the world. The environment performance evaluation goal has aroused strong attention from many countries, the BREEM of UK (Larsson, 1998), LEED of United States (Crawley and Aho, 1999), Green Star of Australia (Seo et al., 2006), and the BREAM of Hong Kong (Davies, 2001). In particular, the GBTool (Cole, 1998) is considered the most comprehensive framework, which has been applied and conducted among the international collaboration in over 20 countries.

The construction activities of subway projects often take place in congested urban areas. Environment protection is usually strict in controlling the noise, dust and road damage caused by construction activities. Such construction projects often create excessive noise which is a nuisance to the surrounding community. For example, the findings by the study of Cheuk (2000), are indicating that the noise from construction project site would influence the residents' frequency hearing, distractibility and several perceived behavior. Koushki et al. (2003) measured the noise pollution levels at various construction sites in the Metropolitan area. In this context, other researchers have conducted studies on the construction activities at night to check whether the noise can be reduced. After reviewing several practical approaches for mitigating community noise impacts from nighttime construction, Towers (2001) believed that the most important thing was to identify the noise problems at the design phases of the project so that appropriate mitigation measures can be specified proactively, prior to the start of the construction. Besides, during the construction process, the dust which comes from transportation vehicles and liberated when rock is blasted also generate pollutions (Berit et al., 2001). The dust will affect the air quality in the working and living areas of the residents as a subway project usually lies in the crowded city center. It is found that tunnel construction inevitably disturbs stratum, ground settlement with different level which usually generate unfavorable effect on the safety of a subway construction and the surrounding environment, such as roads, bridges, underground pipelines and ground buildings in the urban districts (Yao and Wang, 2006).

### 2.2. Social impact

Urban infrastructure projects have broad and long-term social impacts. Construction operation consumes energy, creates substantial noise, and produces large quantities of waste (Gambatese and Rajendran, 2005). Civil infrastructure system is a major consumer of raw materials and energy. Commercial and residential buildings account for around 40% of global raw materials consumed per year (U.S. Green Building Council, 2005). In addition, it may affect the community growth (more people) and community demographics (Forkenbrock et al., 2001), and change the land use pattern (Wegener, 2004). It may replace some of the residents near the construction site (Tilt et al., 2009) and also brings about inconvenience of the community nearby (Roberts, 1995; Zhang, 2011). Construction workers' safety and health play a major role in achieving sustainable socio-economic development in the construction industry (Rajendran and Gambatese, 2009). The sustainable safety and health concept aim to sustain a construction worker's safety and health during a single project; for each future project a worker is involved in; and during the worker's remaining lifetime after retirement (Rajendran and Gambatese, 2005). Many studies have quantified sustainability in terms of indicator and indexing methods. Such metrics have the potential to translate the concept of sustainability into numbers for quantifying and optimizing. There are many studies of safety management in a subway construction. Teizer et al. (2010) established an autonomous proactive real-time construction worker and equipment operator proximity safety alert system. Grabowski et al. (2007) also echoed that recognizing alerts and signals before an accident clearly offers the potential of safety enhancement.

In referring to the subway construction of other Chinese cities, a sustainable construction needs to be addressed. For instance, the subway project in Beijing was thoroughly estimated and analyzed from the social view during the process of project plan, project implementation and project operation. According to the needs of the stakeholders from the project implementation region and the implementation difficulties, relevant stakeholders were encouraged to participate in project activities. Potential social risks were predicted and analyzed in advance. Suggestions and measures were proposed to optimize construction process and operation plan and to eliminate and reduce the effects from social risks and potential social conflicts (Chen, 2001). Xi'an is a famous ancient & historical culture capital city. In the process of a subway construction, the influence on underground historical sites should be taken into consideration.

### 2.3. Summary of literature review

Most studies about sustainability in engineering project are concerned with a general construction project. Meanwhile, most researches about the sustainability of an infrastructure project include establishing a sustainability assessment index system (Shen et al., 2011), implementing sustainability of urban transportation system (Kumares and Sinha, 2003), planning of sustainability infrastructure (Timmermans and Beroggi, 2000), and so on. Few of the studies investigated the social and environmental impacts of transportation engineering. This paper therefore summarized the environmental and social index of general engineering projects to evaluate the risks arising from sustainable construction of a subway project through analyzing the social and environmental impacts.

According to the analysis of relevant literature and practical situation, the paper identifies four perspectives to study negative impacts of subway construction: travel out, transportation, environment and residents' living. The impact on commuting by subway construction refers to the impact of residents' commuting, such as commute methods, the costs of daily commute, frequency of going out and so on. The impact on transportation refers to the adverse influence on traffic along the subway line's construction, including traffic jams, damage of road utility, parking chaos, traffic accidents and so on. The negative influence to the urban environment for subway construction refers to the construction noise, dust, and pavement damage and the impact on living refers to the negative influence of subway construction in the city residents' daily life, including daily shopping times, the suspension of water, electricity and gas, working emotions and so on.

### 2.4. Theoretical framework

#### 2.4.1. Stakeholder theory

The origin of stakeholder management literature can be traced back to 1963, when the word first appeared in an international memorandum at the Stanford Research Institute (Freeman, 1984). A stakeholder can be defined as: "any identifiable group or individual who can affect the achievement of an organization's objectives or who is affected by the achievement of an organization's objectives"(Freeman and Reed, 1983). Stakeholders must be involved in the process to facilitate the success of sustainability. Walker (2000) identified that "stakeholders can provide tangible value and valuable feedback information about how they are affected and can cooperate in delivering the output".

A subway construction project comprises a series of complex activities. Subway project development, execution, and delivery often include a large number of stakeholders. Different stakeholders can influence the implementation of sustainable construction (Wang et al, 2014). Governments are one of the most important stakeholders in the subway construction. The importance of government can be reflected by various ways. For example, they develop environmental policy plans to define sustainability goals (Bllaauw and Premus, 2000), and set environmental standards for contractors and project participants to improve subway environment performance. The governance regimes must adapt to the specific project and context, deal with emergent complexity, and change as the project development process unfolds (Miller and Hobbs, 2005). Governments establish codes and levels of performance, and authorities and private organizations have to work within the boundaries of the rules (Ngowi, 2001). Contractors may be obligated to improve their environmental performance to respond to a community's requirements. Contractors need to take actions for planning and managing the work regarding the minimization of environmental impacts related to the construction process (Qi et al., 2010). They can use an environmental management system integrating the environmental issue in the organizational processes and procedures (Yip, 2000), and choose sustainable materials and sustainable design alternatives to cater to environmental regulations (Rohracher, 2001). A subway project is an important infrastructure for serving residents. Therefore the public interests have close association with the sustainability of a subway project. The praise and complaints of a community on a subway construction site represents an important factor affecting the subway project's sustainability performance. According to Walker (2000), the environmental impact becomes a crucial issue especially when the interests of the public are affected, in particular, for those large-scale engineering projects. Zhang et al. (2008) show that those pressures from the community play significantly positive roles in engaging firms in improving environmental management performance.

#### 2.4.2. Hypotheses

Based on the above review of environmental and social impact and understanding of stakeholder theory, a theoretical framework is designed as shown in Fig. 1 and the following hypotheses can be introduced:

- *Hypothesis 1: There is a negative relationship between the impact on commute out and the satisfaction of a community.*
- *Hypothesis 2: There is a negative relationship between the impact on transportation and the satisfaction of a community.*
- *Hypothesis 3: There is a negative relationship between the impact on the environment and the satisfaction of a community.*
- *Hypothesis 4: There is a negative relationship between the impact on living and the satisfaction of a community.*

## 3. Research methodology

### 3.1. Structural equation model

SEM is a statistical technique for testing and estimating causal relationships using a combination of statistical data and qualitative causal assumptions. This view of SEM was articulated by the geneticist Wright (1921), the economists Haavelmo (1943) and Herbert (1953), and formally defined by Pearl (2000) using a calculus of counterfactuals.

Relevant research efforts have been done in the construction by using the SEM method. Prasertrungruang and Hadikusumo (2009) characterized and quantified factors that influenced downtime consequences of highway construction equipment based on the SEM approach. According to Molenaar et al.'s study (2000), SEM was used to describe and quantify the fundamental factors that affect contract disputes between owners and contractors in the construction industry. And Debrezion and Pels (2007) have done a research to examine the impact of railway station on property value by using SEM. The findings show that commuter railway stations has a significantly higher impact on the property values compared to light or heavy railway/Metro stations. Cho et al. (2009)used factor analysis and SEM to deduced the overall causal relationship and the level of influence among 17 project characteristics categorized as project characteristics, owner characteristics,

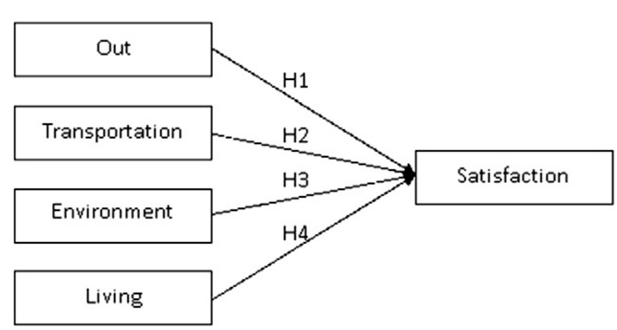


Fig. 1. The theoretical model.

contractor characteristics, environment characteristics, and the five categories of project performance, including construction cost and time.

In this study, the impact caused by a subway construction cannot be reflected in accurate data. Even the 5-point scoring scheme we got in a final questionnaire has errors to a certain degree in formulating the impacts. Combining with the above reasons, the SEM method is used in this study.

### 3.2. Data collection

Survey questionnaire is an important tool for data collection. In this paper, two surveys with semi-structured interviews were conducted near the subway construction site on Xidazhi Street. The questionnaire was printed and mainly filled by specified invited respondents to keep its effectiveness. The interviewees include residents, merchants, office workers, students, and drivers. The first survey was conducted in June 2009. More than 80 people were interviewed by the research team members and the results are shown in Table 1. The results show that the subway construction has great impact on the environment and the neighborhoods' daily life. And the negative impacts can be classified into four categories, including the impact on people's commuting out, the impact on the city's transportation system, the impact on the environment and the impact on daily life.

Based on the results of the first survey, the second survey was designed to investigate the negative impacts of the subway construction. The second one was conducted in October 2009 with two steps. The questionnaire was divided into two parts, where part 1 contained questions about the residents' background information, including age, profession, level of education, distance between home and destination and so on; part 2 covered some questions about "subway construction may have various potential negative impact". The questionnaire design drew suggestions and lessons from the first round of investigation. The questions were designed from five perspectives: the impact on residents' commute, the impact on traffic, the impact on the living environment, the impact on daily life and suggestions. The survey took approximately 8–15 min to complete. Each question was built as a single-choice in a structured format. The questionnaires were distributed and tried to ensure that the differences and extensiveness between the sample areas and characteristics. Along Subway Line one, the questionnaires were printed and distributed. Convenience sampling method and stratified sampling method were combined. The final data analysis showed that the sampling is approximately uniform, and two surveys have received good results. The first step is a pilot survey. Sixty people were invited and 40 completed questionnaires are valid for testing the rationality of the questionnaires. The results showed that the questionnaire has high reliability and validity. The second step is to amend the questionnaire according to the pilot survey and conduct the formal questionnaire survey. 260 questionnaires were sent out and 240 valid questionnaires were received during 27 Oct to 29 Oct 2009. The 5 Likert scale is used to indicate the attendees' view on the listed questions in the questionnaire. The collected data is analyzed by SEM.

Table 1
Results of the 1st survey.

| Interviewees | Opinions | Percentage |
|---|---|---|
| Residents | The time spent on travel has been elongated extensively due to the subway construction | 60% |
| | The construction of subway has caused serious environmental problems. | 34% |
| | The subway construction has great impact on elders. | 6% |
| Merchants | The subway construction has affected their business seriously. | 90% |
| Drivers | Irrational traffic diversion and bad condition of temporary roads result in lower transportation performance. | 90% |
| Students | Students have to spend more time to school due to the subway construction. | 80% |

## 4. Data analysis

### 4.1. Project background

As the capital city of Heilongjiang province, Harbin has started a subway project since September 28, 2008. Up to now, the first phase of the subway projects' construction is still on the way, which will last for 4 years, with a length of 14.33 km. The entire engineering project is located in the city center. Consequently, the adoption of open cut method and massive temporary construction occupation has led to the closure of several roads and bridges. Many inconvenience and problems have been brought into the residents' life along the subway lines and it has also led to an unfriendly working and living environment. It is significant to assess the challenges in managing the subway projects, which can ensure the successful completion of the construction project with minimum negative influence to the surroundings from the social and environmental aspects.

A subway project is an infrastructure project with many public welfare, directly operated and managed by the government administrative agencies and adopt the financing method of government investment as the main body, constructed by provinces and cities and municipal capital raise. The city government investment accounts for about 40% of the total project construction. The provincial government provides financial support at the same time. The rest is bank loans. Meanwhile, along the subway lines, the method of "resource investment" is also adopted. The construction funding gap is filled up through market-oriented means. And the government department is responsible for managing the whole process of the subway project.

### 4.2. Demographic characteristics

Characteristics of the sample data are shown in Table 2. The attendees can be classified by gender, age, occupation, and travel method.

Table 2 shows that the selected sample of the survey are approximately evenly distributed as the target objectives, so

Table 2
Demographic characteristics of respondents.

| Characteristic variables | Type | Frequency | Percentage (%) |
|---|---|---|---|
| Gender | Male | 112 | 50.6 |
| | Female | 119 | 49.4 |
| True age | 18 years of age | 1 | 0.4 |
| | 18–24 years old | 155 | 64.3 |
| | 25–40 years old | 58 | 24.1 |
| | 41–50 years old | 15 | 6.2 |
| | 50 years old | 11 | 4.6 |
| | Missing | 1 | 0.4 |
| Professional | Students | 115 | 47.7 |
| | White-collar workers | 97 | 40.2 |
| | Self-employed | 17 | 7.1 |
| | Retirement | 7 | 2.9 |
| | Other | 5 | 2.1 |
| Are there old or children in your family | Yes | 127 | 54.5 |
| | No | 106 | 45.5 |
| Level of education | High school and below | 54 | 17.5 |
| | University tertiary/undergraduate | 157 | 50.8 |
| | Master and above | 64 | 20.7 |
| | Other | 7 | 2.3 |
| Distance between home and destination | 100 m | 29 | 12 |
| | 100–500 m | 81 | 33.6 |
| | 500–1000 m | 57 | 23.7 |
| | 1000–1500 m | 24 | 10 |
| | Above 1500 | 48 | 19.9 |
| | Missing | 2 | 0.8 |
| Major travel method | Bus | 131 | 54.5 |
| | Taxi | 9 | 3.7 |
| | Car | 11 | 4.6 |
| | Cycling | 7 | 2.9 |
| | Walk | 83 | 34.4 |

that the credibility of the conclusions of the model can be guaranteed. Although an analysis of data on income may not be well-distributed, it is not strongly relevant to the final results of the research and one possible explanation is that most respondents might lie while giving personal information like income.

### 4.3. Exploratory factor analysis

Before a formal factor analysis, we randomly selected 94 samples for exploratory factor analysis to eliminate the disturbance of reusing the same data. In the correlation analysis, the Kaiser–Meyer–Olkin (KMO) and Bartlett's test are used to identify the correlation between individuals, as shown in Table 3. The factor analysis can be done only when the relevance is high. The scale of KMO is 0.699, and the Bartlett test of sphere significance probability is 0.000, less than 0.01, indicating that the sample data are highly relevant, and it is feasible to do factor analysis.

Table 3
KMO analysis.

| Kaiser–Meyer–Olkin measure of sampling adequacy | | 0.812 |
|---|---|---|
| Bartlett's test of sphericity | Approx. Chi-square | 1677.536 |
| | df | 276.000 |
| | Sig. | 0.000 |

(1) Main components information is shown in Table 4, the eigen-values of the former 6 components are bigger than 1, and the cumulative contribution rate is 58.304%, which leads to the results of 6 potential factors.
(2) The Communalities' information is shown in Table 5. It can be seen that most of the communality values are above 0.5, and most of them are close to 0.7, indicating that these factors can well reflect the information that each individual item conveys. R1–R24 separately represent the impact on the residents' commute, the impact on traffic, the impact on the living environment, the impact on daily life and suggestions, details are shown in Table 6.
(3) With the varimax rotation method, the factor loading values of factors on each individual item were calculated. With the results of a preliminary factor analysis and deleting principles, the following items will be deleted: 1) items with inaccurate representation; 2) items with low factor loading values; and 3) items without any factors. The rotated factor analysis results are shown in Table 7 and 13 items were grouped as 4 factors, as shown in Table 8.

### 4.4. Confirmatory factor analysis

The general outline of the application of SEM is as follows: Firstly, according to the previous theories and knowledge, the researcher can form a model of the relationships between the variables on the base of deduction and assumptions. Secondly, a survey is carried out for the data of observation variables and a sample covariance matrix was formed on the basis of analyzing the data. Then, SEM can be used to check the fitting degree of the proposed model and the sample covariance matrix. If the model fits the sample data well, the model is proved to be successful. Otherwise, the model needs to be modified. If there are still unacceptable errors after modification, the model should be denied. In this paper, the negative impacts are the observable variables while the factors arousing the impacts are the latent variables. The collected data from the second survey were used for analysis.

Table 4
Principal component information.

| Principal component number | Original | | | After rotation | | |
|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 5.353 | 22.303 | 22.303 | 2.908 | 12.115 | 12.115 |
| 2 | 3.099 | 12.911 | 35.214 | 2.746 | 11.443 | 23.558 |
| 3 | 1.763 | 7.348 | 42.562 | 2.223 | 9.261 | 32.82 |
| 4 | 1.462 | 6.093 | 48.654 | 2.121 | 8.84 | 41.659 |
| 5 | 1.307 | 5.448 | 54.102 | 2.076 | 8.65 | 50.309 |
| 6 | 1.008 | 4.201 | 58.304 | 1.919 | 7.994 | 58.304 |

Table 5
Communalities of factors.

| Factors | Initial | Extraction | Factors | Initial | Extraction | Factors | Initial | Extraction |
|---|---|---|---|---|---|---|---|---|
| R1 | 1 | 0.687 | R9 | 1 | 0.487 | R17 | 1 | 0.566 |
| R2 | 1 | 0.668 | R10 | 1 | 0.608 | R18 | 1 | 0.515 |
| R3 | 1 | 0.556 | R11 | 1 | 0.716 | R19 | 1 | 0.537 |
| R4 | 1 | 0.656 | R12 | 1 | 0.735 | R20 | 1 | 0.604 |
| R5 | 1 | 0.503 | R13 | 1 | 0.61 | R21 | 1 | 0.588 |
| R6 | 1 | 0.605 | R14 | 1 | 0.544 | R22 | 1 | 0.412 |
| R7 | 1 | 0.584 | R15 | 1 | 0.584 | R23 | 1 | 0.595 |
| R8 | 1 | 0.572 | R16 | 1 | 0.497 | R24 | 1 | 0.564 |

Based on the results of exploratory factor analysis, a SEM was developed for measuring the negative impacts of subway construction. SEM software, the Amos 16.0, was used to carry out the confirmatory factor analysis. The road map of the initial model is shown in Fig. 2.

There are two ways to handle the missing values in a general statistical software, pairwise and listwise. Pairwise can minimize the possibility of data loss, but may result in unevenness of covariance matrix or the correlation coefficient matrix. And listwise reduces the sample by excluding data with missing values. Therefore, the missing values are replaced by using the mean value in this study. For data reliability test, Cronbach's alpha coefficient testing method was used. The average Cronbach's alpha coefficient is 0.818, which indicates that the data are reliable.

There are also four questions in the questionnaire to measure the residents' satisfaction toward the current measures of Harbin municipal department. A new SEM was developed to examine the relationship between the four negative impact factors and the residents' satisfaction to find better solutions in future construction management. The road map and the estimated parameters of the model are shown in Fig. 3.

Maximum likelihood estimation is used for model parameter estimation. CR (critical ratio) and P value are used to test the statistical significance of factor loading values. If all P values are lower than 0.05, it indicates that the road map coefficients are significantly different with zero at the confidence level of 95%. The testing results are shown in Table 9 and all the P values are lower than 0.05 except for two, satisfaction ←transport, satisfaction ← environment (actually, only one satisfaction ←transport from Table 9). It can be concluded that almost all relationships between the negative impact factors and the residents' satisfaction are significant at 95% confidence level.

The fit index of model is shown in Table 10. The absolute fit index CMIN/DF = 1.618 < 5, and the absolute fit index RMSEA = 0.051 < 0.08. The relative fit index NFI is 0.845, the other absolute fit indexes CFI and TLI are both higher than 0.9. Therefore, the fit index of the model meets the requirements. With confirmatory factor analysis, it can be seen that the model has a well fit index for interpreting the relationships between the negative impact factors and the residents' satisfaction. It is not necessary to take further modification.

## 5. Discussion and suggestion

### 5.1. Discussion of findings

It is assumed that all the correlation coefficients between satisfaction and the four factors are negative, i.e. more residents influenced by the subway construction, less satisfactory with current measures. However, as shown in Fig. 3, only transportation and the environment are negatively related to satisfaction, living and travel impact are not.

In terms of the transportation impact, the coefficient is negative and not significant. Currently, the existing measures include traffic defusing design, temporary bus stops, keeping construction site tidy and clean, and timely notification of public transportation changes. On the one hand, obviously, most of these measurements are designed to deal with the impact on short trip and living situations. Consequently, people who feel strongly influenced by these two aspects could be more appreciated for the

Table 6
Key influence factors.

| Travel | | Environment | | Measures | |
|---|---|---|---|---|---|
| 1 | Travel cost | 11 | Noise | 20 | Traffic diversion |
| 2 | Travel methods | 12 | Dust | | |
| 3 | Travel frequency | 13 | Pavement damage | 21 | Policy propaganda |
| 4 | Ride comfort | Living | | | |
| 5 | Bus routes change | 14 | Shopping | 22 | Vehicle scheduling |
| Transportation | | 15 | Emotion | 23 | Transportation planning |
| 6 | Damage of vehicles | 16 | Income | | |
| 7 | Damage of road utility | 17 | Suspension of water, electricity and gas | 24 | Civil construction management |
| 8 | Parking chaos | 18 | Elders' living | | |
| 9 | Traffic jam | 19 | Children growth and study | | |
| 10 | Traffic accidents | | | | |

Table 7
Rotated factor analysis results.

| Items | Factor loading values | | | | KMO value | Significance probability | Total reliability | Factor |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | | |
| R1 | | | | .803 | 0.812 | 0.000 | 0.818 | F4 |
| R2 | | | | .831 | | | | |
| R5 | | | | .620 | | | | |
| R6 | | .568 | | | | | | F2 |
| R7 | | .638 | | | | | | |
| R8 | | .703 | | | | | | |
| R10 | | .742 | | | | | | |
| R11 | .799 | | | | | | | F1 |
| R12 | .833 | | | | | | | |
| R13 | .740 | | | | | | | |
| R17 | | | .672 | | | | | F3 |
| R18 | | | .715 | | | | | |
| R19 | | | .831 | | | | | |

government's effort, in contrast to those who might even neglect this kinds of impact in their daily lives. On the other hand, the results of the roadmap coefficient also show the residents' support to some extent as the more measurement the government took, the more they will be satisfied.

The coefficient between the environment and the residents' satisfaction is negative and significant. It indicates that influence of the subway construction on environment is significant. The residents think that the subway construction has negative impacts on their daily life and the city image. Current measures are not effective to solve the existing environmental problems. Therefore, government departments should take more effort to reduce the impact.

In line with the above research findings, the behavior of the government and the contractors were considered as the key factor among the negative impacts of transportation and environment. It is necessary for the government to urge the authorities to rationally coordinate in the transportation of the subway construction site in order to minimize the impacts for the residents. Contractors should control the negative impacts on the external environment where the subway project is under construction. These actions of the contractors, including the selection of a construction mode, the implementation of green benchmark and the adoption of environment quality management system would affect the environmental benefits directly. These research findings implied that the improvement of the residents' satisfaction highly depends on the collaboration among the stakeholders.

### 5.2. Negative impact factors

According to the above exploratory factor analysis and confirmatory factor analysis, it can be concluded that there are four top negative factors of urban subway constructions, including commute impact factor, transportation impact factor, environment impact factor and living impact factor.

Factor 1 is the impact on the residents' commute and travel behaviors. This factor reflects the negative impact of subway construction on the residents' daily travel, including the costs of daily commute, the commute methods, and the frequency of going out. The results show that this factor has a higher impact on those people who do not have private cars. Moreover, factor 1 has the highest variance value of 29.65%. It indicates that the subway construction has the greatest negative impact on the residents' daily travel and the residents have no other better choices.

Factor 2 is the negative impact on traffic. The subway construction leads to many traffic problems, including damage of road utility, parking chaos, traffic jam and traffic accidents.

Factor 3 is the impact on the environment. The subway construction also has great impact on the environment, including construction noise, dust, road damage, etc.

Factor 4 is the impact on daily life. This factor reflects the negative impact on the residents' daily life, such as frequency of shopping, working emotion, monthly income, the suspension of water, electricity and gas.

The four factors are not equally important. In terms of variance contribution, i.e. the explanation of the total information that all the items conveyed, the most important factor is the impact on the residents' travel. It indicates that most residents feel inconvenient of daily transport. During the interview, it can be seen that the main streets in Harbin are full and in disorder as the routes of public transportation change. It is inconvenient for the residents' daily commute.

Table 8
Impact factor analysis of subway construction.

| Factors | Item | Issue | Load |
|---|---|---|---|
| F4 | 1 | Does metro subway construction cost you more on transportation? | 0.803 |
| Out impact | 2 | You have to change the route due to subway construction. | 0.831 |
| | 5 | Changes of metro bus route due to subway construction have a great impact on you. | 0.620 |
| F2 | 6 | Does subway construction cause damage to vehicles? | 0.568 |
| Transportation Impact | 7 | Is it serious of traffic rush during the subway construction? | 0.638 |
| | 8 | Is it serious of parking chaos due to the subway construction? | 0.703 |
| | 10 | Is it more serious of the traffic jam than before? | 0.742 |
| F1 | 11 | Is the noise problem serious? | 0.799 |
| Environmental Impact | 12 | Is the dust problem serious? | 0.833 |
| | 13 | Is the road damage problem serious? | 0.740 |
| F3 | 17 | Is it serious of the temporary suspension of water, electricity and gas during the construction? | 0.672 |
| Living condition impact | 18 | Does the subway construction bring a lot of trouble to elders' daily life in your family? | 0.715 |
| | 19 | Environmental destruction due to subway construction has negative impact on children growth and study. | 0.831 |

We can sequence the main factors which influence the construction of a subway from graph 2 as follows: R23-irrational planning of traffic diversions during construction period, R20-unscientific auxiliary roads and facilities deployment, R24-noise and dust pollution, road damage incurred by uncivilized production, R21-insufficient guidelines, signs and publicity. Thus, R23 should take priority when the governing department is considering rectifying measures, then R20, R24, and R21 at last.

### 5.3. Suggestions

The construction and operation of this project will inevitably affect the environment along the subway line. Pollution during the construction process is mainly supervised by emphasis on management, construction works standardization, promoting civilized construction and other measures. The impact on operation process is alleviated by a collective decision on subway line's direction and location at the project feasibility stage to make sure that the line is away from buildings that are sensitive to vibration and noise. The measures above aim to strive for sustainable construction of a subway project.

According to the analysis and discussion, it can be seen that relevant effective measures should be taken to reduce the negative impacts of a subway construction. In terms of the four top impact factors, the discussions are presented as follows:

#### 5.3.1. Carrying out rational plans for traffic diversions

Through the research on negative impacts on the traffic, the subway construction leads to many traffic problems, including damage of road utility, parking chaos, traffic jam and traffic accidents. There is an irrational diversion. From the above study results, we concluded that the irrational traffic diversion contributes mostly to the comprehensive impacts on residents. Therefore it should be the priority that the governing department should be taken care of before the subway construction. The irrational diversion will cause unreasonable traffic congestion at some parts of the road, which seriously impacts on the residents' commuting such as increasing the traveling time for workers and students. In addition, it also brings about the rise of the traveling expenses and traffic accidents. Two factors should be taken into account in the planning of traffic diversion before a subway construction is carried out. Firstly, make scientific diversion arrangements for the traffic flow at peak hours of the key traffic joints, so that people and vehicles do not disturb each other. Private cars should be limited on the roads with heavy bus loads to avoid the disturbance among the people, private cars and public transport and ensure the smooth passing of buses. Secondly, the loads of vehicles should not exceed the upper limit of the diversion route, and the traffic flows not exceed the road's capacity to avoid the destruction of the auxiliary road and congestions.

#### 5.3.2. Reasonably setting up auxiliary road and other auxiliary facilities

The establishment of auxiliary roads is critical for traffic diversion and easing the traffic pressure on the main road. As no scientific measure was taken for the auxiliary roads before the subway construction in Harbin, the auxiliary roads were severely damaged, muddy on rainy days and heavy dust on sunny days,

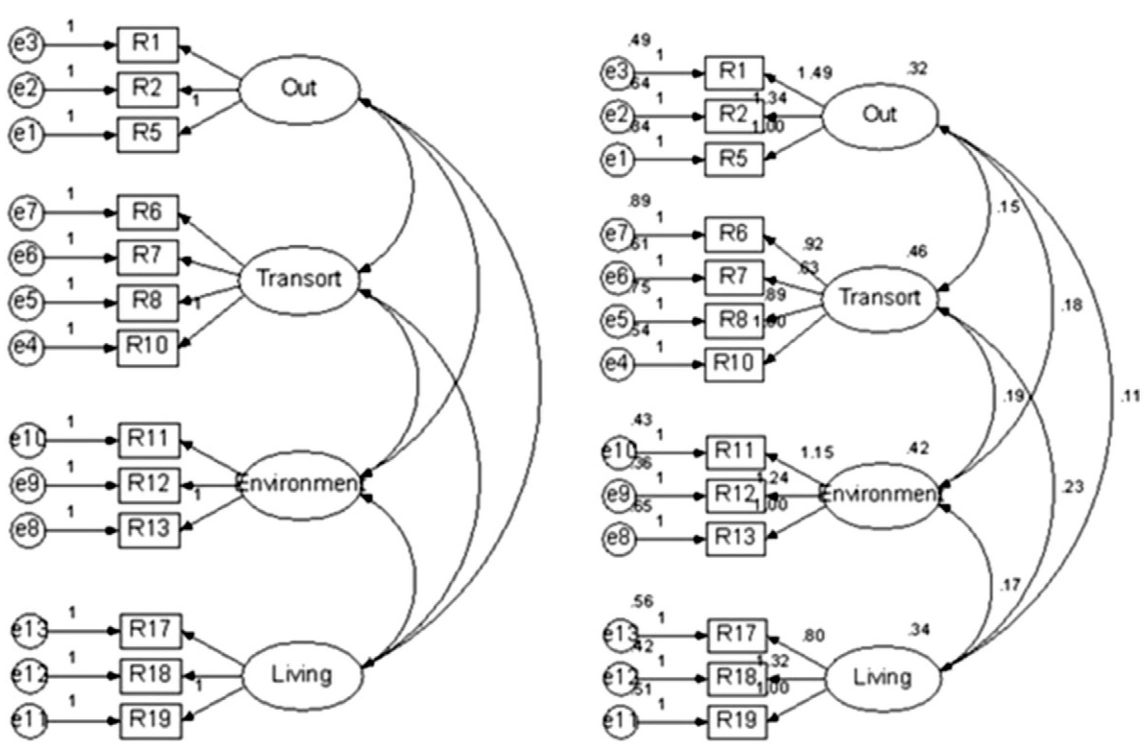


Fig. 2. Road map for initial model.

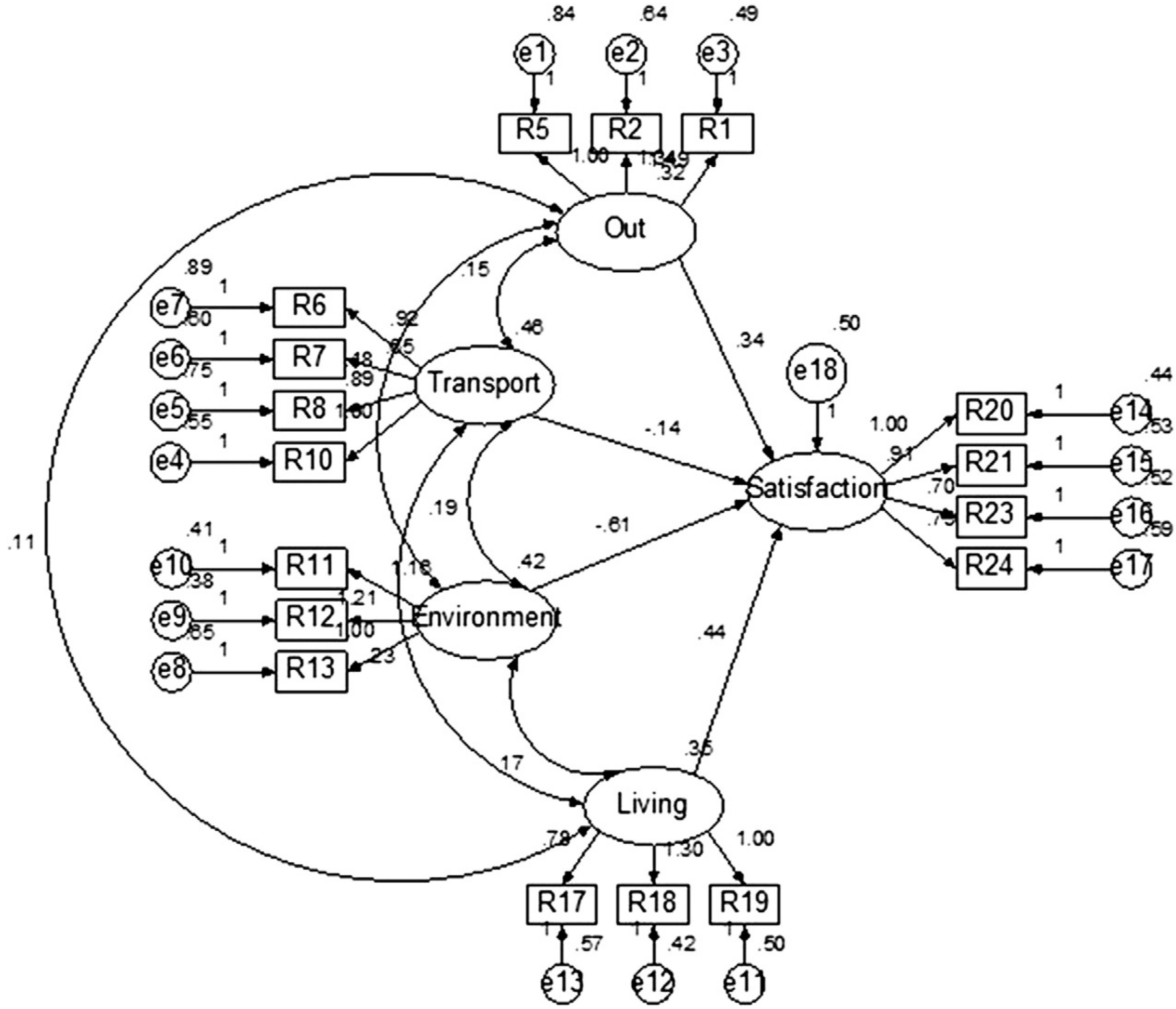


Fig. 3. Road-map of the integrated model.

which greatly reduce their function and bring serious environmental problems. Before the construction work is carried out, consolidation, widening and re-laying works should be done based on the characteristics of the traffic flows planning to divert to the auxiliary roads to avoid the negative impact that may arise due to the damage of the road surface, heavy traffic load and long construction period.

*5.3.3. Reasonable planning and design*

Sustainable performance of a construction project is greatly influenced by design documents. In the feasibility stage, designers and engineering consultants should give professional advice on various alternatives and their influences on the project sustainability. Designers and engineering consultants should be familiar with sustainable construction principles, and they should know how to practice these principles in their professional activities, such as the choice of sustainable design plans, choice of environmentally friendly materials, energy efficient designs for services, and sustainable structure design to enable safer and healthier living and working environment.

*5.3.4. Enhancing civilized production management*

The subway contractor should proceed the works in a civilized manner, control the strength of noise and the overtime works to lower the negative impact on nearby residents' daily life, auxiliary facilities such as anti-noise panels, silencer should be set up in the construction period. Site soil should be properly covered with water sprinkling to reduce the dust pollution; trucks should be clean and sealed before coming out of the site.

*5.3.5. Setting up travel guidelines and increase publicity*

Scientific, complete traffic signs play an important role in the normal operation of urban transport, so the urban traffic management department should set up a special group in charge of the traffic signs and guidelines during the period of subway construction. Timely update on the changes and adjustments information for bus stations, routes and so on, use radio stations, electronic display screens and regional maps to propagandize the policies on forbidden routes, odd and even number lines and the like. To obtain public understanding and support for a subway construction to create a harmonious social

Table 9
Regression weights: (Group number 1 — Default model).

| | | | Estimate | S.E. | C.R. | P | Label |
|---|---|---|---|---|---|---|---|
| Satisfaction | <— | Out | .339 | .156 | 2.178 | .029 | par_16 |
| Satisfaction | <— | Transport | −.142 | .158 | −.898 | .369 | par_17 |
| Satisfaction | <— | Environment | −.613 | .152 | −4.045 | *** | par_18 |
| Satisfaction | <— | Living | .444 | .174 | 2.558 | .011 | par_19 |
| R2 | <— | Out | 1.337 | .208 | 6.417 | *** | par_1 |
| R1 | <— | Out | 1.491 | .239 | 6.247 | *** | par_2 |
| R10 | <— | Transport | 1.000 | | | | |
| R8 | <— | Transport | .888 | .135 | 6.571 | *** | par_3 |
| R7 | <— | Transport | .649 | .119 | 5.439 | *** | par_4 |
| R6 | <— | Transport | .924 | .148 | 6.235 | *** | par_5 |
| R13 | <— | Environment | 1.000 | | | | |
| R12 | <— | Environment | 1.212 | .139 | 8.727 | *** | par_6 |
| R11 | <— | Environment | 1.161 | .138 | 8.397 | *** | par_7 |
| R19 | <— | Living | 1.000 | | | | |
| R18 | <— | Living | 1.302 | .182 | 7.149 | *** | par_8 |
| R17 | <— | Living | .777 | .124 | 6.290 | *** | par_9 |
| R20 | <— | Satisfaction | 1.000 | | | | |
| R21 | <— | Satisfaction | .911 | .092 | 9.851 | *** | par_10 |
| R23 | <— | Satisfaction | .700 | .097 | 7.210 | *** | par_11 |
| R24 | <— | Satisfaction | .793 | .109 | 7.293 | *** | par_12 |
| R5 | <— | Out | 1.000 | | | | |

Note: *** $p < 0.001$

environment, the citizens should be kept informed and involved to mobilize their enthusiasm to support the cause.

To summarize, firstly, relative departments should strengthen civil construction management, and during the construction period, we should use low noise equipment. Considering less noise in the neighborhood, the supervising departments should make sure to maintain a certain distance from the residents' houses. Furthermore, in the process, dust although is inevitable, we should cover the handling of the earth and water the way to reduce flying dust. Last but not the least, the earthwork and material transport should be scheduled at night, to make full use of vehicles.

## 6. Conclusions

The subway construction in cities has a great negative impact on the citizens. There is a need of a systematic re-planning for traffic and transportation to minimize the impact. Therefore, it is a challenge for government departments to make effective solutions to reduce the impact led by using limited resources.

Table 10
Fit index calculation.

| Index Name | Results | Evaluation | |
|---|---|---|---|
| Absolute fit index | CMIN / DF | 1.618 | Well |
| | GFI | 0.923 | Well |
| | RMSEA | 0.051 | Well |
| | RMR | 0.06 | Bearable |
| Relative fit index | CFI | 0.933 | Well |
| | TLI | 0.916 | Well |
| | NFI | 0.845 | Bearable |
| Information index | AIC | 264.393 | – -- |
| | CAIC | 461.906 | – -- |

This paper investigated the negative impacts of a subway construction based on a series of surveys in China. The principle factors are identified by SEM, including the impact on the resident's travel, impact on transportation, impact on the environment and impact on living conditions. The four principle factors make it more focus for decision makers when making relevant measures to reduce the negative impacts of a subway construction. And the suggested solutions are useful references for decision makers to improve the efficiency of the measures. With cooperation with government departments, the specific solutions will be examined in a further research. Although the data applied for the analysis is obtained from the subway projects in China, the research finding also provides valuable reference for conducting similar research on environment and social impacts in other regions' projects. Furthermore, there are still limitations of the study. For example, the sample size is relatively small and a larger sample size will be used in the future.

## Conflict of interest

There is no conflict of interest.

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## References


Arthur, D., 2004. Little limited. Independent Safety Audit of London Underground Limited. Science Park, Milton Road Cambridge, United Kingdom.

Berit, B., Patricia, S., Bente, U., Wijnand, E., 2001. Dust and gas exposure in tunnel construction work. Am. Ind. Hyg. Assoc. 62, 457–465.

Bllaauw, K., Premus, H., 2000. Obstacles and perspectives for sustainable building. Milieu: J. Environ. Sci. 15 (2), 111–115.

Chen, Z., 2001. The impact of urban transit on ecological environment. China Railw. Sci. 22 (3), 126–132.

Cheuk, Fan Ng, 2000. Effects of building construction noise on residents: a quasi-experiment. J. Environ. Psychol. 20, 375–385.

Cho, K.M., Hong, T.H., CHyun, C.T., 2009. Effect of project characteristics on project performance in construction projects based on structural equation model. Expert Syst. Appl. 36 (7), 10461–10470.

Cole, R.J., 1998. Emerging trends in building environmental assessment methods. Build. Res. Inf. 26 (1), 3–16.

Crawley, D., Aho, I., 1999. Building environmental assessment methods: application and development trends. Build. Res. Inf. 27 (4/5), 300–308.

Davies, H., 2001. Environmental benchmarking of Hong Kong buildings. Struct. Surv. 19 (1), 38–45.

Debrezion, G., Pels, E., 2007. The impact of railway stations on residential and commercial property value: a meta-analysis. J. Real Estate Financ. Econ. 35, 161–180.

Forkenbrock, D.J., Benshoff, S., Weisbrod, G.E., 2001. Assessing the social and economic effects of transportation projects. NCHRP Web Document 31 (Project B25-19): Contractor's Final Report. (Available at website: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w31.pdf).

Freeman, E., 1984. Strategic Management: A Stakeholder Approach. Pitman, Boston.

Freeman, R.E., Reed, D.L., 1983. Stockholders and stakeholders: a new perspective on corporate governance. Calif. Manag. Rev. 25 (3), 88–106.

Frisken, F., 1991. The contributions of metropolitan government to the success of Toronto's public transit system: an empirical dissent from the public-choice paradigm. Urban Aff. Rev. 27 (2), 268–292.

Gambatese, J.A., Rajendran, S., 2005. Sustainable roadway construction: energy consumption and material waste generation of roadways. Proc., Construction Research Congress 2005: Broadening Perspectives. ASCE Construction Institute, Reston, Va, pp. 104–110.

Grabowski, M., Ayyalasomayajula, P., Merrick, J., Harrald, J.R., Roberts, K., 2007. Leading indicators of safety in virtual organizations. Saf. Sci. 45, 1013–1043.

Guangming Daily, 2011. http://guancha.gmw.cn/2011-08/15/content_2460837.htm.

Guggemos, A.A., 2003. Environmental impacts of on-site construction processes: focus on structural frames(Ph.D. Dissertation) University of California.

Guggemos, A.A., Horvath, A., 2006. Decision-support tool for assessing the environmental effects of constructing commercial buildings. J. Archit. Eng. 12 (4), 187–195.

Haavelmo, T., 1943. The statistical implications of a system of simultaneous equations. Econometrica 11 (1), 1–12.

Herbert, Simon, 1953. Causal ordering and identifiability. In: Hood, W.C., Koopmans, T.C. (Eds.), Studies in Econometric Method. Wiley, New York, pp. 49–74.

Ieda, H., 2010. Sustainability in urban transport: multidimensional meanings and states. Sustainable Urban Transport in an Asian Context. Springer, Tokyo, pp. 59–80.

Jain, P., Cullinane, S., Cullinane, K., 2008. The impact of governance development models on urban rail efficiency. Transp. Res. A Policy Pract. 42 (9), 1238–1250.

Jaselskis, E.J., Anderson, M.R., 1994. Robotic opportunities in hazardous waste clean-up. J. Environ. Energy., ASCE 120 (2), 359–378.

Koushki, P.A., Kartam, N., AI-Mutairi, N., 2003. Urban development and construction noise: a study in Metropolitan Kuwait. Kuwat J. Sci. Eng. 30 (2), 119–138.

Kumares, C., Sinha, F., 2003. Sustainability and urban public transportation. J. Transp. Eng. 129 (4), 331–341.

La Vigne, N., 1997. Safe transport: security by design on the Washington Metro. In: Clarke, R.V. (Ed.), Preventing Mass Transit Crime. Crime Prevention Studies Vol. 6. Criminal Justice Press, Monsey, NY.

Larsson, N., 1998. Green Building Challenge '98: international strategic considerations. Build. Res. Inf. 26 (2), 118–121.

Mackett, R.L., Edwards, M., 1998. The impact of new urban public transport systems: will the expectations be met? Transp. Res. A Policy Pract. 32 (4), 231–245.

Melchert, L., 2005. The Dutch sustainable building policy: a model for developing countries? Build. Environ. 10, 007.

Miller, R., Hobbs, B., 2005. Governance regimes for large complex projects. Proj. Manag. J. 36 (2), 42–50.

Molenaar, K., Washington, S., Diekmann, J., 2000. Structural equation model of construction contract dispute potential. ASCE J. Constr. Eng. Manag. 116 (1), 135–156.

Ngowi, A.B., 2001. Creating competitive advantage by using environment-friendly building processes. Build. Environ. 36 (3), 291–298.

Paul, L., Sun, X., 2008. Research on sustainable development of Hong Kong MTR. Urbanrapid Rapid Rail Transit 21 (1), 5–10.

Pearl, J., 2000. Causality: Models, Reasoning, and Inference. Cambridge University Press.

People's Daily, 2009. Page 5. http://paper.people.com.cn/rmrbhwb/html/2009–12/09/content_400823.htm (9 Dec).

Prasertrungruang, T., Hadikusumo, B.H.W., 2009. Modeling the dynamics of heavy equipment management practices and downtime in large highway contractors. J. Constr. Eng. Manag. 135 (10), 939–947.

Qi, G.Y., Shen, L.Y., Zeng, S.X., Jorge, Ochoa J., 2010. The drivers for contractors' green innovation: an industry perspective. J. Clean. Prod. 18, 1358–1365.

Rajendran, S., Gambatese, J.A., 2005. Sustainable Construction Safety and Health. Means, Methods, and Trends. Architectural Engineering Institute and Construction Institute, Reston, Va.

Rajendran, S., Gambatese, J., 2009. Development and initial validation of sustainable construction safety and health rating system. J. Constr. Eng. Manag. 135 (10), 1067–1075.

Roberts, J.T., 1995. Subcontracting and the omitted social dimensions of large development projects: household survival at the Carajás Mines in the Brazilian Amazon. Econ. Dev. Cult. Chang. 43 (4), 735–758.

Rohracher, H., 2001. Managing the technological transition to sustainable construction buildings: a socio-technical perspective. Tech. Anal. Strat. Manag. 13 (1), 137–150.

Seo, S., Tucker, S., Ambrose, M., Mitchell, P., Wang, C.H., 2006. Technical Evaluation of Environmental Assessment Rating Tools, Research and Development Corporation, (Project No. PN05.1019).

Shen, L.Y., Wu, Y.Z., Chen, E. H.W., Hao, J.L., 2005. Application of system dynamics for assessment of sustainable performance of construction projects. J. Zhejiang Univ. 6A (4), 339–349.

Shen, L.Y., Wu, Y.Z., Zhang, X.L., 2011. Key assessment indicators for the sustainability of infrastructure projects. J. Constr. Eng. Manag. 137 (6), 441–451.

Siow, B.T., Kivanc, Onder, Bender, Gloria, Evlioglu, Rahmi, Tunasar, C., 2003. Managing airport traffic disruptions during construction. Proceedings of 27th International Air Transport Conference (Airport Engineering and Construction) http://dx.doi.org/10.1061/40646(2003)21.

Teizer, J., Allread, B.S., Fullerton, C.E., Hinze, J., 2010. Autonomous pro-active real-time construction worker and equipment operator proximity safety alert system. Autom. Constr. 19, 630–640.

Tilt, B., Braun, Y., He, D., 2009. Social impacts of large dam projects: a comparison of international case studies and implications for best practice. J. Environ. Manag. 90 (3), S249–S257.

Timmermans, J.S., Beroggi, G.E.G., 2000. Conflict resolution in sustainable infrastructure management. Saf. Sci. 35, 175–192.

Towers, D., 2001. Mitigation of community noise impacts from night-time construction. In: Hancher, D. (Ed.), Proceedings of Construction Institute Sessions, Construction and Materials Issues, ACSE 2001 Civil Engineering Conference, Houston, TX, October, pp. 106–120.

U.S. Green Building Council, 2005. An introduction to the U.S. Green Building Council and the LEED Green Building Rating System. USGBC, Washington, DC.

Vanclay, F., 2002. Conceptualising social impacts. Environ. Impact Assess. Rev. 22, 183–211.

Walker, D.H.T., 2000. Client/customer or stakeholder focus? ISO 14000 EMS as a construction industry case study. TQM Mag. 12, 18–25.

Wang, Q., Xue, X.L., Zhang, L.D., 2014. Construction innovation networks: absorptive capacity perspective. J. Eng. Manag. 2, 22–26.

Wegener, M., 2004. Overview of land use models. In: Hensher, D.A., Button, K.J., Haynes, K.E., Stopher, P.R. (Eds.), Handbook of Transport Geography and Spatial Systems. Elsevier, Oxford: UK.

World Commission on Environment and Development, 1987. Our Common Future. Oxford University Press, Oxford.

Wright, Sewall S., 1921. Correlation and causation. J. Agric. Res. 20, 557–585.

Yao, X., Wang, M., 2006. Statistic analysis of guideposts for ground settlement induced by shallow tunnel construction. Chin. J. Rock Mech. Eng. 25 (10), 2030–2035.

Yip, J.S.L., 2000. New directions of environmental management in construction: accepted levels of pollution. Struct. Surv. 18 (2), 89–98.

Zhang, X., 2011. Social risks for international players in the construction market: a China study. Habitat Int. 35 (3), 514–519.

Zhang, B., Bi, J., Yuan, Z.W., Ge, J.J., Liu, B.B., Bu, M.L., 2008. Why do firms engage in environmental management? An empirical study in China. J. Clean. Prod. 16 (10), 1036–1045.

Zhang, X., Wu, Y., Shen, L., Skitmore, M., 2014. A prototype system dynamic model for assessing the sustainability of construction projects. Int. J. Proj. Manag. 32, 66–76.

Zimmermann, M., Althaus, H.J., Haas, A., 2005. Benchmarks for sustainable construction — a contribution to develop a standard. Energy Build 37 (11), 1147–1157.