Effects of Beijing Subway System on Economic Development Based on Fuzzy Comprehensive Evaluation Model

Lianshi Qiu

University of California, Santa Barbara

320 Storke Rd, Santa Barbara, CA, 93117, USA

lianshiqiu@ucsb.edu

Keywords: Beijing Subway, Economic Development, Fuzzy Comprehensive Evaluation

Abstract: The past decades saw massive expansion in subway system of Beijing, China. However, given large cost in funding this public infrastructure, it is important to substantiate economic benefits of Beijing subway. The study used Analytical Hierarchal evaluation(AHP) and Fuzzy comprehensive evaluation method to study economic impact of Beijing subway system. Eight elements are chosen as criteria level of AHP model and relative weight of each element is derived. The research then moves on to use Fuzzy comprehensive evaluation method to work out level of affiliation in discrete level. It is substantiated that level of affiliation for the criterion of "Excellent" is the greatest (0.52569). Thus, economic impact of Beijing can be described as "Excellent", highlighting value of massive-scale subway construction in Beijing.

1. Introduction

In wake of reform and opening up, the past three decades have witnessed rapid urbanization and economic development in all major Chinese cities, particularly Beijing, Shanghai, Guangzhou and Shenzhen, which are known as "tier one cities" [1]. One evident impact of urbanization was urban sprawl, which profoundly increased demand of automobiles, a major source air pollution that accelerated urban environmental degradation. To mitigate such impact, the central government responded by advocating subway construction in major Chinese cities. Subway system enables rapid flow of substantial number passage with relatively low level of emission, offering a green resolution to problems of traffic congestions and air pollution. However, benefits of subway system extend beyond addressing and resolving environmental concerns. Subway as a form of public transport and infrastructure can be regarded as circulation space of the city that "facilitates intra-urban flow of people, goods, and information" [2], which facilitates economic growth as a positive externality. Moreover, subway and other public infrastructure investment can generate "the corridor effect", which includes "spatially balanced and more sustainable economic development and human well-being in the corridor" [3]. The corridor effect bring about changes in terms of economic growth rate, housing prices, and usage of land near the corridor. As an artificial linear public transport, subway generates corridor effects that are centered around the subway stations and radiates to surrounding area, with ability to attract greater flow of people and demand for land for purposes such as housing or business centers, boosting value of land. Indeed, housing price near stations of Seoul subway line 3 and 4 are much higher than surrounding area [4], while IT companies in Tokyo are typically found within 1 km of the major train and subway lines, with Akihabara station attracting 660 internet firms [5]. These examples effectively tested the validity of corridor effect.

The purpose of this study is to construct a Fuzzy comprehensive evaluation model to analyze economic impact of Beijing subway system on local economic development. Indeed, when judging usefulness of public transport, the impact induced by the system on socio-economic development is essential. The value of subway construction is that it promotes utilization of suburban land, accelerate urban sprawl and development, and attract business along its tracks and stations. These all pave way for rapid urbanization and economic development. To fulfill demands of rapid urbanization, Chinese government increased public investment in subway construction in major Chinese cities since public transport was taken into priority in the 10^{th} five-year plan, in which 200 billion (approximately 30.8 billion US$) Yuan was used in subway construction. During the 11^{th} five-year plan, which took place between 2006-2010, total public investment for subway investment reached 400 billion, with most of new lines built in Beijing, Shanghai, Guangzhou and Tianjin. In this period, subway construction diversified to include innovative forms of transforming ranging from light rail to trams [6]. The latest subway development plan, designed to be completed by 2021, features 276 km of additional line and costs 212 billion Yuan [7], demonstrating the enormous cost of constructing a sound public transport system. Therefore, it is important to study to what extent does subway construction in Beijing benefit local economic development and welfare of its citizens.

The essay begins by presenting an overview of previous research on economic impact of subway construction from a global perspective. It then moves on to introduce Analytical Hierarchal Process (AHP) and Fuzzy Comprehensive Evaluation Model, two mathematical approaches featured in the study. The study move on to use AHP to determine the relative weight of each selected factor of Beijing economy, then attempt to use Fuzzy Comprehensive Evaluation Model to judge the impact of Beijing subway system on each factor to summarize the overall influence of Beijing Subway system on the city's economic performance. The conclusion section would summarize finding of the research and discuss certain drawbacks of the research.

2. Literature review

As subway construction and similar public investment became increasingly prevalent worldwide, researchers discuss the pulling effect of subway construction on urban economic development, using methods ranging from theoretical generalization, statistics, hedonic price model and comprehensive analytical methods. Using theoretical generalization, North explored historic barriers to economic growth and concluded that high transaction cost hampers economic development and a sound public infrastructure is key to economic growth [8]. "circulation space", made up of roads, subways and other infrastructure, is key part of urban land nexus that allow flow of people, goods and information between households and business, as pointed out by Scott and Storper [2]. Numerous research applied statistical methods to show the close relationship between subway construction and economic growth. Laakso [9] conducted research about land value within 1 km of Helsinki hub station and proved that there was a 6% increase in land value.

A case study pertained to Madrid Metro line 12 was designed by Dorantes, Paez and Vassallo and utilized linear regression estimation with ordinary least squares, spatial error and spatial tie to show that line 12 had a positive impact on real estate values adjacent to the line [10]. After studying substantial amount of data, Feng, Li and Zhao established that construction Beijing subway line 5 pulled the price of commodity housing along the way [11]. A study pertinent with Shanghai Metro line 6 showed that there has been an average appreciation of 6% in housing prices, with the greatest rise in value of distant residential properties [12]. A noticeable convergence in research methodologies adopted by researchers over time is hedonic pricing model in econometrics. Using the model, Cervero and Landis examined price of business estates near light-rail station in Santa Clara Country and substantiated that the station had driven a 120% increase in price of estates within 400 meter perimeter of the station [13]. A similar study was designed by Bae, Jun and Park , who used hedonic pricing model to show that distance from Seoul subway line 5 had a positive impact on residential prices "only prior to the line's opening". Moreover, the authors observed that "accessibility to transit had less impact on house prices than other variables", such as school district and recreation [14]. Different spatial hedonic models was used to examine relationship between availability of public transport and housing prices in Lisbon, Portugal. [15]Works of Sun, Wang and Li demonstrated the authenticity to use hedonic price model to analyze sphere of influence of Tianjin metro line 3 on real estate prices, and concluded that the city government should adjust development strategy according to features of subway in various parts of the city [16]. Trojanek and Gluszak analyzed both the space and time effect of Warsaw subway. The hedonic method applied to OLS, SAR, SEM, SGM models indicated steady price premium adjustment prices related to construction of subway lines [17]. The final methodology adopted by many scholars is comprehensive analysis of impact of subway with aid of models. Based works of Haddad and others on higher-order economic impact of São Paulo subway, simulation results from a spatially computable general equilibrium models suggest positive economic benefit that go beyond city limit, with 32% benefiting São Paulo and the rest accrue to the entire metropolitan area [18]. Monajem and Nosratian applied canonical correlation analysis to examine how Tehran's subway system fit into the node place model, showing that streets near subway stations are associated with increase in activities [19]. Since the aim of the research is to examine economic impact of Beijing subway system, relevant models should be applied to reach the goal.

3. Data Research

Armed with the notion that subway construction can spur economic growth, major Chinese cities are actively expanding their subway networks, a quite recent phenomenon compared with cities in industrialized countries. Beijing subway, the subject of the study, was originally constructed as civil defense project in response to deterioration of Sino-Soviet relationships in 1960s [20]. Beijing subway line 1 from Pingguoyuan to Beijing railway station was constructed in 1969. Later expansion was slow, with addition of extension of line 1, line 2 and line 13 in forty years, until 2003. After completion of Batong line in 2005, Beijing had a small subway network of a mere 114 km. To prepare for 2008 summer Olympics and enhance public transport, subway construction of Beijing significantly accelerated [21]. At end of 2009, Beijing subway had 9 lines with total length of 223 km, including addition of line 5, first phase of line 10, a small portion of line 8, and Capital Airport line to Capital international airport. The succeeding decade saw rapid increase in length of subway network, with construction of more lines to satellite cities in suburb and old part of the city. By end of 2019, Beijing had contrasted a subway system with 23 lines and a total length of 699.3 km [22]. Daily ridership is projected to reach 18.5 million trips per day by 2021[23].

Several indicators of wellbeing, traffic, investment and real estate are selected to analyze impact of subway construction. For wellbeing, Gross Regional Product (GRP) per capita, Disposable income per capita and unemployment rate are chosen because they represent a holistic view of citizen wellbeing in Beijing. Although they may be affected by income inequality, citizens of Beijing are relatively affluent compared with other parts of China, as demonstrated by the high disposable income of 67756 Yuan [24]. Annual ridership for Beijing Subway can demonstrate impact of Beijing Subway on efficiency of traffic, while investment is shown by Fixed asset investment and Private firm numbers. Growth in real estate can be indicated by Average per m^2 residential property price and Average per m^2 commercial property price per m^2.

Table 1 shows indicators used in research: GRP per capita (X1), Fixed asset investment (X2), unemployment (X3), Annual ridership (X4), Disposable income per capita (X5), private firm number (X6), Average per m2 residential property price(X7) and Average per m2 commercial property price (X8). An sample was presented for each indicator, with units in Yuan except for unemployment and Annal ridership. Data Source: Beijing Bureau Statistics, National Bureau of Statistics [25].

Table 1 Indicators used in research

	X1	***X2***	***X3***	***X4***	***X5***	***X6***	***X7***	***X8***
Meaning	GRP per capita	Fixed asset investment	Unemplo-y ment	Annual ridership	Disposable income per capita	Private firm number	Average per m^2 residential property price	Average per m^2 commerc ial property price
Value	164220	837 billion	1.4%	3.85 billion	67756	1.6 million	37420.19	34091.03

4. Models

4.1 AHP

This paper uses Analytical Hierarchy Process (AHP) as the main mathematical tool for investigating economic impact of Beijing subway system. Devised by Saaty as a technique to analyze and generate complex decisions, AHP indicates an accurate approach for quantifying weights of the decision criteria, which combines qualitative and quantitative elements. When analyzing difficult decision-making problems, examining influencing factors and determining internal relationships, AHP enables the logic of decision to become mathematical with relatively few certain information, providing convenient solution for complex problems that often have multiple objectives [26].

AHP functions by first divide the abstruse goal or problem into distinct element, then moves on to group different elements based on their relationships and affiliation with the aim of forming a multi-dimensional analytical model in Figure 1. The problem is therefore changed to determining relative importance or influence of each base level (solution, methods) on the top level, which is the final objective. AHP features four key steps [27]:

(1) establish the hierarchy structural model

(2) construct the comparative matrix

(3) single hierarchal ranking and its consistency check

(4) total hierarchal ranking and its consistency check

AHP model has several advantages in context of this research. Firstly, AHP allows the complex goal of analyzing economic impact to be divided into several individual factors. This provides a coherent and logical avenue to analyze the problem. Secondly, AHP requires relatively little authentic information to yield reliable result.

However, AHP also has certain problems. Since it is based on combination between qualitative judgement and mathematical reasoning, sometimes human judgement is obscure and may be unable to assign the correct weight to each element in the second level, leading to major discrepancy in the final result. Moreover, sometimes elements in decision making are entangled with each other and hence hard to be separated from one another, so it will be difficult to use their relationship or affiliation to establish hierarchy structure model. Some researchers also contend that the method lack a sound statistical theory [28].

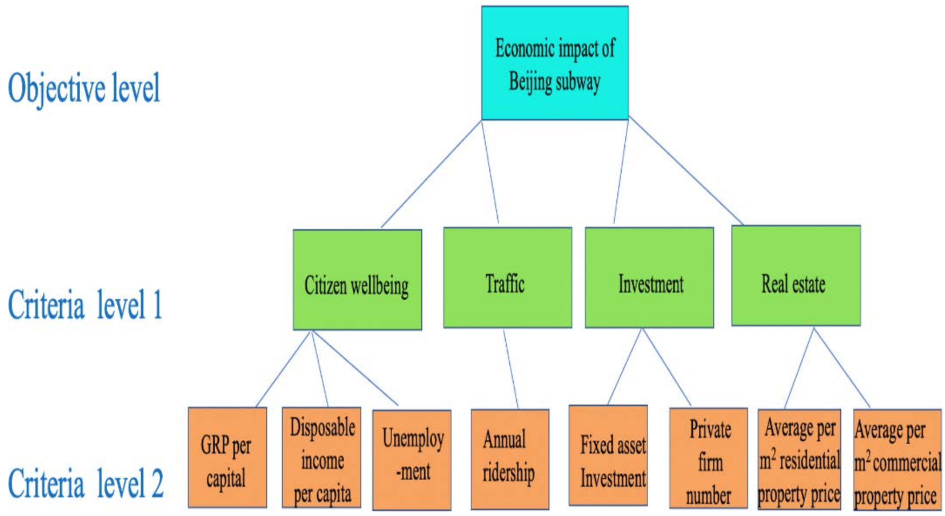

Figure 1 shows the hierarchal structural model based on AHP model. The first level is the objective level while the beneath two levels are criteria level with elements X1-X8.

4.2 Fuzzy comprehensive evaluation method

Fuzzy comprehensive evaluation is the application of fuzzy mathematics in systematic evaluation [29]. It applies fuzzy transformation to deal with unquantifiable indexes and transform them into quantifiable variables. If the variables are difficult to be defined by number or require excessive information to be quantified, Fuzzy comprehension evaluation method can effectively address the issue and solve the problem, paving way for its broad application in evaluation of public infrastructure.

Fuzzy comprehensive evaluation operates based on several steps. First, it is necessary to define the factor set (***U***) of evaluation system, which is to define *m* number of evaluation indexes. Second, determine the comment hierarchy ***V***, which is set of comments given to target of evaluation, with each hierarchy corresponding to one fuzzy subset. Third, single-factor evaluation index shall be examined by constructing fuzzy evaluation matrix denoted by ***R***. Fourth, the system evaluation factor fuzzy weight vector ***W*** should be determined, which means to assign weight to each evaluation index. Each evaluation index should be assigned with a distinct weight to emphasize differences in importance. Fifth, ***R*** and ***W*** are used to solve for vector ***B***, which is result of fuzzy comprehensive evaluation.

The advantage of fuzzy comprehensive evaluation method is that it combines qualitative and quantitative index and achieve quantification of qualitative indexes with application of fuzzy mathematics. In addition, it organizes multiple objectives and features of the comprehensive evaluation system to generate a simple result that can easily summarize overall characteristics of the system. Thirdly, by determining weight of each evaluation index it manages to substantiate the individual impact of various evaluation index on the objective of the system, which increases accuracy of result and mitigates influences of subjective factors [30].

5. Results and Discussion

5.1 Construction of the comparative matrix

When determining relative weight of each element in the second level, rather than arbitrarily assign weight to each element, two elements should be compared respectively. In this way, the accuracy of predictions can be increased by reducing the problem of comparing elements that are not closely related.

To compare relative importance of two selected elements, AHP applies number 1 to 9 to indicate their relative importance in Table 2 and 3. For example, “3” indicates one variable is slightly more important than another variable while “9” indicate extremely more important.

Table 2 The elements with their relative weight (importance).

	Meaning	**relative weight**
X1	GRP per capita	8
X2	Fixed asset investment	7
X3	Unemployment	3
X4	Annual ridership	3
X5	Disposable income per capita	5
X6	Private firm number	4
X7	Average per m2 residential property price	5
X8	Average per m2 commercial property price	6

In the study, ***X1*** (GRP per capita) is designated with relative importance of 8 because it is an authentic indicator of wellbeing of citizens and thus should be put into prominence when examining economic impact of public infrastructure. The second most important factor, being assigned with number 7, is ***X2*** (Fixed Asset investment). Fixed asset involves money used in building, land, machinery and infrastructure [31], so naturally subway construction as a public infrastructure would contribute substantially to this section of economy. ***X5*** (disposable income per capita), ***X7*** (Average per m^2 residential property price) and ***X8*** (Average per m^2 commercial property price) are placed with relatively equal importance, with ***X5*** and ***X7*** the relative importance of 5 and ***X8*** relative importance of 6. As demonstrated by literature review, ample researchers have proved the pulling effect of subway construction of property value. Compared with households, business is more likely to choose location based on availability of transport and consumer flow, so subway construction has more direct impact on price of commercial properties. Indeed, Zheng and Zhuang demonstrated that metro construction had on prominent effect on price of commercial housing in Hong Kong with less impact on residential housing [32], while South Korean researchers showed that South Korean tend to choose residential properties based on proximity to elite schools rather than subway stations [14]. Thus, ***X8*** is more important than ***X7***. ***X3*** and ***X4*** are assigned with least importance of 3 because they partially and indirectly reveal impact of subway construction on economic development of Beijing.

Table 3 The comparable matrix that demonstrates relative relationships between variables X1-X8.

Z	***X1***	***X2***	***X3***	***X4***	***X5***	***X6***	***X7***	***X8***
X1	1	8/7	8/3	8/3	8/5	2	8/5	4/3
X2	7/8	1	7/3	7/3	7/5	7/4	7/5	7/6
X3	3/8	3/7	1	1	3/5	3/4	3/5	1/2
X4	3/8	3/7	1	1	3/5	3/4	3/5	1/2
X5	5/8	5/7	5/3	5/3	1	5/4	1	5/6
X6	1/2	4/7	4/3	4/3	4/5	1	4/5	2/3
X7	5/8	5/7	5/3	5/3	1	5/4	1	5/6
X8	3/4	6/7	2	2	6/5	3/2	6/5	1

5.2 Calculate relative weight of each element

The first step is to obtain the maximum eigenvalue for the matrix. The eigenvalue can be derived by the expression

$$\lambda_{max} = \sum_{j=1}^{n} \frac{(UW)_i}{nW_i}$$

where U stands for determinant of comparative matrix and W is the weight vector.

We get the eigenvalue (λ_{max}) for the matrix in Table 3 is 8. And the is eigenvector is [-0.5241, -0.4586, -0.1965, -0.1965, -0.3276, -0.262, -0.3276, -0.3931].

Based on results of Table 3, it is possible to work out the weight vector. The weight vector can be calculated by the following expression:

$$W_i = \frac{\overline{W_i}}{\sum_{i=1}^{n} \overline{W_i}}$$

where n is order of the comparative matrix, W_i is the *i*-th element of the weight vector

Table 4 The process of obtaining the weight vector

nth row of comparative matrix	Product of elements in each row (M_i)	nth root of Mi $\overline{W_i} = \sqrt[n]{M_i}$	W_i
Row 1	55.4802	1.6520	0.1951
Row 2	6.2248	1.2568	0.1707
Row 3	0.0217	0.6195	0.0732
Row 4	0.0217	0.6195	0.0732
Row 5	1.2917	1.0325	0.122
Row 6	0.2167	0.8260	0.0975
Row 7	1.2917	1.0325	0.122
Row 8	5.5543	1.2390	0.1464

From Table 4, $w = (w_i)^T$= [0.1951, 0.1707, 0.0732, 0.0732, 0.122, 0.0975, 0.122 0.1464]. To ensure credibility of above calculation, the consistency of comparative matrix should be checked by introducing the average random consistency index RI, which is presented by Table 5.

Table 5 Average random consistency index (RI).

n	1	2	3	4	5	6	7	8
RI	0	0	0.58	0.90	1.12	1.24	1.41	1.45

The critical index (CI) = $(\lambda_{max} - n)/(n-1) = (8-8)/(8-7) = 0$. Thus, CR= CI/RI=0/1.45= 0 .Since CR<0.1, the comparative matrix satisfies the consistency test.

According to the calculation result of the combined vector of criteria 2, we sort them by weight. It can be shown that relative importance for ***X1*** (GRP per capita) is 0.1951, relative importance for ***X2*** (disposable income per capita) is 0.1707, ***X3*** (unemployment rate) and ***X4*** (annual ridership) have importance of 0.0732, ***X5*** (fixed asset investment) have relative importance of 0.122. The relative importance of ***X6*** (private firm number) is 0.0975, the relative importance of ***X7*** (Average per m^2 residential property price) is 0.122 and the relative importance of ***X8*** (Average per m^2 commercial property price) is 0.1464.

5.3 Results of fuzzy comprehensive evaluation

Based on principles of fuzzy mathematics, we can settle level of affiliation for elements in Table 1. Due to inability to reach relevant experts to comment on the issue, the study instead determine level of affiliation based on actual performance of each indicator as result of subway construction.

Table 6 evaluate the degree of improvement caused by subway construction on each criteria. Improvements are defined in discrete levels, with Excellent, Good and fair.

Table 6 the degree of improvement caused by subway construction on each criteria

Xn	Excellent	Good	Fair
X1	0.3	0.5	0.2
X2	0.6	0.2	0.1
X3	0.15	0.35	0.5
X4	0.8	0.15	0.05
X5	0.5	0.3	0.2
X6	0.4	0.4	0.2
X7	0.7	0.2	0.1
X8	0.75	0.15	0.1

Based on data from Table 6, it can be calculated that weight for “excellent” is 0.52569, the weight for “Good” is 0.29025, and weight for “Fair” is 0.16709 in Figure 2.

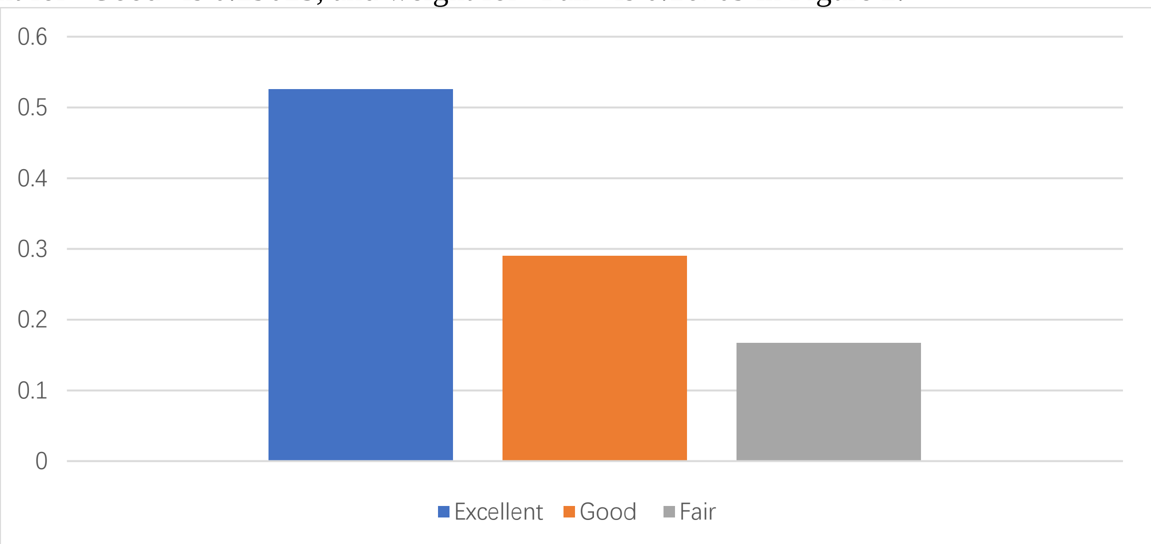

Figure 2 Relative distribution of discrete levels “Excellent”, “Good” and “Fair”.

6. Conclusion

The research focus on evaluation of Beijing subway, a public investment sought to address traffic problems in the sprawling Chinese capital and promote economic growth. After summarizing previous research, it is determined that AHP model and Fuzzy comprehensive evaluation can best suit the goal of this research because they are designed to use multiple criteria to quantify qualitative elements and reach the aim of assessment. Thus, eight elements are chosen as criteria level of AHP model and relative weight of each element is derived. The research then moves on to use Fuzzy comprehensive evaluation method to work out level of affiliation in discrete level. It is substantiated that level of affiliation for the criterion of “Excellent” has level of affiliation of 0.52569, the criterion of “Good” has level of affiliation of 0.29025, and the criterion of “Fair” has level of affiliation of 0.16709. Based on results of fuzzy mathematics, it can be concluded that Beijing subway has good to excellent impact on economic development of Beijing.

The result is expected because as indicated by previous research presented in literature review, subway can cause rise in price of both commercial and residential properties, attract investment, and create additional jobs. The time of evaluation is selected soundly because it takes time for long-term public infrastructure like subway to demonstrate effect. Overall, results of the study show that subway construction is worthy of its substantial public investment, which is in harmony with Beijing’s new subway construction scheme of addition of 276 km of new line. The main advantage of this study is that it innovatively applied AHP method and fuzzy comprehensive evaluation to assess economic impact of Beijing subway, and obtained its aim by dissecting overall economic impact into detailed elements that can be systematically addressed by mathematical models. The major drawback of the research is that only eight elements of economic performance are selected and analyzed. This is due to unavailability of official data in other promising criteria. Future study can address additional elements either by gain official access to such data or apply mathematical techniques to estimate value and importance of these undisclosed elements. Another disadvantage is that relative importance of elements in the study is self-determined based on relevant research rather than given by experts in the field. It would be optimal to survey experts in the field of subway construction or economic development to reach relative importance, but this is yet to be realized due to lack of resources.

References

[1] Cao G., Chen G., Pang, L., Zheng X., Nilsson S. Urban growth in China: past, prospect, and its impacts. Population and Environment [J], 2011, 33(2-3):137-160. doi: 10.1007/s11111-011-0140-6

[2] Scott Allen, & Storper Michael. The Nature of Cities: The Scope and Limits of Urban Theory [J]. International Journal Of Urban And Regional Research, 2014, 39(1), 1-15. doi: https://doi.org/10.1111/1468-2427.12134

[3] Quium, A. Transport Corridors for Wider Socio–Economic Development. Sustainability [J], 2019, 11(19), 5248. doi: 10.3390/su11195248

[4] Won, J.-M., Son, K.-B. Land price impact of subway [J]. Seoul University Capital Region Development Institute Yeongu Nonchong, 1993, 19, 35–47.

[5] Fujita, Kuniko. Neo-industrial Tokyo: Urban Development and Globalization in Japan's State-centered Development Capitalism [J]. Urban Studies, 2003, 40(2), 249-281. Doi: 10.1080/0042098032000040125

[6] Lan, Lan. Reflection on subway construction during the 11th five-year plan and prospects on the 12th five-year plan[J]. Traffic World, 2011, 9

[7] National Development and Reform Commission. Plan for Second Phase of Beijing Subway Construction [R]. Beijing, 2015. Retrieved from https://www.ndrc.gov.cn/xxgk/zcfb/tz/201509/W020190905506339696731.pdf

[8] NORTH, D. C. Institutions, Transaction Cost and Economic Growth[J]. Economic Inquiry, 1987, 25, 419-428. doi:10.1111/j.1465-7295.1987.tb00750.x

[9] Laakso, s. 1992. Public Transportation investment and residential property values in Helsinki

[J]. Scandinavian Housing and Planning Research, 1992, (9), 217-229.

[10] Dorantes Lucia Mejia, Paez Antonio, Vassallo Jose Manuel. Analysis of House Prices to Assess Economic Impacts of New Public Transport Infrastructure [J]. Transportation Research Record: Journal Of The Transportation Research Board, 2011, 2245(1), 131-139. doi: 10.3141/2245-16

[11] Feng Changchun, Li Weixuan, Zhao Fanfan. Influence of Rail Transit on Nearby Commodity Housing Prices: A Case Study of Beijing Subway Line Five [J]. Acta Geographica Sinica, 2011, (8).

[12] Zhou Zhengyi, Chen Hong, Han Lu, Zhang Anming. The Effect of a Subway on House Prices: Evidence from Shanghai[J]. Real Estate Economics, 2019. doi: 10.1111/1540-6229.12275

[13] Cervero, R., & Landis, J. Twenty Years of the Bay Area Rapid Transit System: Land Use and Development Impact[J]. Transportation Research Part A: Policy And Practice, 1997, 31(4), 309-333.

[14] Bae Chung-Hee, Jun Myung-Jin, Park Hyeon. The impact of Seoul's subway Line 5 on residential property values [J]. Transport Policy, 2003, (10), 85-94.

[15] Martinez L.Miguel, Viegas José Manuel. Effects of Transportation Accessibility on Residential Property Values: Hedonic Price Model in the Lisbon, Portugal, Metropolitan Area [J]. Transportation Research Record, 2009, 2115(1), 127-137. doi:https://doi.org/10.3141/2115-16

[16] Sun Hui, Wang Yuning, Li Qingbo. The Impact of Subway Lines on Residential Property Values in Tianjin: An Empirical Study Based on Hedonic Pricing Model[J]. Discrete Dynamics In Nature And Society, 2016, 1-10. doi: 10.1155/2016/1478413

[17] Trojanek Radoslaw, Gluszak Michal. Spatial and time effect of subway on property prices [J]. Journal Of Housing And The Built Environment, 2017, 33(2), 359-384. doi: 10.1007/s10901-017-9569-y

[18] Haddad Eduardo A., Hewings Geoffrey J.D., Porsse Alexandre A., Van Leeuwen Eveline S., Vieira Renato S. The underground economy: Tracking the higher-order economic impacts of the São Paulo Subway System [J]. Transportation Research Part A, 2015, 73, 18-30. doi:http://dx.doi.org/10.1016/j.tra.2014.12.011

[19] Monajem Saeed, Nosratian Farzan Ekram. The evaluation of the spatial integration of station areas via the node place model; an application to subway station areas in Tehran[J]. Transportation Research Part D: Transport and Environment, 2015, 40, 14-27. doi: 10.1016/j.trd.2015.07.009

[20] Cortes Claro. Beijing opens new subway lines for Olympics[N]. 2008. Retrieved from https://www.reuters.com/article/us-china-subway-beijing-idUSSHA30105120080719

[21] McMillen Donald H. Civil Defence in the People's Republic of China[J]. The Australian Journal of Chinese Affairs, 1982, 8, 35-50. doi: 10.2307/2158924

[22] Pei, Jianfei. Beijing: Two new subway lines enter service on Saturday [N]. 2015. Retrieved from http://www.xinhuanet.com/fortune/2019-12/26/c_1125388403.htm

[23] Liang, Shuang. Beijing's subway is going full bore [N] - China - Chinadaily.com.cn. 2017. Retrieved from http://www.chinadaily.com.cn/china/2017-01/12/content_27931764.htm

[24] Beijing Municipal Bureau Statistics. Beijing macroeconomic and social development data base [DB]. 2019. Retrieved from http://hgk.tjj.beijing.gov.cn/ww/MenuItemAction!queryMenu

[25] National Bureau of Statistics. National Data [DB]. 2020. Retrieved from https://data.stats.gov.cn/easyquery.htm?cn=E0103

[26] Beynon Malcolm. DS/AHP method: A mathematical analysis, including an understanding of uncertainty [J]. European Journal Of Operational Research, 2002, 140(1), 148-164. doi: 10.1016/s0377-2217(01)00230-2

[27] Karthikeyan R., Venkatesan K., Chandrasekar A. A Comparison of Strengths and Weaknesses for Analytical Hierarchy Process. Journal Of Chemical And Pharmaceutical Sciences [J], 2016, 9(3), 12-15.

[28] Kangas Jyrki. The Analytic Hierachy Process (AHP): Standard Version, Forestry Application and Advances [J]. Forestry Sciences, 1999, 61, 96-105. doi: 10.1007/978-94-011-4483-4_8

[29] Han Li, Mei Qiang, Lu Yumei. A study of AHP and Fuzzy Comprehensive Evaluation method [J]. Journal of Chinese Security Science, 2004, (07), 89-92.

[30] Chen Jeng-Fung, Hsieh Ho-Nien, Do Quang Hung. Evaluating teaching performance based on fuzzy AHP and comprehensive evaluation approach[J]. Applied Soft Computing, 2015, 28, 100-108.

[31] Blomstrom Magnus, Lipsey Robert E., Zejan Mario.Is fixed investment the key to economic growth?[J] (No. w4436). 1993. National Bureau of Economic Research.

[32] Zheng Xian, Zhuang Yan. The Radius of Influence of Subway Construction on Nearby Housing [J]. Rail Transport and Economics, 2007, 29(6), 45-47