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The Application of Smart Urban Mobility Strategies and Initiatives: Application to Beijing

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Abstract

This research examines the criteria to assess Smart Urban Mobility. The research goal is to define the criteria related to smart urban mobility and to investigate their mutual influences. The study proposes six criteria applied to the analysis of transportation in Beijing city: urban planning, mobility, connectivity, environment, governance, infrastructure and economy. The DEMATEL method of multi-criteria analysis has been applied to analyse the relationship, influence and impact of criteria on each other. Two groups of experts have been evaluated the criteria. The first group consists of six experts from academia; the second group includes five experts from the city administration. All experts have long experience in transport planning. The assessment of criteria has been made individually for each expert from both groups. The results show that the scores of criteria by both groups are close. It was found that the criteria mobility (18.16%), connectivity (16.75%) and environment (16.69%) have a major impact on smart urban mobility. The criteria in the cause group are urban planning, governance, infrastructure, and economy. The criteria in the effect group are mobility, connectivity and environment. They are influenced by other factors. The AHP method has been used to validate the results given by the DEMATEL method. The results of both methods are close. The novelty in this study regards the defined criteria, determined weights and their mutual influences, and the analysis for the situation of Beijing. The proposed methodology can be used in future studies to assess various megalopolises in terms of Smart Urban Mobility.

Keywords:Urban Mobility; Smart city; Public transportation; DEMATEL; Analytic Hierarchy Process (AHP)

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1. Introduction

The idea of smart city is very distinctive and unique. It can be defined in different ways, for example it is such a city which is capable of fulfilling the needs and demands of modern times, yet, taking into account the availability of resources for the future generations and without compromising any such resources was presented by UK (2013). A smart city can also be defined as one in which the municipality takes a keen interest in understanding and solving problems, improving the quality of life, increasing urban operational efficiency and fulfilling the demand of the current generation without compromising the resources of the future generations, as outlined in Sustainable Smart Cities defined by ITU(2014). Smart cities are characterized by resilient, sustainable infrastructure, public capital, modern technology; quick response to growing or incipient problems through community integration was presented by UK (2013).

This study aims at establishing and analyzing the strategies of Smart City Concept, applying those strategies for the assessment and analysis Beijing. It also focuses on the establishment of an integrated criterion for the assessment of Smart Urban Mobility and their mutual influences. The DEMATEL method of multi-criteria analysis has been applied to analyze the relationship, influence, and impact of criteria on each other. Eleven experts separated into two groups, one from academia, and other from the city administration, have been assessed the criteria. The experts' scores are compared by using the Pearson correlation coefficient. The AHP method has been used to compare the results given by the DEMATEL method.

The paper is structured as follows, in section 2 is given a literature review of smart urban mobility; in section 3 is presented the research methodology, which includes the following steps: defining criteria for the assessment of Smart mobility, choice of the multi-criteria methods to determine the weights of criteria; in section 4 an analysis of results in the context of Beijing is made; in section 5 some conclusions are drawn.

2. Literature review

A smart city concept is not a new concept. Many prominent researchers have been involved in this field since the emergence and development of modern communication technologies. The European Commission has listed the important and essential elements which must be included in the ecosystem of a smart city. These elements includes, among others, the clean and green environment, the inhabitants, any governing and administrative body, well established economy and economic activities, a proper and sufficient arrangements for living and mobility and transportation. A small mobility initiative which can be an essential part of a gigantic smart city initiative was presented and evaluated by Manville & Cochrane (2014) and Benevolo, Dameri, & Auria (2016). They investigated the role of Internet Communication Technologies which can possibly play a positive role in the mobility issues and activities in a smart city. They opined that the use of ICTs can enhance the quality of life of the citizens and can positively improve the public value and image of the city. ICTs thus have enormous impacts on individual lives. The objectives of smart mobility are many, but the most important can be categorized in six categories: reducing noise pollution, air pollution, traffic cognition, transfer costs, increasing citizen's safety and enhancing travel speed. On the other hand some other studies, for example Stanković, Džunić, Džunić, & Marinković(2017) and Bencardino & Greco(2014), have indicated 26 indicators which they call smart performance of a city. These indicators have been placed by them in five thematic categories which include governance and urban safety, trust and social consistency, livability and housing conditions, improved infrastructure and environment and employment and finance. Different researchers have adopted different criterion for the evaluation and assessment of a smart city, but an integrated approach is missing. The methods and approach of Multi-criteria Analysis can be applied to assess and analyze the weightings of the criteria and hence the smart cities. For determining the ranking and weights for different cities, researchers have used different methods and approaches, such as TOPSIS method and AHP hierarchy process. The most important group of criteria according to the results drawn for determining the significance of certain groups of smart performances in the model is employment and finance (determined weight 0.517). For this purpose 23 Central and Eastern European Cities have been investigated. The multi-criterion model gives a list of top cities according to which Prague, Tallinn, Cluj-Napoca and Vilnius are the tope cities. Indeed, Lombardi, Giordano, Farouh, & Yousef (2012), adopted the Analytic Network Process method for investigating and ranking European cities; this analytical process has its foundation on the theory of the triple helix.

The advanced triple helix network model, in conjunction with the Comprehensive Evaluation Index system and the AHP, PSF evaluation model and Back Propagation Neural network, was applied to 151 Chinese cities to evaluate the urban intelligent development of the cities by Shi, Tsai, Lin & Zhang (2018). Yang & Zhang(2017)studied smart growth using AHP method and factor analysis, while investigating five main criteria and fifteen sub-criteria. The main criteria are: economics equity; social equity; environmental suitability; many kinds of transportation way; land mix and compact housing. The methodology was adopted to execute the smart growth development of “Jinchang city”. The highest weight was given to the criteria of environmental suitability and many transportation options. Tahir & Malek (2016)studied six criteria of the development of smart cities: smart environment, smart mobility, smart living, smart people, smart economy and smart governance, as required when developing a smart city that addresses the problems of efficiency and sustainability in its administration. The combination of AHP and GIS used for the analysis of transportation and planning of a new network to connect Beijing with another satellite town can be found in other work such as Farooq et al (2018). Other studies carried out in Beijing aim to ensure the pedestrian safety in the capital city Farooq et al (2017), applying the AHP method. The results showed that the

"Environment" criterion gave the highest weight of 0.4132; making the most important factor in the development of a smart city. The criterion ranking second in importance was "Mobility" that has a weight of 0.2781, followed by "Living", with a weight of 0.1639, and "People", with a weight of 0.0754; "Economy" (weight: 0.0399) and "Governance" (weight: 0.0295) took fifth and sixth places in importance respectively with regard to the development of a smart city.

Many researchers,(for example Kai, Hui, & Jui, 2016;Hristos(2017), Jingzheng & Hanwei(2017) and Boselli, Cesarini, Mercorio, & Mezzanzanica, 2015) have used and applied the AHP method for the evaluation and assessment of different criterion to analyse the impacts on each other of smart mobility services. For weight determination of any city, according to Hristos(2017), Analytic Hierarchy Process can be applied while for cities ranking TOPSIS Method can produce good results. In the model, employment and finance emerged as the most important group criteria amid the essential and vital groups of smart performance. In this regard data from selected 23 cities of Eastern and Central European was collected. Based on the findings of the multi-criteria model, the cities at the crest and top are Tallinn, Cluj-Napoca, Vilnius and Prague. The Analytic Network Process (ANP) method, within the theoretical framework of triple helix theory, was adopted and engaged by Lombardi, Giordano, Farouh, & Yousef(2012) for the assessment and evaluation of European cities. They argue that social relationship among the citizens is the most important factor for the evolution of the city system. They designed a sophisticated triple helix network model. On the other hand for urban intelligent development and assessment Shi, Tsai, Lin, & Zhang(2018), presented an ample evaluation index system, which primarily is based on the PSF evaluation model, but also the Analytic hierarchy process (AHP) and neural network are modeling tools used. A model of evaluation of the intelligent development of some 151 cities within China is constructed and evaluated, which is based on the process and method of engaging Back Propagation neural network theory and AHP. Three input criteria and four output criteria have been selected by Anand, Rufuss, Rajkumar, & Suganthi(2017) for the evaluation of these smart cities. The environment, mobility, economy, energy and society are considered as the input criteria by them, while the quality of life, economic prosperity and self-sustenance along with some twenty other sustainable indicators are being identified and declared as the output criteria. The researchers have adopted & engaged the fuzzy-AHP method, along with DEA analysis. This process and method is adapted to highlight and determine the comparative efficiency and competence of each of the sustainability indicators for a smart city in a particular context of input and output criteria. It was found and identified that the administrators and policymakers need to propose policies for energy (0.82) and economic development (0.85), so as to achieve the economic prosperity of the nation. Gatta, Marcucci, & Pira (2017) implemented the smart urban freight planning process in three distinct phases. They used desk approach for data collection and acquisition, an agent-based model approach to evaluate the optimized policies and the living lab approach for fostering stakeholders' engagement in co-creating policies.

For the better quality of life, Heddebaut & Ciommo(2018)analyzed the social organization and transport intermodal infrastructures within smarter cities approach. The study was conducted and figured out for two contingent railway stations i.e. Lille Europe and Lille Flandres. For the smart city of "Águeda in Portugal" Arsenio, Dias, Lopes, & Pereira(2018) investigated and studied the ecology concept of transportation with the use of electric bicycles. The research found that the increase in cycling infrastructure increases the demand for conventional and e-bikes in the city.

3. Research Methodology

The research methodology includes the following steps: defining criteria for assessment the Smart mobility, choice the multi-criteria methods to determine the weights of criteria, analysis of results in the context of Beijing.
In the study the following smart urban mobility criteria are formulated in figure1:
•F1: Urban planning. This criterion is related to Smart City Policies; Increasing Neighbourhood Mobility; Reducing Need to Travel, Launching TOD. The Smart City Policies are including interaction between local municipalities, administration, local societies and management platforms. Increasing Neighbourhood Mobility has a bearing on reducing the use of private cars and increasing environmental protection. Reducing Need to Travel include increasing neighbourhood mobility. Launching TOD (Transit-oriented development) encourages people to make journeys by non-motorized-transportation or public transport.
•F2: Mobility. This criterion has a link with Changing Mobility Behavior; Modal Choice; Prioritizing of Public Transportation. Changing Mobility Behavior means to stimulate the use of public transport. Modal Choice includes variety in public modes of transport and also bicycling and walking. Prioritizing of Public Transportation depends on the existing infrastructure and the efficiency of the public transportation operated by the transport authority.
•F3: Connectivity. This criterion is connected with Launching TOD and launching a 3V framework. 3V further refer towards, where land use, mass transit network, urban qualities and market vibrancy around its mass transit stations.
•F4: Environment. This factor includes attractiveness of natural conditions, sustainable resource management, environmental protection and levels of pollution. It is linked to increase the safety and security of road users; Reducing Need to Travel; Launching TOD.
•F5: Governance. It means improving public services, greater efficiency, better planning and decision-making. This criterion is related to Integration between Administration, Ministries, and Inhabitants; Structural clear vision and planning for smart city development.
•F6: Infrastructure. It is connected to Launching a 3V framework; Promoting NMT (Non-Motorized-Transportation). Launching a 3V framework is important node, place and market potential for each public transport station. The 3V Framework equips policy

and decision makers with quantified indicators to better understand the interplay between the economic vision for the city to achieve smart mobility transportation options in the city. Promoting NMT (Non-Motorized-Transportation) means a policy to promote cycling and walking, through the formation of special paths, pedestrian zones and other measures.

•F7: Economy. It is important that smart cities manage the environment and natural resources. This criterion is linked to Reducing Need to Travel; launching a 3V framework; Increasing Neighborhood Mobility.

The aim is to identify the mutual influences between the factors and their weights, which will be useful to evaluate the related strategies. An appropriate method of making a decision in this case, is the DEMATEL method, multi-criteria analysis to analyze the interdependencies, importance and relationship between criteria.

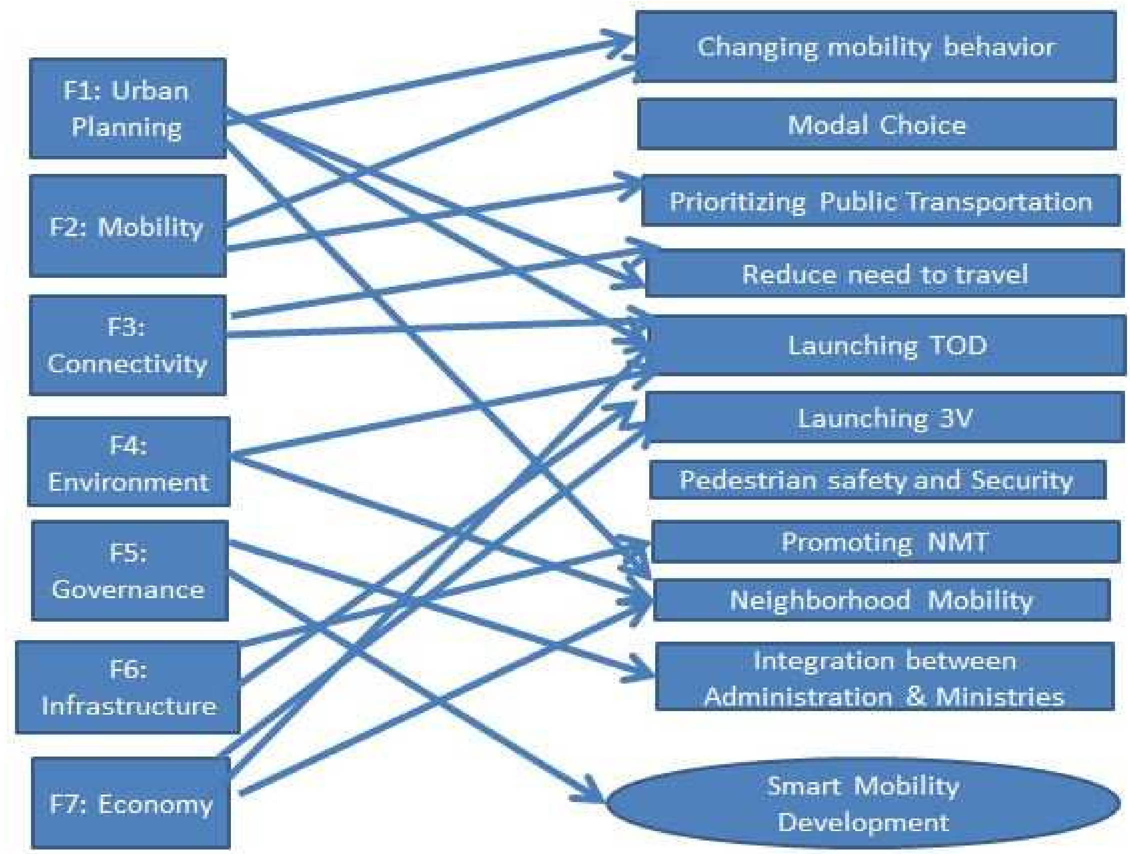

Figure 1: Interrelation between Criteria and Strategies

3.2 DEMATEL Methodology

The DEMATEL method has been applied in different areas of research: Gandhi at al(2015) used this method to investigate criteria in Green Supply Chain Management; Liu, Tzeng, Lee, & Lee (2013) andChen & Lee (2012) applied it to investigate tourism development; Cheng & Lee. (2014) used the DEMATEL method for carbon-based supplier selection; (Ren, Manzardo, Toniolo, & Scipioni (2013) undertook research about sustainability of hydrogen supply chain based of this method; Lin & Tzeng (2009) used it in industrial marketing; Zeynep (2016) applied the DEMATEL method for ship selection criteria in maritime transportation industry; Khanam, Siddiqui, & Talib (2016) used this method to investigate IT Resources; Tzeng, Chiang, & Li (2007) undertook research in the field of e-learning programs; Li & Tzeng (2009) used the DEMATEL method for study services in property mall. In this research the DEMATEL method have been applied to assess the weights of criteria and relationship. Using results of DEMATEL method we could analyze the importance of defined strategies. The DEMATEL method can be described byfive steps derived by HSU (2012), Govindan & Chaudhuri (2016) Stoilova & Kunchev (2017).

Step 1: Expert Perception matrix was defined to evaluate the expert influence on any factors, scored as follows: 0 = no influence, 1 = low influence, 2 = medium influence; 3 = high influence; 4 = very high influence. For each of the experts, a separate matrix with estimates is formed.

Step 2: Compute the average perception matrix.

The elements of average perception matrix A are calculated as follows:

$$a_{ij} = \frac{1}{H}\sum_{k=1}^{H} x_{ij}^{k} \qquad (1)$$

Where$k = 1, \dots, H$indicate the number of experts; $x_{ij}^{k}$are indicates the score which the expert k give to assess the influence of factor i on factor j. The numbers of criteria for which this matrix is compiled are $i = 1, \dots, n; j = 1, \dots, n$

Step 3: Calculate the average normalized perception matrix.

This matrix is formed as a ratio between average perception matrix A and the greater value S of major value of the sum of each column j and the major value of the sum of each row i of the matrix$A$.

The value of S is calculated as follows:

$$S = max\left(\max\,(1 \le i \le n) \sum_{j=1}^{n} a_{ij}\,; \max\,(1 \le j \le n) \sum_{i=1}^{n} a_{ij}\right) \qquad (2)$$

$$D = A/S, \qquad (3)$$

The values of each element in average normalized perception matrix D are between zero and one.

Step 4: Calculate the total relation matrix.

The total relation matrix is calculated using average normalized perception matrix and identity matrix I.

$$T = D(I - D)^{-1} \qquad (4)$$

Step 5: Construct the DEMATEL cause and effect relationship diagram using a threshold value.

This step includes the determination of sums of rows and sums of columns of the T matrix; calculation the threshold value; compiling of cause and effect relationship diagram.

$$R = [r_i]_{nx1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{nx1} (5)$$

wherer_i - the sum of the i-th row in matrix T.

$$C = [c_j]'_{1xn} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1xn} (6)$$

Where c_j- denotes the sum of j-th column in matrix$T$; $'$ - the symbol means transposed matrix.

In the case of$i = j$, term $(r_i + c_i)$ which is called "prominence" indicates the total effects both given and received by the i-th factor. The difference$(r_i - c_i)$, which is called "relation", represents the net effect that the criterion contributes to the system in relation to other factors. When $(r_i - c_i)$ is positive, factor i belongs to the cause group, if $(r_i - c_i)$ is negative factor i belongs to the effect group derived by Kai, Hui, & Jui, (2016).

The normalized degree of influence of each criterion can be determined as follows:

$$e_i = \frac{r_i+c_i}{\sum_{i=1}^{n}(r_i+c_i)}.100,\% \quad (7)$$

To eliminate some minor effects elements in matrix Tit is necessary to calculate the threshold value. In this research the threshold value p is determined as average value as follows:

$$p = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}[t_{ij}]}{N} \quad (8)$$

Where N - the total number of elements in the matrix$T$.

The cause and effect relationship diagram shows the complex interrelationship and gives information about the most important factors and how they influence the affected factors. The coordinate sets of this diagram are $(r_i + c_i)$ and$(r_i - c_i)$.The diagram includes the factors that t_{ij} is greater than the threshold value p.

In this research, the criteria were evaluated by 11 experts considering the influence on any factors using the score presented in Step 1. Each expert has given a score from 0 to 4, according to DEMATEL method. The average values of expert assessment are shown in table 2 in section 4.4.

3.3 Analytic hierarchy process (AHP)

The method of Analytic hierarchy process (AHP) is used to verify the results for the weights of the criteria obtained by the DEMATEL method. The AHP method is based on the following principles: structure of the model; development of the ratings for each alternative for each criterion; synthesis of the priorities. The pairwise comparisons between each criterion are performed by experts using Saaty's scale defined by Saaty (2004)as shown in Table 1.

Table 1:Saaty's scale of pairwise comparison

Intensely of importance	*Definition*
1	*Equal importance*
3	*Moderate importance of one factor over another*
5	*Strong or essential importance*
7	*Very strong importance*
9	*Extreme importance*
2,4,6,8	*Values for intermediate comparison*

Source: Saaty,(2004)

In this method the consistency ratio CR is used to assess the estimates of experts.

$$CR = \frac{CI}{RI} \leq 0{,}1 \quad (9)$$

where: CI is the consistency index; RI is a random index. The random matrix is given by Saaty(2004).

The consistency index is:

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (10)$$

where: $\lambda_{\max}$ is the maximum value of the priority matrix, n is the number of elements in the matrix. Generally, if the CR is less than 0.10, the consistency of the decision-maker is considered satisfactory. But if CR exceeds 0.10, some revisions of judgments may be required.

$$\lambda_{\max} = \sum_{i=1}^{n} \left[\left(\sum_{j=1}^{n} a_{ij} \right) . W_i \right] \quad (11)$$

where: a_{ij} ($i, j = 1, \ldots, n$) are the elements of evaluation matrix; Wi are the weights of the criteria.

4. Beijing Transportation Problems

Transport plays animportant role in social and economic stability; furthermore, it forges the competition. Urban sprawl, motorization, and a decline in the use of public transportation establish a vicious pattern, which reduces accessibility and mobility in emerging developing countries evaluated by Gakenheimer (1999). In Chinese megacities, it is hotly debated how to relieve congestion and reduce travel time elaborated by Peng & Zhu (2007). Motorization is booming in Beijing because the car seems the safest means of transport, while non-motorized transportation modes (walking and bicycling) have become unsafe studied by Gallagher (2006). Peng& Zhu (2007) has shown how most Chinese cities are suffering from traffic jams, longer commute times and congestion at levels which pose an especially challenging task for urban transportation planners. Beijing is a city of bridges, wide roads, vehicles, emissions, and bad air quality. In total there were 14.28 million vehicles for a population of 21.52 million in 2014, along with 17 million parking spaces. Over the last five years the municipality has come up with the heavy infrastructure to combat the traffic situation, but at the moment the city is characterized by high congestion, long travel time and high commute time. A Survey done by IBM(2012); Gao, Newman & Webster (2015); Farooq et al (2018) which aimed to measure the commuting flows in Beijing, showed that it took almost 42 minutes to cover a distance of 6 km, making Beijing one of the worst cities for commuters. The addition of 1200 vehicles per day makes it even more miserable and unsafe for its inhabitants (OSAC (2017).

Growing congestion in Beijing is hugely costly. 25 billion RMB (equal to 2.5% of Beijing GDP) is the cost of delays and air pollution resulting from high emission levels and fuel consumption studied by Xie, Zhang, Ru & Sheng, 2011. It was reported in 2003 that due to traffic jams and congestion, around 40% of people spent more than an hour measured from USCCS-1(2002). The present situation in Beijing is that, due to traffic congestion, average vehicle speed has been reduced to 10km/hour, which is less than the average bicycle speed. Yet the problem of Beijing traffic congestion is still being addressed in conventional ways by increasing capacity Zhao, Lu, &Roo (2010). A

Report for Beijing Transportation has stated that from 2003 to 2010, the municipality increased the transportation infrastructure and capacity but the speed still decreased from 30km/hour to 20km/hour on the arterial road. Secondary roads are more congested than arterial roads, but average speed is less than 15km/hour measured by Jun et al (2016). In China's megacities (Beijing and Shanghai) the operating speed of a bus dropped to 9.2km/hour and 10km/hour in 2003 measured by USCCS-1 (2002). Due to rapid car growth, the situation in Beijing is getting worse day by day; in Beijing, the average travel speed is of 12 km/hour measured by Guilford (2014). The rapid increase in infrastructure development allows cities to expand quickly, attracting more car users studied by Hong, Xinmiao&Qixin (2007). In Beijing, private vehicles reconsidered the major source of emissions, with an annual rate of 46% nitrogen oxide, 74% hydrocarbon, 63% carbon monoxide, and 85% noise pollution due to motor vehicles, emission level measured by Yang, Wang, Shao &Muncrief (2015); Zhu & Kung (2014).

4.2 The attraction of cars in Beijing

China is leading the automobile market studied by Yu (2016) and also the second largest brand user after the United States. According to the China Association of Automobile Manufacturers CAAM (2017), passenger vehicle sales were 22.8 million, and to meet demand in 2017, capacity will increase by 26% analyzed by Fei (2017). In January and February 2016, the production and sales of automobiles in China reached 2,160,000 and 1,939,000 units respectively. Traffic congestion is an ever-increasing problem faced by most megacities worldwideGakenheimer (1999). In 2005 bicycle lanes were cut back in China, on the grounds that cyclists interfered with road traffic by Peng (2005), and from this year 2017 onwards most Chinese cities are starting and encouraging planning for motorization. In most of the megacities in Asia where car-based transit is non-viable in compact congested areas, 20% growth is expected in car ownership till 2050 predicated by Lutz (2014). Attempting to solve this problem by increasing infrastructure capacity, expanding roads, and developing a high transit system to allow more people to travel Gakenheimer&Zegras (2003) is simply unsustainable. The road network in Beijing is a complex dense network and the continuedextension in road infrastructure strongly affects the sake of city along with pushing more people to drive by Farooq et al (2018).

4.3 Emission Problems in Beijing

In the year 2010, 1.3 million premature deaths in China were due to air pollution, and the threat to human life is increasing as air pollution increases (Lelieveld, Evans, Fnais, Giannadaki&Pozzer (2015). Bad air quality has become a distinguishing factor of Beijing for several decades and has reduced the level of visibility measured by Zhao, Zhang, Xiaofeng, & Xiujuan (2011). Low visibility in Beijing directly affects transportation and increases safety risks Zhang, Zhang &Xue (2010). In many people's minds, Beijing is the epitome of pollution (Liu, Li & Li (2016), which is the cause of very many health problems for its citizens Zheng, Pozzer, Cao &Lelieveld (2015).
Motorization in Beijing is the source of 23% of PM10, 80% of hydrocarbons, 75% of NOx, and 50% of suspended particulate matteDameng, Shaopeng, &Xianghua (2008). Ground level emissions were measured by Guo et al (2014) (precursors and particulate matter) are not only limited to cities, but also extended to rural and suburban areas, and to remote regions throughout China Lin et al (2014). The major cause of emissions is the rapid attraction of society towards motorization Liu, Li & Li (2016). The major

causes of emissions in Beijing are power generation, transportation, the residential sector, and industry. In winter the emission level and lower air quality in Beijing almost double due to the household heating system measured by Jun et al (2016).

4.4 Application of DEMATEL Method to assess the weights of criteria

Eleven experts with long experience in transport planning took part in the evaluation of the criteria. Among them six experts are from academia; five experts are from the city administration. Table 2 shows the experts' criteria evaluation on a scale of 1 to 4. Table 3 presents the average matrix of experts' assessments.

Table 2: Expert assessments

Expert	*Criteria*	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*
1	F1	0	2	1	2	0	0	1
	F2	3	0	3	4	3	3	3
	F3	3	3	0	3	2	3	3
	F4	3	3	3	0	1	3	2
	F5	1	0	0	0	0	1	1
	F6	1	2	1	2	2	0	2
	F7	1	2	0	1	0	0	0
	F1	0	2	1	1	1	1	1
	F2	4	0	4	2	2	2	2
2	F3	4	4	0	4	2	2	3
	F4	4	3	2	3	1	2	2
	F5	1	1	1	1	0	1	1
	F6	1	2	2	2	1	0	1
	F7	3	2	1	0	1	1	0
	F1	0	3	1	1	2	1	1
	F2	4	0	0	4	4	3	2
3	F3	4	4	3	0	4	2	4
	F4	4	4	0	3	0	1	3
	F5	1	1	1	0	1	2	1
	F6	1	3	0	2	3	0	1
	F7	3	1	1	1	1	1	0
	F1	0	1	2	1	1	1	1
	F2	3	0	3	4	2	2	2
4	F3	3	3	0	3	2	2	3
	F4	3	3	2	0	3	2	1
	F5	1	1	1	1	0	1	2
	F6	1	1	1	1	1	0	1
	F7	2	1	1	1	0	0	0
	F1	0	2	2	1	1	0	2
	F2	2	0	2	4	.3	3	3
5	F3	3	3	0	3	1	3	3
	F4	3	3	2	0	2	3	2
	F5	1	0	1	0	0	1	2
	F6	1	2	1	2	1	0	2

	F7	2	1	0	2	1	1	0
6	F1	0	2	2	1	0	1	2
	F2	4	0	4	4	2	2	2
	F3	2	2	0	2	3	2	2
	F4	2	2	2	0	2	2	2
	F5	2	1	0	1	0	2	3
	F6	2	2	2	2	1	0	1
	F7	2	1	1	1	2	2	0
7	F1	0	2	1	2	2	2	2
	F2	3	0	2	3	1	3	3
	F3	3	3	0	3	2	2	3
	F4	3	3	3	0	2	1	2
	F5	2	2	2	2	0	1	2
	F6	2	2	1	2	2	0	1
	F7	3	1	2	2	2	2	0
8	F1	0	2	1	2	1	2	2
	F2	4	0	4	3	2	2	2
	F3	3	3	0	2	2	2	2
	F4	3	2	3	0	3	2	2
	F5	1	2	1	2	0	1	1
	F6	1	2	2	2	1	0	2
	F7	3	1	2	1	1	1	0
9	F1	0	1	2	1	1	1	1
	F2	4	0	4	4	2	2	2
	F3	3	3	0	2	1	2	2
	F4	3	2	3	0	2	2	1
	F5	1	1	1	1	0	1	1
	F6	1	1	1	1	1	0	2
	F7	2	1	1	1	1	1	0
10	F1	0	2	2	1	1	1	1
	F2	3	0	3	4	4	4	4
	F3	4	4	0	4	3	3	4
	F4	4	4	4	0	1	4	2
	F5	2	1	1	1	0	1	2
	F6	2	2	2	2	1	0	2
	F7	3	1	1	2	0	0	0
11	F1	0	2	2	1	0	0	0
	F2	3	0	3	4	3	3	3
	F3	3	3	0	3	2	4	3
	F4	3	3	3	0	0	3	2
	F5	2	0	0	0	0	1	2
	F6	2	2	2	2	1	0	1
	F7	2	1	0	2	0	0	0

Source:ResearchStudyassessment model

Table 3: The Average Matrix

Criteria	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*Total*
F1	0	1.91	1.55	1.55	0.73	0.91	1.27	7.92
F2	3.36	0	3.27	3.82	2.27	2.64	2.55	17.91
F3	3.18	3.18	0	2.91	2	2.45	2.91	16.63
F4	3.18	2.91	2.73	0	1.73	2.27	1.91	14.73
F5	1.36	0.91	0.73	0.91	0	1.18	1.64	6.73
F6	1.36	1.91	1.55	1.91	1.18	0	1.55	9.46
F7	2.36	1.18	0.91	1.27	0.91	0.91	0	7.54
Total	14.8	12	10.74	12.37	8.82	10.36	11.83	80.92

Tables 3 and 4 show the result of the total relation matrix along with direct and indirect impact. Using the DEMATEL method the threshold value is 0.263, while in table 4 the bold matrix indicates the criteria that are greater than a threshold value.

Table 4: The Total Relation Matrix

Criteria	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*
F1	0.174	0.239	0.211	0.227	0.145	0.172	0.204
F2	**0.503**	**0.286**	**0.415**	**0.470**	**0.320**	**0.373**	**0.398**
F3	**0.472**	**0.415**	**0.241**	**0.411**	**0.293**	**0.346**	**0.395**
F4	**0.444**	**0.382**	**0.353**	**0.248**	**0.264**	**0.319**	**0.328**
F5	0.199	0.154	0.136	0.156	0.077	0.152	0.186
F6	**0.267**	0.258	0.288	**0.236**	0.182	0.140	0.236
F7	**0.267**	0.185	0.162	0.192	0.138	0.153	0.118

The sum of columns (C) and rows (R) of Total Relation Matrix is (R+C). Itiscalled "Prominence" and indicates that all criteria are relatively significant and important. The difference (R-C) named "Relation" divides the criteria into cause and effect groups, which is dependent on the values (positive and negative) of all the elements in (R – C) column. (R + C) column indicates the importance of the criteria. Taking into consideration, the significance and value of (R - C) score, the criteria have been divided into cause group factors and effect group factors. The cause group factors have a direct and indirect impact on the overall system.

Table 5: The direct and indirect influence

Criteria	*R*	*C*	*R+C*	*R-C*	*Weight*
F1	1.372	2.325	3.697	0.953	14.3%
F2	2.765	1.919	4.685	-0.846	18.2%
F3	2.574	1.747	4.321	-0827	16.8%
F4	2.339	1.966	4.305	-0.373	16.7%
F5	1.059	1.419	2.478	0.360	9.6%
F6	1.574	1.656	3.230	0.082	12.5%
F7	1.214	1.865	3.080	0.651	11.9%

The results in Table 5 show:

- The criteria in the cause group are: F1 (Urban planning), F5 (Governance), F6 (Infrastructure) and F7 (Economy), (R-C) is positive.

- The criteria in the effect group are F2 (Mobility), F3 (Connectivity) and F4 (Environment), (for each of these criteria, (R-C) is negative). They are influenced by other factors.
- F2 (Mobility), F3 (Connectivity) and F4 (Environment) criteria have the highest degree of importance.
- The prioritization is F2> F3>F4>F1>F6>F7>F5.
- F3 and F4 criteria (Connectivity and Environment) have similar values.
- Withinall the effect group, factors F2 (Mobility) and F3 (Connectivity) obtain the lowest (R-C) score, i.e. (-0.846) and (-0.827), which implies that these factors sustain the maximum impact from all other factors. These criteria are in the first and second position of importance, according to the (R+C) score.

Figure 2 presents the cause and effect diagram for the criteria. The results show:
- It can be seen that for F1 (R-C) is positive and (R+C) is large. This indicates that the F1 criterion (Urban planning) is a key factor for solving problems.
- Factors F5 (Governance), F6 (infrastructure), and F7 (Economy) have also positive (R-C) and large (R+C), showing their high importance.
- F2 (Mobility), F3 (Connectivity) and F4 (Environment) criteria have negative (R-C) and large (R+C), demonstrating that they have an indirect impact on the studied system.

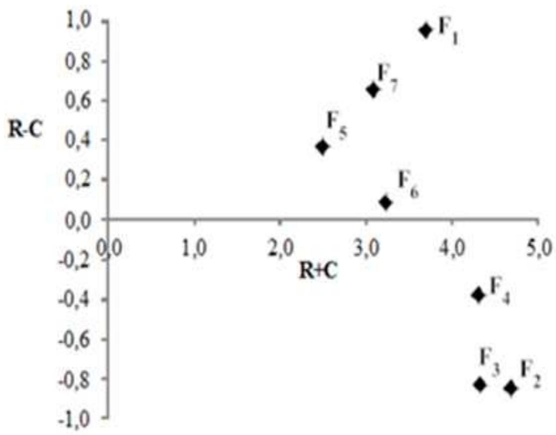

Figure 2: The cause and effect diagram

Figure 2 and Figure 3 present the impact-relation map for the criteria. The results show:
- The criteria F2 (Mobility), F3 (Connectivity) and F5 (Environment) impact for all other criteria.
- The criterion F6 (Infrastructure) impact for F1(Urban planning) and F4 (Environment);
- The criterion F7 (Economy) impact for criterion F1 (Urban planning).

The DEMATEL method has also been used to determine the weights of criteria according to both groups of experts those from academia and others from city administration. Table 6 presents the average matrix of the assessments of academic experts, whileTable 7 shows the same matrix for the other group of experts from city administration. Table 8 indicates the weights of criteria determined by DEMATEL method. The first column of the weights presents the weights given by all experts' assessments; the second column shows those received by the academic experts and the third one those of the administrative experts. The Pearsoncorrelationcoefficient has been used to assess the results by different groups of experts. Table 9 shows the values of Pearson correlation coefficient between different experts groups. The high value of correlation coefficient shows agreement among the experts' answers.

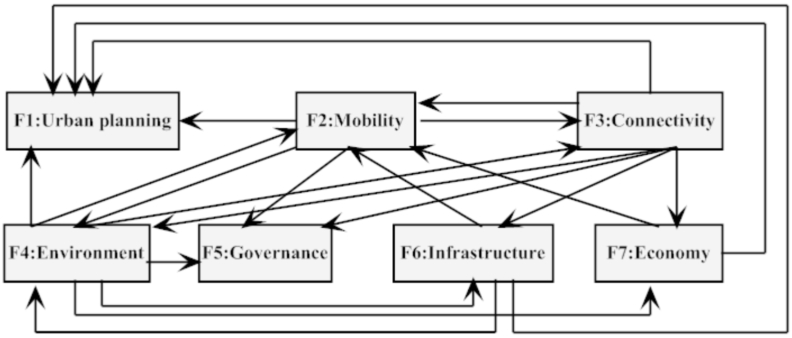

Figure 3: The impact-relation map for the criteria

Table 6: The Average Matrix for expert assessment of experts from academia (experts 1-6)

Criteria	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*Total*
F1	0	2.00	1.50	1.50	0.50	0.67	1.33	7.50
F2	3.33	0	3.33	4.00	2.17	2.50	2.33	17.67
F3	3.17	3.17	0	3.00	2.00	2.33	3.00	16.67
F4	3.17	3.00	2.33	0	1.83	2.17	2.00	14.50
F5	1.17	0.67	0.50	0.67	0	1.33	1.67	6.00
F6	1.17	2.00	1.50	2.00	1.17	0	1.33	9.17
F7	2.17	1.33	0.67	1.00	0.83	0.83	0	6.83
Total	0	2.00	1.50	1.50	0.83	1.00	1.50	78.33

Table 7: The Average Matrix for expert assessment of experts from city administration (experts 7-11)

Criteria	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*Total*
F1	0	1.80	1.60	1.40	1.00	1.20	1.20	8.20
F2	3.40	0	3.20	3.60	2.40	2.64	2.80	18.20
F3	3.20	3.20	0	2.80	2.00	2.45	2.80	16.60
F4	3.20	2.80	3.20	0	1.60	2.27	1.80	15.00
F5	1.60	1.20	1.00	1.20	0	1.18	1.60	7.60
F6	1.60	1.80	1.60	1.80	1.20	0	1.60	9.60
F7	2.60	1.00	1.20	1.60	0.80	0.91	0	8.00
Total	0	1.40	1.40	1.00	0.60	0.80	0.80	83.20

Table 8: Comparison between weights

	Weight		
Criteria	*All Experts*	*Experts from Academia (1-6)*	*Expert from Administration (7-11)*
F1: Urban Planning	14.33%	14.24 %	14.45%
F2: Mobility	18.16%	18.75%	17.67%

F3: Connectivity	16.75%	16.77%	16.87%
F4: Environment	16.69%	16.90%	16.45%
F5: Governance	9.61%	9.12%	10.11%
F6: Infrastructure	12.52%	12.45%	12.53%
F7: Economy	11.94%	11.77%	11.93%

Table 9: Pearson correlation coefficient

	Average	Average 1-6	Average 7-11
Average	1	0.999	0.998
Average 1-6	0.999	1	0.994
Average 7-11	0.998	0.994	1

4.5 Application of AHP Method

The results of the pairwise comparison, using AHP method andSaaty's scale,are given in Table 10. The Consistency ratio is less than 0.1, which means that the expert evaluations are adequate. Figure 4 presents the comparison of the results obtained by both methods. It can be seen that the results are similar. The difference in the weights of the criteria for the two methods is on average 2%. In the first three positions there are the criteria of mobility, connectivity and environment, confirming the findings ofthe study by Tahir & Malek(2016), in which environment and mobility are the two most important criteria.

Table 10: Pairwise comparison by Saaty'scale

Criteria	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*Weight*
F1	1	1/3	1/2	½	1	2	1/2	0.10
F2	3	1	1	½	2	2	3	0.20
F3	2	2	1	½	2	2	2	0.18
F4	1	2	2	1	2	½	2	0.20
F5	1	1	½	½	1	½	½	0.08
F6	½	½	½	2	2	1	½	0.13
F7	2	2	1/3	1/2	2	2	1	0.11
Consistency Ratio= 0.09								

Source: Saaty , 2004

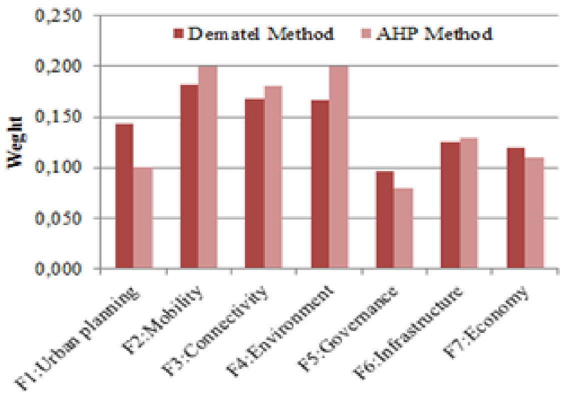

Figure 4: Comparison of results by DEMATEL method and AHP method

As the criteria mobility (F2), connectivity (F2) and environment (F4) have the large weights, this means that the smart strategies Changing Mobility Behavior; Modal Choice; Prioritizing of Public Transportation, Increase the safety and security of road users; Reducing Need to Travel; Launching TOD and Launching a 3V framework are of great importance for the realization of Smart Cities Concept. The criterion urban planning (F1) is a key factor for solving problems; this means thatdeveloping an urbanization plan that focuses on basic facilities and public transportation which satisfied demand, promoted a green environment, reduced congestion, provided clean air quality, reduced pollution and improved the urban living environmentis fundamental for smart city policies.
The criteria urban planning, governance, infrastructure and economy are in the cause group. This means that the Smart cities mobility strategies, which are related to these criteria, i.e. Smart City Policies, Integration between Administration, Ministries, and Inhabitants; Structural clear vision and planning for smart city development, are essential for the development of smart cities.

5. Conclusions

Developing cities have to overcome different obstacles and issues in implementing smart sustainable and modern transport strategies and policies. Smart city development has enormous and wide-ranging social and economic benefits, such as the reduction of Vehicle Motorised Transportation (VMT) and emissions of environment-unfriendly gases, and discouraging car ownership. It will also encourage greater use of the public transport network, which will provide additional space for public parks and recreation centers in megacities. The health conditions of citizens will be also improved as a result of encouraging cycling and other form of active transportation. One big problem in today's big cities is that they are facing severe transportation and mobility problems, which will need a solution not only in terms of smart mobility designs but also by transforming the way of life and thinking of both citizens and decision and policy makers. The present research analyses the application of Smart Urban Mobility Strategies in the context of Beijing. Taking predefined strategies into account, the study defines the criteria to assess them. Two multi-criteria analysis methods (DEMATEL and AHP) have been applied to assess the weights of these criteria. It was found that the both methods give close results. The difference in the weights of the criteria for the two methods is on average 2%.The difference of assessment by DEMATEL method from two groups of experts, one from academia and other from city administration, has been studied. The high value of Pearson correlation coefficient shows agreement among the experts' answers.The paper founds that the criteria urban planning, governance infrastructure and economyare in the cause group; the criteria mobility, connectivity and environment are in the effect group and the results of DEMATEL method estimate that these criteria are altered by other factors. The paper founds that the criteria mobility (18.2%), connectivity (18.8%) and environment (16.7%) are the most important. These criteria are connected to the Changing Mobility Behavior; Modal Choice; Prioritizing of Public Transportation, Launching TOD and Launching a 3V frameworkandReducing Need to Travel. The results can help the city administration to make decision about smart urban mobility. The proposed methodology, extending the sample considered, can be used in future studies to assess various megalopolises in terms of Smart Urban Mobility, changing the defined criteria according to the specific city condition.

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