

Sustainable Urban Transport Assessment in Asian Cities

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ABSTRACT

Effective access and mobility in cities are the basis for achieving urban sustainable development. Today, in Asia, uncontrolled growth of cars and motorcycles has undermined human health, urban environmental quality, economic productivity and social equity. Indicators and practices indicate that efficient public and non motorized transport, and prudent restrictions on private motorized vehicles have been proven effective in not only reducing the negative impacts of unsustainable transport but also in providing a means to improve the basic quality of human life. Some attempts have been made to develop sustainable transport indicators, STI. A few studies actually apply STI to compare sustainability among various cities. In this paper 21 Asian cities ranked in terms of urban sustainable transport composite index and the best and worst Asian cities identified. Then, the key factors that have influenced sustainability in these cities have been extracted. The study database is created from UITP databank: "Millennium cities database for sustainable mobility" or MCDST. Firstly sustainable transportation indicators were selected by reviewing past researches. Some indicators are edited or redefined. Consequently, 3 indicators in each 3 groups of environmental, economical and social were developed. Then composite index was also suggested by combination of 9 standardized indicators. According to composite index various cities were compared. Finally some important factors affecting urban transportation sustainability were determined by using correlation analyses between composite index and cities' characteristics.

Key words: Sustainable development, Urban transport, Indicator, MCDST, Asian cities.

INTRODUCTION

Since 2004, with the development of the "Manila Policy Dialogue on Environment and Transport in the Asian Region", United Nations Centre for Regional Development, UNCRD, in collaboration with the Ministry of Environment of Japan, has sought to create a new paradigm in transport practices for the region. With the assistance of world-leading sustainable transport experts and governmental partners, UNCRD developed the "Aichi Statement" in 2005. This statement outlined specific actions that cities can take across 12 major areas of Environmentally

Sustainable Transport, EST, and now it provides a basis for the participating countries to regularly report upon their progress in reaching the objectives¹. Subsequently, in 2007 and 2008, over thirty Asian cities signed the Kyoto Declaration for the Promotion of EST in Cities, endorsing the objectives underlined in the Aichi Statement. In 2009, the Initiative produced the Seoul Statement towards the Promotion EST for a LOW-Carbon Society and Green growth in Asia². The Bangkok 2020 Declaration (2010) in Asia and the Bogotá Declaration (2011) in Latin America provide the necessary framework for the promotion of EST policies and measures³.

Sustainable development has become a major concern for policymakers and planners in both developed and developing countries since the publication of "Our Common Future on Brundtland World Commission on Environment and Development, 1987"⁴. The Brundtland commission defined sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs⁵. Sustainable development is composed of three main aspects: environmental, economical and social^{4,6-8}.

The CST, Centre for Sustainable Transportation, developed a definition of sustainable transportation: a sustainable transportation system is one that:

- Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
- Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy.
- Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise⁹.

Agenda 21 emphasizes the role of sustainable development indicators to help decision-making¹⁰. The objective of the Partnership for Sustainable Urban Transport in Asia (PSUTA) was to work with stakeholders in Asian cities to identify indicators of sustainable transport for use in the policy making process¹¹. There is an urgent need to build indicators capacity at all levels of government:

- to collect useful information on urban conditions and trends;
- to analyze this information to improve access to and coverage of basic services and other urban infrastructure;
- to improve targeting and operational performance of services;
- to apply that knowledge in formulating and

implementing urban policies and programs.

The development of indicators systems has been a prime response to the need for monitoring in devolved systems within the context of national or regional plans or international agreements¹².

Transportation-related urban environmental problems are common in all big Asian cities regardless of whether they are of developed or developing countries. These include: vehicular air pollution and associated public health and environmental impacts, noise and traffic congestion and economic loss caused by time loss trapped in traffic jams, inefficient use of energy, greater use of non-renewable fossil fuels, and loss of natural habitats. Fifteen mega cities in Asia greatly exceeded the WHO Air Quality Standards from 1990 to 1999. Regarding to the illnesses caused by urban air pollution, it is estimated that 800,000 people worldwide lose their lives each year, of which 500,000 are estimated to die in Asia. Furthermore, 1.2 million people were killed worldwide by road accidents in 2004, which is a 65% increase from the previous twenty years. Almost 60% (720,000 deaths) of accidents happened in Asia¹³. There are Asian cities at both extremes of income and at many levels in between. Comparing transport pattern and income level of Asian cities indicate that wealthy Asian cities typically have much less automobile dependence than cities with similar incomes per capita and even than many cities with much lower incomes¹⁴. The car in Southeast Asia is a symbol of status, success and wealth. It is for most nouveau riche urban societies in the region the paragon of conspicuous consumption. It is also viewed as one of the important industrial sectors by several countries. Thailand, Malaysia, the Philippines and Indonesia all have car manufacturing plants¹⁵. In Asia, few developing cities including, as far as is known, only Bangkok, Manila, Madras, and Kuala Lumpur have allocated extensive road space to bus priority and bus ways. In many Asian cities, it is estimated that over 15 percent of the population is dependent directly or indirectly on informal sector transport for their livelihood¹⁶.

Some attempts have been made to

develop sustainable transport indicators which are listed as STI. A few studies actually use STI to compare and analyze sustainability among various cities of the Asia. Haghshenas and Vaziri developed 9 STI for urban studies, 3 indicators for key dimensions of environmental, economic and social impacts. These indicators are computable from the study database and the UITP databases¹⁷. Then, they redefined one of the social group indicators and made a model which predicts sustainable transportation indicators for the future for different development policies with acceptable error margins¹⁸. But up to now, a comparative and comprehensive study about sustainable transport in Asian cities has not been done. In this paper, various developed and developing Asian cities were ranked in terms of urban sustainable transport composite index and some factors affecting urban transportation sustainability were identified.

MATERIALS AND METHOD

The database

There are a few comprehensive databanks available covering world urban transportation. There are also some other transportation data which are at the country level and not at urban¹⁹. Some studies have collected urban data only about a given country or a specific region of the world^{20,21}. Other studies or databases have collected world cities information but don't have enough quantitative data about urban transportation impacts^{12,22,23}.

Kenworthy and Newman have collected 2 important databases with UITP cooperation that are useful for sustainable transport global comparison. UITP, International Association of Public Transport, has developed two important databases about urban transportation: MCDST, Millennium cities database for sustainable mobility²⁴ and MCD, Mobility in cities database²⁵. MCDST has collected more than 230 indicators about 100 world cities distributed in all world regions in 1995. In MCD, there is transportation information of 50 cities in 2001 which most of them are in Europe. The numbers of Asian cities in UITP database is 21 cities.

The MCDST is the newest databases that

contain relevant data about cities of different world regions. In this respect MCDST is selected for this paper. MCDST contains indicators for cities characteristics, overall urban transportation, and transportation mode operate, citizen trips and impacts of transportation. The information of 21 Asian cities was extracted from MCDST. The list of Asian cities was shown in table 1.

Sustainable transportation indicators development

An indicator is a variable based on some measurements, representing as accurately as possible a phenomenon of interest²⁶. Indicators are variables selected and defined to measure progress toward an objective⁷. Chapter 40 of Agenda 21 states that "indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to a self-regulatory sustainability of integrated environment and development systems"¹⁰ OECD defined sustainable transportation indicators as statistical measures that give an indication of the sustainability of social, environmental and economical development²⁶.

There are some efforts to define indicators to quantify urban sustainable transportation. In some cases, STI's were used and selected from urban sustainable development indicator set. Several authors note that indicator selection should primarily be driven by the questions that the indicators are supposed to answer²⁶⁻²⁹. Indicator should be easily understandable, reasonable, measurable, possible to quantify, accessible, comprehensive, reflect various aspect of study, sensitive to changes over time, independent, standardized for comparison, clearly defined and capture long-term processes²⁷⁻³⁰.

Also Joumard *et al* in chapter 4 of their recent research, introduce 10 criteria for indicator selection which were categorized in 3 main groups²⁶.

- Representation: validity, reliability, sensitivity
 - Operation: measurability, data availability, ethical concerns
 - Policy application: transparency, interpretability, target relevance, action ability.
- Haghshenas and Vaziri developed 9 STI's for urban

studies, 3 indicators for key dimensions of environmental, economic and social. These indicators are computable from the study database and the UITP databases¹⁸. These 9 indicators were selected for current research and in the following, suggested indicators are explained in main groups:

- a. Transportation environmental impact indicator (TEII)
TEII's in MCDST are about urban transportation local emission, energy use and land consumption. Land consumption is defined as sum of urban land area allocated to road and public reserved line.
- b. Transportation economical impact indicator, (TCII)
Economical indicators, TCII, are local government budget in transportation sector, time spent in traffic and user cost over GDP per capita. In this research, GDP per capita was selected instead of household's costs.
- c. Transportation social impact indicator (TSII)
The social indicators, TSII, are transportation death per million people, accessibility and variety of transport option.

The concept of accessibility has played a major role for several decades in the literature of regional and transport researches³¹. Definition and measures found in the transport literature can be categorized in 3 clusters: infrastructure related, activity related and mixed measures³². One known accessibility indicator is density of network in area or network length per area³². This indicator is the reverse of average distance of each urban point from system network and shows system accessibility.

Network length per area can be measured for each transport system such as bus, rail and private mode, but the question to be investigated is how could various systems' accessibility be aggregated and urban transport accessibility indicator be developed? The next term regarded to join in definition of various systems' accessibility is passenger-km per capita traveled per network unit length. This term shows relative ability of network unit length of each system for carrying passenger. Therefore, transportation accessibility is defined as

Equation 1:

$$\begin{aligned} \text{Transportation accessibility} &= \sum_i \left(\frac{\text{passenger-km per capita}(i)}{\text{urban area}} \right) \quad \dots(1) \\ &= \sum_{i=1}^3 \left(\frac{\text{network length}(i)}{\text{urban area}} \right) \\ &\times \frac{\text{passenger-km per capita}(i)}{\text{network length}(i)} \end{aligned}$$

i: transportation systems (private transport, public transport and non motorized transport)

This new indicator is more comprehensive, reasonable and easily measurable by the MCDST. Urban area as is defined by the MCDST is urbanized zone of the metropolitan area where farmland, forests and large green spaces are excluded²⁴. Some research considered time or speed in definition of accessibility^{31,32}. In this research time spent in traffic was considered as an economical indicator.

In this paper, variety of transport option is redefined as distance of city modal share from a hypothetical city with equal public, private and non-motorized modal share. Redefinition of transport variety option is shown as Equation 2:

$$\text{Transportation variety} = \sqrt{\left[\frac{(\text{Public share} - 0.33)^2 + (\text{Private share} - 0.33)^2}{(\text{Non motorized share} - 0.33)^2} \right]} \quad \dots(2)$$

According to the aim of this research for sustainable transportation evaluation between Asian cities, all above indicators are reasonable, transparent and measurable by the MCDST. The final indicators used for Asian city comparison based on MCDST database are shown in Table 2.

Sustainable transport composite index

The finally collected STI's are categorized in three groups: environmental, economical and social ones. For urban comparison it is necessary to build composite index to cover the 3 dimensions. The method used in this paper for building composite index is simply additive weighted method. In the first step, Z-score of all indicators are calculated as Equation 3. Z-score is popular to normalize the indicator^{26,33}. Then for each group a composite index is built by adding normalized indicators by regarding equal importance weight as shown in Equation 3 to 6. This is one of the approaches for multi-criteria decision analysis, MCDA, which the weights of objects assumed are the same^{26,33}. Although weighted factor could be

considered by indicator frequency of use in literature as shown in Table5 but it seemed not to be reasonable because some indicators were edited and redefined. In addition, some researchers have been influenced by others and their points of view weren't independent.

There are also some other methods for multi-objective evaluation^{26,34}, however simple additive weighted method was appropriate for correlation analysis in this research between sustainable transport composite index and cities specifications. Sign “-” is used for indicator which the smaller amount of this in sustainable transport is better, like emission, and Sign “+” is used for indicator where larger amount is better, like access.

$$Z_I = \frac{I - Avg(I)}{Stdev(I)} \quad \dots(3)$$

$$I_{TE} = \frac{-\alpha_1 Z_{TEEMPA} - \alpha_2 Z_{TEENPC} - \alpha_3 Z_{TELAPC}}{\alpha_1 + \alpha_2 + \alpha_3} \quad \dots(4)$$

I_{TE} : Environmental composite index and

$$\alpha_1 = \alpha_2 = \alpha_3 = 1$$

$$I_{TC} = \frac{-\alpha_4 Z_{TCHEPT} - \alpha_5 Z_{TCGEPG} - \alpha_6 Z_{TCTIAV}}{\alpha_4 + \alpha_5 + \alpha_6} \quad \dots(5)$$

I_{TC} : Economical composite index and

$$\alpha_4 = \alpha_5 = \alpha_6 = 1$$

$$I_{TS} = \frac{-\alpha_7 Z_{TSFTPC} + \alpha_8 Z_{TSACTS} + \alpha_9 Z_{TSVAST}}{\alpha_7 + \alpha_8 + \alpha_9} \quad \dots(6)$$

I_{TS} : Social composite index and
 $\alpha_7 = \alpha_8 = \alpha_9 = 1$

Overall sustainable transport composite index, I_{OST} , was built by adding the result of normalized composite index based on Equation 7. In this research relative importance of all sustainable transport sectors of environmental, social and economical were assumed equal.

$$I_{OST} = \frac{\beta_1 Z_{TE} + \beta_2 Z_{TC} + \beta_3 Z_{TS}}{\beta_1 + \beta_2 + \beta_3} \quad \dots(7)$$

β_{OST} : Overall sustainable transport composite index and $\beta_1 = \beta_2 = \beta_3 = 1$.

RESULTS

Cities comparison

The I_{OST} was calculated for 21 cities from the database. Table 3 shows the sustainable transportation composite index I_{OST} and its components, I_{TE}, I_{TC}, I_{TS} for the best and worst Asian cities and the rank of these cities were consequently identified. To find effective factors in urban transportation sustainability, the best and worst cities specification are shown in Table4.

Table 1: List of Asian cities in database

Item	City	Country	Item	City	Country
1	Bangkok	Thailand	12	Mumbai (Bombay)	India
2	Beijing	China	13	Osaka	Japan
3	Chennai	India	14	Riyadh	Saudi Arabia
4	Dubai	United Arab Emirates	15	Sapporo	Japan
5	Guangzhou	China	16	Seoul	South Korea
6	Ho Chi Minh	Vietnam	17	Shanghai	China
7	Hong Kong	China	18	Singapore	Singapore
8	Delhi	India	19	Taipei	Taiwan
9	Jakarta	Indonesia	20	Tehran	Iran
10	Kuala Lumpur	Malaysia	21	Tokyo	Japan
11	Manila	Philippines			

Correlation analysis

The correlation coefficient between some specifications of all cities such as GDP, urban density, vehicle ownership, transportation modal share and sustainable transportation composite index I_{OST} and its components, I_{TE} , I_{TC} , I_{TS} were calculated and shown in Table 5.

DISCUSSION

As the table 5 shows, despite the small sample size, a large number of relations are significant at the 0.05 level and it's because of high correlation between variables. Although contents of tables 3 and 4 are based on MCDST and may have changed in recent years but based on the

Table 2: TSI used for Asian city comparison

Symbol	Sustainable transport component	Final indicator	Unit
	Transportation Environmental Impact Indicator (TEII)		
TEEMPA	Transportation emission	Emissions of local air pollutants (CO, VOC, NOx, etc.) per capita	Kg
TEENPC	Transportation energy consumption	Transport energy use per capita	Mj
TELAPC	Transportation land consumption	Land consumption for transportation infrastructure (private, public) per capita	M
	Transportation Economical Impact Indicator (TCII)		
TCGEPG	Transportation cost for government	Local government Expenditures on transportation per GDP	%
TCUEPG	Direct transportation cost for user	Average daily user cost over GDP per capita (%GDP per capita)	%
TCTIAV	Indirect transportation cost for user	Average time spent in traffic	Minute
	Transportation Social Impact Indicator (TSII)		
TSFTPC	Transportation safety	Fatality of transportation per capita	Person
TSACTS	Transportation accessibility	Sum of transportation systems for every citizen passenger-km per area	1/m
TSVAST	Transportation variety	Distance of cities modal share from ideal cities with equal public, private and non-motorized modal share.	-

Table 3: I_{OST} and its components of the best and worst Asian cities

Rank	City	I_{OST}	I_{TE}	I_{TC}	I_{TS}
Best cities					
1	Hong Kong	1.15	0.62	0.77	1.22
2	Singapore	0.57	-0.05	0.50	0.81
3	Mumbai(Bombay)	0.53	0.83	0.09	0.31
4	Shanghai	0.50	0.72	0.71	-0.16
5	Sapporo	0.49	-0.5	0.55	0.98
Worst cities					
20	Dubai	-0.96	-1.63	0.66	-1.12
21	Riyadh	-1.21	-2.15	0.64	-1.17

Table 4: Best and worst Asian cities specifications*

City	Urban density	Private vehicle per 1000 person	GDP per capita\$	%private modal split	%public modal split	%non motorized modal split
Best cities						
Hong Kong	320	50	22969	19%	47%	34%
Singapore	94	160	28578	46%	38%	16%
Mumbai (Bombay)	337	53	913	9%	41%	50%
Shanghai	196	59	2474	10%	15%	75%
Sapporo	72	398	37075	46%	22%	32%
Worst cities						
Dubai	34	252	19800	77%	7%	16%
Riyadh	44	222	5939	97%	1%	2%

*All data from MCDST

Table 5: Correlation between Asian cities specifications and sustainable transportation indexes

Cities specifications		I_{OST}	I_{TE}	I_{TC}	I_{TS}
Urban density	Pearson Correlation	0.552**	0.673**	-0.006	0.328
	Sig. (2-tailed)	0.009	0.000	0.978	0.145
GDP per inhabit	Pearson Correlation	0.234	-0.432*	0.457*	0.409
	Sig. (2-tailed)	0.306	0.050	0.037	0.065
vehicle ownership	Pearson Correlation	-0.382	-0.502*	0.043	-0.227
	Sig. (2-tailed)	0.087	0.020	0.853	0.321
Private share	Pearson Correlation	-0.641**	-0.838**	0.271	-0.579**
	Sig. (2-tailed)	0.002	.000	0.234	0.006
Public share	Pearson Correlation	0.434*	0.432**	-0.402	0.743**
	Sig. (2-tailed)	0.049	0.050	0.071	0.000
Non motorized share	Pearson Correlation	0.431*	0.711**	-0.038	0.102
	Sig. (2-tailed)	0.050	0.000	0.871	0.659

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

assessment of I_{OST} and its components, the important facts about urban sustainable transportation are summarized as:

According to table3, three of five top sustainable Asian cities (Hong Kong, Shanghai, Sapporo) are from East Asia. The main reason for the success of East Asian cities is giving priority to public and non motorized transport. East Asian cities have respectable public transport operating speeds reflecting past investments in rail systems that now carry substantial proportions (30 percent or more) of public

transport passenger kilometers. Hong Kong has built substantial rail mass transit system since 1970s but retain an important role for buses in mixed traffic. Because Shanghai's per-capita road area was extremely low and the majority of its roads were narrow, traffic bottlenecks were numerous. For this reason, most of cyclist were captive user and in this study I_{TS} because of low transport variety dropped. In the past, bicycle infrastructure was purposely neglected by Shanghai city officials in hopes that residents would ditch their bikes and opt for public transportation.

Recently, an increasing reprioritization on sustainability, active transportation, and environmental awareness by Chinese cities has placed bicycles higher on the priority list. In Shanghai, some roads now have bike lanes and the city has even implemented free or low cost bike-sharing programs for residents.

Correlation analysis shows that denser cities have the better I_{OST} . They have also lower resources consumption and emission because of shorter trip distances. For example, Hong Kong and Mumbai concurrently are two of top three in the lists of urban density and I_{OST} . Currently, over 88% of the commuters in Mumbai use public transport (suburban trains & buses). It is the most convenient, efficient and cheap form of transport to a population which is dense to such an extent.

Cities with more private modal share have the worst I_{TE} because of more energy use and emission. Also cities with more car dependency have worse transportation social indicator because of distance from equity share of trips. So, car dependent cities have lower I_{OST} because of environmental and social impacts. In this database, Riyadh and Dubai have the highest private share and the worst I_{OST} . In general, cities in the Middle East due to having nonrenewable fuel sources and accessing to cheap fuel are more car dependent and private transport is a priority for investment.

GDP has positive correlation to sustainable transportation because of economical and social impacts but developed cities with high GDP should be aware about environmental impact. Although, Tokyo have the highest GDP in this database, but hasn't high rank in I_{OST} and it is because of environmental

impact.

In general, growth of vehicle ownership has negative impact on urban environment and reduces I_{OST} . As table 3 and 4 showed, Hong Kong has the lowest vehicle ownership and highest I_{OST} score.

Developing cities such as Mumbai have acceptable I_{TE} because of the lowest car ownership. There is the possibility of I_{TE} and I_{OST} to deteriorate in future by increase in car ownership. Developing city's transport policy makers must be aware of disadvantages of private modal share growth in their developing process. Three aspects of sustainable development should also be balanced.

CONCLUSION

In this research, sustainable transport indicators for ranking and identification of sustainable and unsustainable Asian cities have been applied. Comparative analysis shows that East Asian and Middle East Asian cities have highest and lowest sustainable transportation index, respectively. As correlation analysis showed, concentrating on public and non motorized transport development improves urban sustainability. In other hand, while vehicle ownership and private share increase, urban sustainability deteriorates, respectively. However, the urban transport situation has changed drastically, but the research could be useful in ranking, examination of feedback and extraction of key factors in future studies.

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