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AFRICA'S URBAN SUSTAINABLE TRANSPORTATION IN COMPARISON WITH OTHER REGIONS OF THE WORLD

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ABSTRACT

Transportation activities, services and infrastructure development have significant and long lasting economic, social and environmental impacts, and are among key components of urban sustainability. To assess transportation sustainability, various attempts have been made to develop and deploy quantitative indicators at different geographical scopes. Few studies have applied these indicators to compare urban sustainability. In this paper six selected cities in Africa are characterized, ranked and compared with other world cities in the context of urban transportation sustainability. The relevant information was extracted from centralized databases. The International Association of Public Transport, UITP, was the key source of pertinent information. The study consisted of three major stages. Firstly, the study database was constructed and preliminary statistical analyses were conducted. Secondly, relevant sustainable transportation indicators, reflecting the three major dimensions of environmental, economic and social sustainability, were developed and deployed. Thirdly, utilizing the developed indicators, an overall composite index was developed and suggested. The comparative appraisal of the overall composite index for the selected cities in Africa showed that their positions were far from ideal when compared with other regions of the world. Nevertheless, significant variation was observed among the selected African cities. This study suggests and provides a methodology for comparative appraisal of urban transportation sustainable development. Decision and policy makers may deploy the study approach for other locations and geographical scopes to address issues pertinent to transportation sustainability.

Keywords: Sustainable development, urban transportation, indicator development, comparative appraisal, African cities.

INTRODUCTION

Sustainable development has become a major concern of policymakers and planners since the publication of "Our Common Future" in 1987 by Brundtland World Commission on Environment and Development (Quaddus and Siddique, 2001). The Brundtland World Commission defined sustainable development as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). Sustainable development should be pursued in all three major dimensions of economic, environmental and social (Litman, 2008; Krajnc and Glavic, 2005; Tanguay et al, 2010; Vaziri and Nasseer, 2007). Transportation has significant economic, environmental and social impacts, and is an important facet of urban sustainability. A sustainable transportation system 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. The system should be affordable, operating efficiently, offering choices of transportation modes, and supporting a vibrant economy. The system should limit 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 noise (Gilbert et al, 2002).

The United Nation Agenda 21 emphasizes the development and deployment of sustainable development indicators to facilitate and enhance efficacious decision-making (United Nations, 1992). All around the world, the last fifty years upsurge of urban motorization has been accompanied by social inequalities, traffic congestion, inefficacious public transport, and detrimental impacts on community health due to environmental pollutions. Various attempts have been made to develop sustainable transportation indicators, STI's. A few studies have developed and deployed STI's to compare sustainability among various cities (Haghshenas and Vaziri, 2012). An important urban transportation information source is the International Association of Public Transport, UITP, with the centralized databases. The databases have relevant transportation data for different continents; nevertheless, they cover only a few cities in the Africa. The databases have been used to extract pertinent data for a few cities of mostly developed countries to appraise some of their urban transportation environmental and economic impacts (Newman and Kenworthy, 1999). Use of the UITP databases to study the urban transportation sustainable development in Africa has not been reported in the literature. In this paper, six African cities with reported relevant data were selected for detail analysis. The cities were Cairo of Egypt, Cape Town of South Africa, Dakar of Senegal, Harare of Zimbabwe, Johannesburg of South Africa and Tunis of Tunisia. The cities were characterized, ranked and compared with other regions focusing on urban sustainable transportation development. The study reported herein consisted of three stages. Firstly, relevant information was extracted from the UITP databases, and the study database was constructed. Secondly, using the database, nine sustainable transportation development indicators, STI's, presenting the three major dimensions of economic, environmental and social, were developed. Thirdly, using the developed STI's, three composite indices of environmental, economic and social, and an overall composite index were developed and suggested for urban comparative appraisal.

DATABASE DEVELOPMENT

Among international agency's scarce centralized databanks of urban transportation, the International Association of Public Transport, UITP, has developed two imperative databases namely the MCDSM, Millennium Cities Database for Sustainable Mobility, and the MCD, Mobility in Cities Database, respectively (UITP, 2001; UITP, 2006). The MCDSM has 230 variables for 100 cities for the year 1995 covering all world regions, among which 8 cities are from Africa. The MCD is for the year 2001 covering 52 cities among which only one is for Africa. Consequently, the study focused on the MCDSM for selection of the African cities. The MCDSM breakdown of cities among regions is summarized in Table 1. The table also shows key transportation characteristics of the cities.

Table 1: MCDSM breakdown of cities and their characteristics

Region	**Number of cities**	**Vehicle per 1000 persons**	**Urban persons per km**	**Per capita GDP in dollars**	**Private car modal split**	**Public transport modal split**	**Non-motorized modal split**
Africa	8	117	101	2593	32%	26%	42%
Asian developed	5	283	134	34797	39%	32%	29%
Asian developing	16	202	169	4885	41%	24%	35%
Europe	41	430	57	29150	47%	22%	31%
Latin America	10	175	71	5880	35%	36%	29%
North America	15	580	19	27865	86%	5%	9%
Oceania	5	589	15	19775	79%	5%	16%

For the database 100 cities of the year 1995, urban vehicle ownership in decreasing order belonged to Oceania, North America, Europe, Asian developed countries, Asian developing countries, Latin America and Africa, respectively. Urban population density in decreasing order belonged to Asian developing countries, Asian developed countries, Africa, Latin America, Europe, North America and Oceania, respectively. Per capita GDP in decreasing order belonged to Asia developed countries, Europe, North America, Oceania, Latin America, Asian developing countries and Africa, respectively. Average daily trip private auto travel modal split in decreasing order belonged to North America, Oceania, Europe, Asian developing countries, Asian developed countries, Latin America and Africa, respectively. Average daily trip public transportation travel modal split in decreasing order belonged to Latin America, Asian developed countries, Africa, Asian developing countries, Europe, North America and Oceania, respectively. Average daily trip non-motorized travel modal split in decreasing order belonged to Africa, Asian developing countries, Europe, Asian developed countries, Latin America, Oceania and North America, respectively. The table reflects the extensive urban auto usage in the developed countries.

Indicators are variables selected and defined to measure progress toward an objective, herein sustainable transportation. The chapter 40 of United Nation 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 (United Nations, 1992). The important properties for suitable indicators include: being easily understandable, reasonable, statistically independent to avoid overlap and autocorrelation, measurable and possible to quantify, accessible, being comprehensive and reflecting various aspects, being sensitive to changes in the system over time, being standardized for comparison, clearly definable, and capturing long-term processes (Herzi and Hasan, 2004; Litman, 2009; Nourry, 2008; Zhang, 2006).

There have been several studies to define indicators for urban sustainable transportation development assessment (Tanguay et al, 2010; Vaziri and Nasseer, 2007; Haghshenas and Vaziri, 2012). Transportation environmental indicators, TEI's, often included: transportation air pollutant emissions per capita, transportation greenhouse gas emissions per capita, transportation infrastructure land consumption, transportation energy use per capita, transportation renewable energy use per capita, and population exposed to transportation noise level of more than 55dBA. Transportation economic indicators, TCI's, often included: percent of household transportation expenditure of the budget, percent of transportation expenditures of the gross domestic product, GDP, time spent in traffic per capita, transportation delay and reliability. Transportation social indicators, TSI's, often included: per capita number of fatalities, injuries and accidents, percent of population with accessible public transportation, variety and quality of transportation options, quality of transportation for disadvantaged groups of disabled, elderly, children, non-drivers and women. Table 2 shows more frequently used indicators that were also selected by the study reported herein. These indicators were extractable from the MCDSM, and consequently, nine indicators representing the three major dimensions were selected for detailed analysis. Using MCDSM, the study database consisting of nine indicators was created for the 100 cities including the six selected cities in Africa. The database was created in SPSS Software format for further analysis. The univariate analysis of the database showed significant variability.

Table 2: Study transportation sustainable development indicators

Name	Description
I. Transportation environmental indicators, TEI's	
TEEMPA	Emissions of air pollutants (CO, VOC, NOx, etc.) per unit of area
TEENPC	Transportation energy use per capita
TELAPC	Land consumption for transportation infrastructure per capita
II. Transportation economic indicators, TCI's	
TCHEPT	Average trip cost as a ‰ of the GDP per capita
TCGEPG	Local government expenditures on transportation per GDP
TCTIAV	Average time spent in traffic
III. Transportation social indicators, TSI's	
TSFTPC	Fatality of transportation per capita
TSACTS	Access to transportation systems (private, public, transit)
TSVOPP	Variety of transportation options available for each person

All the selected indicators, except TSACTS and TSVOPP, were directly extractable from the MCDSM database. The transportation accessibility indicator TSACTS was defined by Equation 1 as:

$$\text{Transportation accessibility indicator} = \sum_{i=1}^{3}\left(\frac{\text{network length}(i)}{\text{urban area}} \times \text{average speed}(i)\right) \quad (1)$$

Where the transportation systems i=1, 2, 3 present private, bus and transit, respectively. The network length per area, or transportation network density, reflects system's accessibility, a measure in reverse of the distance, often walking distance, for different urban locations from the system weighted by the transportation system's speed. This newly developed indicator is comprehensive, reasonable and easily measurable.

Variety of transportation modal options, TSVOPP, was defined as the total options available on the average to any urban resident. For each transportation option, variety indicator is obtained by multiplying number of vehicle per capita by capacity of the vehicles. Average daily vehicle capacity was determined for various modes from average daily passengers of each mode, derived from the MCDSM data of all the 100 cities. This became 4.5 persons for private vehicle, 545 persons for bus and 1488 persons for metro wagon, respectively. The information about non-motorized vehicles was not available in the MCDSM. The indicator of transportation variety option was derived by Equation 2:

$$\text{Variety of transportation option indicator} = \sum_{i=1}^{11} \frac{\text{vehicle(wagon)(i)} \times \text{daily capacity(i)}}{\text{capita}} \quad (2)$$

Where the transportation options i=1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 present private car, taxi, bus, mini bus, tramway, light rail, metro, suburban rail, heavy rail, ferry and non-motorized modes, respectively.

Urban comparative appraisal

In the study database, each of the 100 cities was presented by nine indicators, profiling it by nine important facets of urban transportation sustainable development. Comparative appraisal of indicators could be organized at individual indicator level, nevertheless, the study focused on multi-criteria approach by combining indicators into composite indices. Firstly, for each of the three groups, a composite index was built by combining standardized indicators as presented by Equations 3 to 6. Equation 3 standardization overcame the indicator "I" dimensionality issue, and resulted in dimensionless standardized variable Z_I, for nine indicators listed in Table 2. For indicators that sustainable development would be enhanced by their reductions, negative sign was deployed in their summation. This is reflected for Z_{TEEMPA}, Z_{TEENPC} and Z_{TELAPC} in Equation 4, Z_{TCHEPT}, Z_{TCGEPG} and Z_{TCTIAV} in Equation 5 and Z_{TSFTPC} in Equation 6, respectively.

$$Z_I = (I - \text{Average } I) / (\text{Standard deviation } I) \quad (3)$$

$$I_{TE} = - Z_{TEEMPA} - Z_{TEENPC} - Z_{TELAPC} \quad (4)$$

$$I_{TC} = - Z_{TCHEPT} - Z_{TCGEPG} - Z_{TCTIAV} \quad (5)$$

$$I_{TS} = - Z_{TSFTPC} + Z_{TSACTS} + Z_{TSVOPP} \quad (6)$$

Where I_{TE} is the environmental composite index, I_{TC} is the economic composite index, and I_{TS} is the social composite index. Overall sustainable transportation composite index, I_{OST}, was then built by combining the standardized composite index. Again, Equation 3 standardization overcame the composite index "I" comparability and dimensionality issues, and resulted in dimensionless standardized Z, for three composite indices of I_{TE}, I_{TC} and I_{TS} of Equations 4 to 6. Equation 7 presents the summation for the three indices:

$$I_{OST} = Z_{TE} + Z_{TC} + Z_{TS} \quad (7)$$

The I_{OST} was calculated for the cities in the database. Among the database 100 cities, overall 14 cities, including 2 African cities, were omitted because of missing data for some of the nine indicators. Consequently, six African cities of Cairo, Cape

Town, Dakar, Harare, Johannesburg and Tunis remained for further analysis. Table 3 shows the averages for the sustainable transportation composite index I_{OST} and its components I_{TE}, I_{TC} and I_{TC} for cities in different world regions.

Table 3: Average I_{OST} and its components for cities of various regions

Region	I_{OST}	I_{TE}	I_{TC}	I_{TS}
Africa	-0.64	0.80	-2.01	-0.71
Asia developed	0.79	0.77	0.80	0.80
Asia developing	-0.26	0.16	-0.45	-0.49
Europe	0.50	0.31	0.44	0.74
Latin America	-0.68	0.72	-1.45	-1.30
North America	-0.60	-1.50	0.24	-0.53
Oceania	-0.33	-1.18	0.30	-0.11

On the average, the composite environmental indicator, I_{TE}, was weakening among cities in Africa, Asian developed countries, Latin America, Europe, Asian developing countries, Oceania and North America, respectively. On the average, the composite economic indicator, I_{TC}, was diminishing among cities in Asian developed countries, Europe, Oceania, North America, Asian developing countries, Latin America and Africa, respectively. On the average, the composite social indicator, I_{TS}, was shrinking among cities in Asian developed countries, Europe, Oceania, Asian developing countries, North America, Africa and Latin America, respectively. Environmental sustainable development good standing of African cities is evident from the table. The overall composite index, I_{OST}, was lessening among cities of Asia developed countries, Europe, Asian developing countries, Oceania, North America, Africa, Latin America, respectively. Table 4 shows the I_{OST} overall composite index and rankings of African cities. The table also shows the I_{TE} environmental composite index, the I_{TC} economical composite index, and the I_{TS} social composite index for each of the selected six African cities of Cairo, Cape Town, Dakar, Harare, Johannesburg and Tunis. Among the 86 cities of the database, Table 4 shows the I_{OST} in decreasing order of ranking for Dakar, Cape Town, Tunis, Harare, Cairo and Johannesburg, respectively.

Table 4: African cities ranking based on overall composite index

I_{OST} Ranking	City	Country	I_{OST}	I_{TE}	I_{TC}	I_{TS}
46	Dakar	Senegal	-0.04	1.79	-0.49	-1.42
48	Cape Town	South Africa	-0.12	0.66	-1.42	0.41
59	Tunis	Tunisia	-0.38	1.07	-1.57	-0.64
79	Harare	Zimbabwe	-0.94	1.09	-3.37	-0.54
83	Cairo	Egypt	-1.14	0.42	-2.51	-1.32
84	Johannesburg	South Africa	-1.21	-0.21	-2.72	-0.71

Table 4 shows also in decreasing order of composite environmental indicator, I_{TE}, were cities of Dakar, Harare, Tunis, Cape Town, Cairo and Johannesburg, respectively. In decreasing order of composite economic indicator, I_{TC}, were cities of Dakar, Cape Town, Tunis, Cairo, Johannesburg and Harare, respectively. In decreasing order of the composite social indicator, I_{TS}, were cities of Cape Town, Harare, Tunis, Johannesburg, Cairo and Dakar, respectively. All the six selected African cities had negative I_{OST}, which signifies below average standing as compared with all 86 cities. Cities in developed part of Asia and Europe showed higher overall composite sustainable transportation index and can be used for show casing of good practices. The reasons for their good standing could have routes in their economic prosperity and emphasis on public and non-motorized transportation. Public and non-motorized modes have lower emissions, resources consumption and transportation costs as compared with private transportation. The study results could have significantly enhanced if time-series data had been accessible, and time stability of Table 4 had been confirmed. Collection of relevant urban transportation sustainable development time–series data is a preliminary step toward achieving urban sustainability. The pertinent information gathering, deliberation, standardization and management can be undertaken by international and regional agencies, and should be emphasized and pursued by individual member states. Development of public and non-motorized modes is conducive to enhanced variety and accessibility. Comparing the six African cities, not always Cape Town and Johannesburg belonging to South Africa with higher GDP, became superior to others for individual composite indices. Efficacious urban transportation management and planning would be the key ingredients of achieving urban sustainability. Further study is needed to address local issues. Nevertheless, Dakar and Cape Town urban transportation sustainability highlights can be learned from by other cities.

CONCLUSION

The study offers the methodology and conclusions of a comparative macroscopic study in connection with urban sustainable transportation development in Africa. In order to facilitate sustainable transportation development which is an imperative facet of urban sustainable development, the paper describes an attempt to shed some light on urban transportation patterns for a selected number of African urban areas. The accessible databases were overwhelmed by data incompleteness and missing values. This significantly curtailed the reliability of the results and quantitative interpretations. Collection of relevant urban transportation sustainable development time–series data for African cities is a preliminary step toward achieving urban transportation sustainability. The pertinent information gathering, deliberation, standardization and management can be undertaken by international and regional agencies, and should be emphasized and pursued by individual African member states. Among international agency's scarce centralized databanks of urban transportation, the International Association of Public Transport, UITP, database of Millennium Cities Database for Sustainable Mobility, MCDSM, was identified and evaluated as the only and main pertinent information source for the study reported herein. Indeed, the MCDSM has 230 relevant urban transportation variables for 100 cities for the year 1995 covering all world regions, among which 8 cities are from Africa. After preliminary evaluation of the database, 86 urban areas around the world including 6 cities in Africa were selected for detailed analysis. The cities were Cairo, Cape Town, Dakar, Harare, Johannesburg and Tunis. Reviewing past developed sustainable transportation development indictors, nine indicators presenting the three major dimensions of environmental, economic and social were selected for database development.

Comparative appraisal of selected cities was undertaken by focusing on a multi-criteria approach of combining indicators into composite indices. Firstly, for each of the three groups, a composite index was built by combining their three pertinent standardized indicators. Subsequently, an overall composite index of sustainable transportation development was developed by combining of the three composite indices. All selected African cities showed negative overall composite index, which signifies their below average standings when compared with other regions of the world. Based on overall composite index, in decreasing order and ranking, the selected six cities were Dakar, Cape Town, Tunis, Harare, Cairo and Johannesburg, respectively. Cities in developed part of Asia and Europe had highest overall composite sustainable transportation index, and could be used for show casing of good practices, and could be learned from their planning and resource allocation. African cities should be encouraged to develop more public and non-motorized transportation instead of focusing on private transportation infrastructure development. Although the study findings are based on a very limited database, the methodology can be applied to other periods or geographical scopes for addressing pertinent urban sustainable transportation development issues.

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