Measurement 63 (2015) 30–40

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

An urban mobility index for evaluating and reducing private motorized trips

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ARTICLE INFO

Article history:
Received 28 August 2014
Received in revised form 7 November 2014
Accepted 27 November 2014
Available online 9 December 2014

Keywords:
Sustainable urban transportation
Urban mobility index
Urban transportation evaluation
Urban mobility indicators
Private motorized trips

ABSTRACT

Modern cities seek policies to sustain their urban mobility by reducing car externalities. To maintain sustainability, urban designers and planners should consider different social, economic, and environmental indicators. Currently, efforts are being made to evaluate the relationship between urban structure and car usage. However, few studies have been conducted to evaluate private motorized trips at the macro-level. This study attempts to create a foundation for evaluating private motorized trips at the city level by introducing an urban mobility index (UMI). UMI is a measure for evaluating transportation in cities at the macro-level. This research presents urban mobility indicators that are correlated to a percentage of daily trips made through private motorized modes in order to calculate UMI. An analytical point system comparing existing cities to the best existing value is proposed in order to estimate this UMI. This research employs the International Association of Public Transport (UITP) as a database. Although this method can be utilized for cities worldwide, this research uses it to assess Hong Kong and Chicago. This method can identify existing problems and can be used to propose solutions for reducing car usage.

1. Introduction

Mobility forms a complex system within urban areas due to having several effective interactions [44]. In the past, contributing more transport supplies such as increasing the number of new roads and the addition of facilities had been desirable, and as a result, mobility suffered from problems such as high car usage and congestion, factors that have led to unsustainable transportation systems [61,44]. Sustainable mobility (transportation) plays a key role in achieving a sustainable urban environment [2,76]. To achieve sustainable mobility, environmentally friendly travel modes (public transport and non-motorized) and travel costs are among the important factors that need to be reviewed [15].

Sustainability is one of three key elements (sustainability, safety and smartness) of a modern transportation system [26,44] and has recently become a fundamental component of transport planning and policy implications [6,16,44]. A number of studies have addressed sustainable mobility and/or sustainable urban transportation (e.g., [3,7,12,55,69,74,1,40,5]); however, studies that propose sustainability assessment tools at the city level for transportation are limited.

Jeon et al. [48] used several performance measures to propose indexes that represent parameters of sustainability. The composite sustainability index tool and multiple criteria decision making methodology were combined in their study to evaluate future transportation and land use plans that have been proposed for the Atlanta Metropolitan Region. This study can be used to compare aspects of

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http://dx.doi.org/10.1016/j.measurement.2014.11.026
0263-2241/

sustainability among different plans that have been proposed for a specific region. Haghshenas and Vaziri [41] also suggested some sustainable transport indicators, using the UITP database [80] to compare sustainability among various regions of the world.

Frei [37] introduced a sampling mobility index (SMI) that was employed to evaluate Assis city in Brazil. Sidewalk width, free walking pass, pedestrian traffic lights, cycling lanes, vehicle occupancy, traffic law and traffic signals were indicators used to calculate SMI. Frei's study evaluates micro-level facilities and cannot represent a macro-level urban mobility index. Miranda and Rodrigues da Silva [58] also proposed benchmarking sustainable urban mobility for Curitiba city in Brazil. Although they considered macro-level and micro-level factors to calculate the index of sustainable mobility, they were unable to calculate all the included indicators, since there was no specific logical role for measuring some indicators, as data were not available for them. In addition, it can be difficult and sometimes impossible to collect data for a large number of micro- and macro-level indicators.

What is most surprising about previous studies on urban structure and travel behavior is the lack of reliable and easy to follow measures for evaluating sustainable urban transportation at city level. Although relationship models have been developed in different cities, the results of these models are not sufficient for evaluating existing transport patterns [25]. One of the reasons for this has been an approach to urban transportation evaluation that considers different indicators from a neighborhood level view instead of a city level view. Thus, researchers have not been successful in developing methods for assessing city level transportation conditions. As a result, the current models only cover a narrow range of relationship models and may not be applicable for evaluating existing conditions at the city level.

Consequently, the objectives of this paper are set out in different stages. The identification of effective indicators that affect car usage is the first stage. The introduction of a practical urban mobility measure employing a point system is the second stage. The final stage is the assessment of some UITP cities by utilizing the proposed model to identify mobility problems and to present issues for improvement. Accordingly, this research proposes an UMI model that covers various indicators for urban mobility, with different ranges of sustainability based on best existing value where car usage is concerned. This method is useful for improving existing conditions and is easily interpreted.

2. Background

Cities can be different in some significant ways, but urban areas have the same indicators worldwide [38]. A considerable number of studies have analysed the relationship between land use and travel behavior (e.g., [43,53,59,66,62]). Cervero and Kockelman [19] examined the impacts of density, diversity and design (the 3Ds) on trip generation and mode choice. Their work was extended to the 4Ds by adding the accessibility of destinations [17,27,30,31]. Population and employment density (density), employment ratio and mixed land use (diversity), non-motorized environment design variables such as walking facilities and route directness (design), and accessibility to other activities (destination accessibility) are key factors that influence vehicle usage ratio [27].

The amount of vehicle miles traveled (VMT) is not correlated to density only [23,28,42,67]. However, population and employment densities are land use indicators that have been considered by many studies as factors that affect travel behavior (e.g., [13,22,32,33,35,39,68,72,75,79,85]). Doubling the density reduces the number of cars and VMT per household [46]. Burchell et al. [14] and Ewing [29] found that higher densities reduce VMT. Kitamura et al. [49] concluded that the proportion of non-motorized trips is positively related to residential density. Dwelling unit density influences daily automobile usage per household [84]. Commercial density is also effective for vehicle kilometers traveled (VKT) per person [45]. Household density is another factor that influences VMT [11,21,47,51].

Mixed land use that effectively provides walkable destinations reduces car usage [63]. Therefore, ample studies have examined the impacts of mixed land use indicators on VKT and VMT (e.g., [20,35,36,45,50,52,51,73,79]). Mixed land use also provides a better job-housing balance. In this regard, vehicle travel can be reduced by having an employment balance per housing of around 1.0 [53,83]. Crane and Chatman [24] found that a 5% increase in the percentage of employment can reduce the average commute distance by 1.5% in a metropolitan area. Therefore, job-housing balance has been considered in various studies as an effective factor for influencing VKT and VMT (e.g., [19,32,33,39,52]).

More walkable communities lead to less driving [4,43]. Cervero and Kockelman [19] examined the effect of the width of sidewalks on VMT per household. Fan [34] considered sidewalk length as an effective factor for miles traveled per person. Bicycle lane density also affects VMT per household [9,10]. Non-motorized travel facilities and street patterns are effective factors for urban travel behavior. Hedel and Vance [45] examined the impacts of street density on VKT per person. Many studies have also considered a relationship between street pattern and VMT (e.g., [20,33,35,36,39,22]).

Parking facilities are among the design factors that influence travel behavior. More parking spaces cause more private motorized daily trips [60,64]. With more and cheaper parking, car ownership and usage has been increased as a result of convenience and lower cost [54,57,65,77,82]. Vaca and Kuzmyak [81] reported that a 10% increase in parking costs correlated to a 1–3% vehicle trips reduction. Park and ride facilities are also provided to encourage car users to change their travel mode from private motorized to public transport [70]. However, recently, these facilities have been criticized as contributing to the expansion of car parks; land is consumed to construct car parking that encourage people to at least drive to a public transit station [71]. These facilities also have negative impacts on the car reduction strategies that were the goals of their policies [56].

Destination accessibility is another key factor that influences travel behavior. Bhat and Eluru [9] found that accessibility to shopping areas affected VMT per household.