Implications of Transport Diversity for Quality of Life

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Abstract: Different transport stakeholders have different needs for transport infrastructure and services. Meeting the needs of stakeholders implies a tradeoff of benefits and costs between supply and demand and creates issues of transport diversity. However, the literature has largely ignored these issues. This study aims to provide a framework evaluating transport diversity to promote quality of life. Transport diversity is defined as the satisfied level of stakeholder needs in this study and measured as the gap between the expected goal and present values of stakeholder needs in the form of the Shannon–Weaver index. Transport diversity can assess whether the level to which important needs are satisfied equitably, and monitor whether the transportation system is moving toward sustainability via confirming the targets and the basic level of quality of life. This study hopes that the conceptual framework developed can assist decision makers in understanding the relationship between transport diversity and sustainability, and provide a new assessment method for improvements in quality of life.

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Introduction

Transportation systems consist of infrastructure, modes, and stakeholders. Different transport stakeholders with diverse demands have different needs for transportation infrastructure and services resulting in diversity of needs. Diversity describes the variety and difference of individuals and groups in a system (Hunter 1990). The concept of diversity recently has come into vogue in research (Point and Singh 2003). Ecologists believe that ecosystems are influenced by various levels of diversity. From the perspective of system analysis, the diversity of components in ecosystem has been useful in constructing feedback loops among elements (May 1976). Links among feedback loops have enabled nutrient cycles and information feedback as well as provided a basis for ecosystem self-regulation (Odum 1983). Ecosystem resilience has resulted from system diversity, as well as energy and information flow speed (Ferguson 1996). Furthermore, Rammel and van den Bergh (2003) suggested that higher diversity may contribute to ecosystem stability. Diversity thus critically influences ecosystems. Additionally, several studies have attached importance to the relationship between diversity and stability in socioeconomic systems. Malizia and Ke (1993) identified diversity and competitiveness as important influences on unemployment and stability. Furthermore, Templet (1999) examined the relationship between diversity and economic development via empirical studies of energy consumption. Templet proposed that sustainability is enhanced by strategies that promote diversity and resource use efficiency in economic systems. Moreover, de Vasconcellos (2005) proposed that transportation policies should consider the social diversity expressed by income level to meet the demand of nonautomobile users.

In fact, in transportation planning, transport policy makers must simultaneously consider the tradeoff between differences in the supply of transport infrastructure or modes, in addition to the various needs of stakeholders. Transportation needs are derived from daily life and comprise diverse urban activities. Failure to satisfy basic stakeholder needs can negatively impact quality of life. Quality of life is defined by the World Health Organization Quality of Life (WHOQOL) Group (1998) as the perceptions of individuals regarding their goals, expectations, standards, and concerns. Furthermore, Diener et al. (1999) defined quality of life as a multidimensional construct, comprising the level of satisfaction of important individual needs. As a result, the simultaneous consideration of richness and evenness creates issues related to transport diversity, such as the definition of transport diversity, how to measure it, and how it impacts daily life. However, few studies have discussed the effects of transport diversity on quality of life.

Accordingly, this study aims to construct a framework for evaluating transport diversity based on the needs of stakeholders. The conceptual framework can help planners understand the relationship between transport diversity and sustainability, and clarify issues and implications related to transport diversity and quality of life. Furthermore, transport diversity, considered at the commencement of planning, is a new tool for assessing improvement in quality of life.

This paper is divided into three parts: the first part introduces the definition and measurement of transport diversity, while the second part explores the relationships among transport diversity, sustainability, and quality of life. Finally, the third part develops a conceptual framework to evaluate the transport diversity based on sustainability and quality of life.

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Table 1. Example Describing Relationship between Diversity and Evenness

System	Diversity value	Proportion of species			
		Species 1	Species 2	Species 3	Species 4
A	0.940	0.7	0.1	0.1	0.1
B	1.386	0.25	0.25	0.25	0.25

Transport Diversity

Diversity has been considered in analyses of the heterogeneity of community structure. Indicators used to measure biodiversity are based on two essential factors, namely species richness and evenness (Hamilton 2005). Richness refers to the species number, while evenness denotes the relative abundance of the different species. The most common index used to assess diversity is the Shannon–Weaver index, also known as entropy, shown as Eq. (1) (Odum 1993)

$$H = -\sum_i P_i \times \ln P_i \quad (1)$$

$$P_i = \frac{n_i}{\Sigma_i n_i} \quad (2)$$

where n_i denotes the number of individuals belonging to species i; P_i represents the proportion of the population of species i to the total population; and H=value of diversity. The diversity index has a value exceeding 0. Evenness, shown as Table 1, shows to that the distribution becomes more uniform with increasing diversity while Systems A and B include an equal number of species. In contrast, higher diversity indicates a larger number of species under the same distribution of each species population. For example, System A with a richer species has a higher diversity while both systems have a uniform distribution in Table 2. In fact, Reeves (2005) believed that diversity without equity could only address difference. From the perspective of transport diversity, richness indicates that stakeholder needs are considered more comprehensively. Conversely, evenness denotes a condition in which needs are satisfied more equitably. Therefore, greater diversity indicates that as the distribution between compartments becomes more equitable, the gradients between compartments reduce, and larger numbers of compartments become involved in the system (Muller 1998).

Diverse transport stakeholders have different needs for urban transport infrastructure and services. The main issue in transport diversity thus becomes how to more equitably satisfy diverse stakeholder needs. Transport diversity is defined as different levels of satisfaction within stakeholder needs, expressed as appropriate indicators and measured using the variations in achievement among indicators. Additionally, minimizing the indicator gaps, the remainder of the needs achievement between the expected goals and present values [as shown in Eqn. (3)] is a key objective in urban transportation planning. The normalized value prevents indicator gaps resulting from differences in unit scale

$$m_i = \frac{O_i^{\mathrm{Max}} - V_i}{O_i^{\mathrm{Max}} - O_i^{\mathrm{Min}}} \quad (3)$$

where m_i denotes the normalized gap of indicator i; O_i^{Max} and O_i^{Min} represent the expected goal and minimum threshold of indicator i, respectively; and V_i=present value of indicator i. The value of the normalized gap exceeds 0, and the degree of need satisfaction increases as the gap approaches 0. Meanwhile, n_i denotes the positive remainder of the gap of indicators, namely the achievement indicated by Eq. (4), which is plugged into Eq. (2). Moreover, transport diversity represents the equal satisfaction of stakeholder needs in the form of the Shannon–Weaver index, presented in the form of Eq. (1). Transport diversity calculated with Eq. (1) comprises two components: richness, measured by the number of stakeholder groups, which determines the number of terms in the summation, and equability, measured by the evenness of needs distribution across groups

$$n_i = \mathrm{Max}(0,\ 1 - m_i) \quad (4)$$

Measurement with Goal and Threshold Value

Based on Muller (1998), higher transport diversity implies that needs are satisfied more equitably when they are considered more comprehensively. Different transport stakeholders, such as users of different modes, operators, engineers, planners, and regulators, have diverse needs in relation to transportation infrastructure and services (Eckton 2003; Koontz 2003; Sohail et al. 2006; Soltani and Allan 2006). Additionally, the needs of vulnerable groups, including low income, disabled, elderly, and remote users, should not be neglected (de Vasconcellos 2005; Loo and Chow 2006). Urban transportation system quality should be acceptable to all individuals, and moreover should consider their specific needs and abilities. Higher transport diversity may be caused by planners taking more stakeholder needs into consideration. However, transport diversity is not increased by policy makers considering the involvement of more stakeholder needs but ignoring the need to provide for different needs equitably. For instance, given four needs with achievements of 0.2, where system diversity is 1.39, if a new need with achievement of 0.9 is added to the system, then system diversity will reduce to 1.34. Therefore, more comprehensive consideration of stakeholder needs within an urban transportation system cannot ensure higher diversity. The equity of the level of needs satisfaction thus should be regarded as the essential factor for transport diversity.

Biodiversity depends on both richness and evenness. In this context evenness describes the equality between the populations of every species in Eq. (2). However, formal equality does not represent the substantive equity from the perspective of social science. For example, the equality between mode shares, including mass transit, private vehicle, taxi and bicycle, denotes that each mode shares 25% of the trips in a transportation system. This sharing would increase diversity but would not be a sustainable target in urban development. To make the equity of needs satis-

Table 2. Example Describing Relationship between Diversity and Richness

System	Diversity value	Proportion of species				
		Species 1	Species 2	Species 3	Species 4	Species 5
A	1.609	0.2	0.2	0.2	0.2	0.2
B	1.386	0.25	0.25	0.25	0.25	—

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faction meaningful, setting targets and thresholds is crucial to diversity analysis. Planners could set targets and thresholds for each mode. For instance, the mode-share target and minimum level of transit might be set at 60 and 30%, respectively. The achievement of transit would be 0 while the present value (25%) would be lower than the threshold (30%), which would reduce diversity. Loo and Chow (2006) demonstrated that the threshold value for sustainability varies with the perceptions of stakeholders, which differ across time and space. Moreover, goals reflecting the expectations of management as well as stakeholder needs must be accepted at the commencement of the process (Barlas and Yasarcan 2006). Additionally, Steg and Gifford (2005) proposed that governments should set target and monitor transport system progress towards sustainability. Consequently, goal and threshold values should be set via collaborative planning, specifically through consensus building, based on stakeholder and public opinions, along with feedback from experts.

Priority of Needs

No consensus norm exists for the best method of achieving the stakeholder needs equitably in transport diversity to suit all conditions because the diverse cities provide distinct development backgrounds. In fact, critical priorities, standards, and constraints differ among groups, time and space (Steg and Gifford 2005; Jeon et al. 2006). Issues related to the weighting method thus become important. Ordinary weighting methods weigh the criteria according to importance through a preference survey. For example, the proportion of needs achievement including w_i, the weight of indicator i, with simple additive weight (SAW) can be calculated by Eq. (5)

$$P_i = \frac{w_i n_i}{\sum_i w_i n_i} \qquad (5)$$

However, Eq. (5) appears not to represent the different importance of needs but rather of needs achievement, leading to loss of a convincing planning rationale. Accordingly, the traditional weighting method does not need to be applied to the importance of needs in this study. This study thus suggests that the importance of needs should be implied by the goal and threshold value settings. Studies of service quality reveal that expected satisfaction can substitute for the priority of importance (Chen and Chang 2005; Deng 2007) while needs are one-dimensional quality elements (Kano et al. 1984). The more important needs require higher threshold values to promote sustainable quality of life. This study thus sets the weight of stakeholder needs regarding transport diversity by setting the goal and threshold values via consensus building meeting in which stakeholder needs are surveyed via questionnaires, sustainable targets, and the basic level of quality of life. The needs that are the furthest from the target, especially those not reaching threshold, should be given the highest priority.

Quality of Life and Sustainability

Although the common identified definition of sustainability is not available (Pope et al. 2004; Loo and Chow 2006; Jeon et al. 2006), van Kamp et al. (2003) examined the overlap between the concept of quality of life and sustainability, as a result of which the two concepts are frequently used as synonyms. In fact, Yang (2002) argued that the need for quality of life involves not only individual health, safety, social justice, income, and freedom, but also relationships with salient features of the environment, such as fresh air, clean water, and natural surroundings. Besides, Shafer et al. (2000) identified sustainability as the ability to develop good quality of life in both the present and the future. In addition to indicators, the Commission of the European Communities (2002) introduced the sustainability impact assessment (SIA) process for developing an integrated assessment system based on existing fragmented sectoral systems, for identifying impacts of policies, and for determining the tradeoff among competing objectives. McMahon (2002) examined whether the needs should combine both top-down and bottom-up approaches to measure quality of life and to monitor sustainability.

The concept and content of quality of life and sustainability are similar. However, satisfaction of needs differentiate quality of life from sustainability in this study. Quality of life represents the basic level of needs satisfied with which stakeholders certainly live without deficiencies. Likewise, Topolski et al. (2004) believed that quality of life, utilized as a descriptor, evaluative report, or normative statement, may assess the living status referring to the limitations of socio-economic activities. In comparison, sustainability indicates the expected target of sustainable development. Sustainable development is generally conceived as finding a balance among environmental, social, and economic qualities (George 2001; Kasemir et al. 2003; Steg and Gifford 2005; Ness et al. 2007). Moreover, the World Commission of Environment and Development (1987) defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Additionally, Pope et al. (2004) suggested that it is necessary to explore not only the direction to the sustainable target but also the distance from sustainability.

The fundamental of transport diversity fits both the concept of quality of life and sustainability in terms of the transport needs. Accordingly, the method used here to assess transport diversity considers the balance between sustainable development and quality of life objectives through consensus among stakeholders, government, and experts. By setting goal and threshold values, as well as measuring progress toward targets, the framework presented in this study effectively assesses sustainability and quality of life.

Conceptual Framework

Stakeholder needs are determined based on criteria of sustainability as well as quality of life. The emerging consensus is that sustainable transport systems should efficiently provide users with equitable and safe access to basic needs effectively, stimulate economic development, and not cause environmental harm (Pope et al. 2004; Jeon et al. 2006). Sustainability and quality of life have recently become key planning objectives. Items widely considered in measuring sustainability and quality of life in relation to the transport system include social justice, accessibility, safety, universal design, economic health, environmental quality, etc. (McMahon 2002; Pope et al. 2004; Jeon et al. 2006; Ness et al. 2007). Improving the sustainability and quality of life with regard to transportation requires the support of transport diversity. The conceptual framework used to assess transport diversity for promoting sustainability and quality of life is shown in Fig. 1 based on the references above. Fig. 1 shows the stakeholders affecting or affected by subsystems, such as roads, mass rapid transit (MRT), parking, and pedestrian lanes. Since transportation needs prevail over those of daily life including diverse socio-economic

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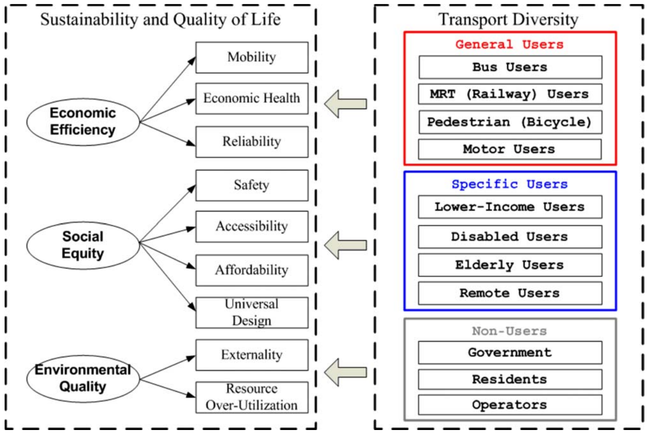

Fig. 1. Conceptual framework

activities, the constitution of diversity indicates different needs for daily activities based on quality of life.

Economic Efficiency

The construct of economic efficiency is composed of mobility, economic health, and reliability. Mobility refers to the efficiency of vehicle movements through the road system. Moreover, mobility describes individual ease of movement (Levine and Garb 2002; Levinson 2003). As a result, satisfying the user need for mobility refers to developing the capability to overcome spatial resistance. Besides, both short-term and long-term cost efficiency should be considered in the construct of economic health. Stakeholder needs in this construct include robust public funding, economic growth, technical research and development, and the revenue of operators (McMahon 2002; Pope et al. 2004; Topolski et al. 2004; Loo and Chow 2006; Jeon et al. 2006). Furthermore, reliability describes the consistent, stable, and standard outcomes when the experience is repeated under the same conditions. Sanchez-Silva et al. (2005) addressed the fact that a reliable transport system should provide a stable level of service. Therefore, the key factor influencing needs satisfaction with regard to reliability thus represents whether the extraneous travel time and expenses are invested.

Social Equity

Social equity issues in transportation involve equitable accessibility to major socio-economic centers and equitable level of safety (Jeon et al. 2006). Safety is defined as minimizing risk of hurt, injury, or loss. Traffic accidents are a major socio-economic problem, accounting for millions of fatalities and injuries, as well as billions of dollars of economic losses worldwide. Safety thus is an important criterion in social equity with regard to McMahon (2002), van Kamp et al. (2003), Pope et al. (2004), Steg and Gifford (2005), and Ness et al. (2007). To achieve the need for safety, planners should consider methods of decreasing the traffic accidents and mitigating associated casualties. Additionally, accessibility is utilized to evaluate network development in transportation planning and to measure the potential of regional economic performance in urban planning. In fact, Martellato et al. (1998) demonstrated that accessibility refers to potential opportunities with regard to the interactions among urban spatial patterns. Levine and Garb (2002) measured accessibility using the ease of interactions between network nodes. Besides, accessibility represents the connection between origins and destinations or between activities (Wachs and Koenig, 1979). Additionally, accessibility indicates differences in attraction between activities (Burns 1979).

Moreover, a poverty gap caused by income level and distribution leads to issues of affordability to support socio-economic activities (van Kamp et al. 2003; Steg and Gifford 2005; Jeon et al. 2006; Loo and Chow 2006; Ness et al. 2007). Likewise, de Vasconcellos (2005) noted that there was the problem of low-income users paying the highest proportion relative to disposable income to make essential trips of any group of public transport users. Consumption of daily essentials may have to be reduced in the event of transportation becoming unaffordable. Quality of life thus is negatively affected. Therefore, ensuring the affordability of basic trips is necessary for achieving an equitable society. Besides, universal design, otherwise known as barrier-free design, relates to infrastructure and services satisfying the basic needs of vulnerable groups, such as the handicapped, disabled, or elderly users (Loo and Chow 2006). Furthermore, universal design could improve the safety, comfort, and convenience of transportation systems. As a result, the level of universal design should be the critical item in constructing social equity.

Environmental Quality

Governments have traditionally constructed extensive transport infrastructure to enhance transportation efficiency. Motor-vehicle emissions have contributed to the greenhouse effect and ozone hole, and consequently threatened the very ecological system upon which human life depends (OECD 2001). Emissions also influence health and quality of life. Past research on environmental quality focused on negative externalities, like emissions, noise, waste, water pollution, and habitat destruction (McMahon 2002; van Kamp et al. 2003; Pope et al. 2004; Steg and Gifford 2005; Jeon et al. 2006; Soltani and Allan 2006; Ness et al. 2007). In response to such research, transportation policies in developed countries have changed during recent years to mitigate adverse environmental impacts. Moreover, excessive use of resources, especially of nonrenewable resources, should also be considered in relation to environmental quality (McMahon 2002; van Kamp et al. 2003; Pope et al. 2004; Steg and Gifford 2005; Loo and Chow 2006; Ness et al. 2007). As a result, the development of green energy and energy-saving vehicles offer a means of addressing concerns in this area.

Conclusion

The study proposes a conceptual framework that integrates diverse stakeholder needs to evaluate transport diversity based on sustainability and quality of life. This study defines transport diversity as the level of satisfaction of stakeholder needs and measures it as the gap between the targets for stakeholder needs and current achievement of those needs in the form of the Shannon–Weaver index. Transportation planning attempts to maximize diversity to comprehensively and equitably satisfy needs. The evaluation of transport diversity is involved in the process of sustainability assessment to confirm the sustainable targets and the basic level of quality of life to satisfy the stakeholder needs more equitably. Additionally, this study covered most but not all contents of sustainability and quality of life. The contents are utilized as the needs of stakeholders for evaluation of transport

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diversity. Failure to satisfy basic stakeholder needs may negatively impact quality of life.

Accordingly, diversity can assist planners in resource allocation to promote quality of life in two ways. First, quality of life should be improved in areas with the least diversity. Second, the infrastructure or service should be invested based on the need with the largest gap between target and present value, i.e., that with the least achievement. Planners can propose appropriate transportations systems, i.e., determine the basic quality of life standard and the expected sustainable target by setting goals and threshold values. Consequently, the city following transport diversity principles can benefit by comparing improvements in quality of life and sustainability strategies for resource allocation. Such an evaluation could help policy makers determine which plans would maximize transport diversity to satisfy stakeholder needs and which plans would produce a more equitable and sustainable development and quality of life. Therefore, the assessment of transport diversity should be considered at the commencement of planning and policy making. Moreover, diversity is useful for assessing the improvement in quality of life and resource allocation. The investments should be allocated to reduce any gap in needs. This investigation found that urban requirements may vary according to the dynamics of a city such as the level and distribution of income, urbanization, and the target for sustainable urban development. Furthermore, goal values and threshold values indicating the expected satisfaction and acceptable quality of life of needs, respectively, may differ according to the dynamics of a city.

Further research is recommended to determine an optimal indicator system for transport diversity. Such a system should identify stakeholder needs and determine appropriate indicators that reflect those needs via questionnaires and professional information. The contents of quality of life could be tailored to fit different sustainable development targets due to different targets of sustainable development. Additionally, the approach outlined in this study should be replicated in different collaborative groups, as well as in a diverse spatial scope to establish a typology for the number and type of indicators that should be involved and the processes necessary for transport diversity. Moreover, the causal relationship between policies and stakeholder needs should be established to assess what and how much the policies impact transport diversity. For example, the impact of a bus exclusive lane can be assessed to determine how it would affect mobility and accessibility in an urban area and transportation. A causal system can help policy makers assess which investments achieve the greatest improvements in sustainability and quality of life.

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