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共同主持人：  
計畫參與人員：謝承憲、陳妍方、林欣萍、王世寧

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## 一、中英文摘要

### (一) 中文摘要

不同運輸權益關係人對於運輸設施與服務的需求是多元化的，要滿足這些權益關係人的需求，必須在供需之成本效益中進行權衡考量，也產生了運輸多樣性的課題。然而，過去的研究甚少探討此一議題，故本研究目的在於建構一評估運輸性以增進生活品質之架構。運輸多樣性之定義為不同權益關係人其需要被滿足的程度，滿足程度則量測權益關係人對該需要的預期水準與實際情況間之落差，並以 Shannon-Weaver 指數計算之。運輸多樣性可以用以評估各重要需求是否被公平地滿足，並可在確認發展目標與基本生活品質門檻之前提下，監測運輸系統是否具備永續性。本研究期望所發展的概念架構可以協助決策者了解運輸多樣性與永續性間的關係，並提供一新的評量方法用以改善生活品質。

關鍵詞：運輸多樣性、生活品質、永續性

### (二) 英文摘要

Different transport stakeholders have different needs for transport infrastructure and services. Meeting the needs of stakeholders implies a trade-off 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 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 towards 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 assessing method for improvements in quality of life.

Keywords: transport diversity, quality of life, sustainability

## 二、報告内容

### **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 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 feedbacks 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 non-automobile users.

In fact, in the transportation planning, transport policy-makers must simultaneously consider the trade-off 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 (1997) as the perceptions of individuals regarding their goals, expectations, standards, and concerns. Furthermore, Diener et al. (1999) defined quality of life as a multi-dimensional 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 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.

## 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 Eqn. 1 (Odum, 1993).

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

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

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  $H$  is the value of diversity. The diversity index has a value exceeding 0. Evenness, shown as Table 1, refers to that the distribution becomes more uniform with increasing diversity while system A and system B include equal number of species. In contrast, higher diversity indicates a larger number of species under the same distribution of each species population. For example, the 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 come to be involved in the system (Muller, 1998).

**Table 1** An example describing the relationship between diversity and evenness

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

**Table 2** An example describing the relationship between diversity and richness

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

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.

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

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  $V_i$  is the 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 Eqn. 4, which is plugged into Eqn. 2. Moreover, transport diversity represents the equal satisfaction of stakeholder needs in the form of the Shannon-Weaver Index, presented in the form of Eqn. 1. Transport diversity calculated with Eqn. 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

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

### *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 Eqn. 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 satisfaction 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.

## *The 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 & Gifford, 2005; Jeon et al., 2006). Issues related to weighting method thus become important. Ordinary weighting methods weigh the criteria according to the importance through preference survey. For example, the proportion of needs achievement including  $P_i$ , the weight of indicator  $i$ , with Simple Additive Weight (SAW) can be calculated by Eqn. 5.

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

However, Eqn. 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 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, the sustainable targets, and the basic level of quality of life. The needs which 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 so 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 trade-off 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.

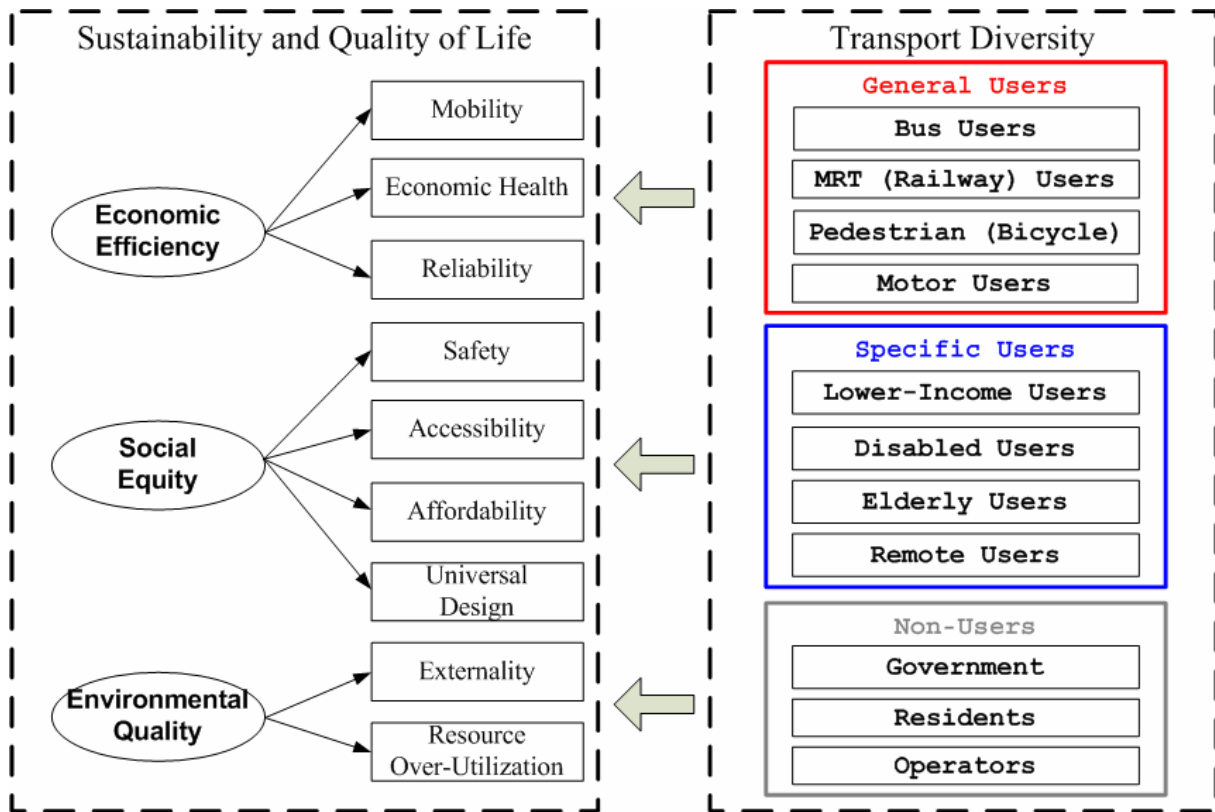
The concept and content of quality of life and sustainability are similar. However, satisfaction of needs differentiate quality of life from sustainability in this study. Quality of life represents the basic level of needs satisfied with which stakeholders certainly live without deficiencies. Likewise, 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 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 towards 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 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, MRT, parking and pedestrian lanes, are. Since transportation needs prevail over those of daily life including diverse socio-economic activities, the constitution of diversity indicates different needs for daily activities based on quality of life.





**Fig. 1** Conceptual framework

### *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; Ness et al., 2007). To achieve the need of 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 the 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, 1976). 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) addressed that 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 (Organization for Economic Co-operation and Development, 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 non-renewable 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 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 presents covered many but not all contents of sustainability and quality of life. The contents are utilized as the needs of stakeholders for evaluation of transport 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 principle 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, 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 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 the questionnaires and professional information. The contents of quality of life could be tailored to fit different sustainable development targets due to the different target of

sustainable development. Additionally, the approach outlined in this study should be replicated in different collaborative groups, as well as in 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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### 三、計畫成果自評

本研究內容與原計畫相符，主要係回顧多樣性、生活品質與永續性之相關文獻，並進行多樣性、生活品質與永續性之間相關性等議題之探討，進而彙整出評估運輸多樣性所應分析之重要因素，並探究其影響以及可能因應之情況，且根據前述重要結論，構建運輸多樣性評估之概念架構。至民國 97 年五月底前已達成預期之目標，完成第一年之工作項目。研究成果部份已投稿至 *Journal of Urban Planning and Development - ASCE* 並獲接受刊登。

此外，依照第二年之工作預定進度表，由民國 97 年 8 月 1 日起，本研究將基於前一年度所建構之運輸多樣性架構，建立都會區運輸系統，並探討系統中各項變數之因果關係。以系統動態學、模糊認知圖及感受性模型等系統方法進行系統模擬，其以建立並驗證運輸多樣性在都會區運輸系統之穩健性與可操作性外，並將藉由情境分析、敏感度分析及政策模擬，評估運輸資源配置對於系統運輸多樣性之影響。