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Evaluating sustainable transport strategies for the counties of Taiwan based on their degree of urbanization

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ABSTRACT

The purpose of this study was to evaluate sustainable transport strategies for the 23 counties of Taiwan. The 23 counties were grouped into four clusters based on their degree of urbanization. Subsequently, a hybrid approach based on the Analytic Hierarchy Process (AHP) and the Dempster–Shafer theory (DST) was used to deal with incomplete information in prioritizing the strategies. The results showed that the focuses of decision makers in each county were different. For the counties in Cluster 1 (highly urbanized counties), the three top-ranked strategies were: improving the accessibility of non-motorized modes, improving Demand Response Transportation System (DRTS) services, and improving accessibility for elderly and handicapped persons. For the counties in Cluster 2 (rapidly developing counties), and Cluster 3 (developing counties with distinct urban and rural patterns), the three top-ranked strategies were: improving transit services, improving the accessibility of non-motorized modes, and improving DRTS services. For the counties in Cluster 4 (under developed counties), the focuses of decision makers were significantly different from the focuses of decision makers in other counties. The three top-ranked strategies were: promoting the use of electric motorcycles, improving DRTS services, and improving the accessibility of non-motorized modes. The analytical results of this study justified the application of the principle: tailor measures to suit local circumstances.

1. Introduction

Sustainable development is becoming a common vision around the world in response to climate change issues. Developing an indicator system for measuring transport sustainability has been broadly discussed. A typical example is the Transport and Environment Reporting Mechanism (TERM) published annually by the European Environment Agency (EEA) since 2000 (EEA, 2000). The TERM fact sheets reflect data gathered during the period 2000–2011 (EEA, 2011). Similar to the EU's contribution, the Centre for Sustainable Transportation (CST) initiated the Sustainable Transportation Performance Indicators (STPI) project in 2000 to monitor the state of transport sustainability in Canada (Gilbert and Tanguay, 2000). Most literature has reported indicators for nationwide transport sustainability, and there has been a lack of literature reporting indicators designed to monitor the development of sustainable transport at the local level (for example, at the county level). Awasthi and Chauhan (2011) proposed a Transport Sustainability Index (TSI) for measuring the impact of a carsharing strategy on transport sustainability at the city level. The results showed that a carsharing strategy could improve the transport sustainability of a city. Browne et al. (2008) compared the ecological footprint for travel-commuting patterns for the residents of an Irish city-region. The results showed that reduced transport demand and technological improvements in fuel economy were the optimal policy mix, and that no one policy strategy was a panacea for sustainable transport. Yedla and Shrestha (2003) evaluated the priority of three alternative transport options applied in Delhi, including 4-stroke 2 wheelers, Compressed Natural Gas (CNG) cars, and CNG buses. The strategies considered were restricted to those using alternative energy and vehicle technologies. Tzeng and Shiau (1987) proposed a set of comprehensive energy conservation strategies for city development. They used a deterministic evaluation method to treat incomplete information. However, their evaluation did not take the societal aspect into consideration.

There are a variety of urbanization patterns among the 23 counties in Taiwan. Although the central and local governments have reached a consensus regarding the goal of improving transport sustainability, different counties may have different strategic priorities due to differing urbanization pattern. This study is an extension of the previous study on Taipei City application (Shiau, 2012). The purpose of this paper is to evaluate sustainable transport strategies for the different counties of Taiwan. The 23 counties were grouped based on their degree of urbanization. Additionally, a hierarchical framework was proposed to generate

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strategies for the counties. Subsequently, the ranking of strategies was evaluated according to local circumstances. A hybrid approach based on the Analytic Hierarchy Process (AHP) and the Dempster–Shafer theory (DST) was used to deal with incomplete information in evaluating the ranking of strategies.

2. Classification of counties

2.1. Analytical framework

This paper applied Principal Component Analysis (PCA), Cluster Analysis (CA), and Discriminant Analysis (DA) to classify each county of Taiwan based on its degree of urbanization. The analytical procedure started with the application of PCA; 37 socioeconomic variables with respect to degree of urbanization were used as input data. These socioeconomic variables included demographic statistics, economic development indicators, distribution of public facilities and utilities, land use status, and transportation services. The PCA reorganized these socioeconomic variables into independent principal components. Subsequently, these independent principal components were used as input data by using CA. The clustering of counties was based on the hit rate obtained by using DA. Fig. 1 shows the flowchart of the analytical procedure.

2.2. Principal component analysis

Principal component analysis is an eigenvector-based multivariate analysis method that uses an orthogonal transformation to convert a set of possibly correlated explanatory variables into a set of uncorrelated principal components. The 37 variables could be correlated with each other, but were not suitable for classifying the 23 counties. PCA transformed the 37 variables into independent variables, and provided a suitable basis for classifying the 23 counties. The analytical process of PCA is summarized as follows:

Step 1: Calculate the correlation matrix based on the cross-sectional data of the 37 variables.
Step 2: Calculate the eigenvectors and eigenvalues of the correlation matrix.
Step 3: Rearrange the eigenvectors and eigenvalues in descending order.
Step 4: Choose components and form a feature vector.
Step 5: Derive the new data set based on the principal components.

The new data set ensures the principle of independence, and can be used as input data for cluster analysis.

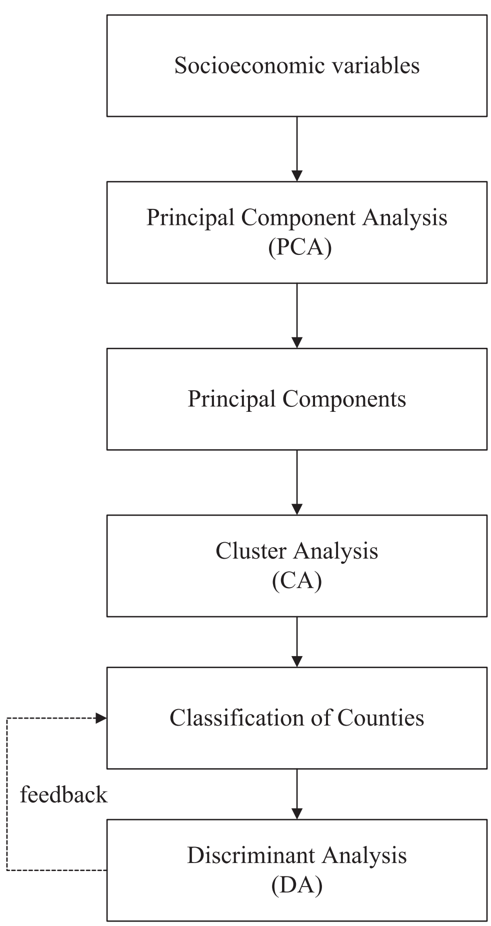

Fig. 1. The analytical procedure of clustering the 23 counties.

2.3. Cluster analysis

Cluster analysis was applied in this study to group the 23 counties into groups (called clusters) so that the counties assigned to the same cluster were more similar to each other (with respect to degree of urbanization) than to counties in other clusters. The analytical process of CA can be summarized as follows:

Step 1: Calculate the proximity matrix based on the new data set obtained from the application of PCA.
Step 2: Construct a hierarchy with a treelike structure based on agglomerative methods.

The application of CA results in a treelike hierarchical structure. This hierarchical structure indicates the relative closeness (with respect to degree of urbanization) of the 23 counties to each other.

2.4. Discriminant analysis

Without suitable judgment criteria, it was difficult to determine how many clusters should be formed after the application of CA; Discriminant Analysis (DA) was used to provide a suitable judgment criterion for clustering. The analytical process of DA is summarized as follows:

Step 1: Create a clustering of the 23 counties by cutting the treelike hierarchical structure arbitrarily.
Step 2: Derive discriminant function based on the results of clustering in Step 1.
Step 3: Compute the hit ratio, which reveals how well the discriminant function classified the counties.
Step 4: If satisfied with the hit ratio (for example, over 90%), then accept the results of clustering in Step 1; otherwise, go to Step 1 and repeat the analytical procedure.

2.5. Results of classification

The cross-sectional data of the 23 counties with respect to the 37 socioeconomic variables were collected. Manipulating the analytical procedure (Fig. 1) with SPSS software, four clusters were obtained (98% of the hit ratio). The characteristics of each cluster are described as follows:

Cluster 1: Highly urbanized counties
The counties in this cluster exhibit a highly concentrated land use pattern. Taipei City, the capital of Taiwan, was the only city