# Decision-making on Transport Policy: A Comparison between Scholars and Stakeholders

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**Abstract**: This study proposes a hybrid MCDM model to analyze the transport policy decision-making process and the various perspectives from stakeholders and scholars are discussed in detail. DEMATEL is employed to construct NRM, ANP is adopted to evaluate the weights of criteria, and VIKOR is used to select the best transport mode. The empirical results reveal that stakeholders are most concerned about Feasibility & Execution and Political Climate. The three criteria with the strongest impact levels are Economic Development, Social Security, and Environmental Protection. Social Security, Equity & Justice, and Environmental Protection have the highest weights. The main concerns of scholars are Political Climate and Environmental Protection. The three criteria with the greatest impact are Feasibility & Execution, Equity & Justice, and Political Climate, while Social Security, Environmental Protection, and Equity & Justice have the highest weights. Railway is the best choice among the four transport modes for stakeholders and scholars.

*Keywords*: MCDM (multiple criteria decision-making), DEMATEL (decision-making trial and evaluation laboratory), ANP (analytic network process), VIKOR, NRM (network relation map)

## 1. INTRODUCTION

A country’s transport infrastructure is closely connected to its economy, society, environment, and politics. The construction of transport infrastructure is usually welcomed by local governments, due to benefits such as greater convenience and growth in the local economy, tourism industry, and employment rate. However, environmental protection must be taken into consideration when such projects are proposed, as poor in decision-making can not only lead to considerable waste in both time and money, but also may cause long-term damage.

The various conflicting opinions and interests of different groups can make transport policy decision-making a difficult task for government authorities. The question thus arises as to whether it is possible to develop a systematic and scientific decision support system to consider a diverse range of conflicting factors associated with transport policies, and to find an optimal compromise solution.

This study proposes a hybrid MCDM (multiple criteria decision-making) transport policy decision-making model by investigating the case of eastern Taiwan. The DEMATEL-ANP-VIKOR model is used to identify the network of influence and priority of criteria, and select the best compromise solution for a complicated transport policy problem. In particular, the diverse perspectives of local stakeholders and neutral scholars are discussed and compared in detail. The results of this work show the potential of this new decision-making approach to improve outcomes for government authorities. This paper sheds light on the consensus building by realizing the different causal modeling systems of different groups. Accordingly, the in-depth communication between different groups may avoid time-consuming arguments since the weight of criteria and rank of alternatives may be actually similar. It is believed that the effectiveness and efficiency of decision-making on public policy should be improved significantly.

## 2. DECISION-MAKING ON TRANSPORT POLICY—AN OVERVIEW

Public policy decision-making may be regarded as the process by which a government translates its political vision into projects and actions to achieve desired outcomes in the real world. Many techniques are available which can assist with in this process, such as Political System Theory (Easton, 1953), the Garbage Can Model (Cohen *et al*., 1972), and Rough Sets Theory (Pawlak, 1991).

The various departments of the Executive Yuan in Taiwan are staffed by many experts and scholars, and most cabinet members have doctoral degrees. On the other hand, Taiwanese society is highly democratized, with two major parties that campaign to win public office at all levels of the system. In other words, the Taiwanese political system has two conflicting characteristics: elitism and populism. Moreover, the context in which policies have to be developed is becoming increasingly complicated, uncertain and unpredictable, as seen in debates around some key national issues, such as transport infrastructure, economic development, social security, and environmental protection, which are intertwined and cannot be dealt with easily by individual departments acting alone.

Although several traditional approaches have been proposed for solving public policy decision-making problems, different techniques may yield different results for the same problem. The MCDM method (Zeleny, 1982) is a way to aggregate individual judgments into a group judgment, and has become a very active field of research although few such studies are devoted to examining transport policy decision-making (Tsamboulas *et al*., 1999; Hanaoka and Kunadhamraks, 2009; Shelton and Medina, 2010).

Yedla and Shrestha (2003) examined the impact of including various qualitative criteria to select the alternative transportation options in Delhi. Based on six different criteria: energy saving potential, emission reduction potential, cost of operation, availability of technology, adaptability of the option, and barriers to implementation, three alternative transport options: two-wheelers, cars and buses were prioritized. Integrated quantitative and qualitative criteria gave contrasting results as compared to those obtained from the conventional quantitative and qualitative approaches, which can explain the reasons for the failure of many potential alternative urban transport options.

Tudela *et al*. (2006) compared the outcome of the multi-criteria method and traditional cost benefit analysis for an urban transport project. The results showed that the outcome of the multi-criteria method was different to that obtained from the cost benefit analysis, but matched the final decision made by the authority. These two earlier studies show that it is possible to improve transport policy decision-making by using an MCDM model.

MCDM has also proved its usefulness in various fields, such as economics, management and engineering (Tzeng *et al*., 2002; Liou *et al*., 2008; Liou and Chuang, 2010). Therefore, this study proposes a transport policy decision-making process using a hybrid MCDM to examine the dependent relationships among various transport related criteria. DEMATEL is employed to construct the Network Relation Map (NRM), which illustrates the network of influence in the transport policy decision-making model. In addition, ANP is adopted to evaluate the weights of criteria, and VIKOR is used to select the best transport mode.

Yeh *et al*. (2009) stated that transportation projects do not follow a united process in Taiwan. In their study, four dimensions: economy, society, environment, and policy, were measured by 24 attributes extracted from previous studies that reviewed the contextual aspects of Taiwan's transport policies. For example, the following seven attributes were included in the economy dimension: local economic development, tourism development, employment opportunity, investment cost, maintenance cost, transport cost, and travel time.

However, too many criteria may dramatically increase the difficulty of completing the DEMATEL and ANP questionnaires, as the number of questions produced by pairwise comparisons is proportional to the square of the number of criteria. In addition, the network of influence in a model with too many criteria may become too complicated to analyze. Therefore, 24 attributes are condensed to eight criteria, as follows:

1) Economic Development ($C_1$): local economic/tourism development, and employment opportunities.
2) Eligible Cost ($C_2$): eligible investment, maintenance, and transport cost, and reasonable travel time.
3) Equity & Justice ($C_3$): resident rights, balanced development, and mass transport.
4) Social Security ($C_4$): safety, reliability, accessibility, and disaster reduction.
5) Environmental Protection: ($C_5$) ecological and natural resources protection.
6) Energy Efficiency & Carbon Reduction ($C_6$): green transport, pollution prevention, and sustainability.
7) Political Climate ($C_7$): the aggregate, current mood and opinions of the government, pressure groups, and public.
8) Feasibility & Execution ($C_8$): engineering technology, feasibility, laws and regulations.

This set of criteria provides this study with an overall evaluation system that will facilitate further prioritization using the DEMATEL, ANP, and VIKOR techniques.

Travel north of Hualien now mainly relies on the Suao-Hualien highway and the northern line railway. The Suao-Hualien highway starts at Suao, Yilan, and ends at Hualien, and both landform and geological structure mean that it is often affected by landslides caused by typhoons, heavy rain, and earthquakes. In order to provide a safer route, in 2002 the Executive Yuan approved plans to build a new "Suao-Hualien National Freeway" to improve the relatively poor infrastructure of eastern Taiwan. However, this project has now been suspended after it failed to pass an environmental impact evaluation. In 2010, the Executive Yuan approved the "Suao-Hualien Highway mountain sections improvement plan" to replace some dangerous sections of the original highway. By avoiding geologically fragile areas, the initiative is expected to increase both the safety and carrying capacity of the highway, and reduce the journey time.

While the island-wide railway network, including western, eastern, northern, and southern lines, is often very convenient for passengers, it is difficult to get train tickets during the holidays and weekends. In addition, while some flights connect Hualien and Taipei, the volume of passengers is relatively limited. From 1975 to 1983, passenger shipping traveled between Hualien and Keelung, but this was often affected by typhoons in the summer and monsoons in the winter. Moreover, with the opening of the northern line railway in 1980, the number of passengers going by sea declined very rapidly, and this service was discontinued. After the weights of criteria are determined, the selection of transport mode among these four alternatives, highway, rail, marine and air, is undertaken in this work based on the VIKOR method.

In general, MCDM questionnaires are distributed to experts or scholars to take advantage of their independence, neutrality and specialist knowledge. Therefore, stakeholders' opinions are seldom included in the analysis in spite of multicriteria analysis should summarize the stakeholders' implicit priorities, possibly weighting stakeholders in terms of importance (Beria *et al*., 2012). Regmi and Hanaoka (2012) compared the feedback of related government officials and private sector transport service providers, and the results showed similarities in final priority rankings of the proposed logistics centers. However, some differences in the weights of the evaluation criteria were noted for the public and private sector models.

The opinions and needs of local stakeholders must be taken into consideration even though the number of local people is obviously much lower than the population of the whole country, and they usually have a narrow focus on their own immediate interests. This is because the successful implementation of public policy usually strongly relies on the acceptation or compliance of local people, and any conflicts that arise with them will induce time-consuming arguments and serious delays, making the related negotiations and implementation very difficult. Therefore, in this work questionnaires were also distributed to local government officials, elected representatives, and opinion leaders to gather the opinions of local stakeholders, and it is believed that by combining these with those of the neutral scholars, a more comprehensive overview of this complicated problem can be obtained.

## 3. METHODOLOGY—DEMATEL-ANP-VIKOR MODEL

### 3.1 The DEMATEL approach

The DEMATEL technique, which originates from the Geneva Research Centre of the Battelle Memorial Institute, is used to investigate and solve complicated problems (Tzeng *et al*., 2007), and is particularly useful for visualizing the structure of complicated causal relationships with matrices and diagraphs. DEMATEL has recently attracted more attention in Japan and Taiwan, and has been widely applied in many contexts, including transportation (Liou *et al*., 2007; Hsu *et al*., 2010), tourism (Liu *et al*., 2012), and many other industries (Shieh *et al*., 2010; Wei *et al*., 2010). The DEMATEL approach can be summarized as follows:

Step 1: Obtain the direct influence matrix based on scores given by respondents.

The respondents are asked to indicate the direct effect they believe that each factor *i* exerts on each factor *j* using an integer scale ranging from 0, 1, 2, 3, and 4, with 0 meaning "no influence" and 4 "a very high influence". Each element of the direct influence matrix $[A]$ is the average of the same elements in the different matrices of the respondents.

Step 2: Calculate the initial influence matrix.

The initial influence matrix $[D]$ is obtained by normalizing the direct influence matrix $[A]$ as

$$[D] = \tfrac{1}{k}[A] \tag{1}$$

where

$$k = Max\left( \underset{i}{Max}\sum_{j=1}^{n} A_{ij},\ \underset{j}{Max}\sum_{i=1}^{n} A_{ij} \right)$$

Step 3: Derive the total influence matrix.

As $0 \le D_{ij} < 1$ and $\lim_{m\to\infty} [D]^m = [0]$, the total influence matrix $[T]$ can be obtained as

$$[T] = [D] + [D]^2 + [D]^3 + ...... + [D]^m = [D]\left([I] - [D]\right)^{-1} \tag{2}$$

where

$[I]$ denotes the identity matrix.

Step 4: Calculate the sum of rows and the sum of columns.

$$\{r\} = \left[ \sum_{j=1}^{n} T_{ij} \right] \quad (3)$$

$$\{c\} = \left[ \sum_{i=1}^{n} T_{ij} \right]^T \quad (4)$$

where $r_i$ shows the sum of direct and indirect effects of factor *i* on the other factors, $c_i$ shows the sum of direct and indirect effects that factor *i* has received from the other factors. Furthermore, $r_i + c_i$ shows the impact level (the strength of influences given and received) that factor *i* has with regard to the problem. If the relation level ($r_i - c_i$) is positive, then factor *i* is affecting other factors, otherwise it is being influenced by them.

Step 5: Construct the Network Relation Map.

In order to reduce the complexity of the Impact Relation Map (IRM), a threshold value for the influence level may be decided by the decision maker or based on the opinions of respondents. Only elements whose influence levels are higher than the threshold value are chosen and converted into the IRM. However, the process of setting the threshold value is sometimes difficult and contentious. Liu *et al* (2012) suggested constructing a Network Relation Map (NRM) without the threshold value and using single-headed arrows to represent the impact direction, in which the net influential impact in the network flow may be expressed as

If $T_{ij} > T_{ji}$, the flow is drawn from factor *i* to factor *j*.

If $T_{ij} < T_{ji}$, the flow is drawn from factor *j* to factor *i*.

### 3.2. The ANP method

The ANP method (Saaty, 1999) is an extension of the AHP approach (Saaty, 1996) that is used to overcome the problem of interdependence and feedback between criteria. The ANP method can be summarized as follows:

Step 1: Obtain the unweighted supermatrix based on scores given by respondents.

The initial step of the ANP is to compare the criteria in the entire system to form a supermatrix through pairwise comparisons. The relative importance is determined using a scale of 1–9 representing equal importance to extreme importance (Huang *et al*., 2005).

Step 2: Derive the weighted supermatrix.

After forming the unweighted supermatrix, the weighted supermatrix $[w]$ is derived by transforming all the columns sum to unity exactly.

Step 3: Compute the weight of each criterion.

The weighted supermatrix is raised to limiting powers to calculate the overall priorities. Each row of the limit supermatrix represents the weight of each criterion.

$$\underset{m \to \infty}{Lim} \, [w]^m \quad (5)$$

### 3.3. The VIKOR method

The VIKOR method was developed to determine the compromise ranking list with the given weights for multicriteria optimization of complicated systems (Opricovic, 1998). It focuses on ranking and selecting from a set of alternatives in the presence of conflicting

criteria (Opricovic and Tzeng, 2004). This compromise ranking algorithm introduces the multicriteria ranking index based on a measure of closeness to the ideal solution (Opricovic and Tzeng, 2007). The VIKOR method can be summarized as follows:
Step 1: Obtain the evaluation matrix based on scores given by respondents.
The respondents are asked to indicate the evaluation of the *i*th criterion function and *j*th alternative using an integer scale ranging from 1, 2, 3, 4, and 5, with 1 meaning "strongly disagree" and 5 "strongly agree".
Step 2: Determine the best and the worst values of all criteria.
If the *i*th criterion function represents a benefit then:

$$f_i^* = \underset{j}{Max}\ f_{ij} \tag{6}$$

$$f_i^- = \underset{j}{Min}\ f_{ij} \tag{7}$$

Step 3: Compute the distance from each alternative to the positive ideal solution.

$$S_j = \sum_{i=1}^{n} X_{ij} \tag{8}$$

$$R_j = \underset{i}{Max}\ X_{ij} \tag{9}$$

where

$X_{ij} = w_i(f_i^* - f_{ij})/(f_i^* - f_i^-)$, $w_i$ represents the weights of criteria, $S_j$ is the distance of the *j*th alternative achievement to the positive ideal solution, and $R_j$ implies the maximal regret of each alternative.
Step 4: Compute the index value.

$$Q_j = \nu(S_j - S^*)/(S^- - S^*) + (1-\nu)(R_j - R^*)/(R^- - R^*) \tag{10}$$

where

$S^* = \underset{j}{Min}\ S_j$, $S^- = \underset{j}{Max}\ S_j$, $R^* = \underset{j}{Min}\ R_j$, $R^- = \underset{j}{Max}\ R_j$, and $\nu$ is the weight of the decision-making strategy, representing the majority of criteria. In Eq. (10), when $\nu$ =1, it represents a decision-making process that can use the strategy of maximum group utility. On the other hand, when $\nu$ =0, it represents a decision-making process that can use the strategy of minimum individual regret. The best alternative is the one with the minimum value of $Q_j$.

## 4. EMPIRICAL RESULTS

To obtain a comprehensive perspective, the local stakeholders, including government officials, elected representatives, and opinion leaders, were invited to assess the relationships among the eight targeted criteria. Twenty-four questionnaires were distributed, and 14 valid samples were returned, with the respondents including five government officials (head of Hualien county, head of tourism and public affairs department, etc), four elected representatives (councilors of Hualien county), and five opinion leaders (president of Hualien County tourism association, political pressure groups and leaders, etc).

In addition, scholars who either teach in transportation, tourism, economics, and ecology related departments in Taiwan, or have carried out related research, were also invited to participate in the evaluation. Twenty-four questionnaires were distributed to this group, and 16 valid samples were returned, with the respondents including five transportation, five tourism, two economic, and four ecology experts.

### 4.1. Measuring the relationships by DEMATEL

Based on the local stakeholders' viewpoints, the average direct influence matrix $[A]$ is an 8×8 matrix obtained by pairwise comparisons in terms of influences and directions between the eight criteria (Table 1). The normalized initial influence matrix $[D]$ is obtained through Eq. 1. The total influence matrix $[T]$ is then derived by using Eq. 2 (Table 2).

Table 1. The direct influence matrix

| Criteria | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0 | 2.8571 | 3.1429 | 2.7857 | 3 | 2.8571 | 2.3571 | 2.9286 |
| $C_2$ | 2.2143 | 0 | 2.4286 | 3 | 2.3571 | 2.7857 | 2.2857 | 2.8571 |
| $C_3$ | 2.6429 | 2.5714 | 0 | 2.9286 | 2.6429 | 2.7143 | 2.7857 | 2.5 |
| $C_4$ | 2.7857 | 3 | 3.0714 | 0 | 2.7857 | 2.5714 | 2.7143 | 2.9286 |
| $C_5$ | 3.1429 | 2.9286 | 2.7143 | 2.9286 | 0 | 3.2143 | 2.2857 | 2.3571 |
| $C_6$ | 2.8571 | 3.0714 | 2.4286 | 2.2857 | 3.2857 | 0 | 2 | 2.2143 |
| $C_7$ | 2.6429 | 2.2857 | 2.9286 | 2.4286 | 2.3571 | 2.4286 | 0 | 2.2857 |
| $C_8$ | 3.0714 | 2.8571 | 2.7857 | 3 | 2.7857 | 3 | 2.1429 | 0 |

Table 2. The total influence matrix

| Criteria | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | 2.3902 | 2.5467 | 2.54 | 2.517 | 2.5118 | 2.5435 | 2.1905 | 2.3828 |
| $C_2$ | 2.2765 | 2.2047 | 2.2971 | 2.3106 | 2.2737 | 2.3238 | 2.0008 | 2.1783 |
| $C_3$ | 2.3824 | 2.4089 | 2.2785 | 2.397 | 2.3735 | 2.4112 | 2.0988 | 2.2484 |
| $C_4$ | 2.502 | 2.5411 | 2.5269 | 2.3839 | 2.4925 | 2.5215 | 2.1956 | 2.3731 |
| $C_5$ | 2.4874 | 2.5104 | 2.4843 | 2.483 | 2.3426 | 2.5177 | 2.1535 | 2.3241 |
| $C_6$ | 2.3254 | 2.3629 | 2.3209 | 2.3073 | 2.3337 | 2.2264 | 2.0102 | 2.1758 |
| $C_7$ | 2.2296 | 2.2428 | 2.2533 | 2.2247 | 2.2102 | 2.2456 | 1.8431 | 2.0958 |
| $C_8$ | 2.496 | 2.519 | 2.4984 | 2.4973 | 2.4763 | 2.5209 | 2.1577 | 2.2288 |

Table 3. The results of the criteria analysis

| Criteria | $r_i$ | $c_i$ | $r_i+c_i$ | $r_i-c_i$ |
|---|---|---|---|---|
| Economic Development ($C_1$) | 19.6225 | 19.0894 | 38.7119 (1) | 0.5331 (3) |
| Eligible Cost ($C_2$) | 17.8654 | 19.3365 | 37.2019 (7) | -1.4710 (8) |
| Equity & Justice ($C_3$) | 18.5987 | 19.1994 | 37.7981 (4) | -0.6006 (6) |
| Social Security ($C_4$) | 19.5367 | 19.1209 | 38.6576 (2) | 0.4158 (4) |
| Environmental Protection ($C_5$) | 19.3029 | 19.0143 | 38.3172 (3) | 0.2887 (5) |
| Energy Efficiency & Carbon Reduction ($C_6$) | 18.0626 | 19.3107 | 37.3733 (6) | -1.2481 (7) |
| Political Climate ($C_7$) | 17.3451 | 16.6504 | 33.9954 (8) | 0.6947 (2) |
| Feasibility & Execution ($C_8$) | 19.3945 | 18.0071 | 37.4016 (5) | 1.3875 (1) |

Note: The numbers in parentheses denote rankings.

Using Eqs. 3 and 4, the influences given to and received by each factor are shown in Table 3. The $r_i+c_i$ values represent the total influence levels. The $r_i-c_i$ values represent net influence levels, where positive values indicate that the factor influences other factors more than other ones influence it. The impact levels of the eight criteria can be prioritized as Economic Development ($C_1$) > Social Security ($C_4$) > Environmental Protection ($C_5$) > Equity & Justice ($C_3$) > Feasibility & Execution ($C_8$) > Energy Efficiency & Carbon Reduction ($C_6$)

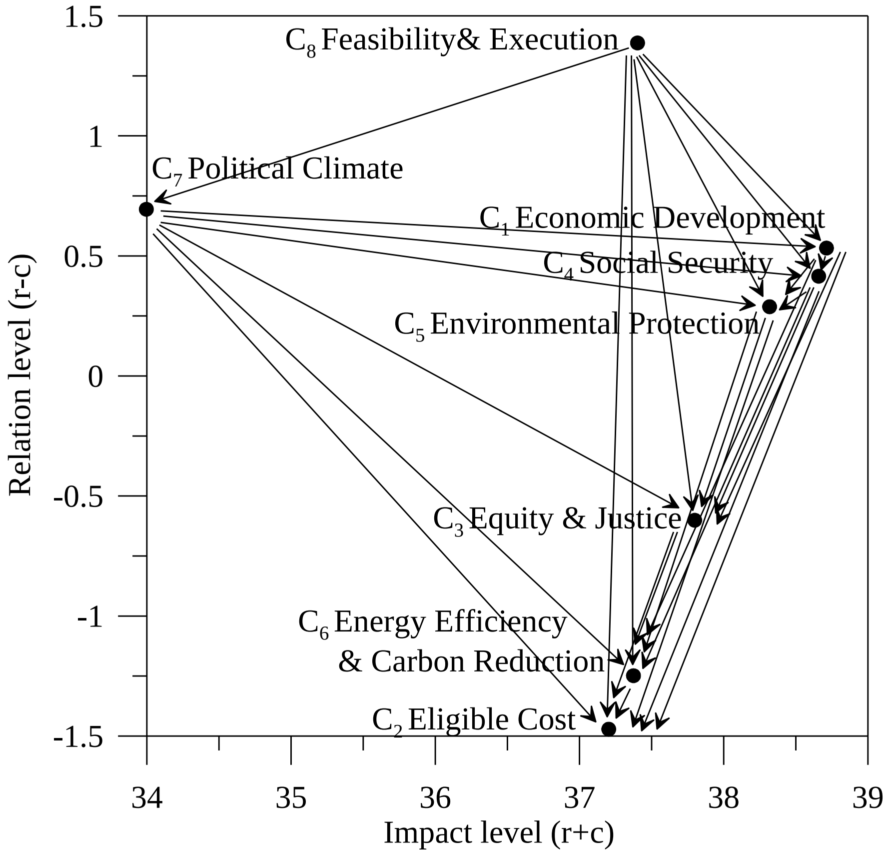


Figure 1. Network relation map (local stakeholders)

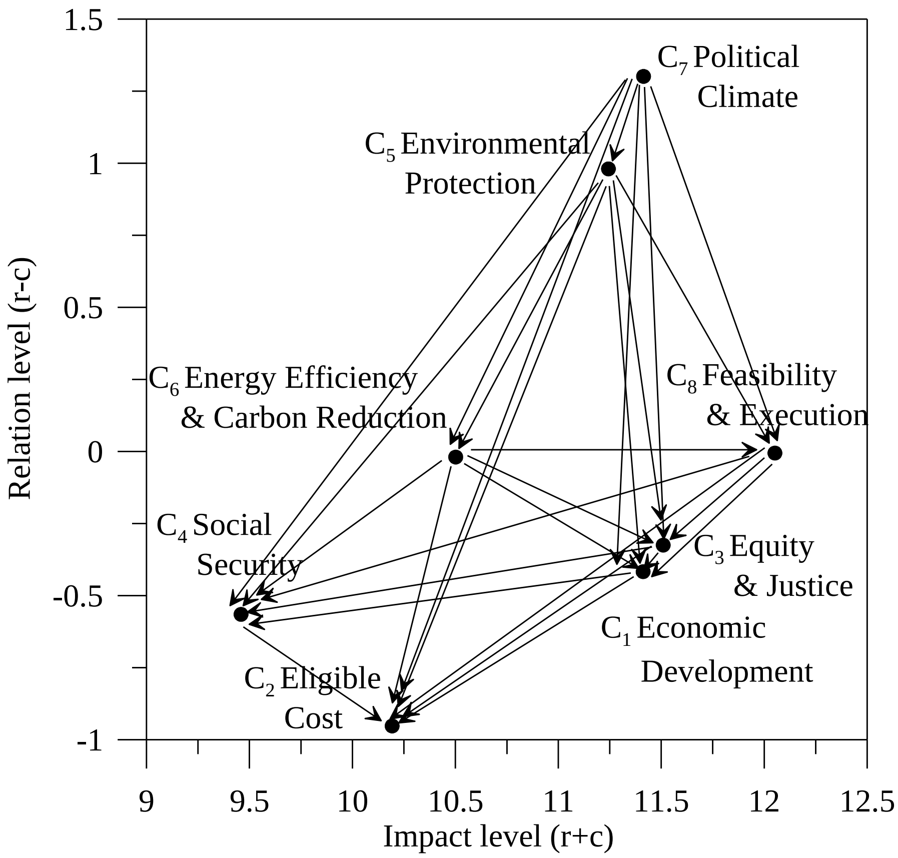


Figure 2. Network relation map (neutral scholars)

> Eligible Cost ($C_2$) > Political Climate ($C_7$) based on the $r_i + c_i$ values. Based on the $r_i - c_i$ values, Feasibility & Execution ($C_8$), Political Climate ($C_7$), Economic Development ($C_1$), Social Security ($C_4$), and Environmental Protection ($C_5$) are net causes, whereas the others are net receivers.

The net influential impact in network flow may be determined by comparing $T_{ij}$ and $T_{ji}$, and the NRM is obtained and shown in Fig. 1. In fact, the net influential impact in the NRM may also be easily determined by comparing the vertical coordinates of the criteria. The upper criteria in the NRM affect the lower ones.

Similarly, the NRM obtained based on the views of the scholars is shown in Fig. 2. The impact levels of the eight criteria can be prioritized as Feasibility & Execution ($C_8$) > Equity & Justice ($C_3$) > Political Climate ($C_7$) > Economic Development ($C_1$) > Environmental Protection ($C_5$) > Energy Efficiency & Carbon Reduction ($C_6$) > Eligible Cost ($C_2$) > Social Security ($C_4$). Political Climate ($C_7$) and Environmental Protection ($C_5$) are net causes, whereas the others are net receivers. In this comparison between the different perspectives, some repeated matrices and tables based on the scholars' views are omitted due to space limitations.

### 4.2. Deriving the weights of criteria by ANP

ANP is adopted to form an unweighted supermatrix (Table 4) through pair-wise comparisons undertaken by the local stakeholders. The limiting power of the weighted supermatrix is obtained until a steady-state condition is reached (Table 5). Each row represents the weight of each criterion, and the top three priorities in the evaluating system are: Social Security ($C_4$) (16.88%), Equity & Justice ($C_3$) (14.7%), and Environmental Protection ($C_5$) (14.41%).

Table 4. The unweighted supermatrix

| Criteria | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | 1 | 1.7689 | 0.6992 | 0.4832 | 0.8106 | 0.7633 | 1.9597 | 1.1026 |
| $C_2$ | 2.9371 | 1 | 0.8105 | 0.6462 | 0.7109 | 1.1095 | 1.6889 | 0.9531 |
| $C_3$ | 3.1786 | 3.0893 | 1 | 1.1312 | 1.8217 | 1.6809 | 2.9508 | 1.9508 |
| $C_4$ | 3.7143 | 3.5893 | 2.4388 | 1 | 1.7334 | 1.9477 | 2.8258 | 1.9687 |
| $C_5$ | 3.5238 | 2.8095 | 2.1138 | 1.7643 | 1 | 1.1294 | 2.4071 | 1.4929 |
| $C_6$ | 3.1667 | 1.9048 | 1.3816 | 1.6869 | 1.9786 | 1 | 1.8536 | 1.0544 |
| $C_7$ | 2.1102 | 1.7024 | 1.4335 | 1.6597 | 0.9429 | 1.1964 | 1 | 0.9372 |
| $C_8$ | 2.3 | 1.6786 | 1.6174 | 1.8542 | 1.4524 | 2.2619 | 2.6309 | 1 |

Table 5. The limit supermatrix

| Criteria | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0.0762 | 0.0762 | 0.0762 | 0.0762 | 0.0762 | 0.0762 | 0.0762 | 0.0762 |
| $C_2$ | 0.0824 | 0.0823 | 0.0824 | 0.0824 | 0.0823 | 0.0824 | 0.0823 | 0.0823 |
| $C_3$ | 0.147 | 0.147 | 0.147 | 0.147 | 0.147 | 0.147 | 0.147 | 0.147 |
| $C_4$ | 0.1688 | 0.1688 | 0.1688 | 0.1688 | 0.1688 | 0.1688 | 0.1688 | 0.1688 |
| $C_5$ | 0.1441 | 0.1441 | 0.1441 | 0.1441 | 0.1441 | 0.1441 | 0.1441 | 0.1441 |
| $C_6$ | 0.1305 | 0.1305 | 0.1305 | 0.1305 | 0.1305 | 0.1305 | 0.1305 | 0.1305 |
| $C_7$ | 0.1072 | 0.1072 | 0.1072 | 0.1072 | 0.1072 | 0.1072 | 0.1072 | 0.1072 |
| $C_8$ | 0.1438 | 0.1439 | 0.1439 | 0.1438 | 0.1439 | 0.1438 | 0.1438 | 0.1438 |

### 4.3. Selecting the best transport mode by VIKOR

After the weights of the evaluating system are determined, the selection of transport mode is then carried out based on the VIKOR method. The performance score for each transport mode, and the results of the VIKOR and traditional simple additive weight (SAW) method based on the stakeholders' and scholars' views are shown in Tables 6 and 7, respectively.

Table 6. The results of the VIKOR and SAW analyses (local stakeholders)

| Criteria | Weights | Highway | Rail | Marine | Air |
|---|---|---|---|---|---|
| Economic Development ($C_1$) | 0.0762 (8) | 4.2143 | **4.2857** | 3.8571 | 3.3571 |
| Eligible Cost ($C_2$) | 0.0824 (7) | 4.1429 | **4.4286** | 4.0714 | 3.2143 |
| Equity & Justice ($C_3$) | 0.1470 (2) | **4.3571** | 4.2857 | 3.7143 | 2.9286 |
| Social Security ($C_4$) | 0.1688 (1) | 3.9286 | **4.4286** | 3.7857 | 3.2857 |
| Environmental Protection ($C_5$) | 0.1441 (3) | 3.7143 | **4.3571** | 4.2143 | 3.3571 |
| Energy Eff. & Carbon Red.($C_6$) | 0.1305 (5) | 3.5714 | **4.2857** | 4.2143 | 3.2857 |
| Political Climate ($C_7$) | 0.1072 (6) | 3.4286 | **3.7143** | **3.7143** | 2.9286 |
| Feasibility & Execution ($C_8$) | 0.1438 (4) | 3.7857 | **4.2857** | 3.4286 | 3.2143 |
| $S_j$ | | 0.391 | 0.0074 | 0.3654 | 1 |
| $R_j$ | | 0.0932 | 0.0074 | 0.115 | 0.1688 |
| VIKOR ($Q_j$) $v$ =1 | | 0.5318 (2) | 0 (1) | 0.6670 (3) | 1 (4) |
| $v$ =0.5 | | 0.4592 (2) | 0 (1) | 0.5139 (3) | 1 (4) |
| $v$ =0 | | 0.3865 (3) | 0 (1) | 0.3608 (2) | 1 (4) |
| SAW | | 3.8794 (2) | 4.2706 (1) | 3.8629 (3) | 3.1945 (4) |

Note: The numbers in parentheses denote rankings, and those in bold denote $f_i^*$.

Table 7. The results of the VIKOR and SAW analyses (neutral scholars)

| Criteria | Weights | Highway | Rail | Marine | Air |
|---|---|---|---|---|---|
| Economic Development ($C_1$) | 0.1452 (4) | 3.9375 | **4** | 3.375 | 3.25 |
| Eligible Cost ($C_2$) | 0.0881 (7) | 3.8125 | **4.1875** | 3.5625 | 2.9375 |
| Equity & Justice ($C_3$) | 0.1519 (3) | 3.625 | **4** | 3.25 | 3.0625 |
| Social Security ($C_4$) | 0.1698 (1) | 3.375 | **4.4375** | 3.25 | 3.25 |
| Environmental Protection ($C_5$) | 0.1613 (2) | 2.75 | **3.9375** | 3.1875 | 2.9375 |
| Energy Eff. & Carbon Red.($C_6$) | 0.1040 (5) | 2.9375 | **4.375** | 3.375 | 2.6875 |
| Political Climate ($C_7$) | 0.0758 (8) | **3.625** | 3.5625 | 3.0625 | 3.125 |
| Feasibility & Execution ($C_8$) | 0.1039 (6) | 3.4375 | **4** | 3.5 | 3.5625 |
| $S_j$ | | 0.6014 | 0.0088 | 0.7868 | 0.9424 |
| $R_j$ | | 0.1597 | 0.0088 | 0.1630 | 0.1630 |
| VIKOR ($Q_j$) $v$ =1 | | 0.6383 (2) | 0 (1) | 0.8342(3) | 1 (4) |
| $v$ =0.5 | | 0.7928 (2) | 0 (1) | 0.9171(3) | 1 (4) |
| $v$ =0 | | 0.9473 (2) | 0 (1) | 1 (3) | 1 (3) |
| SAW | | 3.4123 (2) | 4.0866 (1) | 3.3104 (3) | 3.1081 (4) |

Note: The numbers in parentheses denote rankings, and those in bold denote $f_i^*$.

Based on the local stakeholders' views, rail has the highest scores in seven criteria, and highway has the highest in only one. In addition, marine shares the highest scores with rail in Political Climate ($C_7$). On the other hand, air transport has the lowest scores in all criteria.

Moreover, the scores for Equity & Justice ($C_3$) and Political Climate ($C_7$) are less than three, and thus do not reach the threshold value for these criteria.

The $S_j, R_j$, and $Q_j$ values may be calculated using Eqs. 8-10, with rail having the lowest $Q_j$ value. Since $Q_j$ represents the gap between the alternative and ideal solutions, a smaller $Q_j$ value is desirable. As may be expected, rail contains the smallest gap (0) according to a VIKOR analysis for three cases ($v$=1, 0.5, and 0), while rail also holds the highest value (4.2706) based on the SAW method. The ranks of the overall scores of the four transport modes were found to be rail $\succ$ highway $\succ$ marine $\succ$ air, where A $\succ$ B represents that A is preferred over B. Surprisingly, the ranking between marine and highway is changed if the strategy of minimum individual regret is used ($v$=0).

Based on the scholars' views, rail has the highest scores in seven criteria, and highway has the highest in only one. On the other hand, air transport has the lowest scores in five criteria, while marine transport and highway have the lowest scores in two. The scores for Environmental Protection ($C_5$) and Energy Efficiency & Carbon Reduction ($C_6$) are less than three for highway, while the same is true for air transport in Eligible Cost ($C_2$), Environmental Protection ($C_5$), and Energy Efficiency & Carbon Reduction ($C_6$).

Rail consistently has the smallest gap (0) according to the VIKOR analysis of three cases ($v$=1, 0.5, and 0), while rail consistently has the highest value (4.0866) based on the SAW method. The ranks of the overall scores of the four transport modes were found to be rail $\succ$ highway $\succ$ marine $\succ$ air.

## 5. DISCUSSION

The proposed hybrid MCDM model provides a systemic approach to analyze the transport policy decision-making process. This model simultaneously considers the strategy with maximum group utility and minimum individual regret while quantifying many subjective judgments, which is necessary for the evaluation of different alternative transport modes by VIKOR. The weights and complicated relationships among criteria are provided by ANP and DEMATEL. The results show some differences between the opinions of the local stakeholders and neutral scholars with regard to the relationships among the criteria and their relative priorities although the first choice among the four transport modes stays the same. Rail beats other transport modes in most criteria, except for Equity & Justice ($C_3$) from local viewpoints and Political Climate ($C_7$) from neutral viewpoints.

As shown in Fig. 1, local stakeholders are most concerned most about Feasibility & Execution ($C_8$) and Political Climate ($C_7$), while they also regard Economic Development ($C_1$), Social Security ($C_4$), and Environmental Protection ($C_5$) as relevant causes. On the other hand, the neutral scholars regard Political Climate ($C_7$) and Environmental Protection ($C_5$) as the main concerns and causes (Fig. 2). In other words, Feasibility & Execution ($C_8$), Economic Development ($C_1$), and Social Security ($C_4$) are added as causes by the local stakeholders, thus revealing that the local government favors, both development and a safer transport network. In addition, the balance between Political Climate ($C_7$) and Environmental Protection ($C_5$) deserves more attention before infrastructure projects are approved. A comparison of these two figures thus yields interesting and useful results.

Economic Development ($C_1$), Social Security ($C_4$), and Environmental Protection ($C_5$) are the top three criteria with the strongest impact levels based on the views of local stakeholders (Fig. 1), while Feasibility & Execution ($C_8$), Equity & Justice ($C_3$), Political Climate ($C_7$) are the top three with the strongest influences based on the views of the neutral scholars (Fig. 2). The differences in the rankings and relationships among the criteria reveal the different preferences of the local stakeholders and neutral scholars.

However, the weights of the criteria are quite similar from both groups. Based on the local opinions, Social Security ($C_4$), Equity & Justice ($C_3$), and Environmental Protection ($C_5$) are the top three priorities with the highest weights (Table 6), while based on the neutral ones, Social Security ($C_4$), Environmental Protection ($C_5$), and Equity & Justice ($C_3$) are the most important (Table 7).

These results do not necessarily imply that less attention should be paid to Political Climate ($C_7$) and Feasibility & Execution ($C_8$). In fact, Fig. 1 indicates that local stakeholders are most concerned about Feasibility & Execution ($C_8$) and Political Climate ($C_7$). Figure 2 indicates that Political Climate ($C_7$) has the highest relation level, which shows that it will influence the other criteria more than it is influenced by them. On the other hand, Feasibility & Execution ($C_8$) has the highest impact level, which means that it will affect the other criteria and will also be significantly affected by them. The ranks of the impact level are different from those of importance based on the weights. The results thus show that the proposed hybrid model is capable of handling the various interdependencies in the complicated relationships among the various criteria.

A more detailed comparison of weights of the criteria from the different viewpoints is shown in Table 8, which includes the opinions of the 16 neutral scholars, as well as those of the five government officials, four elected representatives, and five opinion leaders. Based on government officials' views, Social Security ($C_4$), Equity & Justice ($C_3$), and Feasibility & Execution ($C_8$) are the top three criteria, while the top three for the elected representatives are Equity & Justice ($C_3$), Social Security ($C_4$), and Environmental Protection ($C_5$), and for the opinion leaders the list is Feasibility & Execution ($C_8$), Energy Efficiency & Carbon Reduction ($C_6$), and Social Security ($C_4$). In summary, government officials and opinion leaders pay more attention to Feasibility & Execution ($C_8$), and this may be because the funding for infrastructure projects usually comes from the Executive Yuan, and the implementation of such projects is generally long-term and challenging work. In addition, Energy Efficiency & Carbon Reduction ($C_6$) is also regarded as an important criterion by opinion leaders.

Table 8. The detailed weights of criteria

| Criteria | Local Stakeholders | Government Officials | Elected Representatives | Opinion Leaders | Neutral Scholars |
|---|---|---|---|---|---|
| $C_1$ | 0.0762 (8) | 0.1230 (5) | 0.0292 (8) | 0.0811 (7) | 0.1452 (4) |
| $C_2$ | 0.0824 (7) | 0.0718 (7) | 0.0942 (7) | 0.0755 (8) | 0.0881 (7) |
| $C_3$ | 0.1470 (2) | 0.1692 (2) | 0.1686 (1) | 0.1075 (6) | 0.1519 (3) |
| $C_4$ | 0.1688 (1) | 0.2049 (1) | 0.1642 (2) | 0.1495 (3) | 0.1698 (1) |
| $C_5$ | 0.1441 (3) | 0.1235 (4) | 0.1550 (3) | 0.1485 (4) | 0.1613 (2) |
| $C_6$ | 0.1305 (5) | 0.1160 (6) | 0.1286 (5) | 0.1532 (2) | 0.1040 (5) |
| $C_7$ | 0.1072 (6) | 0.0661 (8) | 0.1249 (6) | 0.1269 (5) | 0.0758 (8) |
| $C_8$ | 0.1438 (4) | 0.1255 (3) | 0.1353 (4) | 0.1578 (1) | 0.1039 (6) |

Note: The numbers in parentheses denote rankings.

Railway is the most favored of the four transport modes in the views of both local stakeholders and neutral scholars (Tables 6 and 7). The magistrate of Hualien County once stated that Hualien residents need a safer way to travel, and called for the building of a new national freeway, this putting political pressure on the Executive Yuan. However, the results of this study show that Political Climate ($C_7$) has a low weight, rail beats highway in most criteria, even in Social Security ($C_4$), which is the most important criterion with the highest weight. Therefore, rail is the best transport mode for the route between Hualien and Yilan, and may explain why the new “Suao-Hualien National Freeway” project was temporarily suspended by the Executive Yuan. In addition, it also indicates a change in public opinion, with rail now being favored over a road link.

It is worth noting that the railway score for Equity & Justice ($C_3$) is lower than that of highway based on the opinions of local stakeholders. This reflects the fact that the eastern railway constructed along East Rift Valley has relatively poor accessibility to the east coast region of Hualien due to Coastal Range. In addition, local people are frustrated with the rail service because it is difficult for them to buy train tickets. The seamless transition between Hualien city, East Rift Valley and east coast region should thus be improved to overcome the negative view of local residents with regard to the current transport policy of Ministry of Transportation and Communications.

Some have argued that marine transport could be a good alternative transport mode for this region, and that the new national freeway could be replaced by a “blue highway”. Based on the local opinions gathered in this work, marine transport is the second most favored mode if the strategy of minimum individual regret is used. This suggests that local residents strongly desire to have multiple transport modes, even though passenger shipping is currently not available. In addition, air transport is not an appropriate mode due to its innate disadvantages and lowest scores in most criteria.

In summary, according to a VIKOR analysis for three cases ($v$ =1, 0.5, and 0), rail is the best choice of transport mode, as it shows the smallest gap. It is interesting to note that the value of $Q_j$ increases as $v$ rises for the highway and marine modes based on the views of local stakeholders. This means that these two modes are more likely to be adopted if the strategy of minimum individual regret is used. On the other hand, the value of $Q_j$ decreases as $v$ increases for these two modes based on the views of the neutral scholars. In other words, these two modes are more likely to be adopted if the strategy of maximum group utility is used. This reveals the different viewpoints of local stakeholders and neutral scholars, with the former being more interested in more alternative modes of transport available for use.

The case of eastern Taiwan examined in this work demonstrates the possibility of using the proposed hybrid model to solve a complicated problem and find the best compromise solution. The local stakeholders’ and neutral scholars’ opinions were collected and a group decision-making process was carried out in a systematic fashion. The primary results (weight and rank) are almost the same for both groups, although the relationships that they posited among the criteria are very different. Based on the empirical results, the relevant authorities are advised to make more efforts to communicate with the public to make them realize the advantages of rail transport, as it is believed that they will respond better to reasoned explanations than to orders or arguments thus an agreeable consensus may be reached.

In addition, the Executive Yuan will be reorganized in 2013, with the Ministry of Transportation and Communications becoming the Ministry of Transportation and Construction, and the Environment Protection Administration becoming the Ministry of Environment Resources. In this process, better horizontal communication and cooperation between these new departments will provide a stronger foundation for the successful implementation of government policies.

## 6. CONCLUSIONS

The hybrid MCDM model provides a simple decision support system to solve complicated hybrid problems that are faced by many different departments or units in the real word. The case of transport in eastern Taiwan is used to demonstrate this approach, and the empirical results reveal both the power and effectiveness of the proposed model with regard to identifying the network of influence among various criteria, as well as their relative priorities. It is thus confirmed that the model proposed in this work can be used to select the best compromise solution for a complicated problem.

In particular, the views of both local stakeholders and neutral scholars are discussed in detail in this work, and the main results are almost the same for both groups, with rail being the favored transport mode. The results show that although the different opinions of different groups can lead to the different approaches and causal modeling system, the ranking of the weights may be similar, and the choice of an alternative may be the same. If rational communication and discussion between different groups can be encouraged, then it is more likely that an agreeable consensus solution can be reached.

This work has several limitations that suggest avenues for future research. First, it is limited to a Taiwanese context using samples of local stakeholders and neutral scholars, and the findings may not be directly applicable to other contexts. Larger and more diverse groups of samples from different countries are thus necessary to enhance the robustness of the proposed method. In addition, a longitudinal study to record changes in public opinion is also encouraged, and it is believed that more useful results could be obtained if sufficient data and resources are available.

## REFERENCES


Beria, P., Maltese, I., Mariotti, I. (2012) Multicriteria versus cost benefit analysis a comparative perspective in the assessment of sustainable mobility. *European Transport Research Review*, 4(3), 137-152.

Cohen, M. D., March, J. G., Olsen, J. P. (1972) A garbage can model of organizational choice. *Administrative Science Quarterly*, 17, 1-26.

Easton, D. (1953) *The Political System: An Inquiry into the State of Political Science*. Alfred A. Knopf, New York.

Hanaoka, S., Kunadhamraks, P. (2009) Multiple criteria and fuzzy based evaluation of logistics performance for intermodal transportation. *Journal of Advanced Transportation*, 43(2), 123-153.

Hsu, Y. L., Li, W. C., Chen, K. W. (2010) Structuring critical success factors of airline safety management system using a hybrid model. *Transportation Research Part E*, 46(2), 222-235.

Huang, J. J., Tzeng, G. H., Ong, C. S. (2005) Multidimensional data in multidimensional scaling using the analytic network process. *Pattern Recognition Letters*, 26(6), 755-767.

Liou, J. J. H., Chuang, Y. T. (2010) Developing a hybrid multi-criteria model for selection of outsourcing providers. *Expert Systems with Applications*, 37(5), 3755-3761.

Liou, J. J. H., Tzeng, G. H., Chang, H. C. (2007) Airline safety measurement using a hybrid model. *Journal of Air Transport Management*, 13(4), 243-249.

Liou, J. J. H., Yen, L., Tzeng, G. H. (2008) Building an effective safety management system for airlines. *Journal of Air Transport Management*, 14(1), 20-26.

Liu, C. H., Tzeng, G. H. and Lee, M. H. (2012) Improving tourism policy implementation – The use of hybrid MCDM model. *Tourism Management*, 33(2), 413-426.

Opricovic, S. (1998) *Multicriteria Optimization of Civil Engineering Systems*. Faculty of Civil Engineering, Belgrade.

Opricovic, S., Tzeng, G. H. (2004) Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operation Research*, 156(2), 445-455.

Opricovic, S., Tzeng, G. H. (2007) Extended VIKOR method in comparison with outranking methods. *European Journal of Operational Research*, 178(2), 514-529.

Pawlak, Z. (1991) *Rough Sets: Theoretical Aspects of Reasoning about Data*. Kluwer Academic Publishing, Dordrecht.

Regmi, M. B., Hanaoka, S. (2012) Application of analytic hierarchy process for location analysis of logistics centers in Laos. Paper presented at the 91th Annual Transportation Research Board Meeting, Washington, DC, January 22-26.

Saaty, T. L. (1996) *Decision Making with Dependence and Feedback: Analytic Network Process*. RWS Publications, Pittsburgh.

Saaty, T. L. (1999) Fundamentals of the analytic network process. Paper presented at the International Symposium on the Analytic Hierarchy Process, Kobe, Japan, August 12-14.

Shelton, J., Medina, M. (2010) Integrated multiple-criteria decision-making method to prioritize transportation projects. *Transportation Research Record: Journal of the Transportation Research Board*, 2174, 51-57.

Shieh, J. I., Wu, H. H., Huang, K. K. (2010) A DEMATEL method in identifying key success factors of hospital service quality. *Knowledge-Based Systems*, 23(3), 277-282.

Tsamboulas, D., Yiotis, G. S., Panou, K. D. (1999) Use of multicriteria methods for assessment of transport projects. *Journal of Transportation Engineering*, 125(5), 407-414.

Tudela, A., Akiki, N., Cisternas, R. (2006) Comparing the output of cost benefit and multi-criteria analysis: An application to urban transport investments. *Transportation Research Part A*, 40(5), 414-423.

Tzeng, G. H., Chiang, C. H., Li, C. W. (2007) Evaluating intertwined effects in e-learning programs: a novel hybrid MCDM model based on factor analysis and DEMATEL. *Expert Systems with Applications*, 32(4), 1028-1044.

Tzeng, G. H., Teng, M. H., Chen, J. J., Opricovic, S. (2002) Multicriteria selection for a restaurant location in Taipei. *International Journal of Hospitality Management*, 21(2), 171-187.

Wei, P. L., Huang, J. H., Tzeng, G. H., Wu, S. I. (2010) Causal modeling of web-advertising effects by improving SEM based on DEMATEL technique. *International Journal of Information Technology & Decision Making*, 9(5), 799-829.

Yedla, S., Shrestha, R. M. (2003) Multi-criteria approach for the selection of alternative options for environmentally sustainable transport system in Delhi. *Transportation Research Part A*, 37(8), 717-729.

Yeh, M. S., Hsiao, Y. L., Liu, H. H. (2009) A study on different decision-making models applying for transportation policy – using Su-Hau Highway as an example. Paper presented at the 2009 International Conference and Annual Meeting of Chinese Institute of Transportation, Taoyuan, Taiwan, December 3-4. (in Chinese)

Zeleny, M. (1982) *Multiple Criteria Decision Making*. Mc-Graw-Hill, New York.