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THE EVALUATION INDICATORS FOR SUSTAINABLE INTERCITY TRANSPORTATION IN SOCIAL EQUITY ASPECT

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Abstract：

"Sustainable Development" is generally discussed on three dimensions: social equity, economical efficiency, and environmental preservation, however, social equity is seldom discussed before. Since a transportation sector may generate some negative effects on these three and intercity transportation has some special characteristics, the sustainable development of intercity transportation becomes an important issue.

The purpose of this study is to develop indicators to evaluate the sustainable development of intercity transportation in social equity aspect. The indicators are generated by an issue-based framework and screened by the examination of functional overlap, the weights, and data availability. The fuzzy inference method is used to integrate the evaluation indicators to show the comprehensive and realizable evaluation results.

Key Words: intercity transportation, sustainable development, social equity, fuzzy inference.

1. INTRODUCTION

In 1992, sustainable development became a main issue in the Global Summit Conference in Brazil and was concerned up to now. How to utilize limited resources in earth to meet the needs of the present and the future generations has turned into the most significant issue in the world.

In order to evaluate which polices should be done and to measure performances of such polices, the evaluation of sustainability is a key factor. Hinterberger et al (1997) considered that sustainability is difficult to define, measure, and judge. Different groups, fields, or individuals may contribute to different descriptions. For example, World Commission on Environment and Development (1987) proposed, "Development that meets the needs of the present without compromising ability of future generations to meet their own needs"; Phillis and Andriantiatsaholiniaina (2001) argued, "one system is sustainable if its dynamics never drive it outside the boundaries of acceptable values of certain criteria." Munasinghe (1993) advocated that sustainable development should pursue equilibrium among environmental preservation, social equity, and economic efficiency. Because of vague and intricate concepts of sustainability, some papers, like Phillis and Andriantiatsaholiniaina (2001), use fuzzy logic to evaluate the sustainability of economic system from ecological and human aspects.

Sustainable development is to pursue the equilibrium among environment preservation, social equity, and economic efficiency. However, there were few researches about social equity in the past. It may be attributed to that assessing the equity is very complicated and debatable. Berne and Stiefel (1984) had proposed three equity concepts: horizontal equity, vertical equity, and equity opportunity. Actually, equity opportunity is the most essential principle. Waters (2000) used a concentration coefficient derived from Gini coefficient and Atkinson distributional measure to evaluate the equity of hospital service accessibility in different districts. Kou (2002) used the ratio of floor space to site area to evaluate the equity of land use. However these two papers had the premise that each individual has the same value or preference; as a matter of fact, everybody has different satisfied feeling for the same objective. Thus, only relying on quantitative indicators could not truly reflect the principle of equity opportunity. By the same token, to combine subjective satisfied senses with objective and quantitative indicators could be seen a better way to resemble the reality of social equity. Since we find that to define and measure such subjective satisfied senses is not facile, fuzzy theory is a suitable tool to handle these problems. Because some indicators of sustainable development belong to subjective items, it is difficult to evaluate such indicators with quantitative methods. Fuzzy theory is mainly applied to properly express linguistic variables and uncertain information.

Transportation system could be classified into highway, railway, airway, and waterway in terms of mode type, and into international transportation, urban transportation, intercity transportation, in terms of transportation service area. Intercity transportation has several characteristics such as long travel distance, easy mode switching behavior, and affected by regional land use planning. Since long travel distance is not very distinct, due to a small island of Taiwan characteristics should be deeply investigated from sustainable development perspectives.

Many researches, like Marbek Resource Consultants (1996), OECD (1998), Jones and Lucas (2000), built indicator systems to evaluate the degree of sustainable development in transportation, but these indicator systems could be keenly studied into the meaning of sustainability and integration of indicators. In summary, this study would focus on social equity, sustainability measurement, and indicators integration.

Therefore, the purpose of this study is to build an indicator system to evaluate the sustainable development of intercity transportation in the social equity aspect. Through this general inter-regional indicators system, the study would perform the sustainable condition of different regions in the social equity aspect. The research results could contribute to clarify related issues in the social equity; and provide a platform for evaluating the whole sustainable system in the future. Moreover, the results could become useful guidelines for decision-makers in the government to determine future sustainable policies.

2. ISSUES OF SOCIAL EQUITY

To achieve the objective of social equity of transportation systems, this study has established sustainable indicators framework as follows. The study defines four kinds of issues of social equity in transport area including transportation users of different modes, groups, regions, and generations, as shown in Figure 1. To begin with, the users of different modes, since they did not fairly pay the cost of construction, operation and social cost of different transportation systems, this study will expect that the cost that users actually pay is equal to the cost that users should pay. Second, for different groups, existing transportation services and facilities do not fully consider the basic needs of the old and disabled, women, children, and people living in remote districts. Hence, to equally fulfill the basic needs of different groups is our concern. Third, for different regions, because different region's demands and physical environment are different, it is not reasonable to make each region obtain identical level of transportation service. However, in terms of equity, to maintain and to fulfill basic transportation needs is a primary planning direction. Finally, between different generations, we should assure both needs of future generations and the present generation are well addressed, even though only very limited amount of resources are in earth. The study generates indicator systems based on the issues shown in Figure 1.

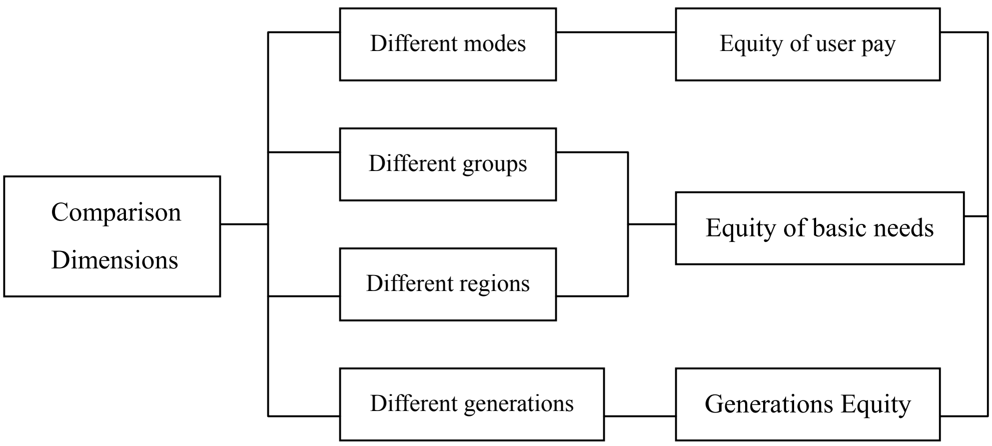

Figure 1 Issues of Social Equity

3. INDICATORS SYSTEM

To establish indicators, this study will describe the processes of indicators generation, screening and integration.

3.1. Indicators Generation

3.1.1. Different Modes

There are seven indicators for the different modes and a general form of sustainability indicator SV_i, shown in formula 3.1.

$$Min \quad SV_i(t) = \left| \sum_j CR_{ij}(t) - \sum_j CS_{ij}(t) \right| \qquad \forall i, t \qquad (3.1)$$

$CR_{ij}(t) > 0$, $CS_{ij}(t) > 0$

$i = 1,2,\ldots, I$

$j = 1,2,\ldots, J$

$SV_i(t)$: the difference between the cost actually paid and the cost should be paid by the *ith* type mode user in a given time t (in this study t is one year.)

$CR_{ij}(t)$: the *j*th cost should be paid of the *ith* type mode users in a given time t.

$CS_{ij}(t)$: the *j*th cost actually paid of the *ith* type mode users in a given time t.

If the difference between $CR_{ij}(t)$ and $CS_{ij}(t)$ becomes larger, for other type (without the *ith* type) mode users, it tends toward more inequity. The study generates seven indicators based on the issue-based framework to evaluate the equity and sustainability in different modes. So the larger difference represents more inequity, furthermore, it means more unsustainable.

It is impossible at the present time to evaluate such indicators with quantitative methods simply because of the problem of data availability. For the lack of complete and precise cost statistics, the study applies such seven indicators by means of qualitative methods to maintain the consistence of indicators.

3.1.2. Different Groups

There are eight indicators in this part and a general form of sustainability indicator SG_i, as shown in formula 3.2.

$$U^* = Max\left[\sum_j U_{ij} , \sum_j U'_{ij} \right] \qquad (3.2)$$

$$Max \qquad SG_i = \left| U^* - \sum_j U'_{ij} \right| \qquad (3.3)$$

U^*: utility of the *ith* type group's ideal needs with the *jth* transportation service

U_{ij}: utility of the *ith* type group's real needs with the *jth* transportation service

U'_{ij}: utility of the *ith* type group's basic needs with the *jth* transportation service

SG_i: the difference between U^* and U'_{ij}

If the basic needs of certain disadvantaged minority are satisfied, we consider this meets the principle of equity opportunity. Thus, for these indicators, we mark the "plus" for sustainability. It means the better utility of a disadvantaged minority, the more equity and sustainability.

The 8th, 9th, 11th, 14th, and 15th indicators in table1 belong to the qualitative indicators. Because of lacking objective data, we assume utility to describe these indicators. Utility is a nonobjective preference and qualitative meaning, and fuzzy theory is mainly applied to properly express linguistic variables and unclear information. Thus, we measure utility in Table 1 by fuzzy theory. Take the 8th indicator, "utility of the elder's basic needs," as an example, the 8th indicator is to evaluate whether the existing intercity transportation system can meet the elder's basic needs. "The elder" means person who is older than 65 years old. "The handicapped" in the 9th indicator represents people with mental or physical impairment, corresponded to the legal rules of disabled related laws. "The residents in remote districts" denote people who live in mountainous regions, off-shore islands, or areas within a radius of 2 kilometers without any transportation services. "The school children" in the 14th indicator denotes children who are below twelve years old.

The 10th, 12th, and 13th are attributed to quantitative indicators. The 10th indicator, "the ratio of barrier-free environment," means the ratio of existing areas of barrier-free environment to minimum legal areas of barrier-free environment. The 12th indicator, "the number of runs of scheduled buses annually in remote districts," is desired to realize the level of public transportation service in remote districts. The 13th indicator, "the days that the roads could be usable annually in remote districts," is designed to realize the condition of roads in remote districts, which are usually destroyed by many typhoons and earthquakes. In general, the value of these three indicators is the larger the better. Thus, the ranking of sustainability is "plus."

3.1.3. Different Regions

There are three indicators in this part and a general form of sustainability indicator $SP_i(t)$, is shown in formula 3.6. First, to realize whether existent transportation services and resources meet the basic needs of people in different regions. Second, to realize whether existent transportation services and resources in different regions correspond to the principle of equity opportunity.

$$P_i^x(t) = \frac{\sum_j S_{ij}^x(t)}{\sum_j D_{ij}^x(t)} \qquad \forall i,t \qquad (3.4)$$

$$P_i^y(t) = \frac{\sum_j S_{ij}^y(t)}{\sum_j D_{ij}^y(t)} \qquad \forall i,t \qquad (3.5)$$

$$Min \quad SP_i(t) = \frac{\left|P_i^x(t) - P_i^y(t)\right|}{P_i^x(t) + P_i^y(t)} \qquad \forall i,t \qquad (3.6)$$

$S^x_{ij}(t)$: supply amount of transportation service for users in region x with the *ith* transportation system and the *jth* mode in a given time t.

$S^y_{ij}(t)$: supply amount of transportation service for users in region y with the *ith* transportation system and the *jth* mode in a given time t.

$D^x_{ij}(t)$: demand amount of transportation service for users in region x with the *ith* transportation system and the *jth* mode in a given time t.

$D^y_{ij}(t)$: demand amount of transportation service for users in region y with the *ith* transportation system and the *jth* mode in a given time t.

$P^x_i(t)$: utility of basic transportation needs for users in region x with the *ith* transportation system in a given time t.

$P^y_i(t)$: utility of basic transportation needs for users in region y with the *ith* transportation system in a given time t.

$SP_i(t)$: the difference between $P^x_i(t)$ and $P^y_i(t)$ in a given time t.

The 16th, 17th, and 18th are attributed to quantitative indicators. Take the 16th indicator for example. The 16th indicator is the difference between ”the ratio of passenger-kilometer of highway transportation in region x annually to seat-kilometer of highway transportation in region x annually” and ”the ratio of passenger-kilometer of highway transportation in region y annually to seat-kilometer of highway transportation in region y annually.” The study assumes seat-kilometer and passenger-kilometer instead of supply and demand amount of transportation service, so such indicators could be expressed by quantitative methods. If the output of $SP_i(t)$ approximates to 0, it means that distribution of transportation services and resources in different regions becomes more equitable; on the other hand, if the output of

$SP_i(t)$ approximates to 1, it means more inequity. A larger output value means more inequity, so the ranking of sustainability is ”minus.”

3.1.4. Different Generations

There are three indicators in this part and a general form of sustainability indicator $S_{ur}(t)$, is shown in formula 3.7 .The purpose is to make each generation have enough resources. The 19th indicator is the difference between ”the average real consumption of non-recyclable energy resources in intercity transportation each person per year” ($C'_{ur}(t)$) and ”the average reasonable consumption of non-recyclable energy resources in intercity transportation each person per year”($C^*_{ur}(t)$). Because petroleum is the main non-recyclable energy resource, the study uses average consumption of petroleum during past 10 years to describe the average reasonable consumption. There are two reasons: (1) data availability, and (2) for simplicity. The existing statistic data are generally classified by decade. 10 years is a properly time span to observe and describe the reasonable consumption. Furthermore, using 10 years average could make the problem more simplicity. If the output of $S_{ur}(t)$ is positive, it means that the average real consumption of non-recyclable energy resources in this year is more than the average reasonable consumption. In this case, it violates the principle of generation equity and tends toward unsustainable. Therefore, the ranking of sustainability remarks ”minus.”

$$S_{ur}(t) = C'_{ur}(t) - C^*_{ur}(t) \qquad \forall t \qquad (3.7)$$

The 20th indicator is the difference between ”the real expenditures ($I'_r(t)$)” and ”the reasonable expenditures ($I^*_r(t)$)” of recyclable energy development in intercity each person per year. Not only to economize on non-recyclable energy resources is important, development of recyclable energy is also significant. Recyclable energy resources contain solar energy, wind power, magnetic force, and other kind of natural energy that is never diminished with utilization. According to a reliable estimation, the known deposits of petroleum would become shortage in fifty years. As a matter of a fact, development of recyclable energy seems to be imperative. The study would observe the trend of the development of recyclable energy by the 20th indicator. Hence, the study uses average expenditures to develop recyclable energy during past 10 years to describe the reasonable expenditures ($I^*_r(t)$) per year. The computation of $S_r(t)$ grows larger means that government pay more attention to develop recyclable energy resources. Thus, the ranking of sustainability is remarked as ”plus.”

$$S_r(t) = I'_r(t) - I^*_r(t) \qquad \forall t \qquad (3.8)$$

The 21th indicator is the difference between ”the average soil consumption cost in intercity transportation each person per year ($C_l(t)$)” and ”the soil recovery expenditures each person per year ($R_l(t)$).” No matter waste soil from construction or soil consumption from building material may have an adverse impact on our natural environment. Thus, the rate of recovery must catch up with the rate of destruction. The ranking of sustainability remarks "minus."

$$S_l(t) = C_l(t) - R_l(t) \qquad \forall t \qquad (3.9)$$

Table1 Initial Set of Indicators

Comparison Dimensions	System Type	Initial Indicators	Sustain-ability
Different Modes	Highway	1. The degree of difference between cost actually paid and cost should be paid for private mode users	—
		2. The degree of difference between cost actually paid and cost should be paid for highway passenger transportation users	—
		3. The degree of difference between cost actually paid and cost should be paid for highway freight transportation users	—
	Railroad	4. The degree of difference between cost actually paid and cost should be paid for railroad passenger transportation users	—
		5. The degree of difference between cost actually paid and cost should be paid for railroad freight transportation users	—
	Air	6. The degree of difference between cost actually paid and cost should be paid for air passenger transportation users	—
	Water	7. The degree of difference between cost actually paid and cost should be paid for water freight transportation users	—
Different Groups		8. The utility of elders' basic transportation needs	+
		9. The utility of handicapped peoples' basic transportation needs	+
		10. The ratio of barrier-free environment	+
		11. The utility of remote district peoples' basic transportation needs	+
		12. The number of runs of scheduled buses annually in remote districts	+
		13. The days that the roads could be usable annually in remote districts	+
		14. The utility of school children's basic transportation needs	+
		15. The utility of general public's basic transportation needs	+
Different Regions	Highway	16. The difference of "the ratio of passenger-kilometer to seat-kilometer" between region x and region y in highway passenger transportation	—
	Railroad	17. The difference of "the ratio of passenger-kilometer to seat-kilometer" between region x and region y in railroad passenger transportation	—
	Air	18. The difference of "the ratio of passenger-kilometer to seat-kilometer" between region x and region y in air passenger transportation	—
Different Generations		19. The difference between real and reasonable consumption of non-recyclable energy resources in intercity transportation each person per year	—
		20. The difference between real and reasonable expenditures of recyclable energy development in intercity transportation each person per year	+
		21. The difference between soil consumption cost and reasonable soil recovery expenditures in intercity transportation each person per year	—

3.2. Indicators Screening

3.2.1. Screening by Functional Overlap

The purpose of the Screening by functional overlap is to delete indicators with similar functions. In this stage, the 10th, 12th, and 13th indicators would be eliminated. The 10th indicator could be included into the 9th one, because general basic transportation needs should be considered about the ratio of barrier-free environment. By the way, the 12th and 13th indicators could be included into the 11th one, as a result of three reasons. First, remote district is attributed to subjective definition without any unequivocal rules. Second, based on the first reason, the 12th and 13th indicators would lack of correct data and statistic without precise definition of remote districts. Last, the utility of generalized basic transportation needs could cover these two indicators.

3.2.2. Screening by Relative Weights

The purpose of the Screening in this stage is to delete indicators with lower relative weights. Relative weights are calculated from AHP survey with 40 samples (Chen, 2002). Samples are composed of traffic engineer consultants, employees of the Ministry of Communications and Transportation, professional transportation researchers, and the public. Each group has 10 samples in this study. Consequently, the 14th indicator would be eliminated resulted from lower relative weight. The possible reason is that basic transportation needs of school children may be smaller than the old, the handicapped, and the remote district residents. Besides, school children's trip generation often accompany their parents, not the apparently disadvantaged minority. However, to eliminate the 14th indicator would benefit other disadvantaged minority.

3.2.3. Screening by Data Availability

The purpose of the filtration in this stage is to delete or modify indicators due to data unavailability. During the procedure of data collection, we found that existing database about intercity transportation is insufficient. According to relative weights calculated from AHP survey, certain indicators without data and with lower weights would be deleted in advance. If we obtained the sufficient data of such eliminated indicators in the future, the study could re-adopt these indicators to analyze. Besides, to maintain the integrated function of indicator system, certain indicators without enough data but with higher weights would be modified to a proxy indicator, so they could be applied more practically. Finally, the 16th, 18th, and 19th indicators should be modified, and the 20th and 21st indicators would be removed.

The study selects ”total roads area” to be an alternative variable of supply side in the 16th indicator, because of no data about ”seat-kilometer in highway transportation.” Moreover, data of ”passenger-kilometer in highway passenger transportation” are attributed to aggregated information, but lack of individual data. Thus, the study adopted ”passenger-kilometer in private highway passenger transportation” to instead of ”passenger-kilometer in highway passenger transportation.” Similarly, ”the number of flights in air passenger transportation” would be instead of ”seat-kilometer in air passenger transportation,” and ”the number of passengers in air passenger transportation” would be instead of ”passenger-kilometer in air passenger transportation” in the 18th indicator. At last, existing data could not clearly defined the reasonable consumption, so we regard this indicator as a qualitative concept and deal with it by fuzzy theory. Thus, the 19th indicator would be modified to ”The difference between real and reasonable consumption of non-recyclable energy resources in transportation sector each person per year” and this indicator is regarded as a qualitative one. The reasonable consumption of non-recyclable energy resources are on the basis of the experts’ aspects and opinions by questionnaires. The remnant fifteen indicators are shown in table 2.

Table 2 Final Set of Indicators

Comparison Dimensions	System Type	Initial Indicators	Sustain -ability
Different Modes	Highway	1*. The degree of difference between cost actually paid and cost should be paid for private mode users	—
		2*. The degree of difference between cost actually paid and cost should be paid for highway passenger transportation users	—
		3*. The degree of difference between cost actually paid and cost should be paid for highway freight transportation users	—
	Railroad	4*. The degree of difference between cost actually paid and cost should be paid for railroad passenger transportation users	—
		5*. The degree of difference between cost actually paid and cost should be paid for railroad freight transportation users	—
	Air	6*.The degree of difference between real cost and accurate cost for air passenger transportation users	—
	Water	7*.The degree of difference between cost actually paid and cost should be paid for water freight transportation users	—
Different Groups		8*. The utility of elders' basic transportation needs	+
		9*. The utility of handicapped peoples' basic transportation needs	+
		10*. The utility of remote district peoples' basic transportation needs	+
		11*. The utility of general public's basic transportation needs	+
Different Regions	Highway	12*. The difference of ”the ratio of passenger-kilometer in private highway passenger transportation to total road areas in highway transportation” between region x and region y	—
	Railroad	13*. The difference of ”the ratio of passenger-kilometer to seat-kilometer” between region x and region y in railroad passenger transportation	—
	Air	14*. The difference of ”the ratio of number of passengers to number of flights” between region x and region y in air passenger transportation	—
Different Generations		15*. The difference between real and reasonable consumption of non-recyclable energy resources in transportation sector each person per year	—

3.2.4. Analysis of Indicators Screening

Although we screen few indicators by data unavailability, we still check the relative weights of them. If the relative weights of screening indicators are very significant, we do not directly delete such indicators; however, we may revise or replace these indicators. Even if the indicator system could not work objectively due to the restriction of data availability, the study uses some qualitative indicators to solve the problem. If the study could barely use indicators without sufficient data to evaluate, the incomplete indicators may cause biased evaluation results. But if government or certain institutions could collect, build, and maintain an ample and adequate statistic database, it may have a better result on relative researches in the future.

3.3 Indicators Integration

”Sustainability” is an ”ill-defined” concept and most evaluation indicators in social aspect are attributed to qualitative indicators, so traditional multiple criteria decision making method could not be proper to the integrated indicator system. Fuzzy logic and fuzzy inference are applied to handle this problem. Fuzzy inference is one segment of fuzzy logic, and fuzzy logic is one specific part of fuzzy theory. Actually, fuzzy inference is the core of fuzzy logic and is to simulate the decision-making procedure of human and express subjectively qualitative indicators to a definite value through fuzzy inference rule base. Take this study for example, the final indicator system is the input, and the degree of sustainability is the output.

Fuzzy logic procedures are as shown in figure 2. First, to transfer inputs (the final indicator system in this study) into linguistic values by an operation called fuzzification. Fuzzy rules base is expressed by form of IF-THEN rules, and such rules are applied to transform linguistic values into fuzzy statements by fuzzy inference. Consequently, a final definite output value would be obtained by defuzzification.

3.3.1. Fuzzification

Fuzzification is to transform definite values of quantitative indicators or subjective opinions of qualitative indicators into suitable linguistic variables. According the suggestion of membership function and membership grades in Chen et al (1992), the study adopts five levels triangular membership function as shown in figure 3. Each level is corresponded to a certain linguistic value, based on the meanings of indicators, such as ”very low (VL), law (L), medium (M), high (H), very high (VH),” ”very bad (VB), bad (B), medium (M), well (W), very well (VW),” ”very low (VL), law (L), medium (M), high (H), very high (VH),” ”very unequal (VUE), unequal (UE), medium (M), equal (E), very equal (VE),” and ”very unsustainable (VUS), unsustainable (US), medium (M), sustainable (S), very sustainable (VS).” The value of quantitative indicators are normalized and ranged over [0,1], then corresponded to the horizontal axis of normalization and to the vertical axis of membership grades to obtain linguistic values. The linguistic values of qualitative indicators are directly judged by expert's questionnaires.

3.3.2. Fuzzy Rules Base

Fuzzy rules base is formed by a series of IF-THEN rules to describe the relationship of system inputs and outputs. For example, if indicator x is A, then sustainability y equals to B. We simplified to denote ”If x is *A*, then y is B”. The description after ”If” is input (antecedent), and the description after ”Then” is output (conclusion). The fuzzy implication R(A→B) is as shown in formula 3.10.

$$\mu_R(x,y)=\min\{\mu_A(x),\mu_B(y)\}=\{\mu_A(x)\wedge\mu_B(y)\} \qquad (3.10)$$

$\mu_A(x)$: the membership grade to factor x of fuzzy set A.

$\mu_B(y)$: the membership grade to factor y of fuzzy set B.

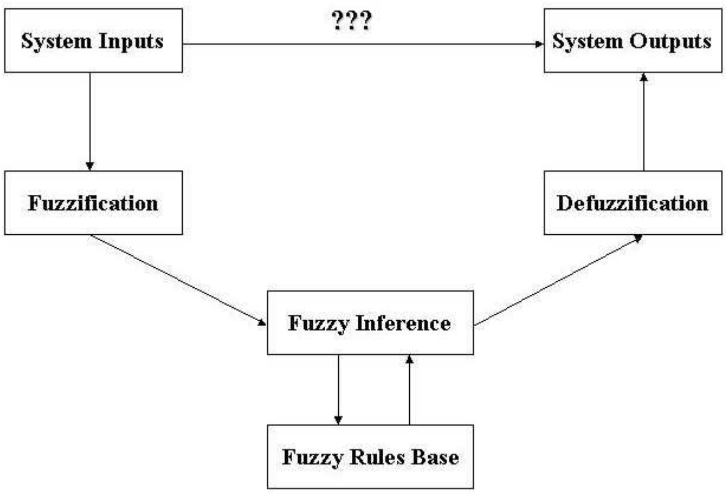

Figure 2 Fuzzy Logic Procedures

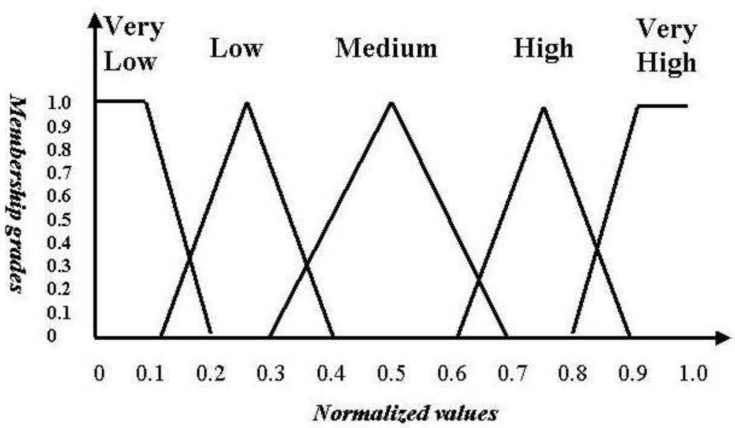

Figure 3 Membership Function and Linguistic Values

While operating fuzzy logic, fuzzy inference is like human's brain and rules base is like learned knowledge in brain. There are three methods to build the fuzzy rules base: first, to interview experts; second, to establish a specific group by retraining; third, to exercise by analytic software such as Matlab. Users illustrate membership function on Matlab and decide linguistic variables and weights of indicators, so fuzzy rules base would be generated.

We simulate Matlab and build rules base by three principles: first, to endow linguistic value level scores; second, to assume the critical boundary existed; third, to use the approximate reasoning principle. The number of rules base is associated with the number of inputs. If we want to realize the degree of equity in highway transportation, we could obtain the 5^3 = 125 rules through three indicators and five linguistic levels. Based on above three principles, linguistic level scores are endowed as”5, 4, 3, 2, 1”. The critical boundary is to set up the critical relationship such as ”IF the 1st, 2nd, and 3rd indicators in Table 2 are very low (VL), THEN the degree of equity in highway transportation is very equal (VE).” In this relationship, the score of ”very equal” in highway transportation is equal to”5” and could be expressed as”5 * weight of the 1st indicator (0.4434) + 5 * weight of the 2nd indicator (0.3255) + 5 * weight of the 3rd indicator (0.4434).” Similarly, if the 1st indicator is ”VL”, the 2nd indicator is ”VL”, and the 3rd indicator is ”M”, then the degree of equity in highway transportation is ”VE”. The score of ”VE” in highway transportation is equal to ”4.5378”, more close to ”5”; based on approximate reasoning principle, the result should be attributed to ”VE”. In short, (0.4434, 0.3255 and 0.4434) are relative weights calculated from the AHP questionnaire. Each relative weight multiplied by the score of linguistic variable is the number of one indicator at first layer. To sum up the numbers at first layer is the number of one indicator at second layer (4.5378).

3.3.3. Fuzzy Inference

Fuzzy inference is the core of fuzzy logic. System inputs are transformed into linguistic outputs by rules base, fuzzy computation and composition. ”Max-min operation” is the primary composition method in this study, and other detailed processes of composition could be introduced by Jang et a (1995)、Bonivento et al (1998) and Teodorovic (1999). Take formula 3.10 for instance. This reasoning process is called ”modus ponens” or ”generalized modus ponens.”

Input: $x \text{ is } A'$

Rules: *If x is A, Then y is B*

Output: $y \text{ is } B'$

According to composition of approximate reasoning and reasoning, it could be shown as:

$$y = A' \circ (A \rightarrow B)(= B')$$

If we choose max-min operation method, then above formula would equal to formula

3.11.

$$\mu_{B'}(y) = \max_x \left[\min\left(\mu_{A'}(x), \mu_{A\to B}(x,y)\right)\right] = \vee_x \left[\wedge\left(\mu_{A'}(x), \mu_{A\to B}(x,y)\right)\right] \qquad (3.11)$$

3.3.4. Defuzzification

Defuzzification is to transform the output of fuzzy inference into a crisp value. The approach of defuzzification in the study is ”center of gravity defuzzifier,” as shown in formula 3.12. Defuzzification could transform membership function into a definite number, and we could realize the outcome by observing its membership grade and linguistic value. Take ”If *x* is *A*, then *y* is *B*” for example:

$$Def(B) = \frac{\sum_j y_j \cdot \mu_B(y_j)}{\sum_j \mu_B(y_j)} \qquad (3.12)$$

Def（*B*）: the defuzzification outcome of fuzzy set B.

y_j: the value of the jth factor of fuzzy set B.

$\mu_B(y_j)$: the membership grade to y_j of fuzzy set B.

4. CASE STUDY

The case study is conducted in Taiwan and contains two parts: the evaluation of current condition and sensitivity analysis of strategies. To begin with, the evaluation of current condition would be applied with data in 2001. The indicator system in this study is composed of four groups and 15 indicators, especially two groups of qualitative indicators. Each indicator would be performed as ”very well, 0.75” (linguistic value, membership grade). The evaluation result for sustainable intercity transportation in social equity aspect is shown in table 3. In the case study, we found:

1. The overall performance of sustainable intercity transportation in social equity aspect in Taiwan is ranked as ”Medium.” Different regions indicators' performance is better than others, however, different groups indicators' performance is the worst. Since different groups obviously have an inferior position in social equity aspect, such result may indicate that government should make some policies to improve the utility of different groups' basic transportation needs. In addition, utility of elder and handicapped people are achieved only on ”Bad” level and should be improved in a top priority.
2. Although the equity between Eastern and Western regions seems well, highway

transportation merely performed on an ”Unequal” & ”Medium” level and also should be improved in the future. On the contrary, railroad and air transportation did develop more equally, and it shows that past construction and development really kept region's balance.

3. With comparison of different modes, users' cost equity of railroad, air, and water intercity transportation all performed the ”Medium” level, but cost difference of the 1st and 3rd indicator are performed ”High.” If government would make some policies to add tax or fees on auto users, certainly, it may reduce the cost difference of private modes in highway intercity transportation. Furthermore, do these policies affect overall sustainability in social equity aspects? Sensitivity analysis of such strategies could solve this question. In this case, strategy 1 could reduce cost difference of the 1st indicator from ”High” to ”Medium,” then outputs of different modes and the overall system do not change. But if strategy 2 could reduce cost difference of the 1st indicator from ”High” to ”Low,” then outputs of different modes would improved to ”Medium” & ”Equal,” and the overall system still has no change.

Therefore, improvement of single indicator may only raise equity of sustainability on certain parts. But if the purpose is to improve equity of the overall system, to ameliorate multi-indicators at the same time may be feasible.

Table 3 Intercity Transportation Sustainability of Taiwan in Social Equity Aspect

Overall Result in Social Equity: ”M, 0.32”	Comparison Dimensions	System Type	Indicators
	Different Modes: ”M, 0.36”	Highway: ”M, 0.36” & ”UE, 0.19”	1. The degree of difference between cost actually paid and cost should be paid for private mode users ”H, 0.82”
			2. The degree of difference between cost actually paid and cost should be paid for highway passenger transportation users ”L, 0.36” & ”M, 0.19”
			3. The degree of difference between cost actually paid and cost should be paid for highway freight transportation users ”H, 0.6”
		Railroad: ”E, 0.45”	4. The degree of difference between cost actually paid and cost should be paid for railroad passenger transportation users ”L, 0.87”
			5. The degree of difference between cost actually paid and cost should be paid for railroad freight transportation users ”L, 0.36” & ”M, 0.15”
		Air: ”M, 1.0”	6. The degree of difference between cost actually paid and cost should be paid for air passenger transportation users ”M, 1.0”
		Water: ”M, 1.0”	7. The degree of difference between cost actually paid and cost should be paid for water freight transportation users ”M, 1.0”
	Different Groups: ”UE, 0.32”		8. The utility of elders' basic transportation needs ”B, 0.77”
			9. The utility of handicapped peoples' basic transportation needs ”B, 0.865”
			10. The utility of remote district peoples' basic transportation needs ”B, 0.22” & ”M, 0.32”
			11. The utility of general public's basic transportation needs ”M, 0.56”

	Different Regions: ”M, 0.39” & ”E, 0.32”	Highway: ”UE,0.39” & ”M, 0.17”	12. The difference of ”the ratio of passenger-kilometer in private highway passenger transportation to total road areas in highway transportation” between Eastern region and Western region ”UE, 0.39” & ”M, 0.17”
		Railroad: ”E, 0.4” & ”VE, 0.4”	13. The difference of ”the ratio of passenger-kilometer to seat-kilometer” between Eastern region and Western region in railroad passenger transportation ”E, 0.4” & ”VE, 0.4”
		Air: ”E, 0.39” & ”VE, 0.41”	14. The difference of ”the ratio of number of passengers to number of flights” between Eastern region and Western region in air passenger transportation ”E, 0.39” & ”VE, 0.41”
	Different Generations: ”M, 0.74”		15. The difference between real and reasonable consumption of non-recyclable energy resources in transportation sector each person per year ”M, 0.74”

5. CONCLUSION

The study first generates initial indicators to evaluate the sustainable development of intercity transportation in social equity aspect. Such indicators are screened by the examination of functional overlap, the weights of indicators, and the data availability. Consequently, we obtained the final indicators composed of four groups and fifteen indicators. In order to handle with the ill-defined concept of sustainability and qualitative indicators, the fuzzy inference method is used to integrate the evaluation indicators to show the comprehensive and realizable evaluation results.

In this study we take the intercity transportation in Taiwan as our case study. Actually, the indicator system could also be applied to evaluate equity of different regions. The results show that the degree of sustainable development for intercity transportation in Taiwan is ranked “Medium” level. The equity among different people groups is the worst. On the other hand, although the equity between eastern and western regions of Taiwan is eagerly expected, the highway transportation in eastern region should have been improved for years. Furthermore, the highway private mode users do not pay the reasonable user cost is another issue to be concerned. If the database could be established better in the future, the indicator system may also be added or modified to improve the results of evaluation.

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